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Roadmap for the digital transformation of the energy sector in Latin America and the Caribbean

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This report is part of the knowledge agenda developed by the Energy Division of the Inter-American Development Bank, which aims to develop new knowledge products and technical assistance programs for the countries of Latin America and the Caribbean. The knowledge products generated are intended to inform, guide and offer a menu of recommendations to policymakers and active participants in energy markets, including consumers, utilities and regulators.

The report was prepared under the direction of Marcelino Madrigal (Head of the Energy Division). The team leader is José Luis Irigoyen. The main authors of the report are Oliverio Álvarez Alonso, Alberto Díaz Echeverria, Noé Afonso Pérez, Alfonso Sánchez Campos, Cecilia Bordiu García-Ovies from Deloitte Spain. Team members include Eric Fernando Boeck Daza, Jairo Alexander Riobó Patino, and María Angelica Pfeifer Vargas. The team thanks Lenin Balza, Arturo Alarcón, Virginia María Snyder, and Adriana Valencia Jaramillo for their comments and review. The team is grateful for financial support from the technical cooperation "InfraDigital - Promoting Digital Transformation for Infrastructure and Energy Services in LAC" (RG-T4098).

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Glossary of Acronyms

SIDEWALK Chilean Association of Renewable Energies and Storage
ADELAT Association of Latin American Electricity Distributors
AMI Media and Information Literacy
ARERA Regulatory Authority for Energy, Networks and Environment
IDB Inter-American Development Bank
BIM Building Information Modeling
CAPEX Capital Expenditures
CFE Federal Electricity Commission of Chile
CIGRE Chilean Committee of the International Council on Large Grids
IOC Chief Information Officer
CONRED National Coordinator for Natural or Provoked Disaster Reduction
CTO Chief Technology Officer
EBITDA Earnings Before Interest Taxes Depreciation and Amortization
ESCOs Energy Service Companies
GW Gigawatt
R+D+i Research, Development and Innovation
ICT Information and Communication Technology
IEA International Energy Agency
IoT Internet of Things
IRA Inflation Reduction Act
LAC Latin America and Caribbean
LCOE Levelized Cost of Energy
OAS Organization of American States
OECD Organization for Economic Cooperation and Development
OLADE Latin American Energy Organization
OPEX Operational expenditures
P2P Peer to peer
REE Spanish Electric Grid
RPA Robotic Process Automation
THEE Information technology
TIC Information and Communication Technologies
IRR Internal Rate of Return
UNGRD National Disaster Risk Management Unit

Executive Overview

The **digital transformation of the energy sector represents a multifaceted endeavor that extends beyond the mere integration of cutting-edge technologies.** It encompasses a comprehensive shift, involving the modernization of assets, tools, and systems, alongside a fundamental transformation of the organizational culture and social dynamics **within energy sector enterprises.**

Within this framework, **the development of a Roadmap for the digital transformation of the energy sector in the Latin American and Caribbean region** constitutes a visionary initiative. This endeavor demands careful consideration of a spectrum of factors, including technological, economic, cultural, and social dimensions.

This undertaking is inherently intricate, primarily due to the **emerging challenges** faced by the energy sector at present and in the foreseeable future. These challenges include the imperative to decarbonize energy systems, the **gradual electrification of energy demand** to ensure **universal access to high-quality electricity**, the assurance of power supply quality in the context of expanding deployment of intermittent renewable technologies, and the **pursuit of heightened energy efficiency** by minimizing network losses.

The necessary digital transformation is underpinned by **four foundational pillars** that have served as the bedrock for the sector's transformation and modernization: (i) the progressive **enhancement of user participation** in energy systems, positioning them as active agents in energy markets, (ii) a transition towards more sustainable and flexible energy generation models is essential, (iii) the need for an **energy system resilient** to the growing incidence of extreme natural events and cyber risks, (iv) a call for a **robust and proximate** value chain.

The development of this transformation process is not uniform, with differing degrees of implementation both within the LAC region and on an international scale. Hence, the identification of success stories in other countries and the potential for their replication in the region are considered key elements in the formulation of a roadmap. This analysis has yielded five noteworthy recommendations for the digital transformation of the region:

1. **A modern and stable regulatory framework ·** Regulation is considered a key driver for encouraging private sector enterprises to invest in the adoption of innovative solutions for the sector's digital transformation. Establishing a common technical framework or well-defined objectives not only ensures stability over time but also imparts legal assurance in the implementation of disruptive technologies and new business models.

It is noteworthy that the countries under examination have either already implemented or are currently in the process of formulating dedicated regulations within the realm of digital transformation. For instance, the United Kingdom utilizes sandboxes to expedite progress and foster active engagement with stakeholders. These sandboxes help identify the primary regulatory impediments encountered during the deployment of digitalization solutions at the sectoral level. In contrast, countries like Italy, Spain, and Portugal are advancing their regulatory frameworks in accordance with specific objectives defined and promoted by the European Union. This is facilitated through the Integrated National Energy and Climate Plans established by the EU.

After analyzing the state of the LAC region, it is recommended, as an initial phase, to foster a collective vision of digital transformation. Concurrently, it is imperative to formulate strategies and plans that delineate well-defined goals and are flexible enough to accommodate the diverse local circumstances. This approach is particularly vital, given that 37% of the sector stakeholders surveyed have identified insufficient regulatory frameworks as a significant hindrance to the advancement of digital transformation within the sector.

2. **Economic incentives for investment in digitalization .** An adequate digital transformation of the energy sector holds the promise of heightened quality and efficiency, potentially translating into economic savings for the energy system. However, to attain this outcome, there is an essential need for economic incentives to stimulate investments that can facilitate a coherent digital transformation of the sector. Among the countries examined, the United States stands out as an exemplary model. It has established economic support programs designed to fortify network infrastructure by incorporating disruptive digital technologies. Notable initiatives include the Inflation Reduction Act and the Smart Grid Investment Program.

Similarly, in European Union member states, a series of measures have been implemented, particularly in the aftermath of the COVID-19 pandemic, utilizing European funds to encourage the development of energy infrastructure and innovation at the sectoral level. These initiatives encompass novel energy models and vectors, bolstering progress in the sector.

In the context of the LAC region, an unequal distribution of costs and benefits among the actors involved has been identified, which may discourage the widespread adoption of digital technologies. Addressing this asymmetry requires the **implementation of policies and strategies that foster equitable access to digital technologies and collaboration between governments, businesses, and organizations.** In this sense, the costs of digital transformation are the main barrier identified, by **67% of the agents surveyed**, for the development of digital transformation.

3. **Technological adoption towards disruptive models and services .** The digital transformation process involves the integration of disruptive digital technologies and harnessing their full potential within the sector. The ultimate objective of this transformation surpasses the mere enhancement of operational efficiency. It encompasses a broader perspective that revolves around the introduction of innovative business models where end-users actively participate as market agents.

The leading nations in digital transformation, as observed in the analysis, share this forward-looking vision. They go beyond merely enhancing the existing system and strive to usher in a more transformative model. South Korea, in particular, boasts a formidable information technology industry, offering a wealth of disruptive digital solutions that can be effectively applied to the energy sector.

From the ideas extracted from the analysis of the current state of the region, it has been observed **that digital technologies tend to be mostly destined to improve existing processes instead of promoting innovation and new business models**, which means that there is still potential to be exploited in the digital transformation of the sector. especially in the most technologically disruptive areas. According to the barriers identified by the agents surveyed, it is considered key to invest in new technologies. **33% of the agents surveyed consider that the current technological infrastructure is weak.** This vision is especially reinforced in the public sector, with more than 41% of public agents in the sector considering it as a barrier to the effective deployment of digital transformation.

4. Digital culture. Together with the progressive digital development, there is a shifting societal awareness propelling the energy sector towards new, increasingly digitized, business models. A shared characteristic identified in the leading nations, and notably emphasized in discussions with influential stakeholders within the sector, is the proactive adoption of strategies and plans by private entities in the energy sector. These initiatives are geared towards fostering digital proficiency and instigating a digital transformation that includes not only the core of these companies but also extends to their customers.

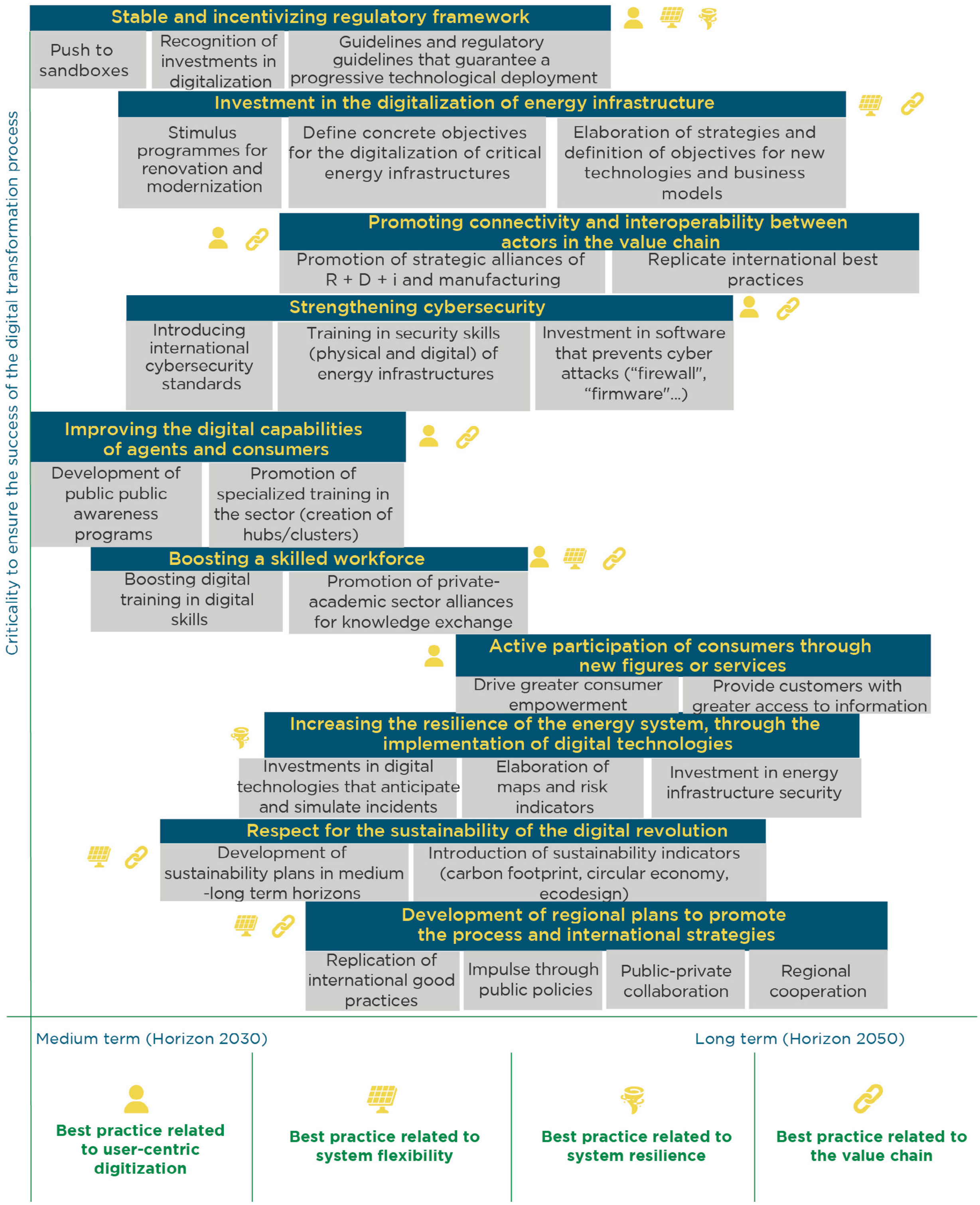
At present, the region reflects a potential for improvement in the **definition of uniform technical indicators and a solid digital culture** that make it difficult to accurately assess progress in the adoption of digital technologies and the promotion of a digital culture in the energy industry. To address these challenges, the **region must invest in the development of digital knowledge and skills in the sector.** In this context, some **limiting factors** highlighted by the agents surveyed for **the advancement of the digital transformation of the sector, in order of relevance, are the lack of a digital culture, ignorance and resistance to change.**

5. Public-private collaboration for digital value chains in the sector . The need for a remarkable deployment of digital technologies to successfully carry out the transformation process, has the potential to catalyze the growth of a more contemporary and sector-specific industry, particularly influencing the evolution of the capital goods manufacturing sector. This endeavor also necessitates considerable private sector investments.

In this regard, regions such as Europe and the United States have introduced cross-sector initiatives aimed at revitalizing industries that were gradually ceding their industrial prowess to other regions.

In particular, the LAC region has important advantages over other regions: **the existence of renewable resources and strategically significant mineral reserves within a region can have far-reaching implications for emerging energy business models.** This dynamic has the potential to yield a beneficial societal impact by way of generating skilled employment opportunities and fostering industrialization.

Nevertheless, it is crucial that **the implementation of these practices follows a gradual and widespread trajectory over the medium and long term.** This approach is essential to fully **unlock the substantial developmental potential** within the energy sector. As demonstrated in the illustration presented in Section 7, **these best practices are organized by their temporal priority and their influence** on digital transformation:



This prospective development is tied to the **technological deployment** and the related functionalities aimed at achieving several key objectives, including, (i) greater user participation in energy markets, enhancing their active involvement, (ii) the cultivation of a more efficient and environmentally friendly energy system, achieved through system flexibility that accommodates the integration of renewable generation technologies, (iii) heightened system security against both natural calamities and cyberattacks, thereby fortifying its overall resilience, and (iv) an augmented value chain with increased significance within Latin American and the Caribbean.

01 Introduction

The **energy transition**, which is happening globally, and its associated emission reduction objectives, **affects the energy sector with great intensity due to its high involvement in the emission of carbon dioxide** into the environment during the stages of energy generation, and in subsequent stages of the value chain. These global goals are largely a consequence of the Paris Agreement, a legally binding treaty signed in 2015 by more than 190 countries, whose main objective is to limit global warming to 2ºC through the reduction of polluting emissions into the atmosphere.

Therefore, the energy sector has been immersed for years in a process of transformation towards new business and management models that are the reflection, among others, of: (i) **technological progress**, applicable to all areas of society, and from which the sector can benefit for the **deployment of digital solutions** and (ii) a profound change in **social consciousness**, which represents a trend towards **more sustainable and decentralized models** in which the user has greater control and information to consolidate itself as another agent in the energy markets.

Figure 1. Main changes in current energy systems. Source: Authors, adapted from the report "Visión FutuRed 2050" (Futured, 2020).

Decarbonization targets are resulting in the **progressive replacement of fossil fuels** by electricity from renewable sources or by other energy sources, such as green hydrogen or other renewable gases. This change at the sectoral level is taking place in a context of electrification of energy consumption.

Although this process of decarbonization of energy production processes and end uses is a **challenge** at the sectoral level, there are also several potential opportunities associated with it. These include the reduction of the LCOE (Levelized Cost of Energy) of renewable generation technologies, which make their deployment more affordable, or processes such as digital transformation, which move the sector towards more efficient energy models.

In this context, it should be noted **that digital transformation is a process that goes beyond** the introduction of advanced technologies, **since it also implies a profound change that covers both** the updating of tools and systems, as **well as the** transformation **of organizational culture and** social interactions in companies and with the rest of the agents.

Similarly, digital transformation is not a one-off, but a **continuous process** that involves the constant evolution of available technologies and does **not have predefined limits.** This process also requires long periods for technological deployment that often result in the coexistence of technologies with different degrees of maturity. The first step to achieve an efficient transformation is to analyze the costs and benefits that technological development will entail, as well as to consider the potential difficulties for its implementation.

From the technological point of view, this process is developed in two areas: (i) the field of **data**, that is, the acquisition of quality information at all points of the network in "real time", from the deployment of **sensing** technologies, which allows the consumer greater interaction with energy systems; and (ii) the scope of decision-making through the **processing of the data**, which uses data analysis methodology, and is executed through the **deployment of actuators and communications that incorporate standardized protocols**[1].

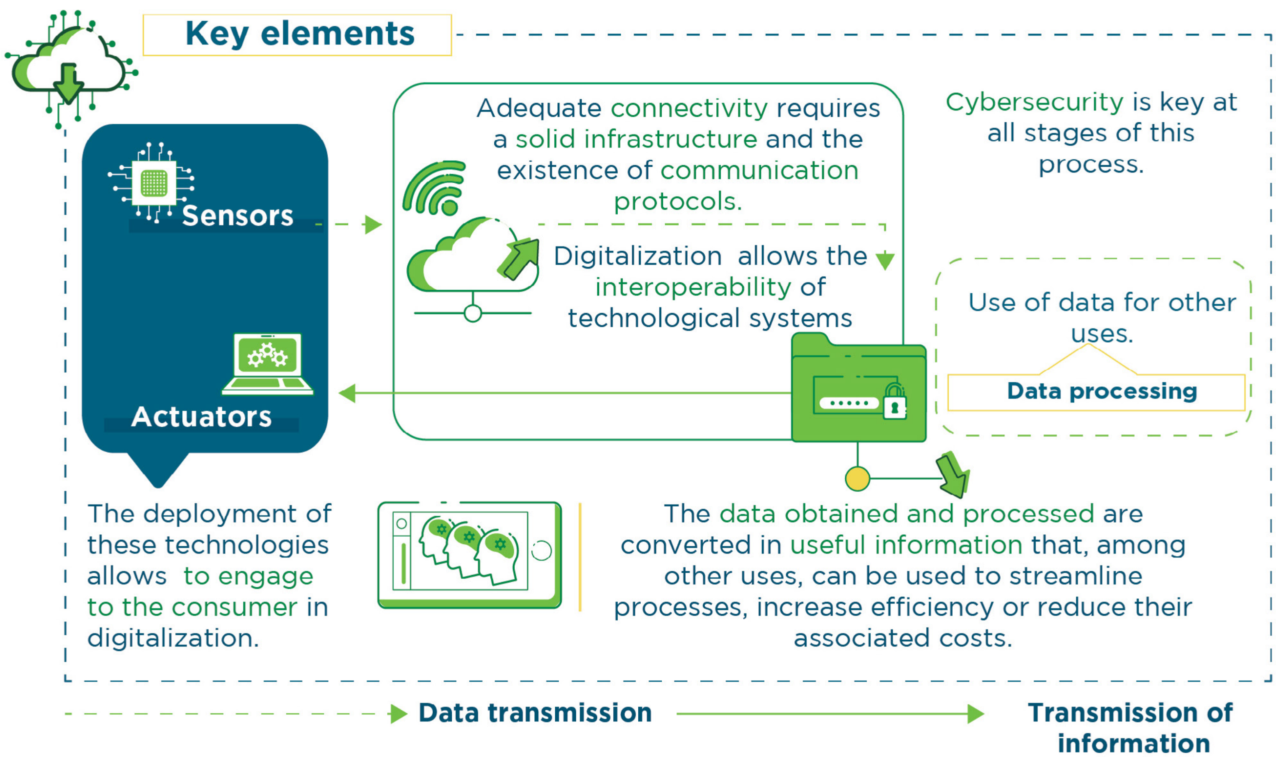


Figure 2. Key elements for the digital transformation of the energy sector. Source: Authors.

The recent digital development of the energy sector is linked to that of information technologies and their constant evolution in recent decades from three concepts: interaction, information, and computing. It should be noted that the beginning of the implementation of these technologies in the energy sector has been variable according to the region and has had an exponential evolution until now, closely linked to the development of the world of telecommunications in all areas of society. In the European Union, the beginning of the deployment started approximately in 2008 when the Commission adopted a European Economic Recovery Plan, which focused on the need to invest in energy efficiency and clean technologies. In this context, the Commission proposed, in the Communication "Investing in tomorrow's Europe today", a package of measures to channel financial support towards energy and high-speed broadband networks. (Deloitte, 2023) (Comisión Europea, 2009)

[1] This chapter "1. Introduction" has been developed based on the knowledge and work experience acquired by the specialists participating in the project.

Undoubtedly, interaction with information technologies has become progressively simpler, intuitive and even immersive. Over the years, the information processed and produced by technology has evolved from mere numerical calculations to predictive analysis, algorithms and Artificial Intelligence that allow decisions based on data. In this context, it should also be noted how the costs of data acquisition and transmission have been progressively reduced.

Regarding the electricity sector, the IEA estimates that digitalization represented a global cost saving of more than 80 billion US dollars per year, or 5% of the total annual costs of power generation. These cost savings are distributed as shown in (International Energy Agency, 2017) **Figure 3.**

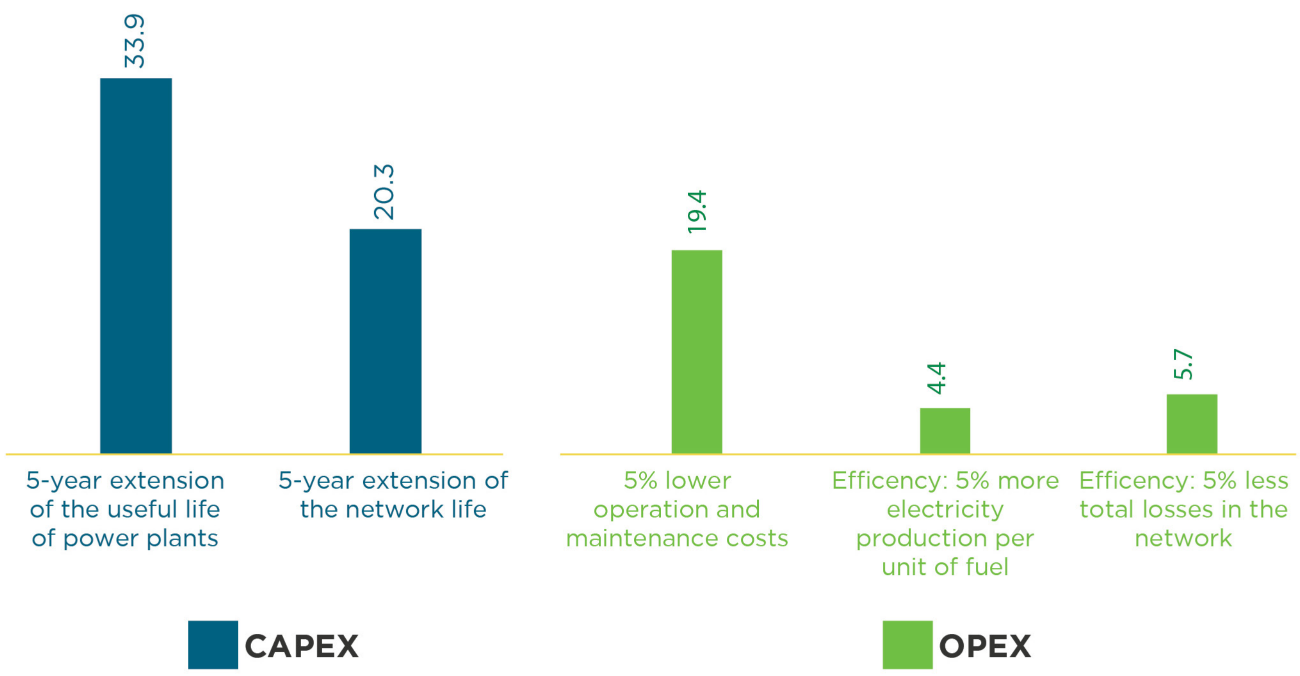


Figure 3. Potential cost savings in the electricity sector, as a result of digitalization, in trillions of US dollars *(International Energy Agency, 2017)*

Additionally, it should be noted that this **necessary** digital transformation is driven by **four basic pillars** that have been the basis of the transformation and modernization of the sector: (i) **a progressive increase in the participation of users** in energy systems, as active agents in the markets, (ii) a **transition towards more sustainable and flexible** energy generation models., (iii) the need for an **energy system resilient** to increasingly extreme natural phenomena and cyber risks, (iv) a **solid and proximity value chain.** For each of these pillars, best practices in the field of digitalization in the countries analyzed have been identified[2]:

[2] This chapter "2.1. Pillars that guarantee the development of digitalization in the sector" has been developed based on the knowledge and work experience acquired by the specialists participating in the project.

User-centered digitalization

User-centered **digitalization** is a key area in the digital transformation process of the sector, motivated by the consumer empowerment that is taking place in the new energy scenario. Currently, the trend in the sector is to move towards a more informed consumer, with the capacity for active participation in energy markets and who demand new services such as self-consumption, electric vehicle charging or advances in energy efficiency in their home. To advance in this, the capture of digital data, its processing and subsequent decision making will be key.

System flexibility to incorporate renewables

The sector increasingly demands **flexibility from the system to incorporate renewable generation** technologies that guarantee the progressive decarbonization of energy systems, through the modernization of energy infrastructures, with the incorporation of digital technologies along the value chain, and the penetration of new energy vectors, such as renewable gases. In this sense, the digital transformation will contribute to eliminating barriers related linked to renewable energy generation, such as intermittency in production or congestion of energy networks.

Resilience of energy systems

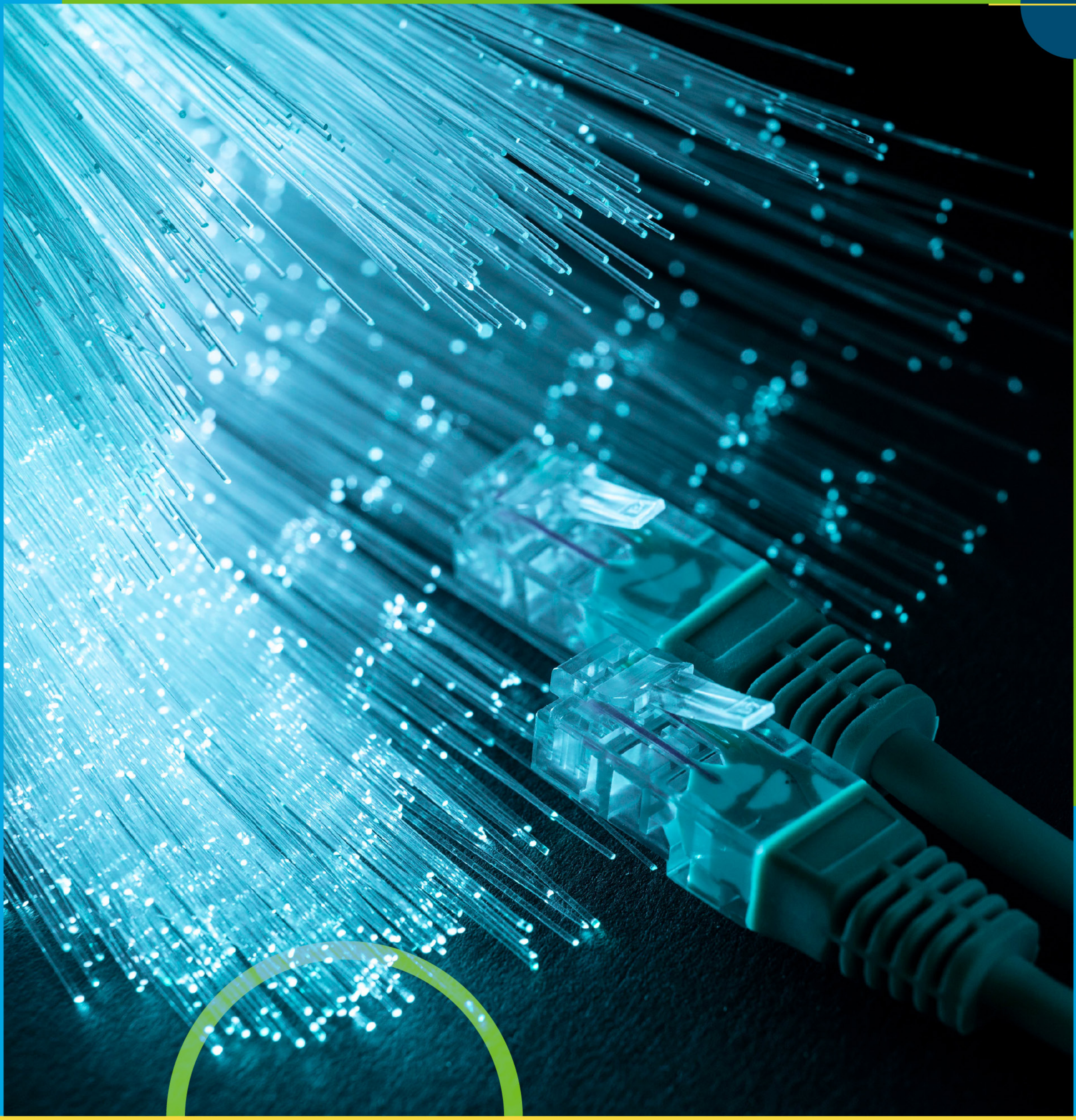
The **resilience** of energy systems is an increasingly critical area for the sector, motivated mainly by the increasing intensity of natural climatic phenomena, which constitute an increasing risk for the energy infrastructure, and additionally, by the digital transformation itself that results in potential cyber risks that can threaten the integrity of the energy system.

Impact on the value chain

Recent events such as COVID-19 or global geopolitical instability have caused a strain on supply chains. Therefore, the success of the digital transformation will also lie in the impact of digitalization along the value chain of the sector, in that, for example, certain processes, such as the supply of digital and technological equipment may be affected, and / or delayed by a strong external industrial dependence.

The digital transformation, focused from these four pillars, provides the energy sector with the tools and technologies necessary to face a series of structural changes, as a result of the ambitious decarbonization objectives and a change in culture, increasingly digital and sustainable.

Therefore, the progressive incorporation of digital technologies under the consideration of these four pillars will be a starting point to progressively achieve the fulfillment of the objectives at the sectoral level. In this sense, the next chapters will analyze which are the most disruptive technologies, an analysis of the best actions in reference countries, and the best practices applicable to promote digital transformation in the LAC region.



02 Technologies for the digitalization of the energy sector

In order to understand the process of digital transformation and the opportunities immersed in the deployment of the different digital technologies available in the market, it is key to know the possibilities offered by each of them. In this sense, there are currently numerous **emerging and disruptive technologies** in the energy sector, which are being progressively implemented, and which cover numerous applications **for the development of the basic pillars of digital transformation.**

The application of disruptive technologies to the four pillars

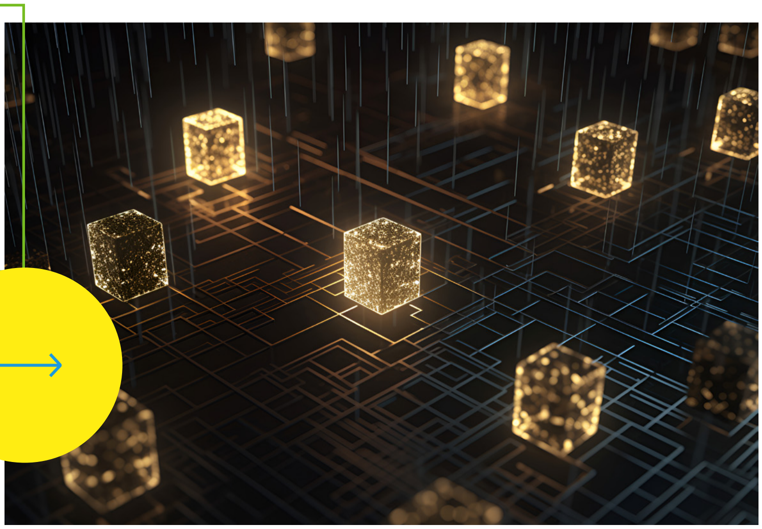
The degree of progress of the digital transformation process and the penetration of cutting-edge digital technologies varies mainly from the maturity of the regulatory framework and the volume of investment in the energy sector of each country, along with other variables that will be detailed in later chapters. In this sense, the most emerging and disruptive technologies are already present in the most advanced and mature energy systems worldwide, giving rise to remarkable benefits for both the agents that develop their activity in the sector, and for consumers. From the point of view of this analysis, it has been considered how these technologies contribute to each of the four pillars of digital transformation.

	User-centered digitalization	System flexibility to incorporate renewables	Resilience of energy systems	Impact on the value chain
Blockchain	●	●	○	●
Big data	●	●	●	○
Cloud computing	●	●	●	○
Sensorization	●	●	●	○
Advanced Metering Infraestructure (AMI) & Smart Meters	●	○	○	○
Artificial Intelligence (AI)	●	●	●	●
Digital Twin	○	●	●	○
Internet of Things (IoT)	●	●	●	●
Robotization	○	●	●	●
Drones	○	●	●	●
Augmented reality	●	●	○	○
5G connection	●	●	●	○
Fiber Optics	●	○	○	○
Edge Computing	○	●	●	○
Cybersecurity	●	●	●	●

Table 1. Classification of innovative emerging technologies in the energy sector. Source: Authors.

The above table, therefore, allows contextualizing the subsequent development and giving a comprehensive vision of the digital transformation of the sector through the deployment of enabling technologies in each pillar. **Appendix A** details the role of each of these and the development possibilities they enable in the energy sector. In addition, the best practices identified for each pillar are closely related to the deployment of the digital technologies reflected.

Having the most advanced technologies allows the sector to develop digital solutions to achieve greater energy efficiency, optimization of resources, a higher quality of supply and innovation in the sector.



03 Main trends in the global energy sector

In order to identify some success stories in countries with a greater degree of progress in digital transformation, as well as their potential replicability, six countries have been selected based on criteria such as:

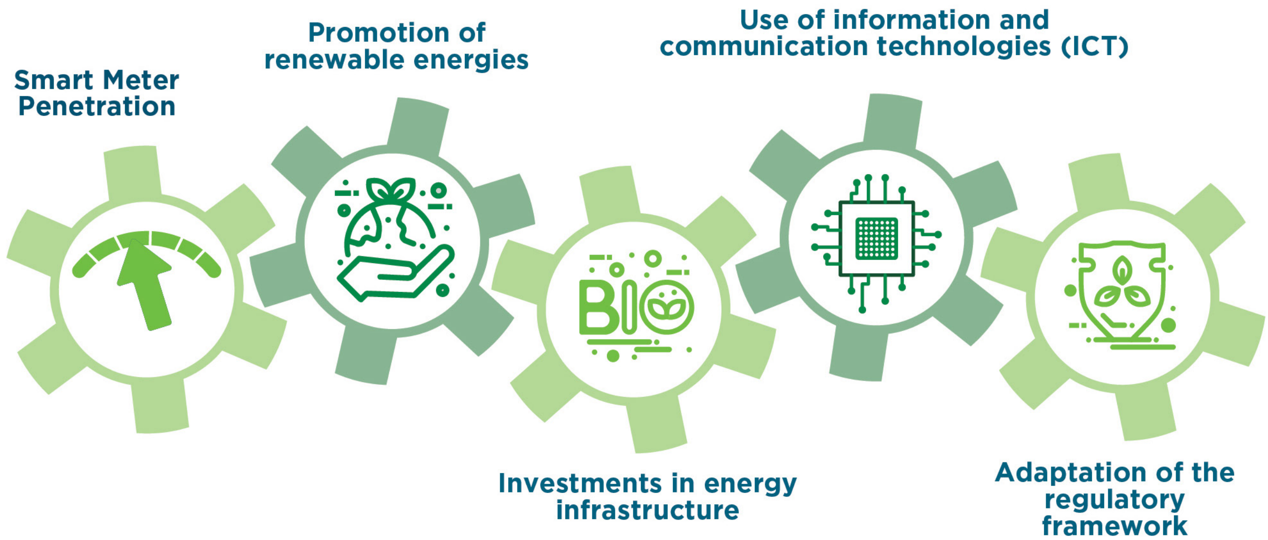


Figure 4. Country selection parameters. Source: Authors.

Degree of Penetration of smart meters: the deployment of smart meters is one of the main digital advances and a key indicator of the degree of digitalization of energy networks since it allows access and use of data from energy consumers to allow optimization in the planning and operation of energy networks.

Promotion of renewable energies: level of deployment of renewable generation technologies, such as solar or wind, and integration of these with energy systems (networks, infrastructures, etc.).

Investments in energy infrastructure: level of investment in the modernization of energy networks. It also includes the assessment of the deployment of investments in automation, and control technologies, as well as the development of smart grids.

Use of emerging digital technologies and information and communication technologies (ICT): assessment of the deployment of innovative technologies in the field of communication and operation of energy networks. It includes the assessment in the development of energy network management software, deployment of cloud tools and data analytics.

Adaptation of the regulatory framework: assessment of the degree of regulatory maturity, with the aim of providing security for infrastructure investments and stimulating investment in the digital modernization of the energy sector.

As a result, the following countries have been selected: United States, Spain, Portugal, Italy, United Kingdom, and South Korea. These countries have experienced significant progress in terms of digital transformation, which will be addressed below, from the perspective of the four defined pillars. Likewise, in **Appendix B** of this document, a greater detail is presented on the analyses and contacts made to the main agents of these countries, private, public, and institutional, universities, research centers and manufacturers.

User-centered digitalization

Digital transformation is enabling the progressive transformation of the energy sector towards a more distributed, intelligent, multidirectional and flexible model, with greater participation of users in their own generation, storage and energy markets, through the figure of the prosumer.

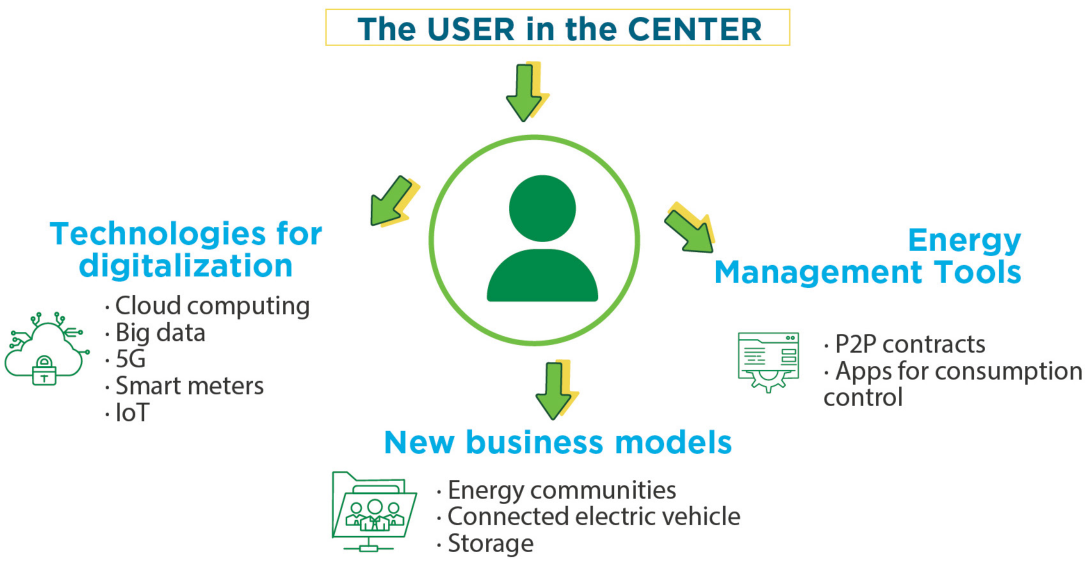


Figure 5. Main trends around user-centered digital transformation. Source: Authors.

In this new scenario, a clear trend has been identified as common in the leading countries in digital transformation: data **collection with the help of digital technology** is a first step to provide intelligence to the elements of energy systems accessible to consumers and enable the development of new business models in energy networks.

Therefore, in this scenario, the deployment of **smart meters** is essential, and is resulting in intense benefits for the system as a whole, in order to have immediate, accessible and reliable data that facilitates decision making by both the client and the Network manager. Likewise, its deployment allows for a more connected, modern, and efficient energy system, and that guarantees the basis for the subsequent development of smart grids or other new business models such as energy efficiency services, highly developed in the United Kingdom.

The effective deployment of this technology in the sector is motivated by factors such as: (i) the existence of an incentivizing regulatory framework; (ii) the development of information technologies that facilitate and integrate the equipment with the rest of the energy infrastructure; (iii) the use of powerful processing tools that ensure the processing and processing of consumption data; and (iv) the development of a resilient technological architecture supported by cloud technologies – cloud computing.

Degree of penetration of smart meters in the electricity sector

Italy, Spain, United Kingdom, United States, Portugal, and South Korea present differences in terms of the degree of implementation of smart meters in their electricity networks. These differences are due, in part, to how they report the data, either in relation to the renovation of the smart meters already installed or the initial implementation of this technology. Despite this, Table 5 shows a comparison of the degree of progress in the deployment of smart meters in each country according to data to 2020 and, below, details how each country has reached its degree of progress in this area:

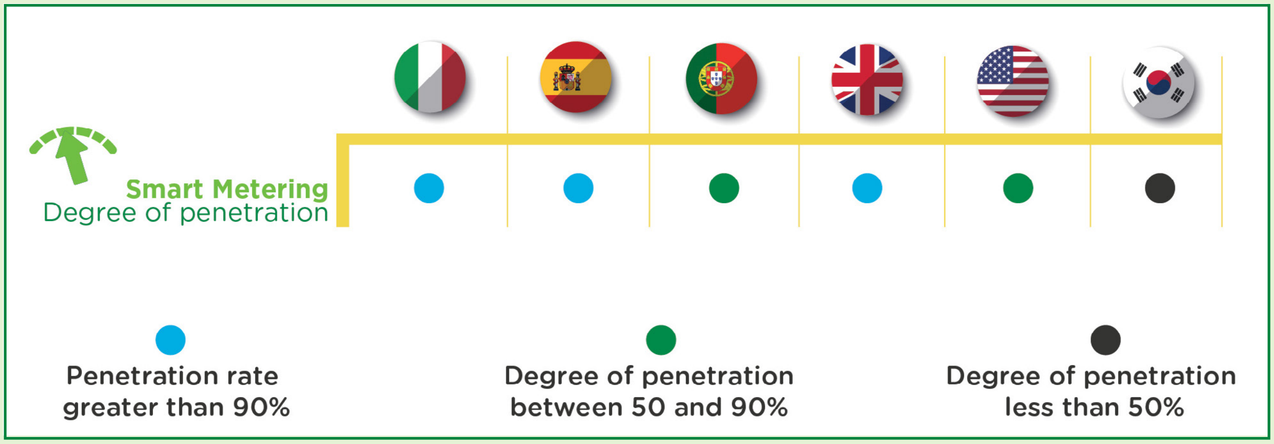


Table 2. Degree of progress of smart metering in selected countries. Source: Authors.

In this regard, **Italy** was the pioneer country in the installation and technology of smart metering. In 2006, it announced its first directive by the regulatory entity (ARERA), which established the mandatory installation of smart meters in the country, with minimum technical characteristics from 2008. This action of the regulator, which had the positive collaboration of the private sector, allowed a successful deployment, reaching a penetration of 95% of digital meters in 2011 – only behind Sweden at European level – with the aim of progressively achieving greater energy savings by making the customer aware of their consumption in real time. By 2025, at least 90% of supply points will need to be equipped with second-generation meters and 96% by 2026. By the end of 2021, about half of 1G meters had already been replaced by 2G meters. Currently, Italy is already planning the third phase of deployment of smart meters, focused on interaction with other network elements, through information systems such as cloud computing. (Eurelectric, 2018) (International Energy Agency, 2023b)

Spain followed the same dynamic. Specifically, Spain began its first wave of replacement of smart meters in 2008 under the Measurement Equipment Replacement Plan promoted by the currently called National Commission of Markets and Competition (regulator) with the aim of achieving almost complete penetration of telemetered and remotely managed meters, a milestone achieved at the end of 2018. Currently, together with Italy, Spain is considered one of the most advanced countries in terms of the digitalization of the sector, since, at the end of 2019, an integration rate of 99.4% had already been achieved. (Comisión Nacional de los Mercados y la Competencia, 2020)

Other European nations, such as **Portugal**, has moderate deployment rates to date. In 2020, the number of smart meters deployed was 2 million - 52% of the total meters. There is a goal by the main energy distribution company to reach an approximate volume of 6.2 million smart meters by 2025. However, in recent years this deployment has been significantly boosted, reaching in 2022, according to E-REDES, more than 4 million smart meters, that is, more than 66% of customers. The Portuguese case exemplifies the importance of modernizing all related infrastructures when implementing digital elements in the energy system. In Portugal, the lack of advances in information transmission systems and connectivity in its energy networks has prevented the widespread adoption of smart meters. This is because the deployment of smart meters must go hand in hand with upgrading or replacing existing electricity infrastructure. (Entidade Reguladora dos Serviços Energéticos, 2020) (International Energy Agency, 2021a)

On the other hand, **United Kingdom** is also lagging in the deployment of smart meters, combining a renewal share of 57%. Although, to combat the low percentage of renewal of the meter park, they have launched disruptive programs of economic incentives for smart meter system projects based on the Internet of Things (IoT). These shock measures, with financing and not only regulation, can produce greater interest from the private sector, and guarantee remarkable levels of success in a short space of time. (UK Department for Energy Security and Net Zero, 2023)

In the case of **United States**, the Smart Grid Investment Grant program economically incentivizes the development of advanced metering solutions and has led to a deployment rate of 69%. (U.S. Energy Information Administration, 2022a)

This program is designed to increase the flexibility, efficiency and reliability of the energy system, with particular attention, in the field of consumption, the integration of distributed renewable capacity, as well as electric vehicles, smart buildings and other devices.

The Smart Grid Investment Grant program is projected to invest up to $3 billion ($600 million a year during fiscal years 2022-2026) in resilience technologies and solutions. (U.S. Department of Energy, 2022a)

Finally, in relation to **South Korea**, its deployment is progressing slowly. In 2019, 8.48 million meters had already been deployed, and the full deployment of 22.5 million meters was expected to occur during 2020 – currently South Korea has approximately 52 million inhabitants. While the deployment project suffered delays as expected in the analyses carried out on the deployment of smart meters & AMI in South Korea, it is currently at a more advanced stage. South Korea has been one of the first Asian countries to deploy initiatives related to smart grids, highlighting its "Smart Grid Initiative", which is mainly aimed at modernizing the country's electric power systems, promoting the development, demonstration, and expansion of smart grid technologies. After that initiative, it has launched others such as the "Law for the Promotion of the Establishment and Use of Smart Grids" to establish the regulatory basis for building a smart grid at the national level. The national smart grid roadmap developed by South Korea has five implementation areas: smart consumer, smart transport, smart renewables, smart grid, and smart electricity services. Alongside this roadmap, KEPCO is developing an advanced power distribution monitoring system to prepare for the variability of renewable generation in the country (International Energy Agency, 2020a).

This analysis reflects that the countries examined consider smart meters as a facilitating instrument for the development of digital transformation through broader concepts that enable new business models in the network that put the user at the center.

Likewise, and as a further degree of progress after the deployment of smart meters, **the development of smart grids is key for the sector.** This must be accompanied by the introduction of technological systems, such as the IoT, and an improvement in intelligent communications and connectivity, introducing technologies such as fiber optics or 5G that allow the **existence of bidirectional flows of electricity** facilitating the development of the energy sector towards new business models that put the user at the center.

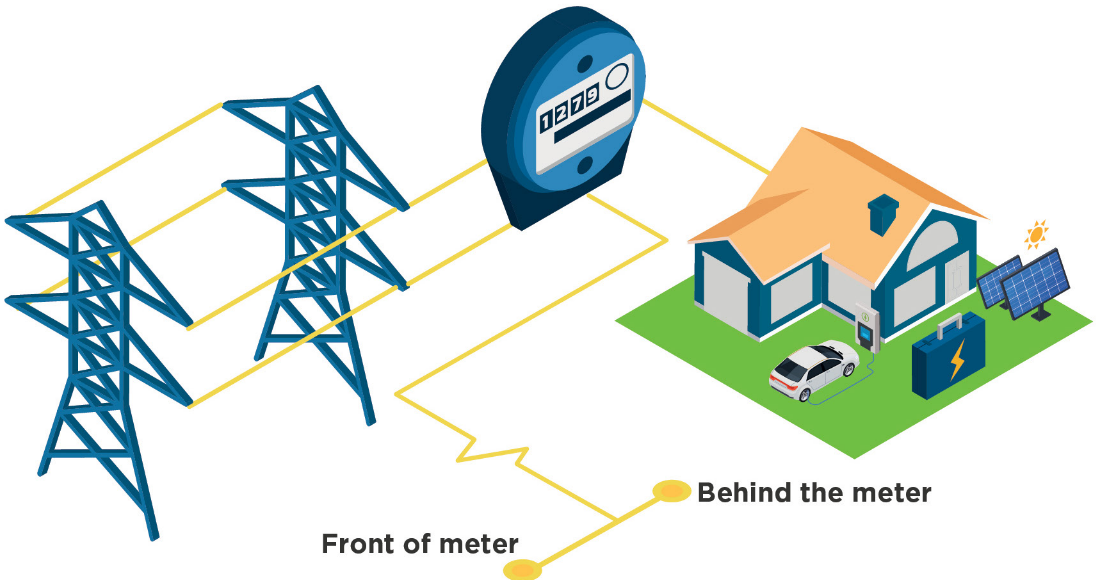


Figure 6. Behind-the-meter business models. Source: Authors.

These **business models**, such as self-consumption, storage or electric mobility, are deployed **behind-the-meter** and are expected to continue growing to meet the ambitious objectives set in the medium and long term, for example, reaching 5 million electric cars by 2030 in Spain. Its deployment gives the user a greater presence and management capacity within the sector and requires, for it to be efficient, the implementation of digital solutions for access, transmission and analysis of data.

In this context, behind-the-meter or submetering consumption management contributes to an improvement in the energy efficiency of facilities (identification of consumption patterns, incorporation of efficiency and energy saving measures, optimal management of installed equipment, etc.) and consumer empowerment. With this, the devices will be completely synchronized and interconnected, and the consumer will be able to decide at any time what actions to take. This is especially relevant in those countries where there is a higher degree of digitalization. Likewise, the availability of detailed information that is enabled thanks to submetering would allow the development of other business models such as microgrids or energy communities in which users exchange energy through P2P (Peer-to-peer) sales.

All these technological developments are not possible without the existence of a **stable regulatory framework that provides security and encourages investment in technological advances and the deployment of new business models.** However, in general, it develops at a slower speed than the sector, creating a barrier to the deployment of digitalization. In this sense, instruments such as sandboxes become important and have a double benefit, for the regulator and for the private sector: (i) on the one hand, it allows companies to have a controlled environment without regulatory barriers to test the validity of their solutions and (ii) on the other hand, it allows the regulator to shorten the deadlines for the development of a regulatory framework, that enables the deployment of technologies and innovation in the sector, thanks to the identification, by companies, of the main regulatory barriers.

With all this, it should be noted that user-centered digitalization has key aspects for its deployment, from the incorporation of technologies that allow access to data, to regulation as an incentive tool for the development of the most innovative and disruptive solutions.

Positive measures of interest identified in other regions

User-centered digitalization, based on the best practices observed in the countries analyzed, is supported by several key points. First, **it promotes the development of plans to implement smart metering and the renewal of existing meters as a starting point for the development of** more relevant concepts for the sector such as smart grids. In addition, a stable regulatory framework is established that provides legal certainty to investors and encourages the financing of digital transformation. The private sector plays a key role in investing in plans that drive the evolution towards an energy model focused on digitalization and the user. To further stimulate this transition, **regulatory and economic incentives are implemented to facilitate the integration of digital solutions and technologies,** thus encouraging the emergence of new business models.

Finally, work is being done to **eliminate obstacles that may limit access and massive analysis of data generated by energy systems.** This is done with a focus on protecting consumer rights and data security, thus ensuring an enabling environment for digitalization in the energy sector.

System flexibility to incorporate renewables

Faced with a social paradigm in which the energy transition is taking on an increasingly important role, plans and strategies, at global and national level, contemplate progressively more and more ambitious objectives in terms of decarbonization.

In this way, the energy mix is in a **process of constant transformation towards a more sustainable mix in which renewable generation technologies are increasingly important**, in line with the objectives of increasing installed capacity by 2030, often covering almost half of the demand with energy from renewable sources in countries such as Spain.

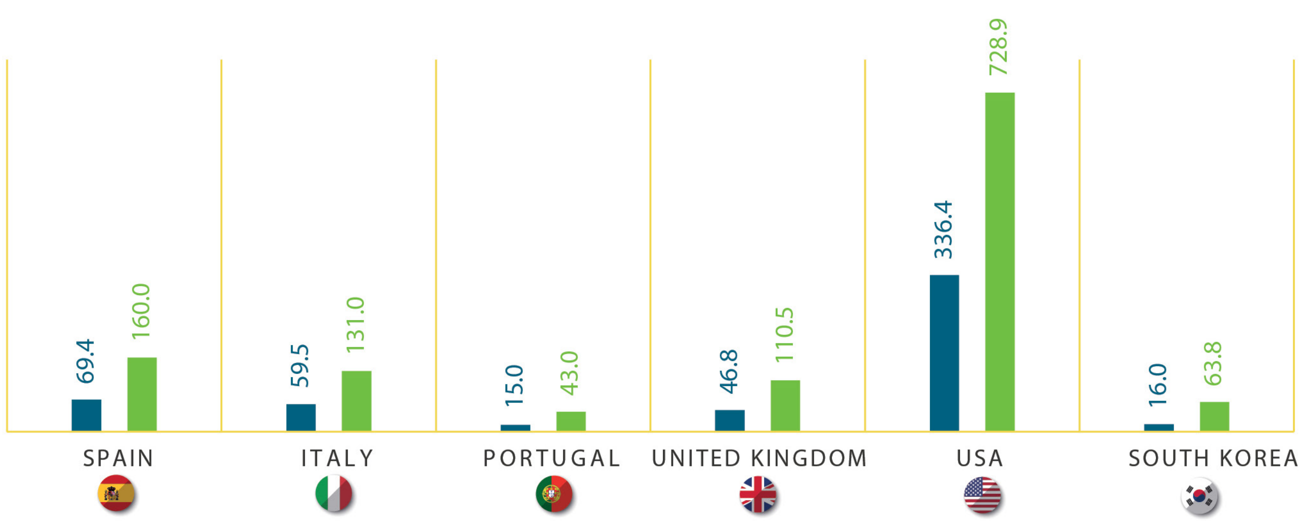


Figure 7. Forecast of renewable capacity to 2030. Source: Authors based on data from the European Commission, REE, Terna, U.K. Government, GlobalData, EIA, EnerData, IEA.

This poses a challenge for energy grids as they have to absorb intermittent and more distributed generation than in traditional generation models. In this context, the **process of digital transformation in the energy sector**, through the use of advanced technologies and intelligent systems, represents a powerful **tool that allows optimizing the generation, distribution and consumption of renewable energy in an efficient and** sustainable way, and limiting the challenges of the integration of generation plants very different from each other (challenge of territorial integration of generation plants in territories far from demand), or concentrated in poles where the renewable resource is greater (challenge of congestion of nodes in energy networks).

The current state of grid flexibility to incorporate renewables

The aspects that define the **current state** of this digital transformation process in the selected countries **are: (i) the deployment of** economic or regulatory incentives **for the development of solutions within the framework of digital transformation**, (ii) the development of **strategies and action plans for digitalization** or (iii) the **implementation of flexibility measures**, among others.

On one hand, in order to have a digitalized network infrastructure with the most innovative technologies, a strong deployment of investments is required, such as the one executed by the **United States** in 2022, where 141 billion dollars have been invested in the energy transition. **Public support, with resources and stimulus policies**, has an **incentive** character to achieve the objectives set.

For all these reasons, it is necessary to establish **regulatory incentive and investment schemes** such as those driven by **Spain and Italy** within its Recovery and Resilience Plans. Specifically, Spain has enabled aid amounting to 525 million euros for digital deployment in energy networks. In the case of Italy, 3,610 million euros have been allocated to improve the reliability, security and flexibility of the national energy system, in order to increase the amount of energy from renewable energy sources to at least 4,000 MW, electrify at least 1,500,000 consumers and open new scenarios in which prosumers, energy consumers-producers can also play an important role, relying on a digital technological deployment and innovative communications included in the Plan itself (fiber optics, 5G etc.) (Gobierno de España, 2021) (Governo Italiano, 2021).

The **Portuguese Government** It is also taking steps to increase the flexibility of the electricity system, such as the deployment of smart grids and pilot projects of dynamic tariffs and demand response market share (International Energy Agency, 2021a).

Thus, the Government of the **United Kingdom**, published in 2021, its first strategy and action plan for the digitalization of the energy sector, which sought through public leadership and collaboration with the sector to develop digital tools and ensure that regulation and policies incentivize its digitization (UK Department for Energy Security and Net Zero, 2021).

Likewise, other countries such as **South Korea** have promoted in previous years programs such as the "Green Deal" or "Digital Deal", which provides for investments worth 30 trillion won, to improve energy infrastructure and production with renewable generation technologies. Also, investments in smart grids, smart metering and technological development are collected. Specifically, the proposed measures include the creation of a big data platform, industrial convergence with 5G networks and the development of Artificial Intelligence in the energy sector (International Energy Agency, 2021). This will help the share of electricity generated from variable renewable sources in Korea to achieve the 2030 and 2040 targets (20% and 30-35% respectively) and therefore requires a resilient and much more flexible electricity system capable of accommodating the growing share of variable and decentralized renewables (International Energy Agency, 2020a).

Therefore, in this scenario, characterized by a more complex operation of energy systems, it is key to have the most advanced and disruptive digital technologies to face their associated challenges. The functionalities of these technologies must cover three areas: the capture of data from the network and its integration into the network, the improvement of communications and the operation, monitoring, decision-making and automation of the same.

The integration **of sensorization technologies** in the sector and their connection through wireless or wired networks of high speed and availability, are essential for **obtaining data from network assets in real time.**

Such sensing technologies in the field of power generation are presented as a valuable resource for the collection of data on the performance of generation assets. This is especially relevant in renewable generation technologies, where their intermittent nature makes their operation more complex, and they also enable data collection in storage systems. Similarly, sensorization is important in improving the efficiency of energy networks, especially in the detection of technical losses and as an aid to the location of energy fraud.

Once the data is captured, technologies such as **cloud computing**, which facilitates **communication and the exchange of information in real time. This leads to faster and more effective decision-making during the operation of energy networks, and other local data processing technologies, such as Edge computing that favors the agility of the operation of the networks**, come into play. Likewise, **5G** connections enable the transmission of information between multiple devices in a fast and agile way between completely decentralized generation resources, as well as between self-consumption and control centers to have an optimal operation of energy networks.

The analysis of these data captured through sensorization implies the need for other technologies, such as **big data**, for the **storage and analysis of a large volume of data** generated during the operation of the energy system. In the field of digitalization of electricity grids, big data has acquired a very high role in recent years as an enabling technology for the massive collection of data in the context of smart grids.

On the other hand, there are a number of technologies that aim to increase the automation of energy systems: **Artificial Intelligence** and the **digital twin.**

In relation to the **Artificial intelligence**, it is worth highlighting its innovative nature and the potential opportunities it offers to the energy sector in the future. Thus, its use is foreseen in future operation of automatic decentralized generation plants, in such a way that through this technology the generation itself can be regulated based on the parameters collected by the sensors enabled in the energy infrastructure and make an adjusted forecast of the demand. Likewise, thanks to the union of Artificial Intelligence with the development of digital twins, simulations of operation and maintenance conditions of these plants can be carried out. Currently, Artificial Intelligence is one of the technologies with the greatest future projection. The market linked to Artificial Intelligence is estimated to grow at an annual rate of approximately 39.4% between the period 2022-2028 (Bloomberg, 2022).

As for **digital twins**, their use is very positive in the early stages of planning and development of the energy system, since their ability to replicate virtually and in real time the parameters of generation and operation of the networks, allows to simulate, predict, and optimize the energy infrastructures as a whole. Although, the use of digital twins implies the deployment of other technologies such as sensors and connectivity tools such as the IoT or technologies such as Artificial Intelligence, with the aim that all data is synchronized between the virtual and real model.

A potential use of digital twins is as a tool for predicting the status of assets, to ensure correct predictive maintenance that avoids failures and interruptions of the energy supply and, therefore, the need to assume higher costs in corrective maintenance tasks.

Positive measures of interest identified in other regions

The increase in installed renewable capacity, as part of efforts to decarbonize the energy sector, **has posed challenges that require digital solutions in the countries analyzed. The need to invest in the modernization and adaptation of energy networks to accommodate the continuous evolution of system operation is emphasized, along with the promotion of pilot tests for innovative solutions aimed at effectively managing decentralized renewable energy, which would contribute to optimizing its integration into the energy system.**

Resilience of energy systems

Energy systems face two key challenges daily in their operation: (i) **the physical integrity of their assets and (ii) the integrity of their connectivity and communications systems.**

The first of the challenges is mainly linked to the challenges posed by the **increase in natural disasters or adverse atmospheric events derived from climate change.** It is increasingly common the existence of heat waves that tend to increase the probability of occurrence of large forest fires, or acute episodes of droughts combined with torrential rains, a consequence of variations in precipitation patterns and changes in temperatures.

All these changes not only generate risks at a general level in society but can also **affect energy systems compromising quality supply.** Thus, by way of example, forest fires can cause irreversible damage to energy networks; hurricanes or high-speed winds can put at risk the integrity of renewable generation facilities, such as photovoltaic plants or wind farms; floods can hinder the development of biomass resources; and droughts can compromise or alter hydroelectric production, especially affecting those countries where this is the majority source of generation.

In this sense, it is necessary **to establish plans to improve resilience** to natural hazards, scaling with technological help, such as with the use of digital twins, in what degree of threat the physical assets of the energy system are. That is why digitalization is necessary to improve factors such as the measurement of hydrology and thus strengthen the resilience of the energy supply.

Climate change impacts

	Temperature changes	Sea level rise	Changes in precipitation patterns	Changes in storm patterns
Implications in the field of energy	• Reduced efficiency of solar panels. • Reduction of the production of thermal power plants due to the limitation of the temperature of the cooling water. • Increased demand for refrigeration.	• Flooding of coastal infrastructure, such as generation, transmission and distribution.	• Reduction of hydroelectric production. • Interruption of supply due to flooding. • Insufficient cooling water.	• Damage to assets - e.g. wind farms, distribution networks. • Economic losses due to power outages.

Figure 8. Challenges of climate change in the field of the energy sector. Source: Authors, adapted from OECD graph – Report “Climate-resilient infrastructure”. *(Organisation for Economic Cooperation and Development, 2018)*

Policies and plans to improve resilience to climate disasters

On the other hand, governments and regulators, with their public policies, can also encourage the development of technologies in the sector. A good example is the National Digital Twin Program (NDTP) of **United Kingdom**, which has entered a new phase in 2023, working closely with industry and academia, aims to centralize national capacity on digital twins, provide an information management framework, to ensure secure and resilient data exchange and effective information management, and coordinate a digital development working group with key actors. (Cambridge University, 2018)

As part of the implementation of the program, in 2021 the Climate Resilience Demonstrator (CReDo) was created, a pioneering digital twin project focused on energy, water, and telecommunications infrastructures. (Digital Twin Hub, 2023)

In addition, Climate change adaptation reports are regularly published in the UK, detailing measures to mitigate the potential risks of climate change for power generators.

Regarding the **United States**, a Roadmap for Resilience in the Energy Sector, or guides to evaluate the potential impact of climate change on the electricity sector has been established through the National Renewable Energy Laboratory.

Other countries, such as **Spain, Portugal, or Italy,** do not yet have any specific guidance generated by public entities in relation to the specific impact of natural phenomena on energy infrastructure, beyond their inclusion in the analysis carried out during the preparation of the Recovery and Resilience Plans within the framework of the Next Generation EU funds.

Likewise, with the progressive integration of digital technologies, such as the IoT, a growing connectivity of devices, and the deployment of technologies such as Big data, cloud computing or Edge computing, which base their operation on the acquisition and analysis of a large volume of data, the threats against energy networks multiply, compromising the confidential information of customers and companies, and even quality supply.

That is why **cybersecurity actions** must be taken in the energy sector that allow private and public agents to detect any alert and cyberthreat. These actions should preferably be developed from public-private collaboration. Key security challenges include:

- **Cybersecurity for renewable energy infrastructures ·** New forms of renewable energy, generally more decentralized in nature, bring with them new cybersecurity challenges. Protection for these new network perimeters is essential.
- **Physical security ·** It is necessary to protect critical infrastructures from cyber threats that can create security problems for employees on site and even for nearby residents. In addition, disruptions in generation, transmission and distribution processes can also make energy unsafe for consumers.
- **Productivity and uptime ·** Cyberattacks on companies in the sector are aimed at causing delays and interruptions in operations, which cause organizations significant financial damage.
- **Operational efficiency ·** The lack of integration between the different coupled security elements, together with architectural fragmentation, increases operational inefficiencies that can delay threat detection, prevention, and response, and even create redundancies in application management or software and hardware licenses, which increase operational expenses.
- **Customer Experience ·** Energy companies now interact with their customer base through a variety of electronic means. Security for electronic communications is critical, as a security breach could expose personal and sensitive customer data.
- **Product integrity ·** Energy companies provide constant and uninterrupted service in particular geographies. Breaches or cyberattacks that cause power outages or downtime must be avoided to provide uninterrupted service to users who rely on these critical infrastructures.
- **Compliance with regulations and technical standards ·** The energy sector is subject to a wide variety of regulations and standards and is usually subject to direct government oversight. While financial penalties for non-compliance can be high, an even higher cost often comes from undermining brand reputation, in the event of non-compliance or service interruption. Organizations must be able to demonstrate compliance with multiple regulations and standards without restaffing strategic initiatives to prepare audit reports.

Cybersecurity strategies and plans are vital to protecting the industry in today's digital landscape. In this sense, the selected countries have developed strategies to face the challenges linked to cyber threats at the national level. However, the energy sector deserves special attention due to its fundamental role in society and its exposure to increasing cyber risks. Of the countries analyzed, only the US has a specific plan to protect the energy sector.

Cybersecurity Strategy

The Italian National Cybersecurity Agency implemented the **Piano di implementazione della Strategia di Cybersicurezza Nazionale 2022-2026** of a crosscutting nature in which the Italian cybersecurity strategy is presented with the aim of planning, coordinating and implementing measures that make the country safe and resilient in the digital domain.
The National Cybersecurity Plan, approved in March 2022, is an initiative of the Government of Spain to protect cyberspace as a vital area to safeguard the rights and freedoms of citizens. It provides numerous actions and an investment of more than 1000 million euros, aiming to implement specific cybersecurity measures in the next three years.
The Portuguese Council of Ministers approved the **National Strategy for Cyberspace Security in 2019**. The objective of this strategy is to strengthen national capacity in cybersecurity and establishes six axes of intervention, which include cyberspace security structure, prevention, education, infrastructure protection, threat response, and national and international cooperation.
The United Kingdom has a government cybersecurity strategy: **Government Cyber Security Strategy 2022-2030.** The government's objective is focused on the management of known vulnerabilities and attack methods. In it, the adoption of good cybersecurity practices is proposed, ensuring that the public organization is prepared for the management of cyber threats, improving the resilience of the country's organizations.
The U.S. Department of Energy has launched the **Clean Energy Cybersecurity AcceleratorTM** (CECA) plan, which drives cyber innovation to defend modern renewable energy technologies against high-priority cybersecurity risks for the energy sector.
The National Security Office of the Republic of Korea includes in its **National Cybersecurity Strategy** that aims to strengthen the security and resilience of the State infrastructure against cyber threats and respond effectively to cyberattacks, while promoting a competitive ecosystem in cybersecurity, balancing the protection of cyberspace with individual rights under the framework of the rule of law and cooperation. international.

Specific Cybersecurity Plans/Strategies for the energy sector

General Cybersecurity Plans/Strategies

Table 3. Cybersecurity strategies in the countries analyzed. Source: Authors, based on data obtained from Agenzia per la Cybersicurezza Nazionale, Departamento Nacional de Seguridad, la Presidência do Conselho de Ministros, Cabinet Office UK Government, U.S. Department of Energy and South Korean Ministry of Science and ICT.

Therefore, cybersecurity applied to the energy sector is an area with development potential in the identified countries and that, without a doubt, needs to be developed to face the challenges derived from technological development in the network.

Positive measures of interest identified in other regions

To address the security and resilience of the energy system, several strategic actions have been identified. First, **it promotes the development of guidelines and recommendations that establish directives to ensure the resilience and integrity of the energy system in the face of natural disasters.** In addition, **the importance of investing in the modernization and digitalization of energy infrastructure is emphasized, which contributes to improving the response capacity and adaptation of the sector to critical situations.**

A key step towards system protection is investing **in the development of virtualization systems,** anticipating scenarios and risks through disruptive technologies. This is complemented by a **preventive approach to cybersecurity, which includes modernizing the communications network architecture and promoting international standards to ensure the security of systems.** Finally, **the public-private collaboration in the creation of specific cybersecurity guides in the energy sector** is highlighted, an approach that further strengthens the security of critical infrastructure in this sector.

Impact on the value chain

The **digital transformation** of the energy sector, to face the ambitious decarbonization objectives set in the sector, has an **impact on its value chain**. Previously, it has been reflected how each pillar of the transformation requires the deployment of different digital and disruptive technologies to enable new functionalities. These, for their proper development and implementation, depend on the existence of a solid value chain for the manufacture of capital goods and digital tools.

The **digitalization of the energy sector is also expected to mobilize a considerable volume** of investment, which the different actors in the value chain can take advantage to attract investment. In this sense, it is considered that **the need to have these disruptive technologies, together with the need to promote the decarbonization** of systems, represents an **opportunity for the deployment of industry in the region.** Similarly, given the current situation of supply chains, the development of proximity industries specialized in digital equipment goods can also contribute to agility in technological deployments and, therefore, to guarantee greater security of supply.

Deployment of reindustrialization strategies applied to the digital transformation of the energy sector

In recent times, as a result of the COVID-19 pandemic and Russia's subsequent invasion of Ukraine, many countries have been affected by a supply chain crisis. This situation has highlighted the need to strengthen local industry and value chains in strategic sectors such as energy.

In this context, the countries analyzed have developed strategies to reindustrialize and reduce their external dependence.

Through the Strategic Projects for Economic Recovery and Transformation, **Spain and Italy** promote measures for the deployment of a solid local industry that allows it to reduce dependence on third countries.

On the other hand, the digital transformation of the energy sector can result in the **transformation of the value chains themselves**, affecting, in one way or another, all phases of the production process. The inclusion of digital technologies throughout the value chain can generate benefits relating, among others, to the management of the supply of raw materials necessary to produce capital goods, to the increase of quality and the reduction of times in the production process itself and to the implementation of channels for effective collaboration between relevant agents of the value chain.

Therefore, the development of local industries specialized in digital equipment goods can contribute to agility in technological deployments and, therefore, to ensure greater security of supply. In turn, the local deployment of value chains for the manufacture of capital goods and other strategic technologies within the energy sector will require the development of **digital capabilities applied to production and** will lead to the **creation of qualified and quality employment** in the region.

Positive measures of interest identified in other regions

To strengthen the participation of local and regional actors in the value chain, several key strategies have been identified. First, it **promotes the creation and promotion of industrial hubs or clusters close to the industrial link** in the value chain and demand, which facilitates collaboration and synergies between local companies. In addition, it advocates the **development of industrial policies that encourage industrial promotion and dynamization.**

To guarantee the participation of regional and local entities, **it seeks to establish strategic alliances with foreign specialized companies, which contribute to the development of a more integrated value chain. Research and training play a crucial role in this process,** with advances in these areas linked to the development of digitalization in the solar sector. Finally, the local value chain is boosted to stimulate job creation in local and regional areas, especially in areas with demographic challenges, thus fostering investment and economic growth in those areas.

04 Current state of digital transformation in the region

In the context of the **digital transformation of the energy sector**, the LAC region presents a heterogeneous degree of progress, motivated, among other factors, by the differences between countries, regarding their **economic development**. In general, a higher economic level of a country could translate into a change in priorities at the sectoral level that affect the capacity to invest in innovation. However, the common priorities and concerns identified by the main actors in the energy sector are:

Latin America and the Caribbean

Priorities
- Renewable energies
- Energy efficiency
- Demand traction
- Urban design
- Access to quality energy

Concerns
- Economic growth
- Product prices
- Climate change management
- Investment promotion
- Market design

Figure 9. Priorities and concerns of Latin America and the Caribbean of the leaders of the energy sector in the region. Source: Authors, adapted from the report "World Energy Issues Monitor 2022" *(World Energy Council, 2022)*

These priorities of the energy sector in the region are closely linked to the objectives of developing **renewable energies** and **access to quality energy**, but also to others such as increasing **energy efficiency** or traction **of energy demand**, which is expected to be greater as new business models are developed within the sector.

In this context, and as has been developed previously, the **deployment of disruptive and emerging technologies** allows us to address these priorities, guaranteeing the availability of energy to meet the demand of all consumers, ensuring access and basic, quality, and continuous energy supply to the entire population considering, in the same dimension, environmental challenges as one of the main challenges facing the countries of Latin America and the Caribbean. However, its effective implementation in energy systems is conditioned by a series of factors such as: **spending on R+D**, which favors innovation in the sector and its digital transformation; having **human capital with digital skills** to achieve an effective integration of these technologies and the use of their full potential; ensuring the existence of an **incentive** regulatory framework investment and development of digital solutions and, finally, sufficient incentives to **encourage private investment**.

Therefore, and in order to evaluate the current state of the region, in terms of its degree of progress in the process of digital transformation, a selection of countries of special interest has been made in the four basic pillars: (i) user-centered digitalization, (ii) the flexibility of the system to integrate renewables, (iii) the resilience of energy systems and (iv) the impact on the value chain. Specifically, the selected countries are the following:

Figure 10. Countries selected to assess the current state of digital transformation in the LAC region. Source: Authors.

User-centered digitalization

Digital transformation includes the development of new business models and digital tools for managing consumer data, which place the user at the center, so that they go from being mere consumers, to becoming, potentially, active participant in energy markets.

A first step in analyzing the deployment of digital technologies in energy networks is to identify the **degree of electrification of the energy sector**. This is mainly due to three reasons: firstly, it follows that in a country with a low degree of physical access to electricity, investing in digitalization is not considered a priority; secondly, the electrification of energy uses is seen as a vector for the decarbonization of energy systems; Finally, the digital technologies deployed seek to have a positive impact on consumers, which can only be guaranteed by having a resilient, continuous and stable energy supply.

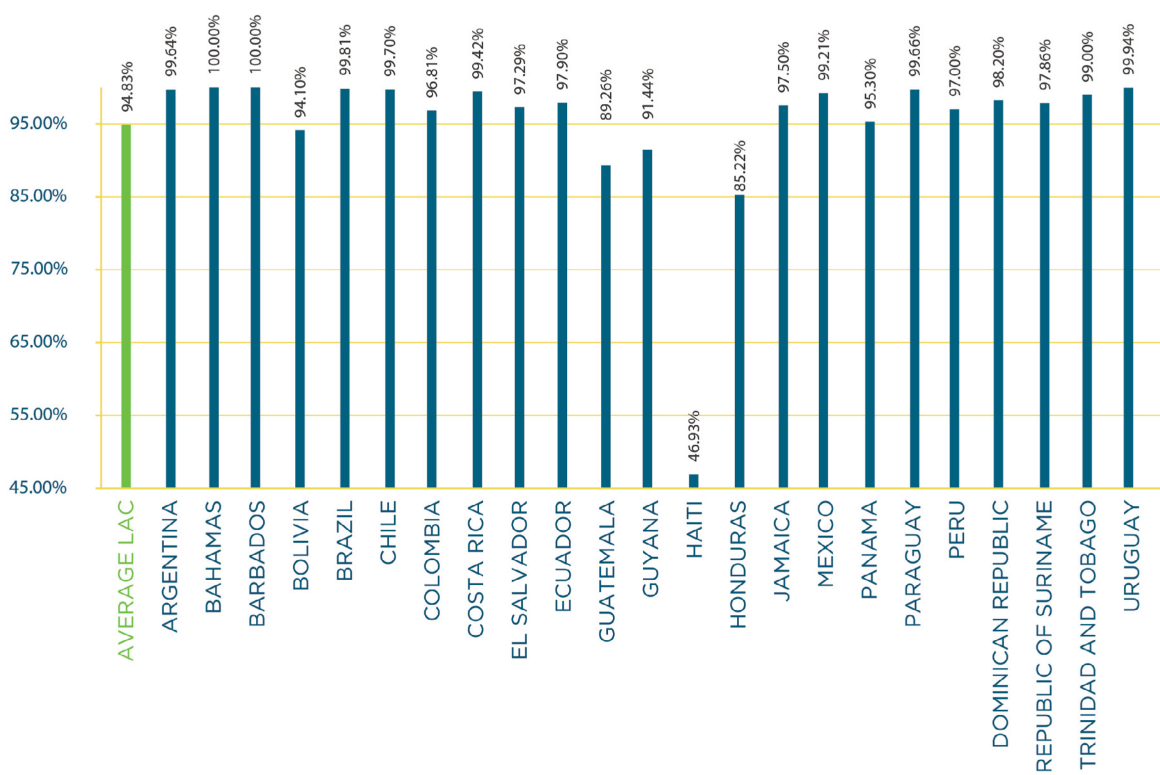


Figure 11. Electrification rate by country. Source: Authors, based on data from the Report "Energy Panorama of Latin America and the Caribbean 2022". *(OLADE, sieLAC, 2022)*

However, the basic pillar for the start of digital deployment in the energy sector in the region is the **incorporation of smart meters**, which is positioned as the starting point of the sectoral technological transformation. Currently, the region is in a process of integration of smart meters that is globally incipient, as reflected in the following graph: (ADELAT, 2022)

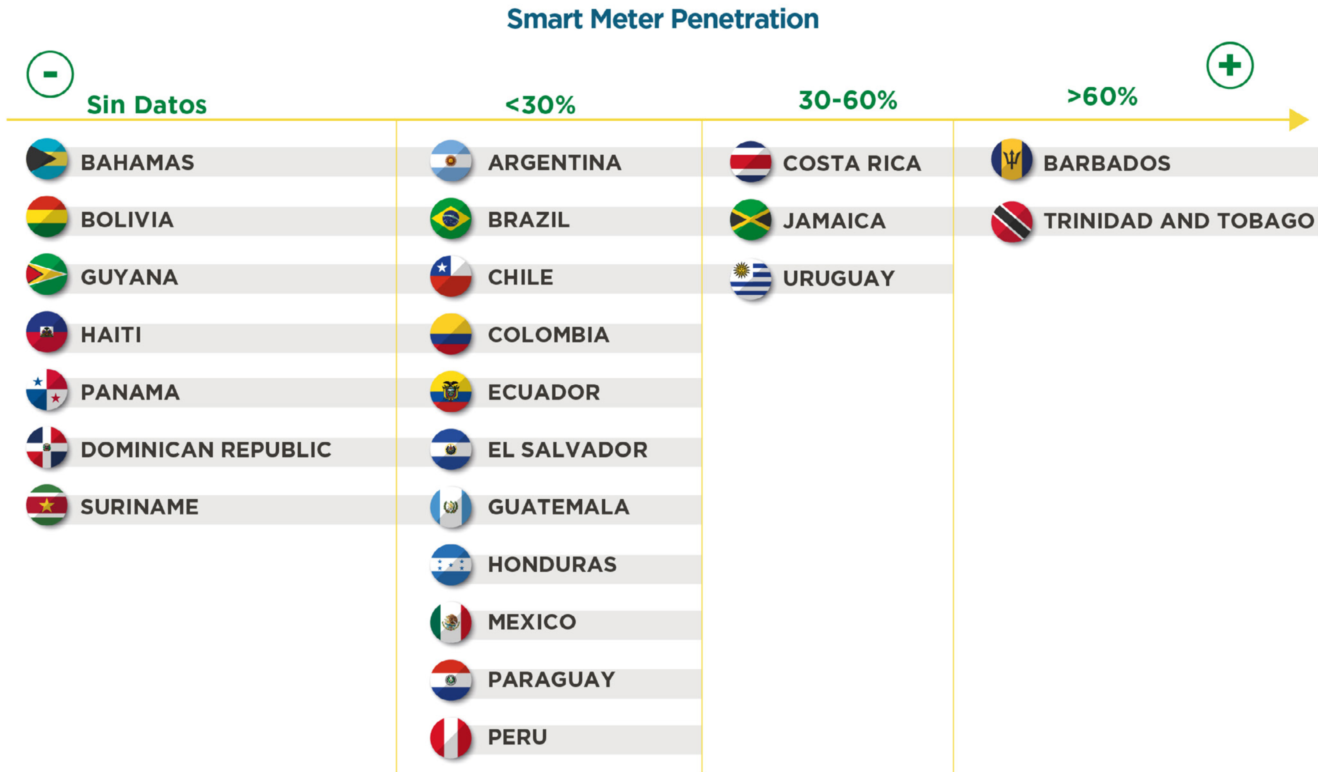


Figure 12. Penetration intervals of smart meters in the different countries of the region. Source: Authors, based on data from the report “smart metering in Latin America and the Caribbean”. *(Banco Interamericano de Desarrollo, 2023)*

In general, and according to the report on “Smart metering in Latin America and the Caribbean”, a higher percentage of deployment of smart meters would be related to the existence of national strategies and specific objectives. Data collection, through smart meters, also favors the development of other user-centered business models such as (i) **distributed generation and self-consumption**, (ii) **the integration of the electric vehicle** or (iii) **the development of local energy communities**, among others.

i. With regard to **distributed generation,** the need for the region to **diversify its sources of renewable generation**, traditionally and mainly linked to the availability of water resources, has recently been highlighted (in 2021 it was the energy source with the highest installed capacity of electricity generation in the region – 41.45% of the total – and also the source with the highest percentage of electricity generation – 42, 8% of the total-), **relying on existing renewable resources**. Thus, decentralized generation through self-consumption or the promotion of energy communities will help the region meet its climate objectives and reduce energy poverty throughout its territory.

In this line, and to achieve a greater deployment of renewable generation in the coming years, the **Strategy for a more renewable Latin America and the Caribbean** puts at the center the priority of introducing other renewable energy sources – especially wind, solar photovoltaic, biomass and geothermal – taking advantage of existing natural resources and diversifying the renewable origin of energy. Likewise, it is committed to distributed generation as a vector to accelerate the energy transition and, in turn, enable access to the electricity grid to all users who, until now, did not have it. (Organización Latinoamericana de la Energía, 2023).

ii.

Another of the electrical uses that places the user at the center is the **deployment of the electric vehicle** and all the electrical infrastructure that surrounds it. The countries in the region in which more electric and plug-in hybrid vehicles were marketed in recent years are Mexico, Colombia, or Brazil. However, the total figure in the region is clearly lower than in other regions such as Europe, China, or the United States.

Despite this, the region has the opportunity to develop electric vehicle value chains thanks to the availability of lithium resources for batteries, in countries such as Argentina, Bolivia and Chile, and the automotive industry present in Mexico and Brazil, among others. This would create opportunities to generate additional value in the manufacturing sector, for example, batteries. (Banco Interamericano de Desarrollo, 2019)

Other countries such as Jamaica or the Bahamas that are also developing mobility strategies, will see their deployments boosted if they manage to link them to other digital technological developments.

iii.

Finally, a solution that could combine self-consumption and electric vehicle charging infrastructure, among other business models, **is the deployment of energy communities or energy cooperatives**, which are increasingly gaining weight in the countries of the region, since, through public support and access to financing, it is considered an alternative for access to energy for low-income households. Likewise, the concept of Energy Community implies the coexistence of new integrated energy services through digital technologies that allow the management of energy flows. The countries of the region that have implemented energy community initiatives are Argentina, Brazil, Chile, Colombia, and Uruguay.

Country	First initiatives	Programs and projects for the implementation of energy communities
ARGENTINA	2016	Renewable Energy Project (PRIER) Potential for the implementation of sustainable energy communities in the province of Córdova, Argentina
BRAZIL	2015	RevuSolar Project
CHILE	2015	Energy Commune Program
COLOMBIA	2019	Transactive Energy Initiative in Colombia
URUGUAY	2017	Energy Communes Program

Figure 13. Pioneering countries in the development of initiatives for the deployment of energy communities. Source: Authors based on national and sectoral information.

These countries are pioneers in the development of initiatives for the deployment of energy communities in the region. However, it is worth highlighting the case of Colombia, through models such as the sale of Peer-to-peer energy

This whole process **of introducing new forms of generation and new business models in the** energy sector, such as those exemplified in the chapter, requires the **deployment of enabling technologies for digitalization, which favor its efficient integration**. The countries of the region that are considered most up to date in terms of the deployment of technologies such as the IoT, cloud computing, 5G or fiber optics, are, among others: Brazil, Chile, and Uruguay.

- The most outstanding milestone in the Uruguayan technological panorama is the launch of the first 5G network in Latin America. In addition, it is the largest exporter of software per capita in Latin America given its early development in Information and Communication Technologies (ICT). (Uruguay Presidencia, 2019)

- In the case of Brazil, it should be noted that, in 2020, the ICT market grew by 12.2% – different from the world average, which fell by 0.3% – and in 2021, the growth was 7% – in the world the growth was 5.4% -, considering the software, IT services, telecommunications and *hardware* (Ministério da Ciência, Tecnologia e Inovação, Softex, 2022).

- Finally, Chile has a vision for the future that includes the improvement of the data infrastructure, through the implementation of 5G technology, which is compatible with a foreseeable increase in storage capacity and contracted data processing capacity. For this, the use of cloud computing is also contemplated to integrate, for subsequent analysis, the data of all the buildings that are part of the same district. (Comisión de Transportes y Telecomunicaciones del Senado de Chile, 2023)

Opportunities for the region in terms of user-centered digitalization

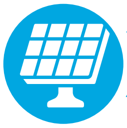
The region presents great opportunities for the development of user-centric digitalization based on a broad deployment of disruptive and emerging digital technologies in the energy sector.

Enable energy access to the population of LAC through electrification and the development of electricity networks in territories that currently do not have access to energy services.

Empower consumers by allowing them to participate more actively in the management of their energy consumption and, in turn, enabling the possibility of deploying decentralized self-consumption.

Promote new services demanded by users, such as the electric vehicle or energy communities, and facilitate access to information on their consumption through technological devices.

Reduce energy poverty, not only by ensuring physical access to electricity, but also its cost affordability and quality of supply.



System flexibility to incorporate renewables

The energy transition is increasingly present in Latin America and the Caribbean, as a large number of countries, in the region, are incorporating these priorities into their energy policy, to achieve resilient and sustainable energy systems. In this sense, **a commitment to renewable generation, diversified in terms of technologies and decentralized throughout the territory, is of vital importance.**

Although, currently, it is one of the regions of the world with the greatest capacity and production of renewable energy, this is fundamentally linked to the presence of hydroelectric generation technologies. However, the **countries of Latin America and the Caribbean present very significant differences regarding the incorporation of new renewable generation capacity.** This is mainly due to historical differences, both in the energy sector and, in many cases, in the economic, political, and even institutional; but the main reason is whether the country is or has been an importer or producer of hydrocarbons (OLADE, 2023).

LAC installed capacity (MW)

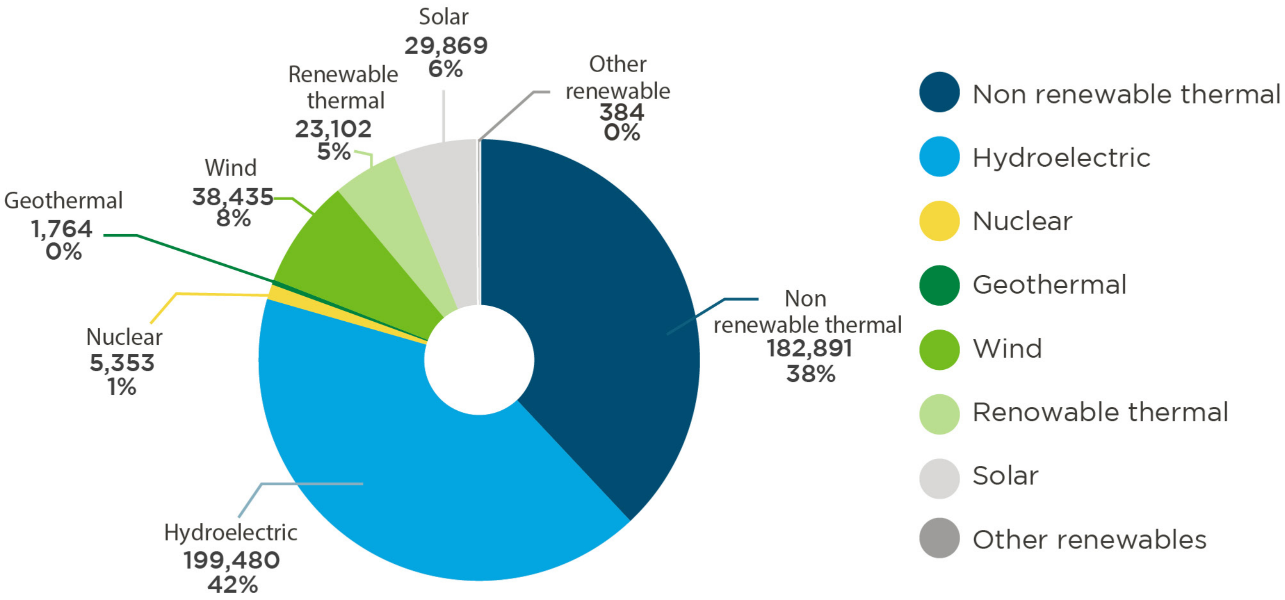


Figure 14. Installed Capacity in the region (2021). Source: Authors based on data from the Energy Outlook Report for Latin America and the Caribbean 2022. *(OLADE, sieLAC, 2022)*

All this is linked to the availability in the region of one of the largest wind and solar resources worldwide, which, although currently underexploited, could favor the achievement of an increasingly renewable generation matrix. As an example, areas such as the Chilean Atacama region have the most intense levels of sunlight on the planet, assuming, therefore, areas of interest for the development of renewable projects. Likewise, other countries such as Guyana, traditionally linked to the production of oil & gas, have set ambitious goals of generating 100% of their electricity from renewable sources by 2025, thanks to the fact that they have abundant solar, wind and hydroelectric resources (American Metereological Society, 2023) (CARILEC, 2023).

Thus, the region is seeking the progressive diversification of its sources of generation, the attraction of new investments in this area, and the consequent reduction of costs. Although this diversification will have different speeds, based on the current starting level of the renewable capacity that each country has in the region (see following figures, information related to the year 2021).

Installed capacity in the region - Countries with largest renewable deployment (GW)

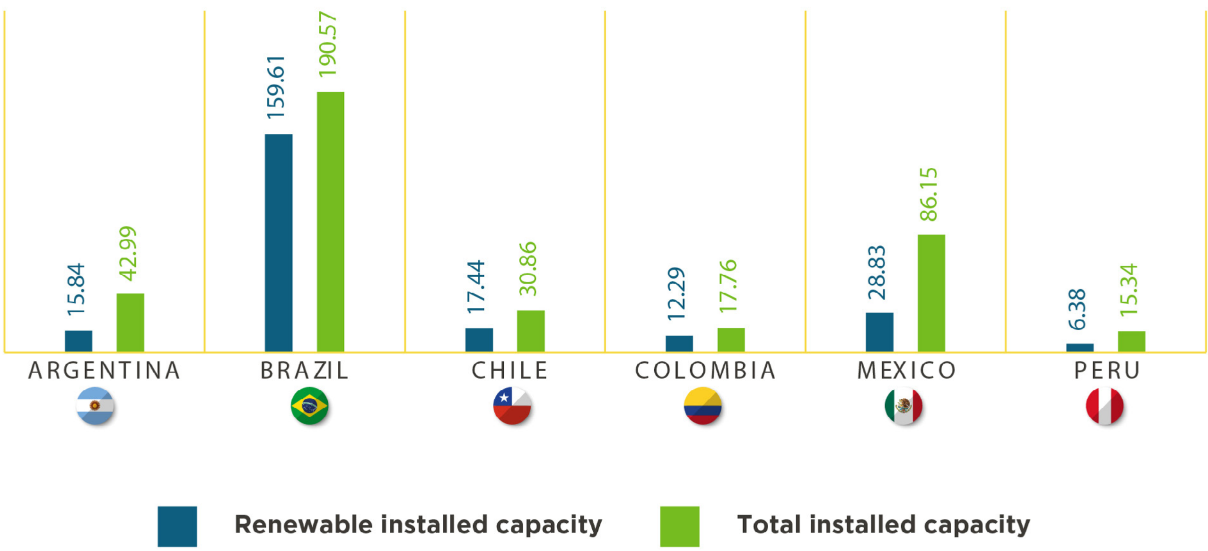


Figure 15. Installed electricity generation capacity in the region - Countries with the highest renewable deployment (GW) *(Hub de energía, 2021)*

Installed capacity in the region - Countries with more moderate renewable deployment (GW)

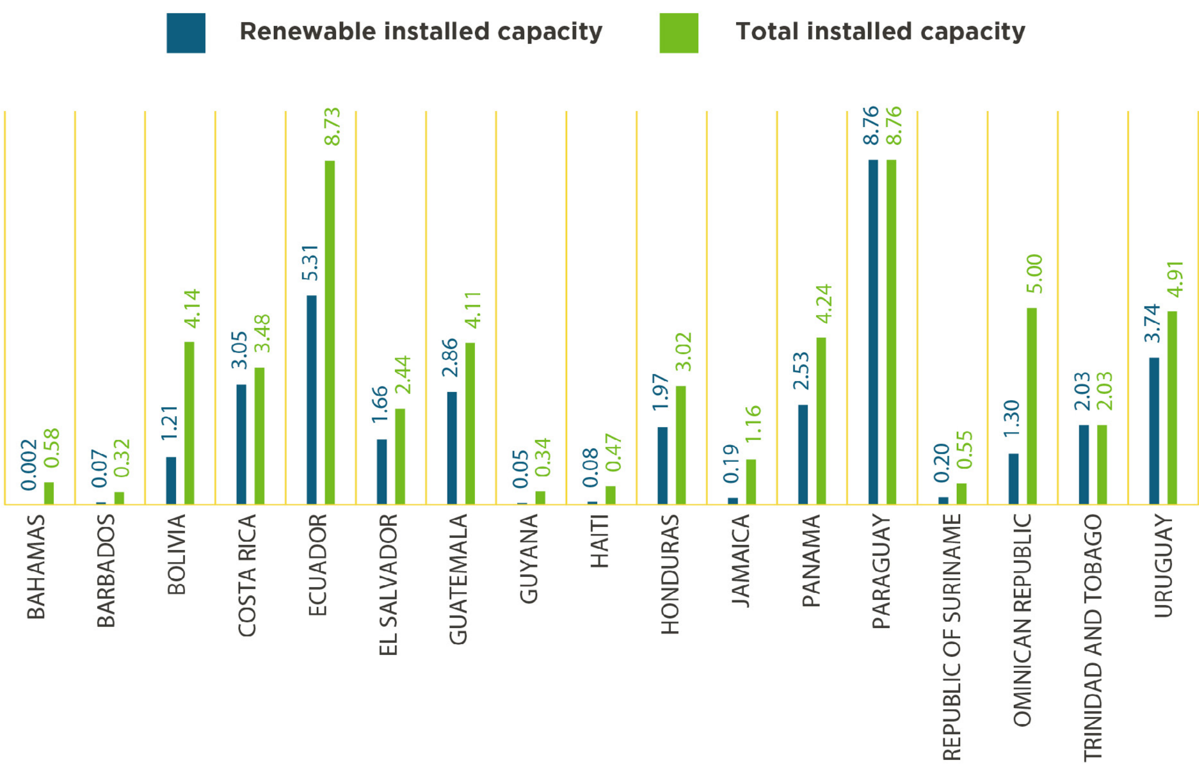


Figure 16. Installed electricity generation capacity in the region - Countries with more moderate renewable deployment (GW) (Energy Hub, 2021) (Macro Data, 2021)

The development of decentralized generation technologies could mean important advances in giving energy access to population centers that do not yet have it. According to an IDB publication, despite the great progress that the region has made, 18.5 million people do not have access to electricity - 4.5 million homes without electricity supply - especially in rural areas. And, therefore, approximately 25 billion dollars would be required to achieve universal access in 2030 in the region (Hub de Energía, 2022) (Banco Interamericano de Desarrollo, 2022).

It is considered that the digital transformation could represent opportunities to advance in the integration of renewables in the LAC energy system and reduce this share of population without electricity supply and that, likewise, it can serve to modernize hydroelectric generation, which has a high presence in the region, to give greater margin to the integration of other renewable sources.

Recommendations to make the energy system in the Region more flexible

- Investment in intrinsically flexible and decentralized generation technologies.
- Modernization of energy networks, through the incorporation of automation and sensorization technologies, which limit congestion and interruptions.
- Investment in control centers that incorporate disruptive technologies, and that guarantee the continuity of the energy supply.
- Incorporation of energy storage systems through batteries, taking advantage of the endogenous mineral resources of the region, and the use of the hydroelectric capacity of the region for large-scale storage.
- Public energy policies that align the objectives of the ecological transition (incorporation of renewables) with the digital transformation.
- Modernization of the rules of the energy markets, as well as creation of internal energy markets in the region.
- Enabling digital transformation through the progressive incorporation of emerging communication technologies (fiber optics, 5G, etc.).
- Promotion of regional integration through the development of common solutions that allow a greater degree of connectivity and flexibility of the system.

Resilience of energy systems

As mentioned in previous chapters, energy **resilience** aims to develop robust energy systems by **preserving the physical integrity of assets in the face of natural disasters**, frequent in some areas of the region, **and safeguarding connectivity and communication systems against potential cyber-attacks.**, increasingly frequent in a context of digitalization of global economic systems.

Globally, extreme natural disasters – earthquakes, hurricanes, tsunamis, volcanic eruptions, tornadoes, and floods – displace millions of people, push many into poverty and claim the lives of thousands. Likewise, they usually trigger a chain of adverse consequences that compromise the integrity and functionality of energy facilities, compromising access to basic services such as electricity or communication. All this has an impact on the economy of approximately 520 billion dollars annually. (TelefónicaTech, 2019)

On the other hand, in 2021, the costs of cyberattacks already amounted to 6,000 billion dollars to organizations in the world, which represents a very relevant economic volume. A large part of cyberattacks are aimed at critical sectors, such as the banking or energy sectors. (IEBS Business School, 2021)

Examples of how the deployment of digitalization technologies in the energy sector has facilitated the prevention of cyberattacks or the minimization of damage following a natural disaster, among others, is illustrated below.

State of the art of the LAC region in the field of resilience

The countries of the region, due to their geographical location, are especially vulnerable to certain climatic phenomena, especially those located in the Caribbean region. This poses a serious threat to the physical assets that are an integral part of the energy system.

In addition, as can be seen in the State of the Climate Report in Latin America and the Caribbean 2022, the increase in exposure to natural disasters derived from sea level rise, droughts or forest fires, among others, is evident. Specifically, it specifies as causes of the increase in this exposure: (Organización Meterológica Mundial, 2023)

- **Sea level rise** at a higher rate in the South Atlantic and subtropical North Atlantic, compared to the global average, endangering inland coastal areas and several countries in the region.
- **Tropical storms,** which have caused significant damage, causing large economic losses and landslides caused by extreme rainfall, causing hundreds of fatalities in the region.
- **Extremely high temperatures and drought conditions,** coupled with low air humidity, have led to unprecedented wildfire seasons in countries in the region.

To provide an agile response to these disasters and minimize the impact they may have on the continuity of energy supply, it is advisable to establish guides and guidelines that guarantee the alignment of actions by all agents involved in the value chain, together with specific contingency plans for the replacement of service in critical infrastructures.

In this regard, Chile, Mexico, Guatemala, and Colombia have developed national strategies and policies aimed at establishing the aforementioned guidelines and minimizing risks in the face of natural disasters, among others.

Chile

National Policy for Disaster Risk Reduction

This policy, within the National Strategic Plan 2020-2030 of the Government of Chile, has five strategic actions to reduce disaster risk:

1. Understanding disaster risk
2. Strengthening disaster risk governance
3. Planning and investing in disaster risk reduction for resilience
4. Provide an efficient and effective response
5. Fostering a sustainable recovery

The approach contained in these actions is beneficial for the security and resilience of the country against possible adverse events. (Ministerio del Interior y Seguridad Pública Gobierno de Chile, 2020)

Mexico

CFE Strategy for the Hurricane Season

In March 2023, the Federal Electricity Commission (CFE) of Mexico, presented a strategy that involves more than 17 thousand workers in its National Hurricane Meeting.

To face the 2023 hurricane season, the focus is to address emergencies caused by weather phenomena and ensure the recovery of electricity supply for its 47 million customers. (Comisión Federal de Electricidad, 2023)

Guatemala

National Response Plan

The National Coordinator for the Reduction of Natural or Provoked Disasters (CONRED) includes in its plan the objective of coordinating actions between government agencies, public and private entities, and organizations in Guatemala for an effective response to natural, technological or health disasters. It seeks to save lives, protect property, and reduce the impact on the population. It also reduces duplication of efforts, establishes coordination mechanisms, and standardizes protocols for comprehensive emergency and disaster management, in addition to strengthening information management throughout the country. (Coordinadora Nacional para la Reducción de Desastres Naturales o Provocados, 2022)

Colombia

National Disaster Risk Management Plan

The National Disaster Risk Management Unit (UNGRD) updated in 2022 the plan that aims to: (i) improve the understanding of disaster risk in the country, (ii) prevent the creation of new risk conditions in territorial development, (iii) reduce existing risk conditions, (iv) ensure an efficient response to disasters, and (v) strengthen governance, education and social communication in risk management, considering differential, gender and cultural approaches. (Unidad Nacional para la Gestión del Riesgo de Desastres, 2022)

Recommendations to achieve a more resilient energy system in the face of natural disasters and cyberattacks in the region

- Establishment of specific guides and guidelines for the energy sector that guarantee the alignment of actions by all agents involved in the value chain, together with contingency plans for the replacement of service in critical infrastructures.
- Investment for the integration of digitalization technologies in energy systems, which allow preventing, detecting and reducing impacts, as well as facilitating recovery after a climate disaster.
- Development of cybersecurity plans and strategies at the sector level, referring to specific measures that allow the agile response capacity against cyber attacks, the safeguarding of critical infrastructure, and the management and protection of assets and data, among others.
- Promotion of public-private collaboration to achieve the effective deployment of cybersecurity solutions, which minimize the risks associated with the integration of digitalization in the energy sector.

Impact on the value chain

The value chain of the energy sector ranges from obtaining raw materials for the manufacture of electrical components to energy generation, distribution, marketing, and energy services provided.

Thus, digital transformation can lead to the emergence of new business models, linked for example to production chains of innovative technological developments, which allow the investment made by other areas of the value chain such as energy companies to fall on promoting an industry specialized in cutting-edge technologies.

In this sense, the region presents a series of challenges and opportunities to boost the sectoral value chain. The need for integrated markets, which unify trade policies and promote free trade agreements, or the promotion of the relocation of the industry are key to ensuring a strengthening and improvement of the resilience of the value chain.

Opportunities for the region derived from digital transformation

The region, whose productive fabric and value chain have a high dependence on foreign markets, can work in its integration and gain strength as an industrialized region. It should be noted that the main causes that gave rise to the existence of an underdeveloped productive fabric and value chain were: (i) its large territorial extension, (ii) its complex geography, (iii) the existing transport infrastructure, (iv) the institutional fragmentation of its market and, finally, (v) its specialization as an exporting region of basic raw materials. (Organización para la Cooperación y el Desarrollo Económicos, 2021)

Likewise, a challenge the region faces is the low degree of integration of its markets. Studies by the Inter-American Development Bank (IDB) indicated that, several years ago, the region could have received more than 11,000 million dollars each year, simply by increasing the unification of free trade agreements or preferential trade agreements among its countries. This, although not only linked to the energy sector, does highlight the need to integrate energy markets in the region in order to increase the cost efficiency of the energy systems of each country and, also, favor investment through the development of the sector in a more unified way in all the countries of the region. (Banco Interamericano de Desarrollo, 2018a)

For all these reasons, the LAC region is in a process of adapting not only to the technological transformations and digitalization framed in the modernization of the energy sector, but also to take advantage of the opportunities to strengthen industrial integration, improve productivity and promote regional collaboration in various sectors including energy. Through industrial policies (to attract knowhow and investment), trade agreements and alliances, and digital integration strategies, the region seeks to overcome historical challenges and maximize the potential of the value chain in a globalized and technologically advanced economy.

Countries have already launched different initiatives implementing solutions focused on integrating the energy sector value chain. Several countries such as Brazil, Ecuador, Honduras, Panama, and Uruguay have combined deployment policies in areas such as renewables with requirements to incorporate locally manufactured products and components for the promotion of renewables to create maximum local value. (International Renewable Energy Agency, 2016)

Additionally, the region has a competitive advantage over other regions of the planet in terms of the availability of strategic raw materials for the development of technologies linked to the energy transition, which makes it one of the regions with the greatest opportunities in the development of a regional/local value chain specialized in the primary stages of the value chain of the energy sector.
As an example, according to the most recent data, Latin America owns 60% of all identified lithium resources in the world. These are mainly found in Bolivia, Argentina, and Chile, sometimes referred to as the "lithium triangle". (Naciones Unidas, 2022)

In this sense, **apart from the necessary private investment in establishing manufacturing centers, it is essential to support these developments based on public policies.** Along these lines, other geopolitical blocs, such as the European Union or the United States of America, have promoted strategic plans that cut across the sector, to promote the reindustrialization of their territories in order to reduce their energy dependence on abroad and develop local industrial chains to supply a significant share of the needs of technologies linked to the energy transition (in the European Union, As an example, it is intended to satisfy internally, at least, 40% of the needs of these technologies). Thus, tax incentives for the location of industrial investment, or the creation of industrial hubs and clusters that align development strategies will be vital to guarantee success.

Positive measures of interest identified in other regions

- Creation and promotion of industrial hubs/clusters close to the industrial link of the value chain and demand.
- Development of industrial policies that encourage the participation of local entities (similar to the NextGeneration EU requirements in Europe).
- Development of alliances with foreign specialized companies that guarantee the participation of regional and local entities in the development of renewable energy projects that incorporate emerging and disruptive technologies in digitalization.
- Promotion of the integrated value chain through strategic alliances between manufacturers of digitalization solutions and energy companies.
- Advances in research and training linked to the development of digitalization in terms of the operation and maintenance of energy infrastructures.
- Promotion of sectors related to energy, such as mining, logistics, manufacture of electrical components, etc., favoring the creation of local qualified employment and regional investment.

05 The vision of the agents of the region on the process of digital transformation

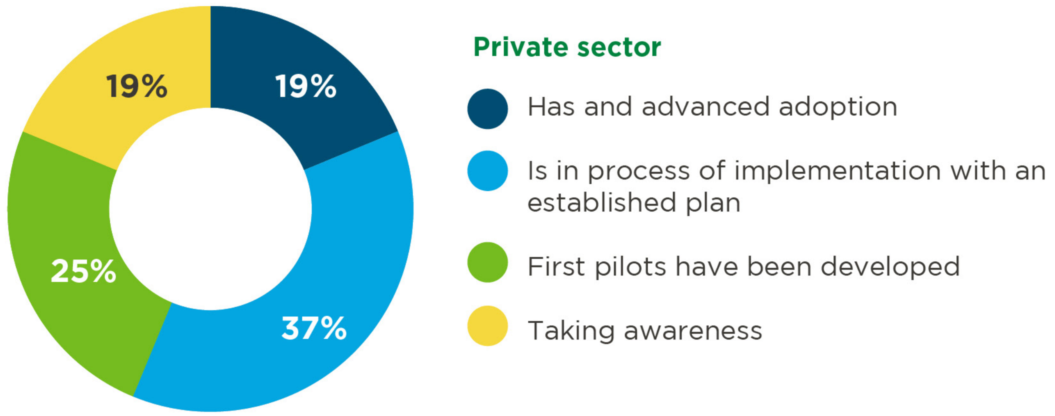
The objective of this chapter is to present the vision on the digital transformation in the energy sector, by public and private agents that carry out their activity within its value chain in the region. To this end, an analysis has been made based on the results of a survey (see Appendix C for more information) carried out among public (agents and institutions) and private representatives of the region. The aforementioned survey was mostly made between the months of July and August 2023.

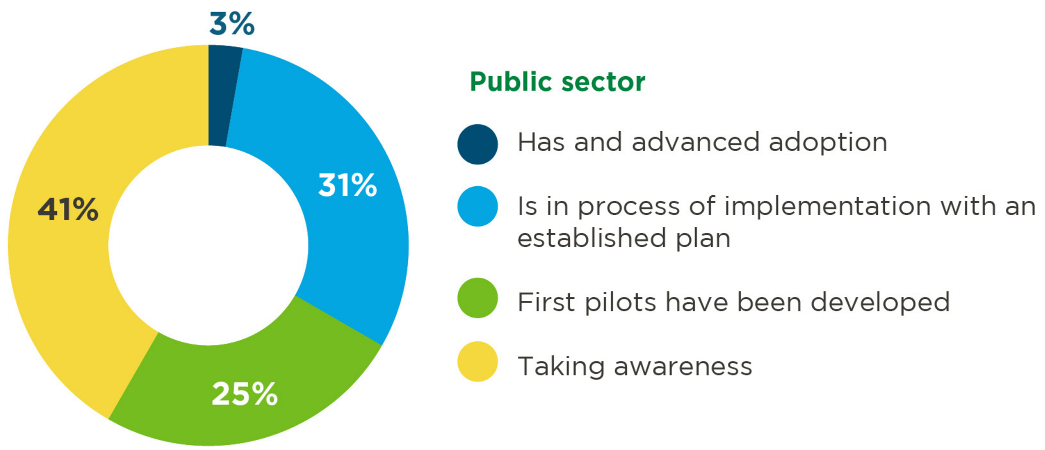
5.1. Degree of progress of digital transformation in the region according to agents

As mentioned in previous chapters, the degree of progress in the region is certainly heterogeneous, depending on the country. Aspects such as regulation, sectoral investment, or the capacity to develop and implement technological solutions, among other factors, have conditioned the degree of technological maturity of each nation.

In this sense, the degree of general progress of the region, in terms of digital transformation of the sector, in general, is still limited. Of the total responses received, only 8% of agents consider that their organizations have a high degree of progress in digital transformation. In turn, approximately 40% of the agents consulted consider that they are in preliminary processes of awareness of the importance of the digital transformation of the sector, and, therefore, have not yet taken any action to initiate the process or are at a preliminary stage.

Current status of digital transformation in the entities surveyed

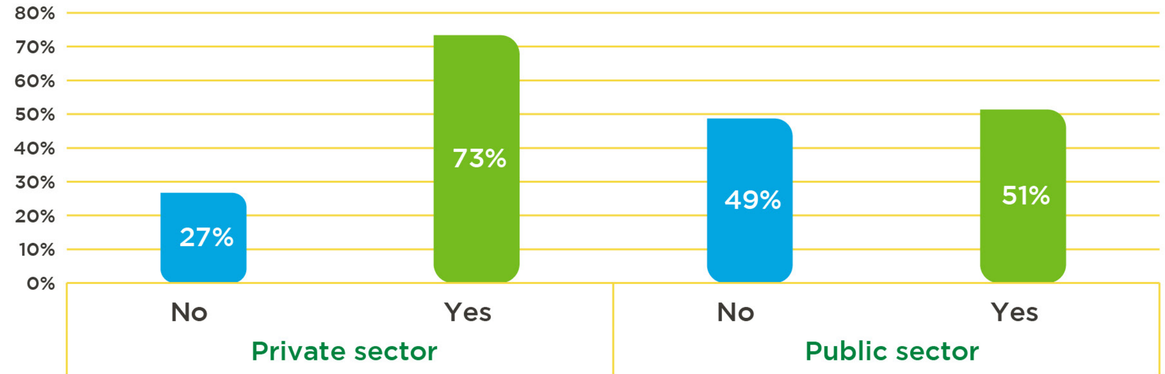




From the responses received, it can also be identified as the public sector lagging further behind in the process of adopting actions for digital transformation, with respect to the private sector. According to what has been analyzed, it is mainly due to the greater investment capacity by private agents, as well as the need to be competitive against other private companies in the sector.

In relation to the promotion of digital transformation, as mentioned in previous chapters, it is key to have a strategy that marks the actions and guidelines to successfully undertake the digital transformation process. In this sense, the different entities surveyed have been consulted if they have a digital transformation strategy, resulting in:

Existence of digital transformation strategies in the entities consulted

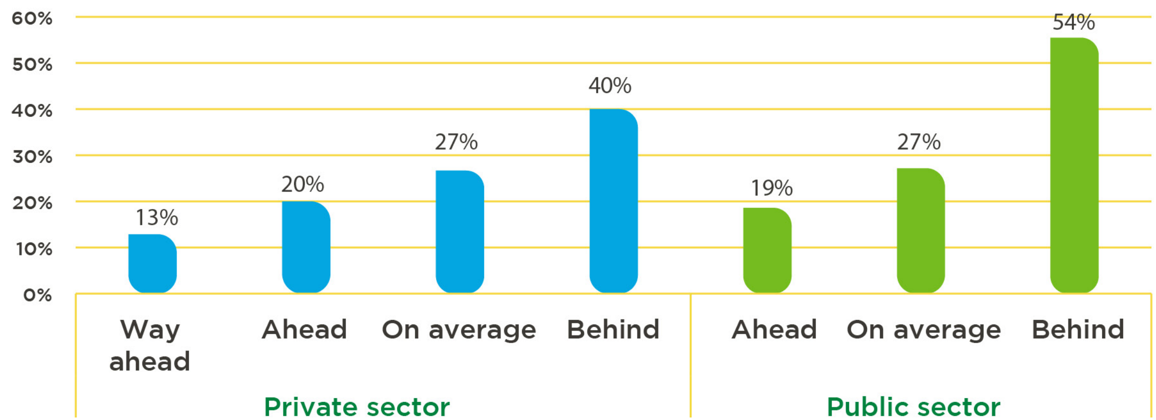


The differences between entities that have a digital transformation strategy and those that do not, are accentuated between the private sector and the public sector.

The results show how private organizations have advanced more in the development of digital transformation strategies of their organizations. From this, it can be interpreted that there is a need for the public sector of the region to accelerate, through the establishment of roadmaps, strategic plans and regulatory adaptations, its involvement in the digital transformation process. It is essential that the public sector takes the initiative and enables an adequate incentive environment for technological deployment, with legal guarantees and that encourages greater private investment.

Regarding the degree of progress of digital transformation in the region, from the point of view of the agents themselves, heterogeneous results have been obtained among the countries:

Vision of the degree of progress of the digital transformation in LAC countries, compared to other countries in the region

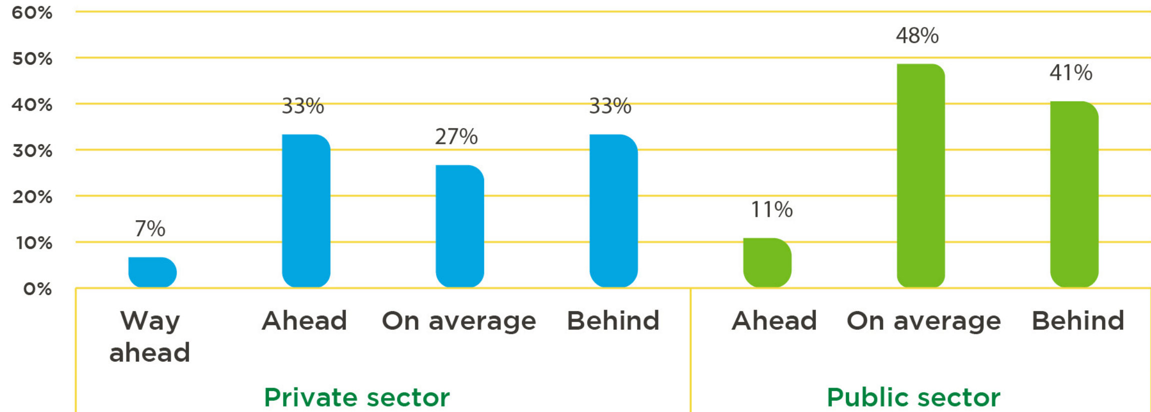


Among the countries consulted, agents from Uruguay, Argentina and Chile stand out with a degree of progress “Very advanced” or “Advanced”. Most of the answers given by the agents, in this sense, consider a relatively homogeneous degree of digital progress in the region.

Although, it is noteworthy that the vision of certain agents with a degree of maturity and development of their energy sector, a priori, higher than the rest of the countries of the region, such as Mexico, consider themselves lagging in the process of digital transformation. It could be because, in these countries with a higher degree of maturity of the sector, there has traditionally been strong foreign investment in the energy sector and, therefore, the vision on the technological trends implemented in the sector has a lot of influence from external technological developments.

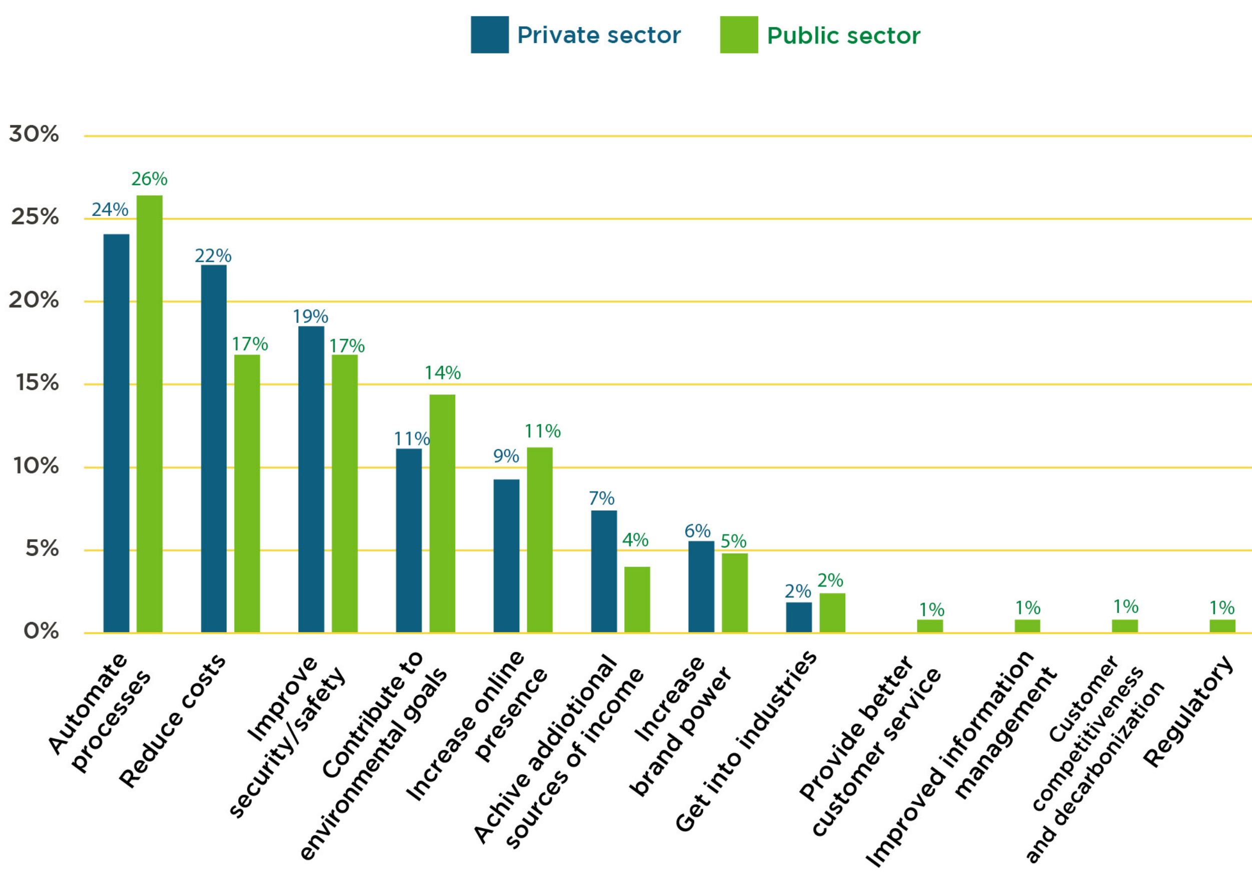
Regarding the progress of the region in terms of digital transformation, taking the leading countries as reference, the responses by the agents show a common thought of feeling that the process of digital transformation in the region is lagging, as can be seen in the following figure, where more than 65% of the agents consulted consider that their organization is "Lagging" or "Very Lagging":

Vision of the degree of progress of digital transformation in LAC countries, compared to leading countries in the digitalization of the energy sector outside LAC



In relation to the objectives that motivate investment in digital technologies in the energy sector, the results are very conclusive, the organizations focus on: "Automate processes", "Improve security", "Reduce costs", "Win online presence", and "Contribute to climate objectives".

Objectives motivating investment in digital technologies in the energy sector



The results automatization of processes, safety improvement, and cost reduction are aligned with the main objectives of the countries analyzed globally. A technological deployment is needed that contributes to optimizing the operation of the energy infrastructure, reducing costs, and making the sector more competitive, without jeopardizing the security of supply and the integrity of the system itself. It should be noted that organizations that develop actions in the area of "Flexibility of the energy system to incorporate renewables" highlight that process automatization is a key factor to successfully undertake digital transformation.

On the other hand, it is noteworthy that a large part of the agents considers relevant as an objective of the digital transformation process, the contribution it has to climate objectives. In the face of the decarbonization of the sector, this vision is key, since collaboration between public regulatory entities and the private sector will be essential to be able to advance in the reduction of emissions, with the help of a clear technological deployment and aimed at also combating climate change.

5.2. Main reflections drawn from the vision of the sector agents surveyed

The analysis of the degree of digital transformation in the energy sector of the LAC region together with the vision of the agents surveyed has led to a series **of reflections on the main challenges and opportunities associated with this transformation.**

- **There is no common (or single) definition of digital transformation.**
  First, it has been highlighted how **the lack of a common definition of what is meant by digital transformation** has led to **heterogeneous results on the degree of digitalization** and, therefore, the need to develop a shared vision and strategies adapted to the different realities.

- **Digital technologies in LAC focus on improving current processes rather than innovating**
  In addition, the observation that mostly, at present, **digital technologies focus on improving existing processes** (automation, robotization, cost reduction, etc.) instead of promoting innovation and the development of new business models, which means that there is still great potential for the development of the digital transformation of the sector in the region.

- There is an **asymmetric distribution of costs and benefits among agents,** which makes this process difficult.
  Another aspect identified is **the asymmetric distribution of costs and benefits among agents,** which hinders the **process of digital transformation in the energy sector of the LAC region.**

  Currently, according to the perception of the respondents, five **technologies are those that monopolize most of the investment** in this transformation: cloud computing, cybersecurity, data analytics / big data, electric vehicle, drones and IoT / Sensors / AMI. These technologies are essential **to modernize and improve efficiency in the energy sector.**

  Looking ahead, the agents **surveyed foresee investment in smart grids and machine learning in the next three years,** to diversify investments and address new areas of innovation. These technologies must be developed at the same time as continuing to invest in the previous ones to achieve a homogeneous digital transformation.

  Inequity in the distribution of costs and benefits could create disincentives for the widespread adoption of digital technologies, limiting the potential development of transformation across the energy sector. To address this asymmetry, it is necessary **to foster a solid regulatory framework through policies and strategies that incentivize and enable access to digital technologies** to achieve a homogeneous digital transformation in the sector. In addition, **collaboration between different actors in the sector, including governments, companies, and other stakeholders**, is essential to ensure that digital transformation is inclusive and beneficial for all in the LAC region.

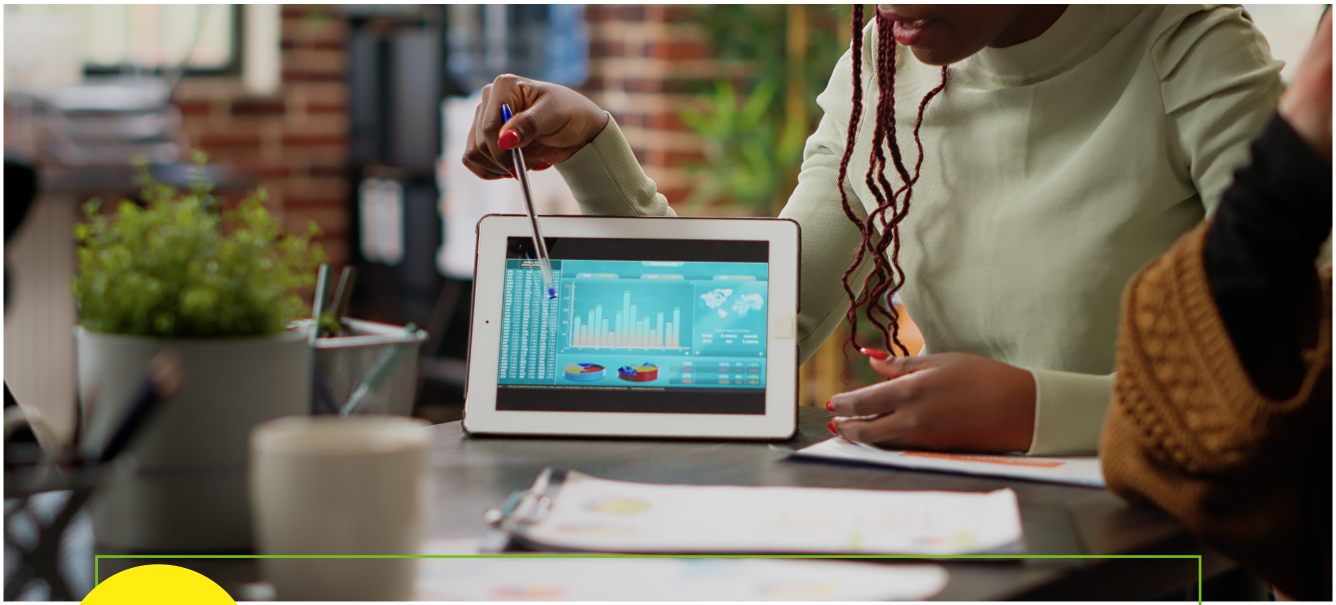
- **There are no homogeneous technical indicators of transformation or digital culture.**
  Likewise, in this process, the **lack of homogeneous technical indicators of digitalization and digital culture** has been revealed. This lack makes it difficult to assess progress accurately and objectively in the adoption of digital technologies and in promoting a digital culture in the energy industry. Without uniform metrics, it is difficult for companies and regulators to consistently measure the degree of progress in digitalization and understand how this advancement relates to digital culture.

- **Implementation costs, inadequate regulation and a lack of digital literacy are the main barriers to the deployment of digital technologies.**
  It should be noted that the main barriers identified in the deployment of digital technologies **are often** interconnected and share common roots. On the one hand, the **high implementation costs** of these technologies represent a significant obstacle to their widespread adoption. In addition, the existence of **inadequate regulation**, which is often not designed to encourage or support the implementation of digital technologies. And, finally, the lack of a **digital culture** that facilitates the implementation of this transformation process.

- **There is a significant deficit of digital knowledge and skills.**
  In addition, these barriers are **related to the deficit of digital knowledge and skills in the sector.** The lack of digital technology skills hinders the adoption and leveraging of digital technologies, which in turn increases the costs and risks associated with digital transformation. Without trained professionals in the energy sector who can effectively understand, implement, and manage these technologies, the process is hampered and limited in their potential impact.

Together, these challenges form a complex landscape that requires an integrated and coordinated approach. The definition of homogeneous technical indicators is essential to measure and evaluate progress towards digitalization and digital culture. At the same time, financial and regulatory barriers need to be addressed, while investing in training and digital skills development to overcome the knowledge deficit. This holistic approach will allow the LAC region's energy sector to move towards an effective and beneficial digital transformation for all actors involved.

06 Global best practices identified and potentially replicable in LAC



After the analysis of success stories from other countries, as well as the potential barriers that have slowed down the processes of deployment of technologies, and together with the vision of the main agents that have been part of the digital transformation process and that have been contacted during the preparation of this report, a series of best practices and lessons learned from the countries that are leading the digital transformation of the digital transformation of the Energy sector.

6.1. Best practices and lessons learned for the digital transformation of the sector

Global best practices identified for the digital transformation of the sector

Based on the analyses carried out on certain countries of interest and their most relevant agents, this section tries to synthesize what basic aspects should be considered to achieve a successful digital transformation of the sector, in three categories: (i) regulation as a key aspect for the development of digital transformation, (ii) collaboration between sector agents for the deployment of digital transformation solutions and (iii) development of digital transformation and existing infrastructure in the energy sector. The focus of this chapter includes the institutional and regulatory vision and that of companies and actors in the sector.

Regulation as a key aspect for the development of digital transformation

- **Development of pilots and learning programs**

  Institutional and regulatory vision: The development of regulations requires the assessment of their impact in the short, medium, and long term. Therefore, the development of pilot programs and sandboxes allow regulatory entities to control the tests that are evaluated and monitored, to subsequently guide their regulation to the demands of the system, always for the benefit of consumers and seeking the efficiency and effectiveness of the investments developed in that regulatory framework.

Vision of the companies and agents of the sector: investments in the energy sector, and especially, those that pretend to be a crosscutting transformation require remarkable economic sums that can hardly be executed without the correct legal certainty and confidence in the regulatory framework that are developed. Therefore, the use of regulatory sandboxes, in limited test environments, allows working together with the regulator to adapt and ensure that the regulatory scenarios developed and tested are positive, and do not produce unwanted effects to the system, such as unnecessary overinvestments or putting at risk certain aspects that guarantee the integrity of the system.

- **Stable and incentivizing regulatory framework that provides legal certainty**

Institutional and regulatory vision: Supranational digitalization plans and strategies are required, along with stimulus programs. One of the main concerns of the regulator lies in facilitating universal access to electricity by consumers at the lowest possible cost, for this, they demand adequate planning of investments in digital assets that allows them to keep track of activities. On the other hand, the use of data in the digital revolution is key. However, it could also lead to vulnerabilities in consumer protection and rights. Therefore, the regulatory framework must encourage consumers to also retain control over their data. This will help consumers demand from a safe and trustworthy environment the increase in the technological and digital endowment of the sector.

Vision of companies and agents in the sector: the deployment of digital infrastructure requires large investments that must be executed mainly by private agents and recovered over long periods of time. These investors demand a stable regulatory framework that provides them with legal certainty that they will recover the investments made with a reasonable return in the long term. Similarly, established legal frameworks need to promote consumer empowerment as well as consumer protection.

Finally, it is recommended to develop long-term tariff methodologies, which do not become a deficit to the system, as well as to create tools to involve digitalization in competitive markets, while protecting investors and entrepreneurs from “down-side” volatilities.

- **Support the development of regional plans to promote the process and international strategies**

Institutional and regulatory vision: energy systems are increasingly exposed to globalization and that is why their development must also be accompanied by the development of international alliances between operators, with other agents in the value chain and even with technology companies that favor and promote similar developments. Therefore, it is especially important that countries in the region establish common strategies to ensure synergies that encourage the deployment of digitalization throughout the region. The creation of a shared vision can favor the emergence of opportunities in the industrial value chain, favoring local production that results in positive impacts in terms of investment and job creation.

Vision of companies and agents in the sector: the digital revolution also involves the modernization of the energy system in the vicinity of the consumer, such as the development of smart cities. This can favor the creation of synergies between cities that undertake these transformations, with the aim of establishing common development parameters that guarantee replicable success models in other locations in the region that are with a lower degree of digital maturity.

Likewise, a positive aspect is the creation and implementation of associative organizations linked to the promotion of the digital transformation of the regions, guaranteeing that the best development models can be replicated through the exchange of knowledge, in other parts of the region. These forums are especially of interest to the most industrial agents in the value chain of the energy sector, such as the equipment production sector or the development of digital software tools, since they can know first-hand the needs of the sector, and in this way focus their investment efforts on responding to the demand of the system.

Collaboration between industry players for the deployment of digital transformation solutions

- **Promotion of connectivity and interoperability between actors in the value chain:**

  Institutional and regulatory vision: regulators are aware of the need to have and promote the deployment of intelligent communications, since without them it would not be possible to take advantage of all the information that is captured and processed on infrastructures.

  Vision of companies and agents in the sector: the key element to digitize any system is access to data. The data, collected through digital devices, are the basis of the transformation process, so the continuous exchange of data between the agents involved in the energy system must be promoted, to optimize the operation and offer a positive impact on consumers.

- **Promote synergies between different sectors and agents of the value chain:**

  Institutional and regulatory vision: cooperation between actors is vital to ensure the success of the digital revolution. That is why the countries of the region should promote cooperation and the creation of innovation systems in which strategic alliances can be created between members of different subsectors of the value chain. Thus, for example, manufacturers of capital goods must know the needs of operators of energy infrastructures, to be able to focus their production and development of new equipment on the demand of the sector. This will result in the value chain aligning its strategies and objectives in such a way that it is a successful cooperation for all parties.

  Vision of companies and agents in the sector: regulators must know the needs in terms of new services and functionalities demanded by energy infrastructure operators, so that they can encourage or promote, through regulatory frameworks, investment in certain areas that they consider more efficient to achieve the digitalization objectives set.

  Likewise, greater public participation is requested in the development of local prototypes and pilots with a low degree of technological maturity and adequate stimulus programs, which avoid industrial relocation.

- **Promote consumer participation through new figures, services, or business models:**

  Institutional and regulatory vision: one of the critical aspects and the purpose of the digital transformation is the importance of providing energy users with greater relevance in the decision-making of the energy system, in such a way that through superior knowledge about their consumption, their possibility of participation in energy markets, and for example, its ability to promote self-consumption through the figure of the prosumer or energy communities, improving the efficiency of the system. Public awareness of energy consumption should be promoted.

  Vision of the companies and agents of the sector: private agents demand clarity in the definition of new business models and which agents of the sector are authorized to carry out each activity. It is key to facilitate access to customers' energy consumption through digital applications.

- **Ensuring and respecting sustainability in the digital revolution:**

  Institutional and regulatory vision: the green transition necessary to curb climate change undoubtedly involves the transformation of the energy sector towards more sustainable models. In this sense, the digital revolution is critical to ensure its success. Although, it is necessary that the technological and digital deployment in the sector be efficient and climate neutral since the processing of the data usually implies high energy consumption. Therefore, it is necessary that the enabling of renewable generation sources, via digitalization, guarantees that the use of energy in the tasks of access, processing and use of data is completely sustainable. Energy transition strategies should be promoted with a very relevant component of promoting sustainability (reduction of carbon footprints of agents and equipment, ecodesigns, circular economy, etc.).

Vision of the companies and agents of the sector: it is positive that technological developments are accompanied by the guarantee through, for example, environmental labels, which guarantee that the digital transformation of the sector is being carried out with the minimum impact on the possible environmental footprint, and with respect for the environment.

At the same time, in addition to complying with local regulations and decarbonization objectives, incentives (regulatory, fiscal, etc.) are demanded to speed up the transformational process.

Development of existing capacities and infrastructures in the energy sector

- **Improve the digital capabilities of agents and consumers:**

  Institutional and regulatory vision: work is being done on the development of social awareness programs digitalization is evolving so fast within our society, that it must be considered so as not to lose opportunities due to lack of capacity. In this sense, it is necessary to ensure that both consumers and agents have the digital capacity to participate in this transformative process and, therefore, the need to ensure accessibility to the majority of consumers to these new digital interfaces, so that their needs are fully met, should be taken into account during the design of digital tools, habits and expectations. This is especially critical considering generational and demographic changes, as older energy users demand support around the digital transition.

  Vision of companies and agents in the sector: special emphasis is placed on the need to develop a digital corporate culture and internalize the use of digital tools. Cultural changes occur from the management of the company to the rest of the employees. For this, it is very important to develop internal digitalization programs adapted to each job.

- **Encourage investment in modernization of energy infrastructure:**

  Institutional and regulatory vision: the digitalization process requires the interaction between agents and devices, and therefore the exchange of a large amount of information and data that provide flexibility and efficiency to the system. The modernization of energy networks, which are the vector of union between generation and demand, is especially critical. This requires coordination and cooperation between public and private agents that mobilize investment in providing intelligence to energy infrastructures.

  Vision of the companies and agents of the sector: support programs are demanded for R + D + i testing and piloting of investments aimed at improving the functionalities of the networks, through the deployment of automation, communication, and sensorization technologies, without forgetting the need for this deployment to be accompanied by cybersecurity developments.

  On the other hand, private agents consider it appropriate for countries to implement transformation programs that encourage digitalization and innovation. In this area, it is critical that national regulators in the energy sector identify efficient investments in terms of digitalization (provide appropriate regulatory signals) and that incentives are granted to actors responsible for carrying out the process of modernizing energy infrastructure, such as operators of energy transmission and distribution networks.

- **Need to promote a qualified workforce that guarantees the success of the transformation process:**

  Institutional and regulatory vision: constant technological evolution requires that the backbone changes of digitalization be applied with sufficient agility to avoid the obsolescence of the technology deployed. Therefore, it is vital that there is a skilled workforce to ensure rapid deployment. To this end, the strengthening of training and education systems in technological, digital and cybersecurity areas, at the regional level, will guarantee the existence of qualified professionals to guarantee the agility of digital transformation.

  Vision of companies and agents in the sector: the private sector reinforces the approaches of the public sector and requests an adequate treatment and/or recognition of investments in digital assets (hardware and software).

  Vision of universities and knowledge centers: The academic sector and the industrial value chain must be aligned in the development of the skills required to ensure that professionals have the necessary skills to guarantee the development and correct deployment and operation of disruptive technologies. Likewise, the roadmaps and stimulus programs that some countries are developing must incorporate specific items and plans to encourage the development of qualified labor in the vicinity of production centers.

- **Increase the resilience of the energy system and its critical infrastructure to adverse weather events:**

  Institutional and regulatory vision: in the current era, the existence of catastrophic natural phenomena derived from climate change is increasingly common. Episodes of major floods, large forest fires, or heavy rainfall can put security of supply at risk, resulting in negative impacts on consumers and production systems that have energy supply as the driving force behind their growth.

  Regulators must ensure that private agents invest in guaranteeing the resilience of their energy assets, not only through the constructive improvement of these elements, but especially through adequate planning of their asset network. For this, the use of digital virtualization technologies of energy systems is vital, such as the use of digital twins that allow simulating extreme conditions based, for example, on adverse weather patterns.

  Vision of the companies and agents of the sector: agents must be allowed to identify and execute actions (investment or operation and maintenance) for each asset, to carry out the most appropriate ones in each case. On the other hand, work is being done on the development of digital twins, among other innovative solutions, to carry out simulations and impact scenarios and, from them, to be able to make contingency plans and better investments in the coming years. In the context of the LAC region, where extreme weather events and hydrological variability can have a significant impact on energy security, it is essential to focus efforts on improving hydrology measurement and refining the projection of climate scenarios.

- **Reinforcement and continuous development of the cybersecurity of the energy system:**

  Institutional and regulatory vision: in this area, it is also key to develop specific cybersecurity strategies by public bodies and regulatory entities, to adopt and/or recognize already established international standards that protect the rights of consumers to secure energy access.

  Vision of companies and agents in the sector: cybersecurity plays a fundamental role in the digital transformation process since it guarantees the reliability of increasingly digitized energy systems. It is necessary that the development of new digital tools is accompanied by the development of new functionalities in terms of cybersecurity, to always guarantee the integrity of the energy system. Likewise, these cybersecurity developments must cover the entire value chain, so that, from production to energy networks and consumers are protected against cyber vulnerabilities.

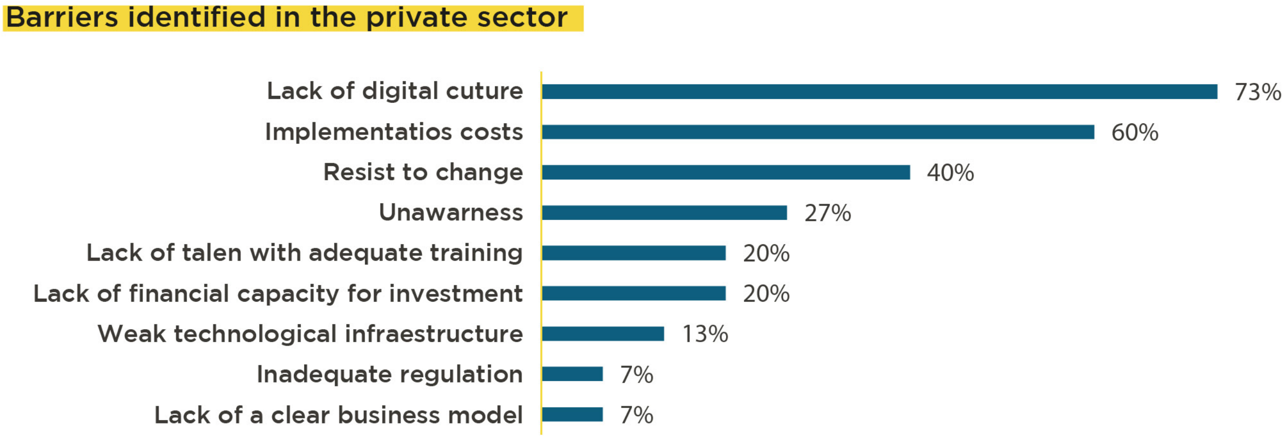
Lessons learned for the digital transformation of the sector

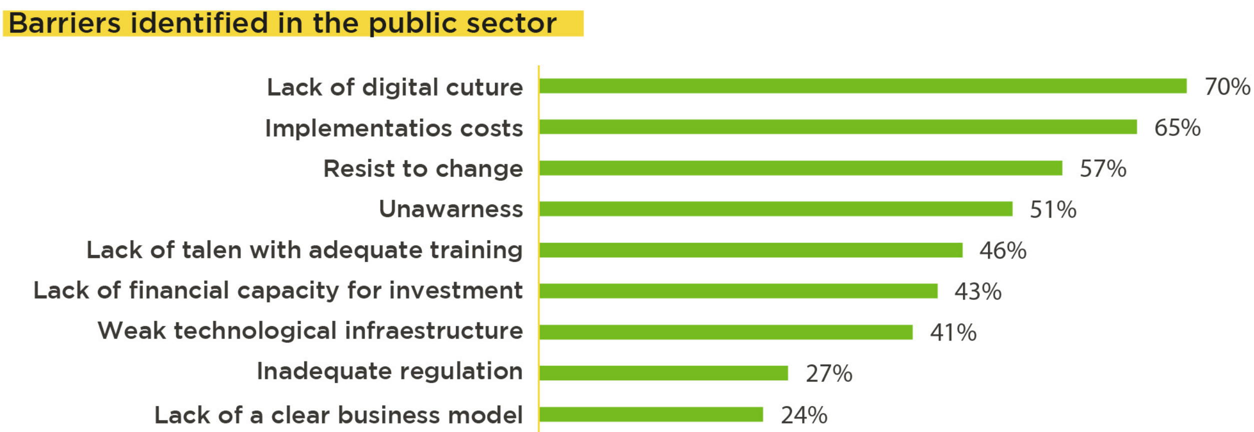
During the work, interviews and engagements with agents of the sector have been carried out, which operate in the countries analyzed. In this process, a number of lessons learned, and key elements have been identified that must be considered to ensure the success of the digital transformation process. They would be as follows:

- Promotion of an **updated regulation aligned with the new demands of the sector** and consumers, **which provides confidence and legal certainty** to investors. As well as a regulation on data governance, which protects the security of user data that is measured and analyzed by industry agents.
- **Cultural, business, and social transformation, and of regulatory bodies**, which guarantees agile and optimal decision-making.
- Promotion **of public-private collaboration for the elaboration of a digital transformation roadmap** agreed between the agents of the sector (public and private).
- Investment in **modernization of the current energy infrastructure**, to guide it to the needs derived from the energy transition (incorporation of renewables and new businesses).
- Identification of parameters that allow to **adequately measure the great progress in the process of digital transformation**, to guide the steps in the medium-long term.
- **Prevention and anticipation of the appearance of potential risks or barriers** that represent a slowdown in the digital revolution of the sector.
- **Provision of economic and human resources** to the tasks aimed at advancing in the process of digital transformation of the sector.
- Advance in the **deployment of disruptive technologies** that empower the consumer, enable new forms of sustainable generation, and increase the resilience of the system.

6.2. Recommendations to accelerate digital transformation in the region

Based on the analysis of the vision of the main agents of the energy sector in the LAC region, **a series of barriers to the effective implementation of digital transformation have been identified.** Although these are different for the agents surveyed in the public and private sectors, as shown in the graph below, it has been shown that the **absence of a solid regulatory framework, the lack of awareness or digital culture and the costs associated with the implementation of this transformation are three of the most relevant barriers.**





Therefore, and in view of the best practices identified in the analysis of digital transformation in the leading countries, **five relevant recommendations have been extracted to accelerate its development in the region:**

1. **A stable modern regulatory framework.** Regulation is considered a key incentivizing aspect for private sector companies to invest in the deployment of new solutions for the digital transformation of the sector. Having a shared technical definition or specific objectives provides certainty over time and legal certainty in the deployment of disruptive technologies or new business models.

It should be noted that the countries analyzed already have or are in the process of developing specific regulations in the field of digital transformation. Some of them, such as the United Kingdom, rely on tools such as sandboxes to achieve rapid development and engage stakeholders by identifying the main regulatory barriers they face when deploying digitization solutions at the sector level. Others, such as Italy, Spain, and Portugal, evolve from specific objectives and encouraged by the European Union, through its Integrated National Energy and Climate Plans.

After analyzing the state of the LAC region, it is recommended, as a first step, the development of a shared vision of digital transformation, as well as developing strategies and plans that define clear objectives and adapt to the various local realities. Since, according to **37% of the agents of the sector surveyed, the existence of inadequate regulation is a restriction for the progress of digital transformation in it.**

2. **Economic incentives for investment in digitalization.** An adequate digital transformation of the energy sector will mean an increase in quality and efficiency, which could translate into economic savings for the energy system. However, to reach that point, economic incentives for investment are required that allow a homogeneous digital transformation of the sector.

Of all the countries analyzed, it is worth highlighting the example of the United States, which has economic support programs aimed at strengthening the network infrastructure through the implementation of disruptive digital technologies, for example, with programs such as the *Inflation Reduction Act* or the *Smart Grid Investment Program*. Likewise, in the countries of the European Union, after COVID-19, a series of measures have been deployed through European funds to encourage the development of energy infrastructure, as well as innovation at the sectoral level, through new energy models and vectors.

In the context of the LAC region, an unequal distribution of costs and benefits among the actors involved has been identified, which may discourage the widespread adoption of digital technologies. Addressing this asymmetry requires the **implementation of policies and strategies that foster equitable access to digital technologies and collaboration between governments, businesses, and organizations.** The costs of digital transformation are the main barrier identified, by **67% of the agents surveyed**, for the development of digital transformation.

3. **Technological adoption towards disruptive models and services.** Part of the digital transformation process integrates the need to have disruptive digital technologies together with the maximum use of their potential in the sector. In other words, the final objective of this transformation transcends the fact of achieving greater efficiency of the processes and has a broader perspective that considers the introduction of new business models that involve the end user as another agent of the market.

The leading countries in digital transformation analyzed share this vision, which goes beyond introducing improvements to the existing system, to give rise to a more disruptive model. In particular, South Korea has a very powerful industry in the field of information technology development that makes it available disruptive digital solutions applicable to the energy field.

From the ideas extracted from the analysis of the current state of the region, it has been observed **that digital technologies tend to be mostly destined to improve existing processes instead of promoting innovation and new business models**, which means that there is still potential to be exploited in the digital transformation of the sector. especially in the most technologically disruptive areas. According to the barriers identified by the agents surveyed, it is considered key to invest in new technologies. **33% of the agents surveyed consider that the current technological infrastructure is weak.** This vision is especially reinforced in the public sector, with more than 41% of public agents in the sector considering it as a barrier to the effective deployment of digital transformation.

4. **Digital culture.** Together with the progressive digital development, there is a change in social consciousness that drives the energy sector towards new business models that are increasingly digitized.

A common aspect identified in the leading countries and, above all, in conversations with relevant agents at the sector level, is the implementation of strategies and plans by private agents in the energy sector to develop digital skills and drive digital transformation from the core of companies to customers.

At present, the region reflects a potential for improvement in the **definition of uniform technical indicators and a solid digital culture that make it difficult to accurately assess progress in the adoption of digital technologies and the promotion of a digital culture** in the energy industry. To address these challenges, the **region must invest in the development of digital knowledge and skills in the sector.** In this context, some **limiting factors** highlighted by the agents surveyed for **the advancement of the digital transformation of the sector, in order of relevance**, are: **(i) the lack of a digital culture, (ii) ignorance and (iii) resistance to change.**

5. **Public-private collaboration for digital value chains in the sector.** The need for a remarkable deployment of digital technologies to successfully carry out the transformation process, can drive the development of a more modern proximity industry and oriented to sectoral needs, such as the evolution of the capital goods manufacturing sector. This also requires private sector investment.

Regions such as Europe and the United States have launched cross-sectoral initiatives to reindustrialize sectors that were progressively losing industrial potential in favor of other regions.

In particular, **the LAC region has important advantages** over other regions: the **presence in its territory of renewable resources and reserves of strategic minerals of interest for new energy business models,** such as copper, aluminum, or rare earths. This can lead to a positive impact on society through the creation of skilled jobs and industrialization opportunities.

6.3. Potential for replicability of best practices in the medium and long term

After the analysis of different best practices that have guaranteed an effective deployment in other regions of the world, the evolution of implementation from the medium term (2030 horizon) to the long term (2050 horizon) in the region should be as follows:

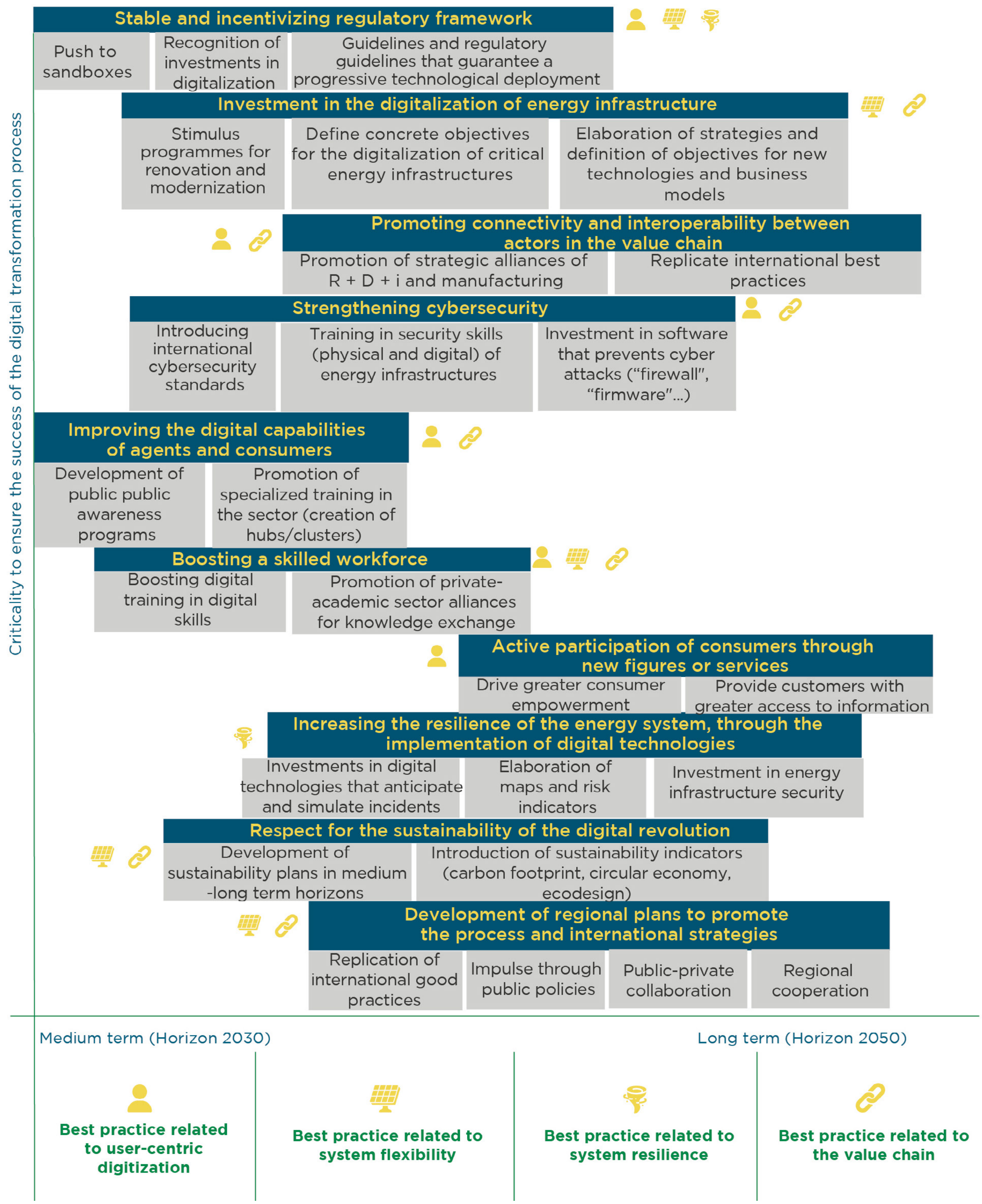


Figure 17. Temporary development of best practices in the environment of the digital transformation of the energy sector. Source: Authors.

After this analysis, **the testing of the suitability and effectiveness of both digital technologies and the regulatory measures** has been identified as a first step for the development of digital transformation processes in the energy sector, that are necessary to achieve the widespread deployment of digital solutions.

This can be a starting point to **establish the bases and an initial regulatory framework** *(stable and incentive regulatory framework)* that provides **certainty, stability, and attracts investment towards the field of technological deployment** in the energy system. To achieve this, it is key to carry out an initial stage of **launching pilot projects** *(Promotion of regulatory sandboxes)*, with the aim of guiding the new regulatory developments of application to the most efficient technological proposals and deployments for energy systems from the point of view of cost-benefit. Likewise, specific objectives must be established, adapted to local realities, based on the best practices identified in the sector, which allow the effective development of digital transformation *(Development of regional plans to promote the process and international strategies).*

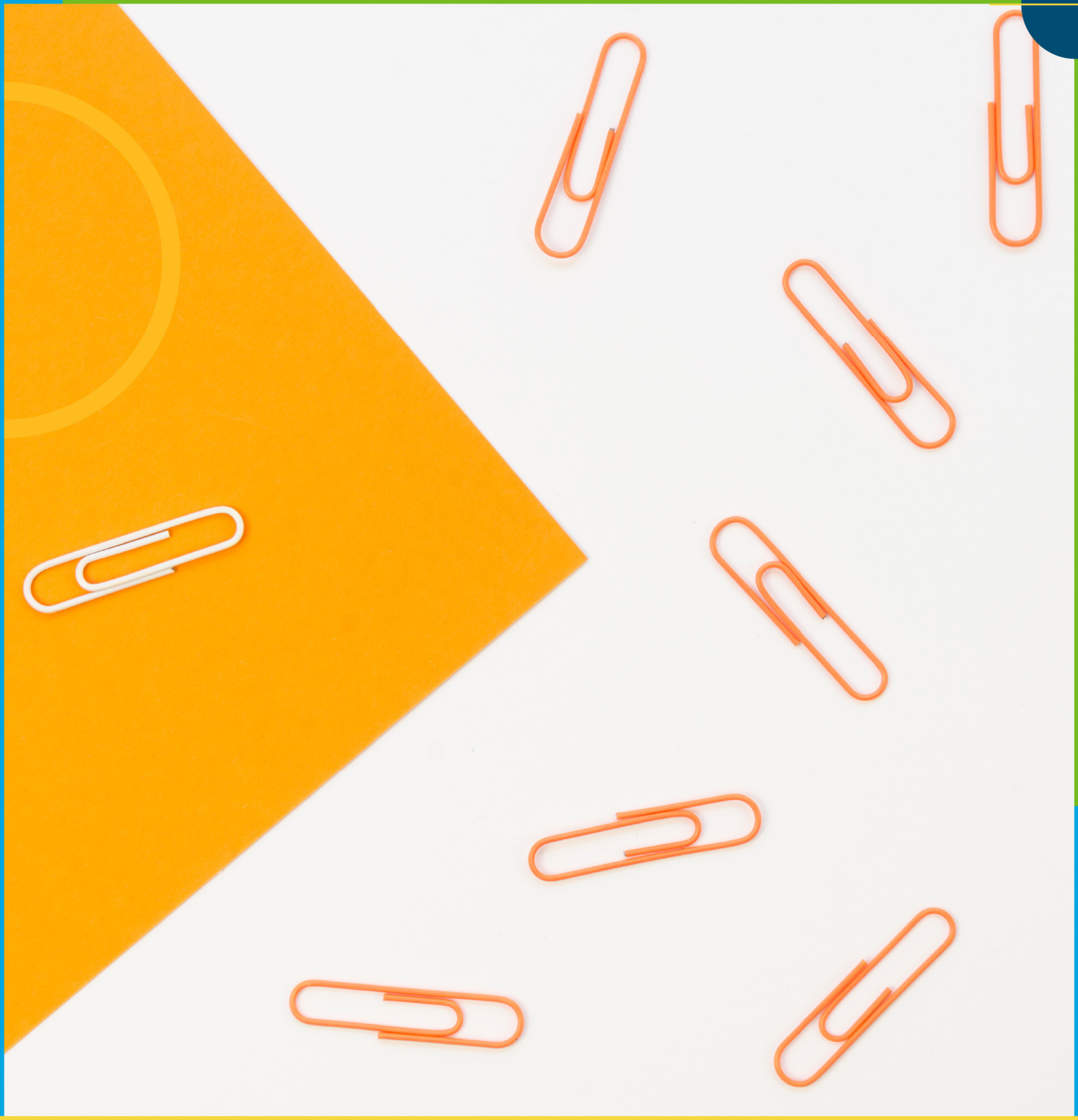
This process must also be accompanied by a progressive cultural and business change, starting from the beginning of the digital transformation, to contribute to a progressive involvement of all agents in the process. Similarly, the change in the cultural and business model of organizations (Improvement of the digital capabilities of agents and consumers) in the medium term, with a *progressive change in the leadership model, will contribute to providing the process with greater financing and promoting professional talent in areas of technological development, dedicating economic and human resources to digital growth* (promotion of a qualified workforce).

Specifically, in the **medium term** (2030 horizon) the guidelines that enable the necessary changes in the sector must also be defined. This **is to invest and modernize the current energy infrastructure** *(investment in the digitalization of energy infrastructure)*, through regulatory and economic incentives that encourage private investment, in such a way that the incorporation of disruptive technologies of interest is allowed when the degree of technological maturity is still low, such as technologies based on intelligent communications, sensorization, or smart metering.

In addition, in the long term (2050 horizon), as **energy systems are provided with digital solutions, which allow increasing their** resilience *(increasing the resilience of the energy system through the incorporation of digital technologies)* with the incorporation of emerging technologies such as Artificial Intelligence, digital twins, or Edge computing, among others, other areas should be developed to ensure **system integrity in this interconnectivity environment, such as cybersecurity** *(strengthening cybersecurity).*

Similarly, from the point of view of public policies in the long term, they must establish **synergies between agents in the sector, to promote strategic alliances that guarantee new opportunities along the value chain** *(promotion of connectivity and interoperability between agents of the value chain)*.

All this development must pursue the objective of achieving greater sustainability in the energy sector *(respect for the sustainability of the digital revolution)*.



Appendixes

Appendix A. Technologies for the digitalization of the energy sector

This section will address the main technologies that are driving the digital transformation of the energy sector globally. To this end, the analysis of the different trends in the deployment of technological solutions implemented in the energy sector, carried out by countries from different regions, and that are having proven success in the advance towards digital, interconnected, reliable and resilient energy systems, has been analyzed.

Emerging technologies in the field of digital transformation

To understand the process of digital transformation, and the opportunities immersed in the deployment of the different digital technologies available in the market, it is key to know the possibilities offered by each of them. In this sense, there are currently numerous emerging and disruptive technologies in the energy sector, which are progressively being implemented:

	User-centered digitalization	System flexibility to incorporate renewables	Resilience of energy systems	Impact on the value chain
Blockchain	●	●	○	●
Big data	●	●	●	○
Cloud computing	●	●	●	○
Sensorization	●	●	●	○
Advanced Metering Infraestructure (AMI) & Smart Meters	●	○	○	○
Artificial Intelligence (AI)	●	●	●	●
Digital Twin	○	●	●	○
Internet of Things (IoT)	●	●	●	●
Robotization	○	●	●	●
Drones	○	●	●	●
Augmented reality	●	●	○	○
5G connection	●	●	●	○
Fiber Optics	●	○	○	○
Edge Computing	○	●	●	○
Cybersecurity	●	●	●	●

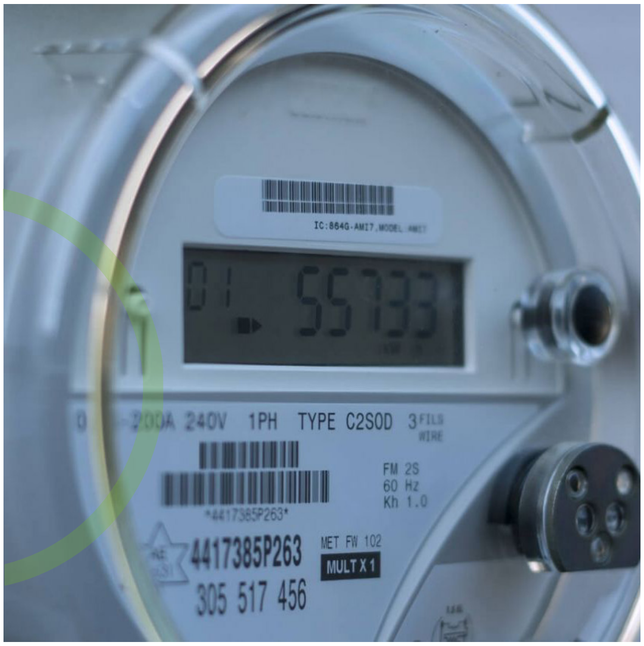
Table 4. Classification of innovative emerging technologies in the energy sector. Source: Authors.

Once the technologies have been classified based on the technological area in which they are framed, it should be noted below what are the specific impacts and benefits that can be expected from each of them in the main areas of development of digital transformation.

User-centered digitalization

The user is changing his role, positioning himself at the center of energy systems. This change requires empowering consumers through data, providing them with real-time information on certain parameters of interest to them, such as consumption, market prices, energy flows in the case of distributed generation and self-consumption, or peer-to-peer transactions.

In this new scenario, the need for technological deployments that guarantee the collection of data within the energy system becomes evident. In this sense, technologies such as advanced and intelligent metering infrastructure (**AMI & smart meters**), can contribute to the capture of information about their status at points of consumption and energy infrastructures. The novelty with respect to electromechanical or analog measurement is that these devices allow the wireless and real-time disposition of consumption data, which can be used in customer decision making. Especially in the electricity sector, smart meters play a fundamental role in smart grids, as they allow the management of system load and resources from the demand side.



This deployment is considered basic to start the process of digital transformation and, that is why, in 2022, the one billion smart meters deployed worldwide were exceeded. In addition, among the advantages of this technology, is the possibility that users have access in real time to their consumption, which facilitates, among other things, the improvement of energy efficiency in homes / industries, Likewise, it is necessary to indicate that without the penetration of smart metering technologies, it is difficult to carry out transactions between different agents of the value chain, as consumers and marketers, or peer-to-peer (P2P) transactions. (International Energy Agency, 2023)

In addition to this, the capture of such a significant volume of data requires the involvement of other technologies to be able to process and store them in an integral and secure way. Thus, technologies such as **big data** allow the processing and analysis of large volumes of data, complex and unstructured, using advanced tools. In the phase of energy consumption, big data is constituted as a fundamental tool for the treatment and analysis of large volumes of information generated by consumers and captured by smart metering technologies.

In the same line, **cloud computing** guarantees that the data collected can be transmitted from the smart meters or **sensors** deployed, with agility to the processing platforms, in such a way that they can be stored and processed in the cloud, and their access can be done online. Therefore, this technology greatly facilitates communication and the exchange of information in real time. They also allow the governance and administration of data by utilities, in addition to their ability to optimize the use of servers, enable the use of other technologies such as machine learning, reduce costs, and allow the administration of authentications and access to information, which results in greater security in data governance.

Along with cloud computing, the use of **blockchain** in applications in the energy sector is increasingly widespread due to the large volume of data that is collected by all digital elements linked to energy infrastructure. Among others, blockchain enables the sale of P2P energy, which favors the existence of new business models focused on the user, such as energy communities.

In this context, other more incipient technologies such as **Artificial Intelligence** can, potentially, process this data, and through algorithms generate decision-making to place the technological devices installed in the energy infrastructure to carry out operations that guarantee an optimization of the processes or an improvement of the efficiency of the operation, with a positive impact on consumers. Additionally, Artificial Intelligence allows advances in other areas such as smart homes, by enabling the control of lighting systems, air conditioning and other smart devices, which allows the reduction and optimization of energy consumption and its active management.

In reference to communications, these are increasingly intelligent and agile to favor access to information in real time by users of the energy system. Thus, disruptive technologies such as **5G** or **fiber optics**, represent enormous advances in connection speed and in the possibility of interconnection of multiple devices that are connected to the energy infrastructure. The first of these, the 5G connection, thanks to its wireless nature, brings important benefits to users who are in more remote territories, providing them with a notable increase in upload and download speeds, more stable connections, and a wider data transfer capacity.

The deployment of these digitalization technologies allows the emergence of new business models and management of urban energy systems such as, among others, smart cities, or electric mobility. On the other hand, **smart cities**, are those that represent a space in which traditional infrastructures and services reach higher levels of efficiency through the implementation of digital solutions, for the direct benefit of their residents and companies. It is not limited only to the incorporation of digital technologies but encompasses a comprehensive approach to optimize resources and reduce emissions. (European Comission, 2022a)

Likewise, within the process of electrification of energy uses, the development of **electric mobility** is experiencing a significant boost. This trend has a positive impact in environmental terms, offering a clearly more sustainable alternative to internal combustion vehicles and, in addition, is currently supported by public aid programs, to establish strong incentives for their deployment, still very heterogeneous in the different regions of the world. In addition to the vehicles themselves, charging infrastructure and energy management applications allow users to get the most out of their electric vehicles, thus increasing the comfort and practicality of this clean and efficient form of transport.

Additionally, it should be noted that all these technological deployments must be developed at the same time as measures in the field of **cybersecurity**, in such a way as to guarantee the integrity of consumer data, as well as their rights. This implies the taking of preventive measures to avoid hacking of the system, and the establishment of standards regarding the treatment of consumer data, etc.

System flexibility to incorporate renewables

Ambitious global climate targets are pushing the energy sector towards transforming its energy mix, to make it more sustainable and decentralized. This involves the incorporation of greater renewable generation capacity. Although, the fact of incorporating renewable generation technologies into the energy system makes important challenges emerge for the sector, such as a more complex operation of energy systems.

Therefore, in this scenario, it is key to obtain data that guarantees decision-making in the operation of the system in an optimal way. A more resilient and modern energy infrastructure requires to measure and capture information to favor monitoring, decision making, and automation. The integration of **sensorization technologies** in the sector and their connection through wireless or wired networks of high speed and availability are essential for obtaining data from assets and networks in real time.

Such sensing technologies in the field of power generation are presented as a valuable resource for the collection of data on the performance of generation assets. This is especially relevant in renewable generation technologies, where their intermittent nature makes their operation more complex, and they also enable data collection in storage systems. Similarly, sensorization is important in improving the efficiency of energy networks, especially in the detection of technical losses and as an aid to the location of energy fraud.

Although, it is necessary to indicate that after the installation an integration process is required, in many cases complex, to the extent that infrastructures with different ages and government systems coexist, so verification, testing, calibration and back-up processes are required, among others, prior to its full exploitation.

Once the data is captured, technologies such as **cloud computing** and **Edge computing** come into play. cloud computing facilitates communication and information exchange in real time, leading to faster and more effective decision-making during the operation of energy networks. Although, like other technologies, the use of cloud computing derives from the need to develop cybersecurity systems that guarantee restricted access to data, guaranteeing proper data governance, in such a way as to reduce the risk of cyberattacks that may call into question access to sensitive information.

In the same way, other local data processing technologies such as Edge computing, which favor the agility of network operation, today require greater protection in relation to **cybersecurity**.

Similarly, these data captured through sensorization are the source for use by other technologies such as **big data**, responsible for storing a large volume of data generated during the operation of the generation energy system or **Artificial Intelligence** and the **digital twin**.

In relation to the **Artificial intelligence**, it is worth highlighting its innovative nature and the potential opportunities it offers to the energy sector in the future. Thus, in the future its use is foreseen in the automatic operation of decentralized generation plants, in such a way that through this technology the generation itself can be regulated based on the parameters collected by the sensors enabled in the energy infrastructure and make an adjusted forecast of the demand. Likewise, thanks to the union of Artificial Intelligence with the development of digital twins, simulations of operation and maintenance conditions of these plants can be carried out. Currently, Artificial Intelligence is one of the technologies with the greatest future projection. The market linked to Artificial Intelligence is estimated to grow at an annual rate of approximately 39.4% between the period 2022-2028. (Bloomberg, 2022)

As for **digital twins**, their use is very positive in the early stages of planning and development of the energy system, since their ability to replicate virtually and in real time the parameters of generation and operation of the networks, allows to simulate, predict, and optimize energy infrastructure. Although, the use of digital twins implies the deployment of other technologies such as sensors and connectivity tools such as the IoT or technologies such as Artificial Intelligence, with the aim that all data is synchronized between the virtual and real model.

An additional use of digital twins, to simulation for planning and development of the system, is its use as a tool for predicting the state of assets, to ensure correct predictive maintenance to avoid failures and interruptions of the energy supply, and, therefore, the need to assume higher costs in corrective maintenance tasks.

In line with the automation involved in system virtualization, another of the most general technologies affecting the value chain emerges: the IoT. This technology includes various sensorization, actuation and communication technologies, which make use of a common network to be interconnected with each other. The use of the **IoT**, therefore, allows to establish a network of physical objects that incorporate technology to communicate and interact with their environment in a digital way. In this sense, the use of IoT throughout the value chain allows digital control of voltage and power measurements in generation plants and networks, as well as enabling the deployment of decentralized generation, energy storage and sensors to control network parameters.

In relation to the new energy markets derived from the growing penetration of decentralized renewable generation in energy systems, the use of disruptive technologies such as **blockchain** is indispensable, which is positioned as a tool to guarantee the integrity of transactions between agents, serving as unchangeable storage hardware tools that guarantee this integrity. Its integration into energy assets brings with it a series of relative benefits, not only to the availability of information, but also to the automation of processes. This is especially critical in contractual areas of the market for this new renewable generation, such as long-term power purchase agreements through Power Purchase Agreements (PPAs) to guarantee, in many of these cases, that the energy supplied has renewable origin. Additionally, thanks to the blockchain, peer to peer (P2P) transactions can be enabled, without the need for the presence of a central intermediary.

As for the large volume of data that is handled in the environment of renewable generation systems, the disruption of big data has great relevance for the energy sector since it allows, for example, to analyze the behavior of supply and demand and optimize the processes related to the operation of the sector.

Likewise, in conjunction with **big data**, machine learning **is being used** in the field of renewable energy production to predict when generation sources will be available and when they should be stored for later use.

In the field of digitalization of electricity grids, big data has acquired a very high role in recent years as an enabling technology for the massive collection of data in the context of smart grids.

Examples such as the use of drones in the supervision of energy networks to avoid supply interruptions and to generate new information that allows the development of cartographic systems, or **robotization**, using robot dogs for access to assets located in areas of difficult access, is increasingly widespread and has had successful results.

Regarding **augmented reality**, the most frequent use in the energy sector is occurring in recent years in the field of energy networks. Especially of interest is its use in the detection of faults of energy networks, though, for example, the use of virtual reality glasses, in which the operator can have information about the network parameters, with the aim of guaranteeing their safety and being able to perform operations with the greatest possible agility.

In the field of communications, **5G** connections enable the transmission of information between multiple devices quickly and quickly between completely decentralized generation resources, as well as between self-consumption and control centers to have an optimal operation of energy networks.

Resilience of energy systems

In an increasingly decentralized, digital, and intelligent energy system, new challenges arise related to the integrity and resilience of the system. Ensuring security of supply to consumers is today an essential aspect of any energy system.

Thus, in the field of the protection of energy infrastructure, against potential disasters and natural phenomena, technologies such as **sensorization**, accompanied by the **big data** It is essential to analyze operating patterns that ensure the proper functioning of energy assets. The technology of the **cloud computing** it enables the storage of data collected in energy networks on a remote server and interaction with them. From the access to the data through sensors, to its storage and subsequent analysis, there is an essential step that is its transmission, through the use of reliable and fast communication technologies such as the (TelefónicaTech, 2022) **5G**, guarantee rapid actions in the network operation that allow to safeguard the assets and guarantee, if there is an appropriate meshing of the energy networks, the energy consumption to the users.

Similarly, technologies such as **Edge computing**, which bring processing power as close as possible to where the data is being generated, (TelefónicaTech, 2022) They enable the possibility of making decisions locally, and therefore gain speed in decision making. The deployment of 5G networks globally will substantially modify the hyperconnectivity of devices, promoting edge computing and **Internet of Things (IoT)** (Deloitte Chile, 2021).

On the other hand, in this area we must also highlight the role of foresight in the face of these phenomena. Thus, the use of **the IoT**, together with the development **of digital twins**, guarantees a correct preparation and planning of the systems based on the simulation of critical scenarios.

Artificial Intelligence enables the implementation of optimal decisions that can protect and provide resilience to the energy system through the development of prediction algorithms, while digital twins can provide greater decision-making capacity in the planning and development stages of the energy infrastructure, allowing the simulation of scenarios on infrastructures and action plans. Likewise, **drones and robotization**, together with the aforementioned technologies, facilitate the operation and maintenance of the physical assets of the energy system.

The use of these technologies allows, therefore, (i) the premature identification of possible adverse weather effects, (ii) the prevention and simulation of the effect of these phenomena on infrastructures, and (iii) a faster recovery after the effects that may occur, facilitating recovery by identifying damaged areas, planning access routes to them and coordinating maintenance teams and brigades for their repair. efficient way, among others.

Equally, the resilience of the sector does not only depend on the integrity of the physical infrastructure. It is also necessary to protect an increasingly digitized energy system from potential cyber risks. In this sense, **cybersecurity** developments are key.

Cybersecurity, also known as computer security, encompasses all elements and practices that are implemented to reduce the risk of unauthorized access to information and operations of digital systems. This implies the adoption of measures both at the software level, such as the use of antivirus and the encryption of communications and information, and at the hardware level, implementing barriers that hinder physical access to the installed devices. Cybersecurity is therefore essential to protect the integrity and confidentiality of systems.

Impact on the value chain

The electrical equipment goods sector, belonging to the industrial value chain of the energy sector, is characterized by being a sector historically linked to products based on iron and copper (transformers, cells, switches, wiring, etc.), which is currently immersed in a profound transformation process to develop new digital products and services.

The specialization of personnel in the development of areas such as **robotization**, automation and the development of **drones** supposes bets for the future since they are areas less explored by energy companies today. Likewise, opportunities emerge around the development of **Artificial Intelligence** models, or developments linked to **blockchain** or **IoT**. The field of **cybersecurity** is also key, and the opportunities it generates are long-term since it is an area that must always be developed in parallel to the emergence of new technologies.

In this context, the generation of strategic alliances between technology providers will also be key, which allow the accelerated development of pilot projects that manage to collect data and experiences for a massive deployment of technologies.

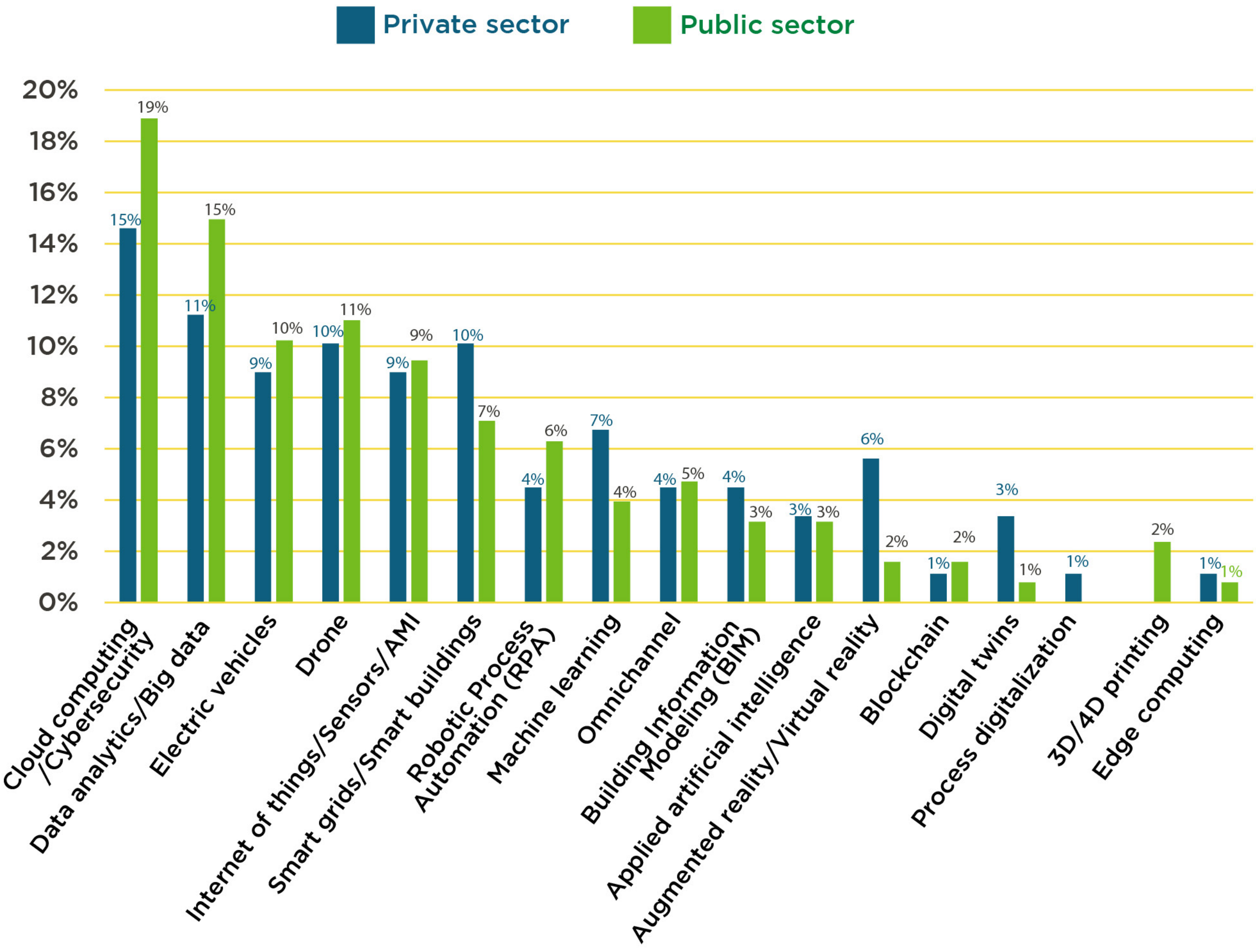
Similarly, the sector can take advantage of this opportunity to incorporate these technologies to also modernize its production processes, which contribute to reducing costs and optimizing manufacturing chains.

Main technologies and areas of digital transformation. The vision of the agents

The progressive incorporation of technologies in the sector seeks to accompany the transformation of the energy system model, providing greater information and decision-making capacity to consumers, so that they can actively participate in energy markets. In addition, a progressive technological deployment will help the massive incorporation of renewables that contribute to decarbonizing the energy system and related production and industrial systems.

In this sense, the survey has focused on the most advanced digital technologies that are being incorporated into the energy systems of the main countries to verify the degree of current digital transformation of companies in the energy sector in the region:

Technologies being targeted for investment in digital transformation



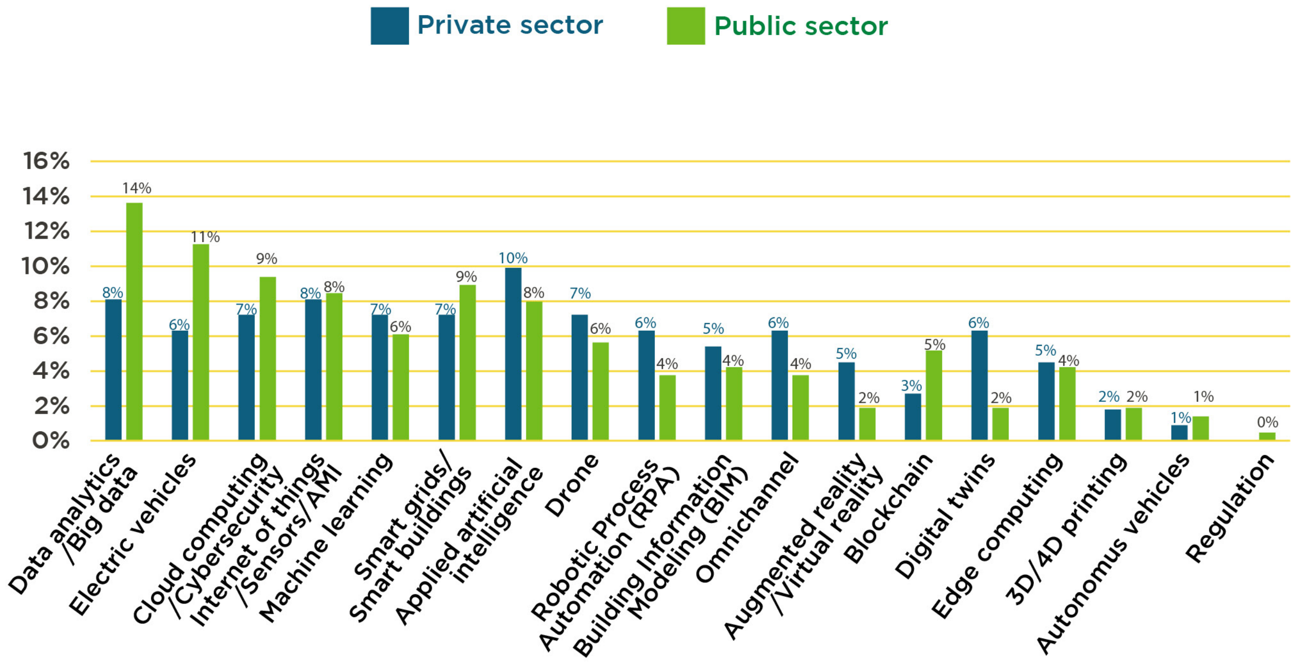
In general, the results show that the sector is now immersed in the incorporation of technologies based on data collection and processing. Therefore, at present, technologies such as cloud computing, Data Analytics, big data prevail over others.

Likewise, the agents show the importance of a key area within the area of User Digitalization, such as the development and promotion of the electric vehicle.

From the results, it is noteworthy the low technological penetration in the digital twin region or augmented and virtual reality. As mentioned in previous chapters, the digital twin is a technology with a very positive impact on the key areas of the development of digital transformation, from the flexibility of the energy system to incorporate more renewables, to increasing the resilience of the energy system. This low penetration of the digital twin or augmented reality, among others, is due to a still low degree of digital maturity in the region, as may occur with use cases linked to Artificial Intelligence or the sensorization of infrastructures, which have not yet been contemplated in many of the countries analyzed.

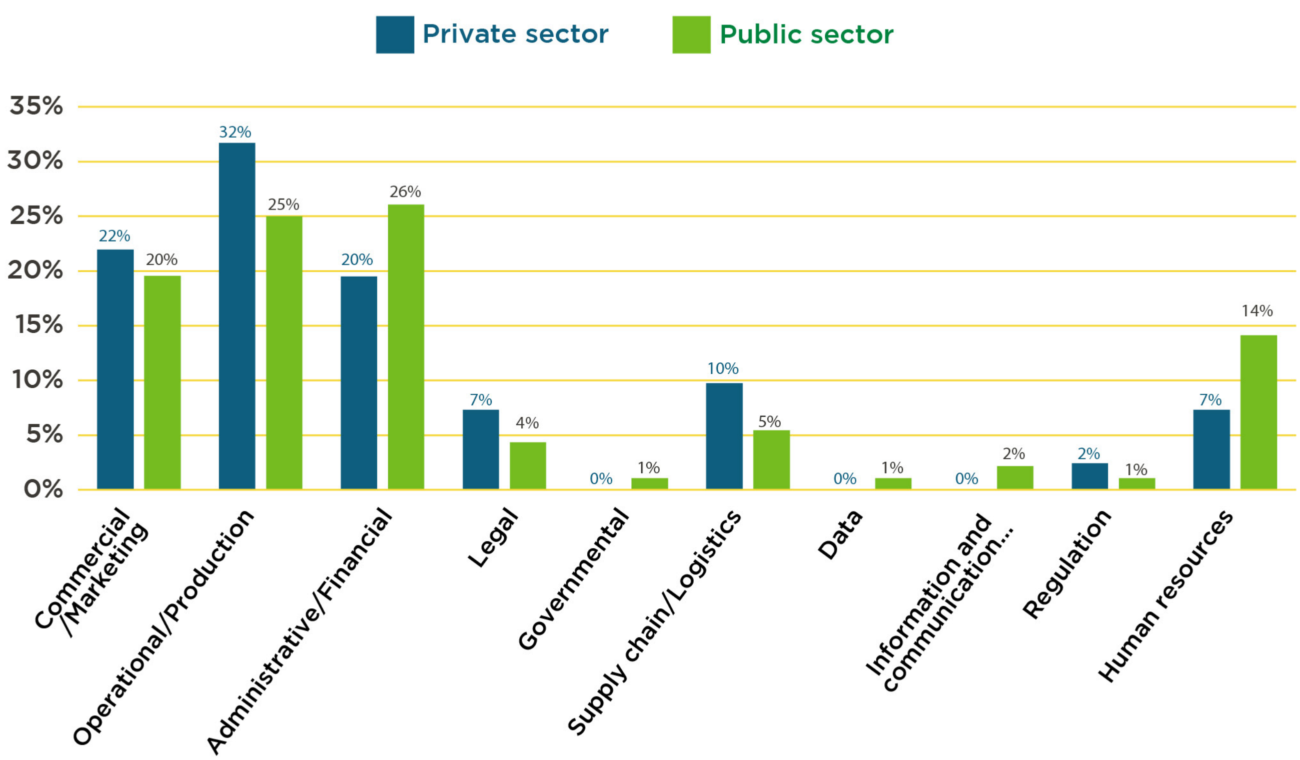
To summarize, the agents have identified the following technologies as relevant for the coming years:

Digital emerging technologies expected to be implemented in the energy sector in the future (3 years)



Among the results, the importance of smart grids & smart homes stands out. These are two key areas in moving towards user-centered digitalization, as well as for the incorporation of decentralized renewable generation resources that contribute to achieving a more flexible system. Additionally, other technologies such as blockchain or Artificial Intelligence, acquire interest from agents for the future.

Areas of dedication of resources within the digital transformation process in the entities surveyed

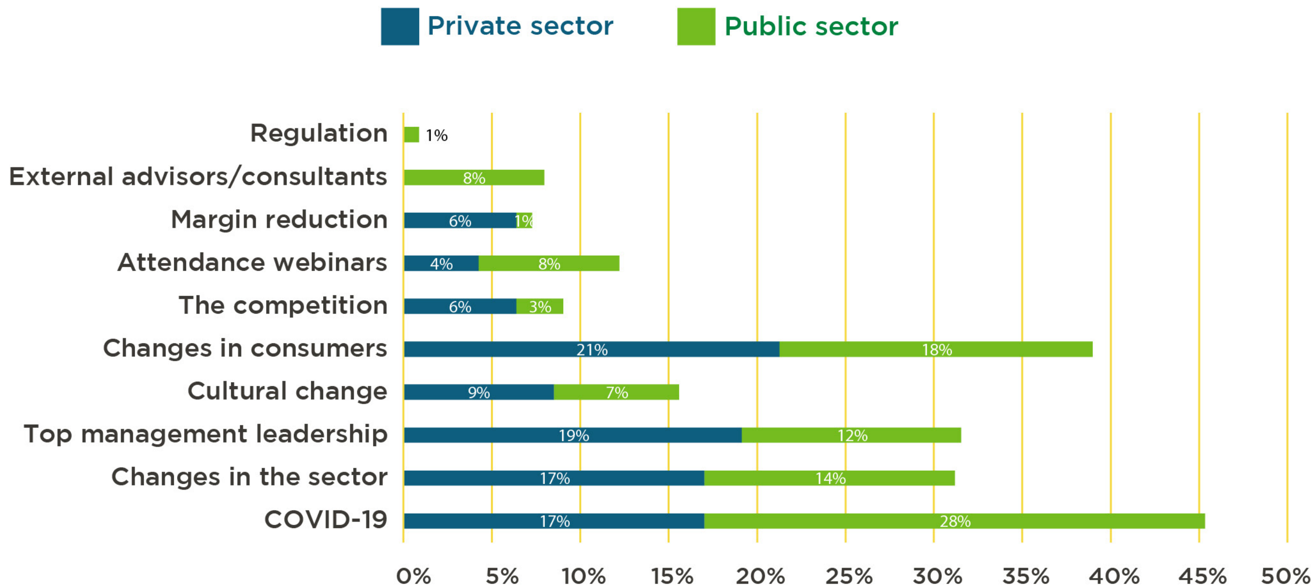


As can be seen, the results show that the areas of greatest dedication to the transformational process are the operational areas of the activity, that is, commercial, operation/production and administrative/financial areas. These high percentages indicate that those areas with the greatest impact on business productivity and consumers are those that prevail at the beginning of the transformation process. On the contrary, more traditional areas and with greater difficulty in the incorporation of technologies such as the legal and governmental sphere, combine low results.

Impact of digital transformation and identified barriers

Agents have been asked which aspects they consider have contributed most positively to the progress of their organization in digital transformation. Identifying these aspects will allow other agents in the region to focus their attention and efforts on the process. The results obtained from this consultation have been the following:

Aspects considered most positive for the progress of organizations in digital transformation

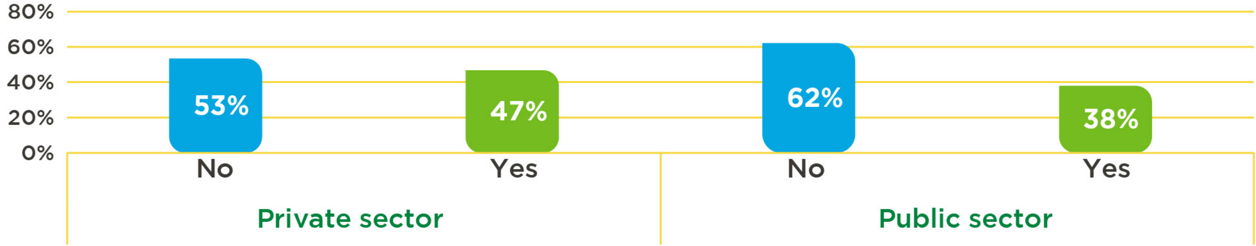


It is very noteworthy that, in general, the COVID-19 pandemic is considered an accelerating milestone of digital transformation. This, according to interviews with agents from outside the region, highlighted the criticality of the energy sector for the rest of the economic activities.

Other important factors are the necessary changes in the sector and in the business environment. This reinforces the need to undertake a cultural transformation of the business model that accompanies the digital transformation process.

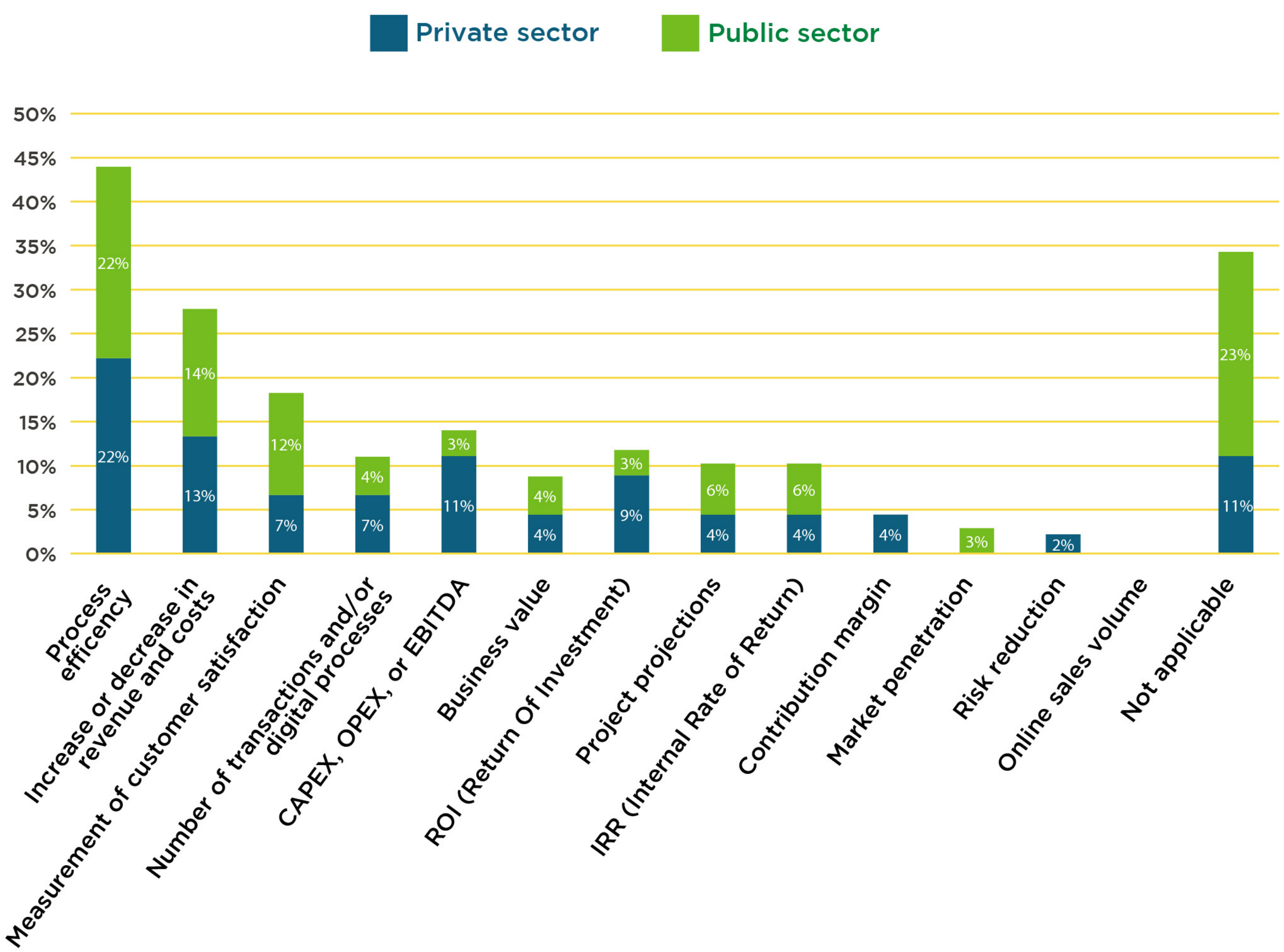
In this regard, only 42% of the agents confirm that they have quantified the impact of the investments that their organization has made in digital transformation, an aspect identified as very relevant according to the interviews held with the agents operating in the reference countries analyzed:

Quantification of the digital transformation process in the surveyed organizations



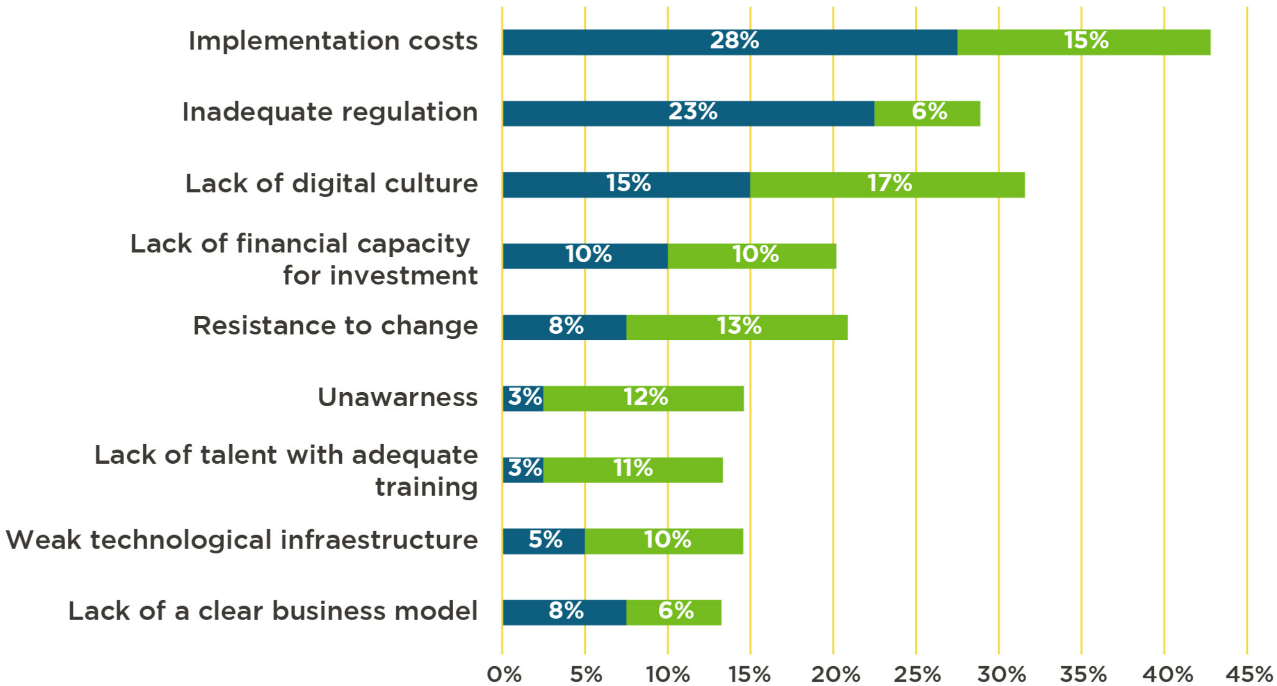
Among the existing indicators to measure the impact of these investments, the efficiency in the processes (25%) and the increase or decrease in revenues and costs (18%) stand out. On the other hand, the low level of response in relation to Risk Reduction (1%) stands out:

Indicators used to measure the degree of progress of the digital transformation process in the consulted organizations



Regarding barriers to digital transformation, along with implementation costs (17%) and lack of digital culture (16%), respondents highlight: (i) lack of financial capacity to undertake the necessary investments, (ii) resistance to change and (iii) ignorance of the digital transformation process.

Barriers identified by the surveyed entities to carry out the digital transformation process



Appendix B. Contacts with public and private actors in the sector

The digital transformation of the energy sector requires the collaboration of all actors, **public and private, to guarantee the success of the process.** Therefore, all of them must be aligned and **collaborate to assume the challenges that arise during this transformational process.**

That is why, as part of this work, different contacts, meetings and interviews have been carried out with different public and private agents, who develop their activity outside the region, in order to know the main challenges and opportunities, around the digital transformation, that their organizations are experiencing, and identify those aspects that they consider critical to successfully carry out this process. These agents belong to the countries selected for the bibliographic study of best practices, and have been divided, according to their field of activity, into the following categories:

	Private agents	Public agents	Academy/Research Centers	Manufacturers
United States	✓	✓	✓	✓
Spain	✓	✓	—	✓
United Kingdom	✓	✓	✓	—
Portugal	✓	✓	—	—
Italy	✓	✓	—	—
South Korea	✓	✓	—	✓

The information and documentation of these agents has made it possible to identify the main areas of interest in relation to the progressive digital transformation of the sector. The overview of the contacts made is that the digital transformation of the sector is not an option, it opens a new paradigm to the energy sector, and should consider the following aspects:

- **Digital transformation is the only lever to successfully undertake such an ambitious renewable generation plan in the global energy mix and will only be achieved with public-private collaboration and collaboration between private agents in the sector** (manufacturers and utilities, for example). It is understood that it is not possible to achieve the objectives set out in the decarbonization plans and commitments without a clear strategy in the digital transformation of the sector. This implies that all the agents present in the value chain must advance jointly and a strong financing impulse to reduce deadlines and make certain investments viable.

- Therefore, the private sector **demands from public agents an updated regulatory framework and regulatory stability and certainty that allows the recognition and recovery of investments. Public agents (regulators) are aware that they have a decisive role to support the digital transformation of the sector,** and, for this, they are carrying out regulatory sandboxes, in such a way that changes are made gradually, without the need to put at risk large investments or develop regulations that do not have a medium-long term path.

- **The basis of digital transformation is associated with three key technological areas: (i) sensorization to obtain data; (ii) data analytics through Artificial Intelligence and algorithms; and (iii) intelligent communications and security** (physical and digital).

- In this context, **the agents consulted also recognize that it is also necessary to make a cultural change in society and organizations in relation to the process of digital transformation, as it is such a disruptive process.** For this, they recognize that it is important the involvement of senior management in this transformative process, which fosters a change in organizations. **They also identify** the need **to invest in the training of the workforce in new digital skills.**

- Likewise, **the need to promote academic and professional training in digital areas is identified, to guarantee innovation and the development of new digital products that respond to needs.**

- Likewise, **they highlight the need to strengthen and/or maintain industrial competitiveness in the new products required by the sector**, especially with the risk posed to many companies in the sector by adapting and transitioning in the manufacturing process from products based on iron and copper, to digital hardware and software products.

- **The technological deployment must be accompanied by resilient developments in cybersecurity,** mainly based on recognized international standards, **which guarantee the integrity of the energy system, and of the data collected and processed linked to consumers.**

Appendix C. LAC Agents Survey Form

Background

The Inter-American Development Bank (IDB) is conducting a study on the state of the digital transformation of the energy sector in Latin America and the Caribbean, from the point of view of the four currently basic pillars of development of the sector: (i) user-centered digitalization; (ii) system flexibility for the integration of renewables; (iii) resilience of the energy system and (iv) the value chain.

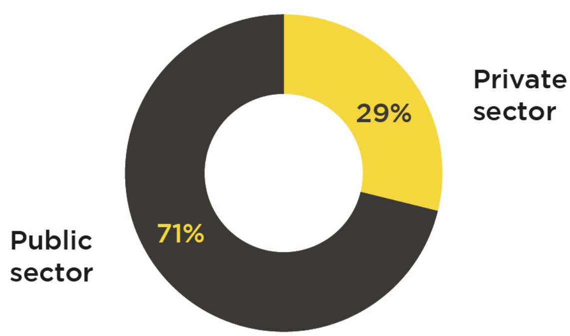
In this context, the IDB has considered it key to have the vision and future perspective of the main agents involved along the value chain, with the aim of knowing first-hand, both by the public and private sectors, the potential advances made in terms of digital transformation in different countries of the region.

The vision of the main agents will be of interest to identify the current state of the modernization process of the energy sector in the region, identifying barriers, opportunities and potential courses of action that promote digital transformation through collaboration and public-private cooperation.

Profile of surveyed agents

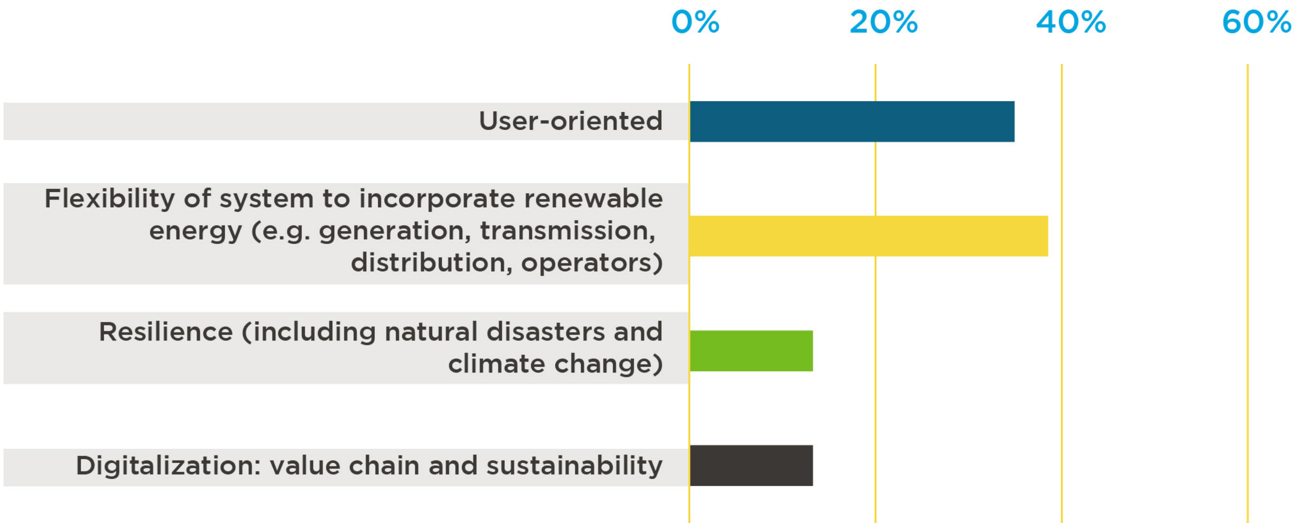
As mentioned above, the elaboration of the digital transformation roadmap for the region has included the consultation on the vision on digital transformation in the field of energy, by public and private agents that carry out their activity within the value chain of the energy sector in the region. To this end, an analysis has been carried out based on the results of a survey of 52 public representatives (agents and institutions) and private representatives of the region. The aforementioned surveys have been carried out between the months of July and August 2023. Similarly, the questionnaire used for the surveys can be found below in this appendix. In the following figure, you can see the breakdown of participants in the survey by area of development of their activity within the sector:

Number of agents surveyed by area of activity



Likewise, the survey has been directed to entities and companies that are framed in different key areas of the energy sector, to give a transversal vision of the needs of the sector.

Key areas of digital transformation in which the surveyed agents carry out their activity



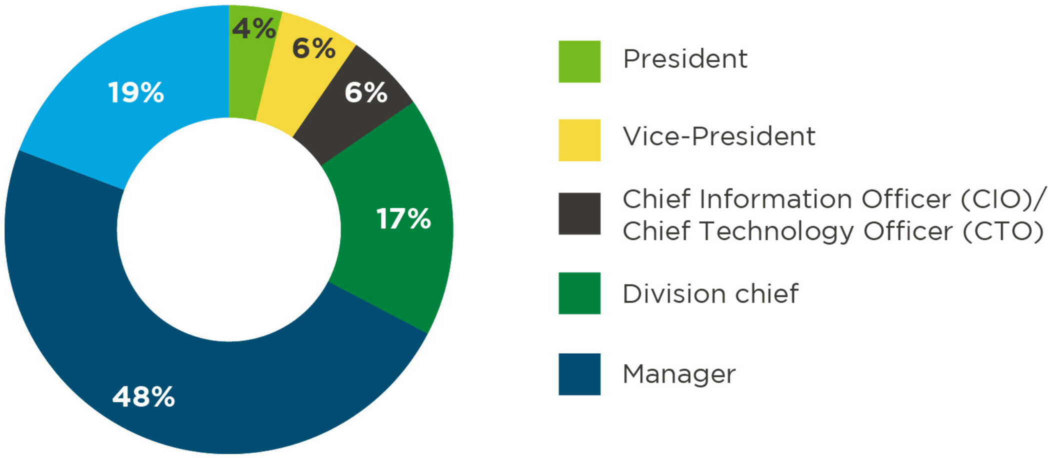
Similarly, in order not to have a biased view of a certain dimension of the entities consulted, we have proceeded to contact agents belonging to organizations with a different volume of employees. In the following table, you can see the categorization of the entities consulted according to the number of employees:

Size of the entities to which the agents belong (by number of employees)

Employees	Private sector	Public sector
1-50	27%	16%
51-500	20%	24%
501-1,000	27%	27%
More than 1,000	227%	32%

On the other hand, the survey was addressed to (i) Presidents of public or private entities; (ii) other management positions of public or private entities; (iii) Chief Information Officer (CIO)/Chief Technology Officer (CTO); (iv) Heads of Division; (v) Managers/Managers; and (vi) Other agents of interest. The result of the answers according to the professional rank has been the following:

Professional category of the surveyed agents



Survey form

Digital transformation in the energy sector in Latin America and the Caribbean

1. Country

Argentina
Bahamas
Barbados
Bolivia
Brazil
Chile
Colombia
Costa Rica
Ecuador
El Salvador
Guatemala
Honduras
Jamaica
Mexico
Panama
Paraguay
Dominican Republic
Suriname
Trinidad and Tobago
Uruguay

2. Which type is your organization?

Public
Private

3. In which sub-sector of energy sector digitalization is your organization primarily active?

User-oriented

Flexibility of system to incorporate renewable energy (e.g. generation, transmission, distribution, operators)

Resilience (including natural disasters, climate change and cybersecurity)

Digitalization: Value chain and sustainability

4. How many employees does your organization have?

1-50

51-500

501-1.000

Over 1.000

5. What is your role in the organization?

President

Vice-president

Chief Information Officer (CIO)/Chief Technology Officer (CTO)

Manager

Division chief

Other

6. To date, how much do you think your organization has made progress in digital transformation?

Nothing

Awareness is being raised

The first pilots have already been developed

We are in the process of implementation with an established plan

It has an advanced adoption

7. Does your organization have a digital transformation strategy?

Yes

No

8. In what areas has your organization been applying digital transformation? Check all that apply.

Administrative/Finance

Commercial/Marketing

Legal

Operational/Production

Human resources

Supply Chains/Logistics

Other

9. How do you perceive your organization's progress in digital transformation issues compared to the average for your sector in Latin America and the Caribbean?

- Far behind
- Behind
- On average
- Ahead
- Way ahead

10. How do you perceive your organization's the progress in digital transformation issues with respect to leading countries worldwide?

- Far behind
- Behind
- On average
- Ahead
- Way ahead

11. What are the investment objectives for digital transformation in your organization? Check all the ones you consider.

- Automate processes
- Reduce costs
- Increase online presence
- Get into other industries
- Achieve additional sources of income
- Increase brand power
- Contribute to environmental goals
- Improve security/safety
- Other

12. Which of the following technologies are you using in your organization? Check all the ones you consider.

- Omnichannel
- Cloud computing/Cyber security
- Data analytics/Big data
- Machine learning
- Internet of things/Sensors/AMI
- Applied Artificial Intelligence
- Robotic Process Automation (RPA)
- Drone
- Building Information Modeling (BIM)
- Augmented Reality/Virtual Reality
- Blockchain
- 3D/4D Printing
- Autonomous vehicles
- Electric vehicles
- Edge computing
- Smart grid/Smart Buildings
- Digital twins
- Other

13. Considering a horizon of up to three (3) years, the digital transformation should be implemented mainly in which areas of your organization? Check all that apply.

- Internal processes of the organization
- Innovation in products and services
- Relationships with customers
- New business models and revenue stream
- New distribution channels
- Talent Management and Human Resources
- Collaboration between companies/third parties
- Safety & Security
- All of the above
- Other

14. Considering a horizon of up to three (3) years, which of the following technologies do you believe should be implemented in your organization? Check all that apply.

- Omnichannel
- Cloud computing/Cyber security
- Data analytics/Big data
- Machine learning
- Internet of things/Sensors/AMI
- Applied Artificial Intelligence
- Robotic Process Automation (RPA)
- Drone
- Building Information Modeling (BIM)
- Augmented Reality/Virtual Reality
- Blockchain
- 3D/4D Printing
- Autonomous vehicles
- Electric vehicles
- Edge computing
- Smart grid/Smart Buildings
- Digital twins
- Other

15. What have been the aspects that have contributed most positively to the progress of your organization in digital transformation? Check all that apply.

- COVID-19
- Top Management Leadership
- Cultural change
- Changes in consumers
- Changes in the sector
- The competition
- Attendance at webinars
- Margin reduction
- External advisors/consultants
- Other

16. Have you quantified the impact of the investments your organization has made in digital transformation?

- Yes
- No

17. If yes, what indicators have you used to measure the impact of these investments? Check all that apply.

- Increase or decrease in revenue and costs
- Process efficiency
- ROI (Return on Investment)
- Project projections
- Online sales volume
- Number of transactions and/or digital processes
- CAPEX, OPEX or EBITDA
- Measuring customer satisfaction
- Contribution margin
- Business Value
- IRR (Internal Rate of Return)
- Market penetration
- Not applicable
- Other

18. What restrictions/limitations have you encountered to advance the digital transformation of your organization? Check all that apply.

- Implementation costs
- Lack of digital culture
- Unawareness
- Lack of financial capacity for investment
- Lack of a clear business model
- Lack of talent with adequate training
- Inadequate regulation
- Resistance to change
- Weak technological infrastructure
- Other

19. Please indicate any observations that you feel are necessary for technological development in your area or sector (optional).

20. Would you like to be contacted later when we have the results of the study?

- Yes (in this case, please provide your contact details below)
- No

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