Energy, water, and health for a better environment

Infrastructure in Latin America's Development
2022

ideal

CAF DEVELOPMENT BANK OF LATIN AMERICA AND THE CARIBBEAN

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Foreword

The health of the planet and the ecological balance of ecosystems are increasingly determining factors in the appreciation of the present and the vision of the future. With that in mind, climate change is the biggest global challenge we face as a society. Since the 1980s, the average temperature of the planet has been increasing at an accelerated rate, reaching 1.1°C above pre-industrial levels in the second decade of the 21st century. The primary cause of this warming is the emission of greenhouse gases.

Over the five years period from 2015 to 2019, Latin America and the Caribbean accounted for around 8.4% of global greenhouse gas emissions (with carbon dioxide emissions at less than 7%). The region's emissions are proportional to its economic activity and population size, which were 8.3% of the world's GDP and population, respectively. However, the region also experienced a sharp increase in the number of natural disasters, which were 2.6 times higher from 2010 to 2021 compared to 1970 to 1980. Material damage was 3.6 times higher, with a cost equivalent to 0.32% of its GDP. To meet the Paris Agreement goal of limiting global warming to below 1.5°C above pre-industrial levels, global carbon emissions must decrease by approximately 6% per year until 2030.

According to the Living Planet Index, the LAC region has experienced the largest reduction in animal populations, with a 94% drop between 1970 and 2016, compared to a global reduction of 68%. Additionally, the forest area in the region decreased by 13% during the same period, compared to a global drop of 4.2%, contributing to the loss of natural habitats. This negative trend in biodiversity conservation in both terrestrial and aquatic ecosystems is a problem related to sustainable development and climate change. In addition to preserving different life forms, ecosystems are also crucial for absorbing CO_2 emissions.

In this context, infrastructure sectors play a crucial role in the sustainable development of economies. Therefore, CAF has conducted an in-depth study of two key economic infrastructure sectors—water and energy—in the "Infrastructure in Latin America's Development " (IDEAL) report. The report also includes transportation due to its significant role in energy consumption. Furthermore, the study analyzes the impacts of these sectors in the conservation of natural capital and the fight against climate change.

In the energy sector, taking the current situation as a starting point, the report analyzes interventions aimed at transitioning to a system based on primary sources with lower emissions and a greater electricity component. This includes incorporating energy intensity policies, technological developments to facilitate the transition, and actions to adapt to climate change. However, the greatest challenge of these interventions is balancing environmental, economic, and social needs while taking into account the region's capacity to achieve this transition at a certain speed.

In the water sector, conserving water resources requires higher levels of cooperation, coordination, and integration. This includes controlling polluting activities, improving efficiency, developing a circular economy, and adopting an integrated resource management approach. The report also reviews policies, regulations, and investments in traditional and green infrastructure to ensure sustainability and promote efficiency while maintaining affordability. Additionally, they analyze the health sector's capacity to respond to possible events. Although the origin of the disruption caused by COVID-19 was epidemiological, the lessons learned are useful for dealing with future health events of this origin or generated by vectors altered by the effects of climate change.

In this new edition of the IDEAL report, CAF aims to contribute to the sustainable development of the region by promoting a results-based approach to interventions and regulations in infrastructure services. This approach provides a comprehensive understanding of the public policies required to enhance the quality of life of the region's inhabitants while also supporting environmental protection and biodiversity preservation.

Sergio Díaz-Granados
Executive President of CAF

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Content

3

4

5

Boxes

Figures

Graphs

Tables

Abbreviations

ADERASA	*Asociación de Entes Reguladores de Agua Potable y Saneamiento de las Américas* [Association of Drinking Water and Sanitation Regulatory Agencies of the Americas]
ANA	Agência Nacional de Águas e Saneamento Básico [National Water Agency]
BAU	Business as Usual
BECCS	Bioenergy with carbon capture and storage
BTU	British thermal units
C&O	Carbon and oil
CCUS	Carbon capture, utilization, and storage
CLAC	Latin American and Caribbean Network of Fair Trade Small Producers and Workers
CO_2	Carbon dioxide
COP	Conference of the Parties
COVAX	Covid-19 Vaccines Global Access
CRED	Centre for Research of the Epidemiology of Disasters
ECDC	European Centre for Disease Prevention and Control
ECLAC	Economic Commission for Latin America and the Caribbean
EIA	Energy Information Administration (United States)
EJ	Exajoule
ENARGAS	Ente Nacional Regulador del Gas [National Gas Regulatory Entity] (Argentina)
ETI	Energy Transition Index
EU	European Union
EV	Electric vehicles
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GHG	Greenhouse gas
GIH	Global Infrastructure Hub
GPMB	Global Preparedness Monitoring Board
$GtCO_2$	Gigaton of carbon dioxide
GW	Gigawatt
GWP	Global Water Partnership
H_2	Hydrogen (diatomic molecule)
HPD	Health professional density
ICTs	Information and communication technologies
ICU	Intensive care unit
IDB	Inter-American Development Bank
IEA	International Energy Agency
IHR	International Health Regulations
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel of Experts on Climate Change
IRENA	International Renewable Energy Agency
ITF	International Transport Forum
IWRM	Integrated water resources management
km	Kilometer
kWh	Kilowatt hour
LAC	Latin America and the Caribbean
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LPI	Living Planet Index

m^3	Cubic meter
MDG	Millennium Development Goals
MERS	Middle East Respiratory Syndrome
$MtCO_2e$	Millions of tons of carbon dioxide equivalent
MW	Megawatt
NbS	Nature-based solutions
NCRE	Non-conventional renewable energies
NDC	Nationally determined contributions
NAP	National Adaptation Plan
NHAP	National Health Adaptation Plan
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
OLADE	Latin American Energy Organization
OWID	Our World in Data
PAHO	Pan American Health Organization
PHEIC	Public health emergency of international concern
PJ	Petajoule
SAIDI	System average interruption duration index
SAIFI	System average interruption frequency index
SARS	Severe acute respiratory syndrome
SDG	Sustainable Development Goals
SG	Smart grid
STEPS	Stated Policies Scenario
tCO_2	Ton of carbon dioxide
tn	Ton
TWh	Terawatt hour
UN	United Nations
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and adaptation
WEC	World Energy Council
WEF	World Economic Forum
WHO	World Health Organization
WMO	World Meteorological Organization

Introduction

Since its establishment, CAF has worked to contribute to the sustainable development and integration of Latin America and the Caribbean. More recently, the institution has taken concrete and determined steps to become the region's Green Bank, strengthening its commitment to protecting biodiversity, advancing toward decarbonizing economies, and supporting the energy transition. These efforts aim to mitigate the impacts of climate change and reduce the region's high vulnerability to the increasing frequency and intensity of extreme weather events.

Complementing these commitments is CAF's strategic interest in promoting the development of sustainable and resilient infrastructure while addressing key issues in the region, such as climate change, digitalization, productivity enhancement, integration, and reduction of inequalities. This approach entails collaborating with national governments, particularly subnational governments, and encouraging the private sector to become more involved.

Infrastructure is considered a key element in achieving this objective and promoting the sustainable development of Latin American and Caribbean economies. The impact of the infrastructure sector as a driver of development—economic growth and productivity—and inclusion has been extensively studied. For example, recent research in Colombia shows that increasing infrastructure investment by an average of 0.5% of GDP per year over the next decade would raise the annual economic growth rate by 0.8 percentage points and reduce unemployment and poverty by 0.5 and 0.6 percentage points, respectively.

For these reasons, CAF is currently undertaking multiple projects in the economic and social infrastructure sectors. These projects account for over half of the bank's current loan portfolio (13.4% in energy, 24.8% in transportation, 6.4% in water and sanitation, and 10.7% in education, health, and social protection). In 2021, within the framework of the Sustainable Development Goals, the allocation of resources placed a strong emphasis on industry and innovation infrastructure (25.1% of approved resources) and clean water and sanitation (25%), with a focus on urban development, water, sanitation, and irrigation projects aimed at improving basic urban infrastructure in multiple cities across the region. Moreover, several projects include components of environmental sustainability through interventions for climate change adaptation and improved management and sustainable use of the environment.

The IDEAL report showcases CAF's analytical work in the region's infrastructure sectors and their connection to sustainable development. In this edition, the central focus of the discussion is the environment. Data on the service gaps and the fulfillment of the Sustainable Development Goals in energy, water, health, greenhouse gas emissions, and energy matrices are collected and analyzed. Using this information, assessments are made and the main sectoral challenges are documented.

Chapter 1 presents the region's main environmental challenges and evaluates the performance of the infrastructure sectors in meeting the environmental targets set in the Sustainable Development Goals. Delving deeper into sectoral analysis, Chapter 2 examines the challenges in the energy sector, particularly the energy transition in the region. Chapter 3 highlights the importance of water resources and proposes approaches that contribute to their conservation. Another prioritized sector in this edition is health, and thus, Chapter 4 aims to address which lessons learned during the COVID-19 pandemic can be useful for advancing toward resilient health systems. Lastly, in Chapter 5, IDEAL presents various approaches and intervention opportunities in the form of regulatory changes, infrastructure investments, and public policies through which countries can tackle the identified challenges.

CAF will continue to focus its efforts on generating specific knowledge that provides a precise and feasible vision of possible paths to attain sustainable development and integration in Latin America and the Caribbean, where the provision of more and better infrastructure—that is resilient and inclusive—is paramount.

Christian Asinelli
Corporate Vice President of Strategic Planning

1

Sustainable development, the environment and infrastructure

Recent trends in sustainable development: The environmental challenge

The sixth report of the Intergovernmental Panel of Experts on Climate Change (IPCC, 2021) highlights that human activities unequivocally caused global warming. It also underscores that the climate change observed in recent decades is unprecedented over many centuries to many thousands of years. Climate change is affecting all geographic regions worldwide, by causing more frequent and severe natural disasters like heat waves, floods, droughts, and tropical cyclones, among others.

Over the period 2010-2021 alone, over 4,500 natural disasters were registered worldwide (2.8 times more than in 1970-1980), which caused more than 530,000 direct deaths and destroyed assets worth over USD 2.4 trillion, equivalent to 0.2% of gross domestic product (GDP). Damages as a result of natural disasters in Latin America and the Caribbean (LAC) were estimated at 0.32% of the region's GDP for the same period, with the Caribbean sub-region shouldering the brunt of the economic costs, equivalent to 2.5% of its GDP and mortality rates,

with 94% of total deaths (CRED, 2022). This will continue to worsen as a result of the sustained increase in temperature expected until at least mid-century (IPCC, 2021).

Calls to transform the current economic paradigm into sustainable, low-emission development with a lower impact on the planet are increasingly frequent. Although sustainable development considerations have long been on the public agenda (see Boxes 1.1, 1.2 and 1.3 for a detailed description of the three framework agendas for this report), only relatively recently has there been a unification of efforts to achieve a global agenda that holistically integrates all aspects of the balance between the environment, society and the economy.

In 2015, the United Nations member states adopted 17 goals as part of the 2030 Agenda for Sustainable Development, with a plan to attain them in 15 years. These goals represented a call for action to promote prosperity and economic growth while protecting the planet (the conception of sustainable development as described on the UN website).[1] They adopted multidimensional coverage of sustainability, including economic, social, and environmental areas (ESCAP, 2015), which requires taking into account the trade-offs involved in any public policy intervention.[2]

At the end of 2015, the 196 parties at the COP 21[3] adopted the Paris Agreement on Climate Change, a legally binding international treaty that entered into force in November 2016. The Paris Agreement set the goal of limiting global warming by reducing the temperature rise to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels by cutting greenhouse gas (GHG) emissions, thereby enhancing the climate-environmental dimension within a context of sustainable development and taking into account the national circumstances. From 2016, countries have been submitting periodically their plans or updates for climate action (known as Nationally Determined Contributions or NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) and have undertaken to submit their long-term strategies. The NDCs state countries' commitments to mitigation (especially reduced emissions) and adaptation (especially to extreme events). The Paris Agreement also included a funding dimension (increasing financial flows, especially from developed countries to developing countries, compatible with low-emission resilient development).[4]

In addition, the Conference of the Parties to the Convention on Biological Diversity was held in 2022. During this conference, 23 targets were adopted within the Global Biodiversity Framework (GBF) to reverse the loss of biological diversity, restore ecosystems, and foster a positive-action approach among people.

1 See https://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/.

2 This approach provides a succinct presentation of the links between sustainability targets and dimensions. For more detailed information, see ESCAP (2015).

3 COP is the acronym for Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). It is held annually to coordinate actions against global climate change. COP 21, held in Paris, was a historical event because it marked the adoption of the first-ever global climate change agreement. The most recent conference, COP 26, was held in Glasgow (UK) in November 2021 after the difficulties involved in the call to hold the COP in 2019 (due to the conflicts in Chile) and the pause in 2020 (due to COVID-19).

4 At the COP 16, developed countries committed to a goal of mobilizing jointly USD 100 billion a year, starting in 2020, to finance mitigation actions in developing countries (article 8 in the Copenhagen Accord adopted in 2009).

Box 1.1
Sustainable Development Agenda

The Sustainable Development Goals (2015) encompass the views on how to achieve development that improves the living standards of people globally without depleting the planet's resources. However, the concern for promoting sustainable development predate-s the publication of the goals by more than two and a half decades. The term "sustainable development" dates back to the late 1980s, with the publication of the Brundtland Report (UN, 1987). Previously, various documents had expressed broad concerns about environmental degradation both at the global level—in "The Limits to Growth," a report prepared for the Club of Rome in 1972 (Meadows et al., 1972)—and at the regional level—in the “Cocoyoc Declaration” adopted by the participants in the UNEP/UNCTAD Symposium on Patterns of Resource Use, Environment and Development Strategies, held in Mexico, in 1974 and the “Latin American World Model” adopted by Fundación Bariloche in 1976.[a]

The year 2000 marked a milestone for this topic, when leaders of 189 countries signed the Millennium Declaration, in which they committed to achieving the Millennium Development Goals (MDGs). This set of eight goals to be achieved within 15 years (by 2015) addressed poverty (MDG 1), education (MDG 2), gender equality (MDG 3), health (MDG 4, 5, and 6), environment (MDG 7) and international cooperation (MDG 8). Compliance with these goals was uneven. Although substantial progress was made to reduce extreme poverty (MDG 1), progress was less promising regarding gender equality in education and salaries (MDG 3) and maternal and neonatal mortality (MDGs 4 and 5) (WHO, 2018).

In 2012, within the framework of the United Nations Conference on Sustainable Development, more widely known as the Rio+20 Conference, a new set of goals to guide sustainable development beyond 2015 was proposed (SDGF, 2015). Two years later, after a public consultation process, the UN General Assembly Open Working Group submitted for approval in plenary a document containing 17 goals to be attained by 2030. The document was adopted in September 2015 and set the stage for the current Sustainable Development Goals (SDGs).

The SDGs differ from the MDGs in that they include goals to be achieved by both developing and developed countries, in addition to covering a broader range of topics. This is reflected in the increased number of goals and targets: 8 goals and 21 targets in the MDGs versus 17 goals and 169 targets in the SDGs. The SDGs attach greater importance to the environmental dimension of sustainability, including climate change as well as the conservation of natural capital. The SDGs broaden and deepen the drive for sustainable development, establishing commitments for all countries (developing and developed) and placing climate change and the environment, in general, at the heart of sustainability.

a. See EquilibriumGlobal (2019).

Box 1.2
Climate Change Agenda

Discussion of climate change has a long history. Although it has been known since the end of the 19th century that the accumulation of carbon dioxide (CO_2) in the atmosphere could increase the earth's temperature (Arrhenius, 1896), this issue has only been high on the public agenda since the 1970s. Even though climate change was not the main topic at the first UN Conference on the Environment, held in Stockholm in 1972, a related issue—chemical pollution—was discussed and, as a result of the meeting, the United Nations Environment Programme (UNEP).

The Intergovernmental Panel on Climate Change (IPCC) was created in 1988 to study the causes and consequences of climate change. Since then, the IPCC has published six assessment reports (the most recent one in late 2021/early 2022). Each report warned of the progressive rise in temperature.

In 1992, the creation of the United Nations Framework Convention on Climate Change—within the framework of the UN Conference on Environment and Development held in Rio de Janeiro—marked another milestone for climate change action. This convention encouraged the implementation of two landmark agreements: the Montreal Protocol (1987), and the Kyoto Protocol (1997). The former, in force since 1989, sought to phase out emissions of substances that deplete the ozone layer, such as chlorofluorocarbons. It achieved positive outcomes and is generally considered a success case in the global coordination of action against climate change.

The Kyoto Protocol, in force since 2005, established binding targets for industrialized countries to reduce GHG emissions, both by adopting national plans containing measures on mitigation (it set a minimum target of 5.2% reduction in GHG emissions for the period 2008–12 compared to 1990), and adaptation. This protocol may be considered the precursor of current NDCs.

In this context, the Paris Agreement was adopted in 2015. It set goals to limit temperature rise, in addition to the obligation to draft national plans for the adoption of mitigation and adaptation measures. The Paris Agreement targets both developing and developed countries and contains ambitious goals regarding reduced emissions—e.g., net zero by 2050—and improved resilience to climate change, in line with the SDGs (SEI, 2019).

Box 1.3
Biodiversity Agenda

Considerations on the importance of biodiversity date back to the 1980s. In 1988, in the framework of the UNEP, the Ad Hoc Working Group of Experts on Biological Diversity was created to analyze the situation and its trends. Subsequently, in the framework of the UN Conference on Environment and Development held in Rio de Janeiro (1992), the Convention on Biological Diversity to preserve biodiversity and ensure its sustainable and equitable use was adopted. In the context of this convention, the Cartagena Protocol (2000) was adopted to prevent any harm to biodiversity when living modified organisms are handled, transferred or used, along with the Nagoya Protocol (2010), which calls for equitable access to genetic resources and their benefits.

Against this background, during the Conference of the Parties to the Convention on Biological Diversity held in 2010 in the Japanese city of Aichi, the “Aichi Targets” were adopted.

These agendas recognize that the conservation of biodiversity is essential to achieve sustainable development. In other words, biodiversity is fundamental to ensure human wellbeing in its multiple dimensions (e.g., food and medicines), in addition to a range of ecosystem services such as clean water, pollination, and plague and disease control, among others.

The importance of biodiversity to sustainable development was included in the SDGs as from target 15.5, “take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.” In broader terms, the SDGs and the Aichi Targets are aligned. Although most of the SDGs should be achieved by 2030, 12 biodiversity targets should have been achieved in 2020 (WWF, 2019).

In this context, SDGs provide an integrating framework that includes the considerations of these environmental agendas while extending the analysis to other dimensions of sustainability (social and economic).

A review of the environmental goals contained in the SDGs, the Paris Agreement, and the Aichi Targets shows concern about meeting the limits to the increase in global temperature (Article 2, subparagraph (a) of the Paris Agreement), the adaptation to climate change and extreme events (Target 2.4 of the SDGs; Article 2, subparagraph (b) of the Paris Agreement), and the conservation of biodiversity (Targets 15.4 and 15.5, the Aichi Targets and the Convention on Biological Diversity). It also reveals the need to reduce mortality from air, water, and soil pollution and contamination (Target 3.9) and extreme events (Target 11.5), develop sustainable and resilient infrastructure (Target 9.1), reduce the contamination of terrestrial (Target 15.1) and marine ecosystems (Target 14.1), and promote their sustainable use (Targets 15.1 and 15.2).

The SDGs contain specific targets for the infrastructure sectors prioritized in this report. In particular, those related to water, energy and health (SDGs 6, 7 and 3, respectively) are sustainable development goals in themselves, reflecting the essential role these sectors play in the development of countries. They also contemplate infrastructure as a whole, through SDGs 9 and 11, which deal with industry, innovation, infrastructure and sustainable cities.

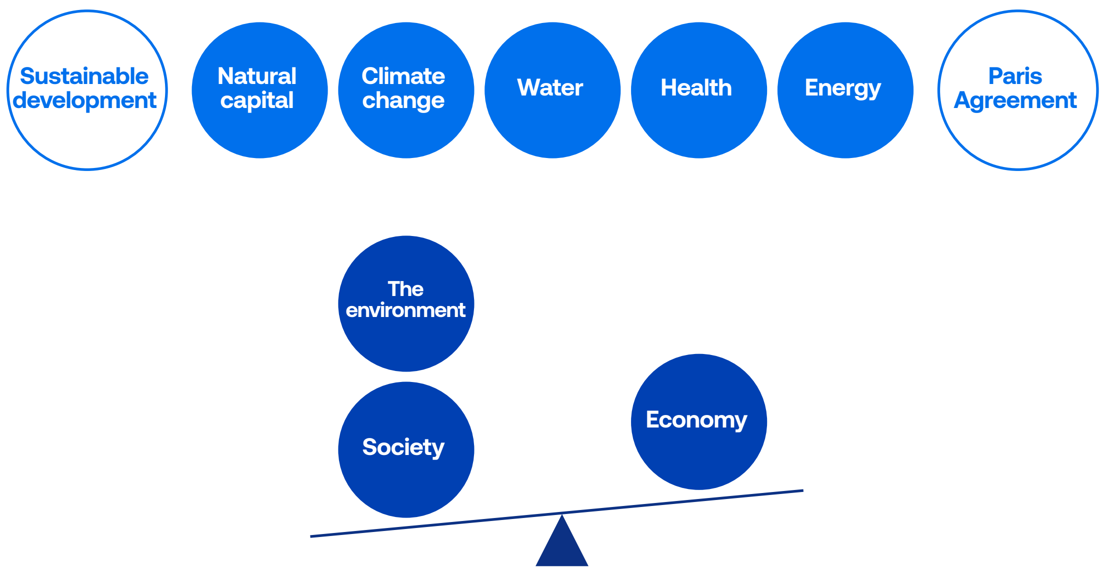
The environmental challenges reflected in the SDGs can be summed up into two main topics:

climate change and the conservation of natural capital. Figure 1.1 summarizes the environmental challenges and highlights the sectors prioritized in this report.

Because of its scope, complexity, and relevance, climate change is currently the main global challenge. In addition to its priority on the international policy agenda (summarized in the Paris Agreement and the COPs), climate change is a critical component of the sustainable development goals. SDG 13 calls upon the states to adopt urgent measures to combat climate change and its consequences. Moreover, climate variability has a cross-cutting effect on all the other goals, with targets aimed at sustainability, resilience, climate impacts, waste management and pollution, use of natural resources, poverty, and inclusion.

Climate change impact is pervading all economic sectors and activities, including the sectors prioritized in this report. The following section describes its main features, indicators, and consequences, focusing on LAC countries.

Figure 1.1
Environmental challenges in sustainable development
Source: Authors.



Global carbon emissions must decrease by approximately 6% per year until 2030 if the objective of limiting temperature rise to below 1.5°C is to be met.

Climate change

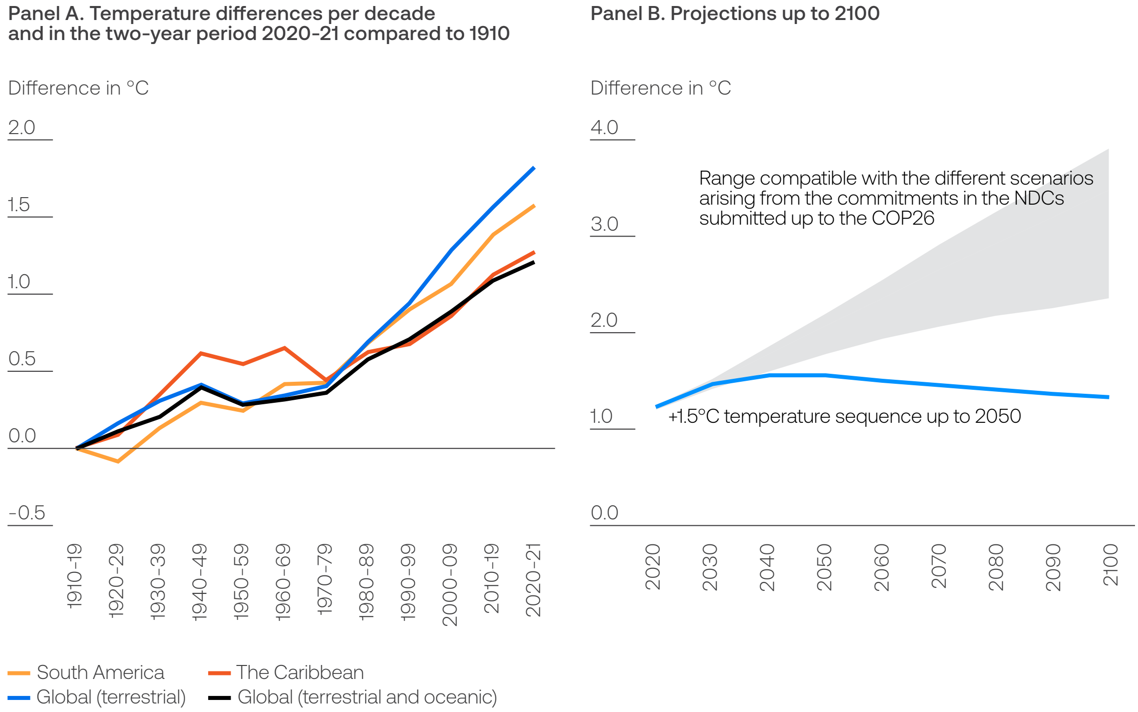
Climate change, a continuous process on Earth, first became a global concern in the 1980s with the creation of the IPCC and the signing of the Montreal Protocol. On the one hand, it causes imbalances in the main climate variables, particularly the long-term increase in the average global temperature (global warming) and its effects, mainly melting glaciers, rising sea level, and ocean warming and acidification. On the other, it has altered the probabilistic distribution of events, with a higher frequency and severity of extreme events—floods, droughts, wildfires, heat waves, and tropical cyclones—and led to changes in territories, with greater impact on the most vulnerable and poorest populations (Hallegatte et al., 2020).

Global climate change indicators

The planet's temperature has risen rapidly since the 1980s. During the second decade of the 21st century, the temperature was 1.1°C above the levels recorded for the period 1850–1900, which is considered representative of pre-industrial temperature levels since it is the oldest period for which global climate data is available. If this trend continues and no concrete actions are adopted to adjust patterns, behaviors, and modes of production, the difference is expected to reach or even exceed 1.5°C within the next 20 years (IPCC, 2021).[5] Temperature rise relative to the long-term global average and for the regions of South America and the Caribbean is summarized in Graph 1.1.

5 Targets to limit the increase in the global average temperature to below 2°C (above pre-industrial levels) and to pursue efforts to limit the temperature increase to 1.5°C are based on climate history, which suggests temperatures were highly variable before stabilizing during the Holocene, at the dawn of civilization. Subsequently, temperatures fluctuated within a range of +/-2°C for thousands of years. See Steffen et al. (2018).

Graph 1.1
Long-term temperature rise in the region and the world (°C)
Source: Authors based on data from the National Oceanic and Atmospheric Administration (NOAA, n.d.) and IPCC (2022b).



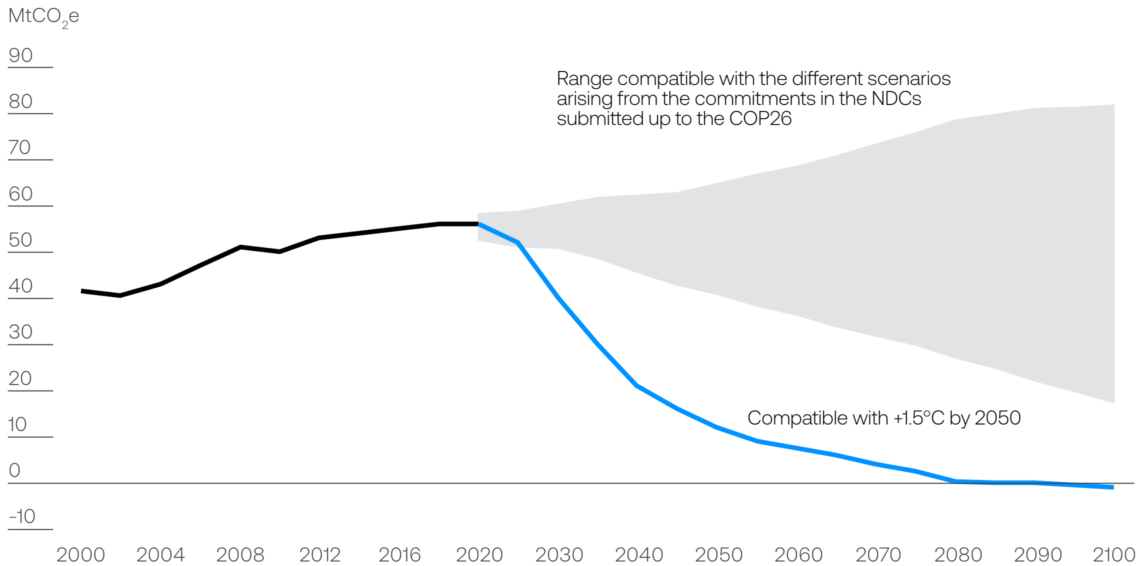
Note: The global series refers to the average temperature rise for the total surface (terrestrial and oceanic) and the terrestrial surface compared to its average during the 1910s. The series for South America measures the terrestrial temperature, while the series for the Caribbean includes terrestrial and oceanic temperatures. The grey area in Panel B represents the range of emissions compatible with the different scenarios arising from the commitments in the NDCs submitted up to the COP26. The blue series represents the trajectory if temperature rise is maintained at 1.5 °C by 2100 with a probability higher than 50%.

The accumulation of GHG in the atmosphere retains the heat from the sun and causes a rise in temperatures (known as global warming).[6] From 1990–2019, global GHG emissions increased by 50%. Meeting the goal of a temperature rise preferably lower than 1.5°C, as established in the Paris Agreement, requires that global carbon emissions drop by approximately 6% per year during the next eight years, up to 2030 (Graph 1.2). This is equivalent to the drop in emissions registered in 2020 during the COVID-19 pandemic, when economies worldwide slowed down as a result of lockdown policies implemented by governments. This reduction of emissions in 2020 was the highest interannual drop in carbon dioxide (CO_2) emissions since World War II. This is indicative of the scale of the challenge ahead.

6 The GHGs that cause global warming are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and three industrial fluorinated gases: hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6). Carbon dioxide contributed +0.8°C to the rise and methane contributed +0.5°C, while the others had a partially offsetting effect.

In LAC, the burning of fossil fuels, agriculture, and land-use changes are the biggest contributors to GHG emissions.

Graph 1.2
Global GHG emissions (in $MtCO_2e$) from 2000 to 2018, and projections to 2100
Source: Authors based on IPCC (2022a).

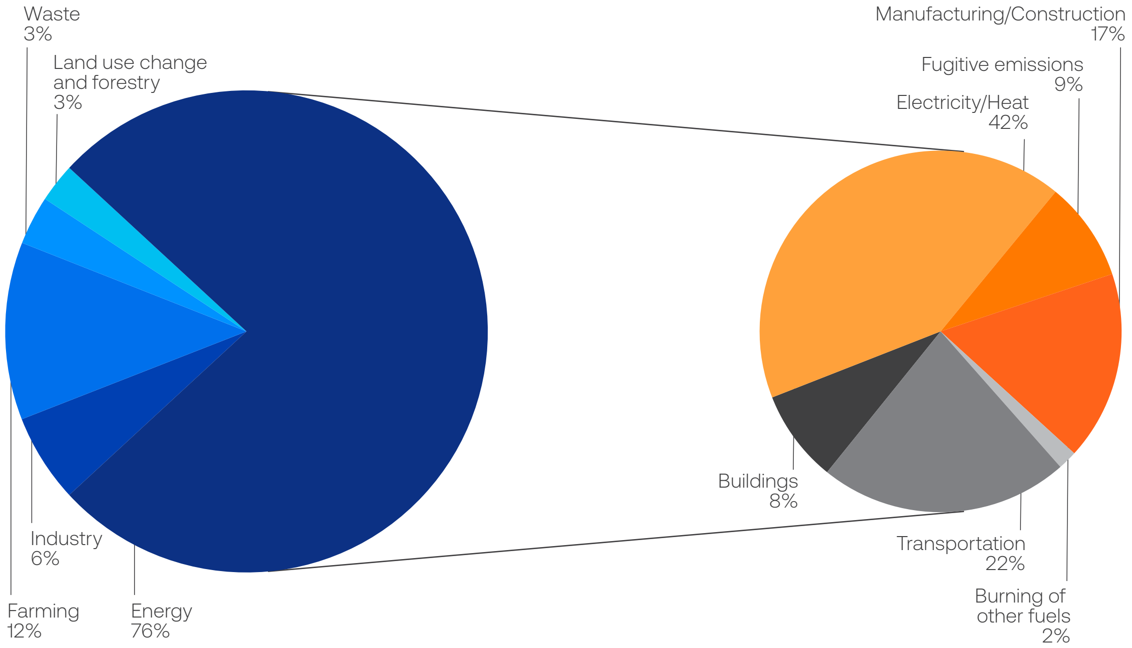


Note: The gray area represents the range of emissions compatible with different scenarios arising from the commitments in the NDCs submitted up to the COP26. The blue series represents the trajectory if temperature rise is maintained at 1.5 °C by 2100 with a probability higher than 50%.

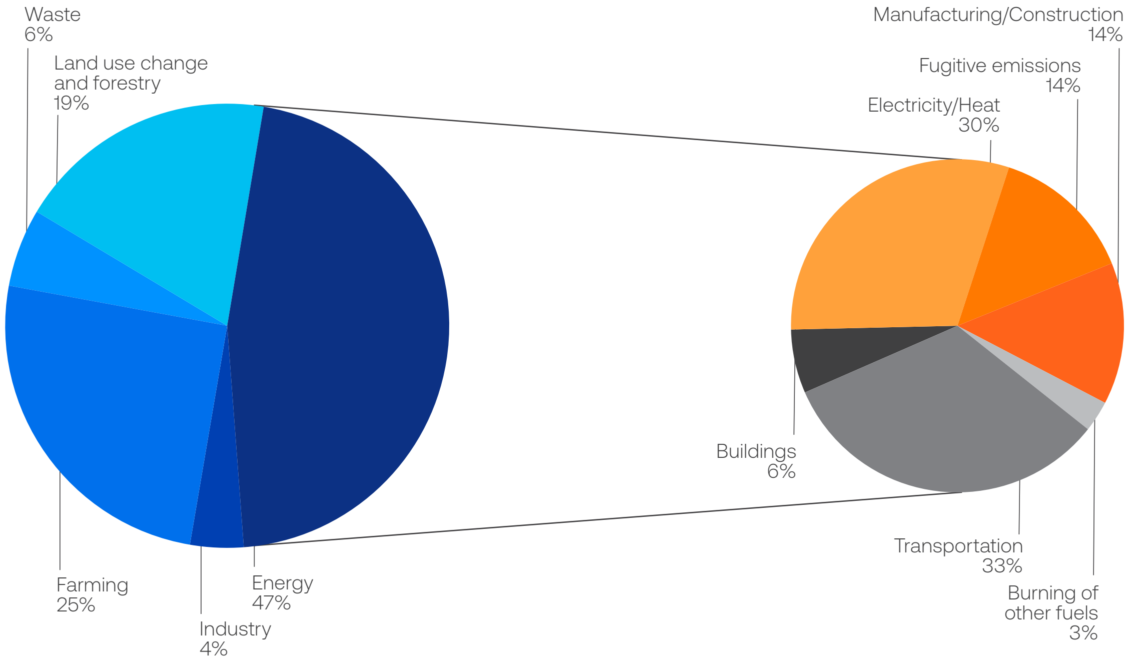
The main contributors to GHG emissions are activities like burning of fossil fuels (e.g., coal, oil, or natural gas), industry (e.g., cement production), deforestation, livestock farming, and the use of fertilizers. However, the relative importance of these factors can vary depending on the region or country being analyzed, as shown in Graph 1.3. Globally, fossil fuel emissions are the biggest contributor, accounting for 76% of emissions over the period 2015–2019). In LAC, farming and land use change are also significant contributors alongside fossil fuel emissions, with the former accounting for 44% and the latter, 46%.

Graph 1.3
GHG emissions per sector for the period 2015–2019
Source: Authors based on data from Climate Watch (n.d.).

Panel A. Global emissions: Average 48,356 $MtCO_2$



Panel B. Emissions in LAC: Average 4,073 $MtCO_2e$ (8.4% of global emissions)



Note: Boiler fuel (bunker) emissions are included in the energy sector (transportation subsector). A substantial portion of the differences in annual emissions reported in this Graph and Graph 1.2 originates in the application of different "conversion factors" (global warming potential) for gases into CO_2. Climate Watch uses the conversion factors from the IPCC Fourth Assessment Report (2007) and the IPCC (2022a) uses the ones from the Sixth Assessment Report (showing an increased conversion factor attributed to methane).

Recent data also show that the evolution of CO_2 and other GHG emissions in LAC are consistent with the region's activity and population size: over a five-year period (2015–2019), LAC produced approximately 8.4% of global emissions (less than 7% of CO_2 emissions), while its GDP, similarly to its population, accounts for 8.3% of global GDP.

Climate change indicators in Latin America and the Caribbean

Climate change indicators in LAC follow a pattern similar to the global pattern. The last ten years have been the warmest recorded in the region. According to the National Oceanic and Atmospheric Administration (NOAA), the average temperature in Central America and the Caribbean increased by approximately 0.4 °C compared to the average temperatures recorded over the period 1980-2010. The average temperature rise for the same period in South America was 0.6°C.

In keeping with the increase in temperature, glaciers in the region are retreating. Loss of ice mass has been on the rise and has accelerated in the Andean region since 2010. Ice melt coupled with elevated water temperature is leading to rising sea levels, which are slightly higher in the Atlantic Ocean than in the Pacific Ocean.

The frequency and intensity of extreme events is another indicator of climate change. For LAC, 2020 was the year with the highest number of tropical storms and hurricanes. With a total of 30 storms during the hurricane season, it surpassed the previous record of 28 storms in 2005. The Caribbean region is particularly vulnerable to the effects of tropical storms, as well as the impacts of droughts, which are often given less attention. Moreover, the frequency of floods in the region increased by 80% in the past two decades compared to the two preceding ones (CRED, 2022).

Impacts of climate change in Latin America and the Caribbean

As a result of climate change, the frequency and severity of days with extreme temperatures and precipitation have increased (Weikert Bicalho, 2021), leading to more natural disasters of different types.[7, 8]

The Caribbean has undergone major drought episodes in recent decades. Some countries in the region had severe droughts in 2020, especially Haiti, the Dominican Republic, and Venezuela, along with large areas in South America (Argentina, Brazil, and Chile). The drought in the Amazon was the worst in recent years, and 2020 was the year with the highest number of wildfires recorded in southern Amazonia.

Table 1.1 summarizes the natural disasters that occurred in the three LAC subregions over the period 2010-2021. The total impact of natural disasters in the region is estimated by CRED to be about USD 231 billion (in constant 2021 values) for the period considered (an average of USD 19 billion per year), causing approximately 250,000 deaths (about 20,000 per year). This damage is equivalent to 0.32% of GDP.

Even though the Caribbean subregion is the least populated and has had fewer disasters, it bore the greater part of economic costs (estimated to be 2.5% of its GDP) and mortality, with 95% of deaths. This suggests that the consequences of these extreme events are context-dependent: countries with more precarious infrastructure and high poverty levels suffer more severe consequences.[9] A regional database, like DesInventar, with country-level disaster microdata and without considering minimum damage thresholds, suggests that

7 According to the IPCC glossary, a disaster is any severe alteration of the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

8 In this regard, in 2015, the United Nations member countries adopted the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015), which outlines seven specific targets associated with natural disasters that should be attained by 2030. Target (d) states: "Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030."

9 The clearest example of damage being context-dependent (the natural disaster magnitude and the impact on each economy) is Hurricane Katrina, which affected New Orleans in 2005, causing an estimated damage of USD 125 billion. In other words, although its geographic effect was limited to one area in the United States, damage caused was equivalent to 60% of the damage recorded in LAC over a 12-year period.

Natural disasters from 2010-2021 accounted for approximately 0.32% of the region's GDP.

these losses are largely concentrated in the destruction of basic infrastructure such as housing, transport networks, and health and educational centers. This accounts for the broad impact of climate change and extreme events on infrastructure in the region.

Table 1.1
Natural disasters by subregion over the period 2010-2021
Source: Authors based on CRED (2022).

Indicator	South America	Central America	The Caribbean
Number of disasters	377	241	159
Most frequent disasters	Floods, landslides, and earthquakes	Storms, floods, and earthquakes	Storms, floods, and epidemics
Deaths	9,087	3,975	234,370
People left homeless	1,091,130	125,359	470,232
Total damage (in billion USD)	77.8	38.8	114.3
Insured damage (in billion USD)	12.5	6.8	37.8
Cost of reconstruction (in billion USD)	4.1	1.2	16.5

Note: "People left homeless" reflects the number of persons whose home was destroyed or severely damaged, and who needed shelter after the disaster. "Total damage" includes the destruction of physical assets (infrastructure, production, the environment, and other). "Insured damage" refers to the proportion of total damage covered by insurance companies. "Cost of reconstruction" includes expenditure on replacing destroyed assets and investment in preparation and mitigation for future events. Damage is measured in 2021 constant values.

Indicator of vulnerability to climate change

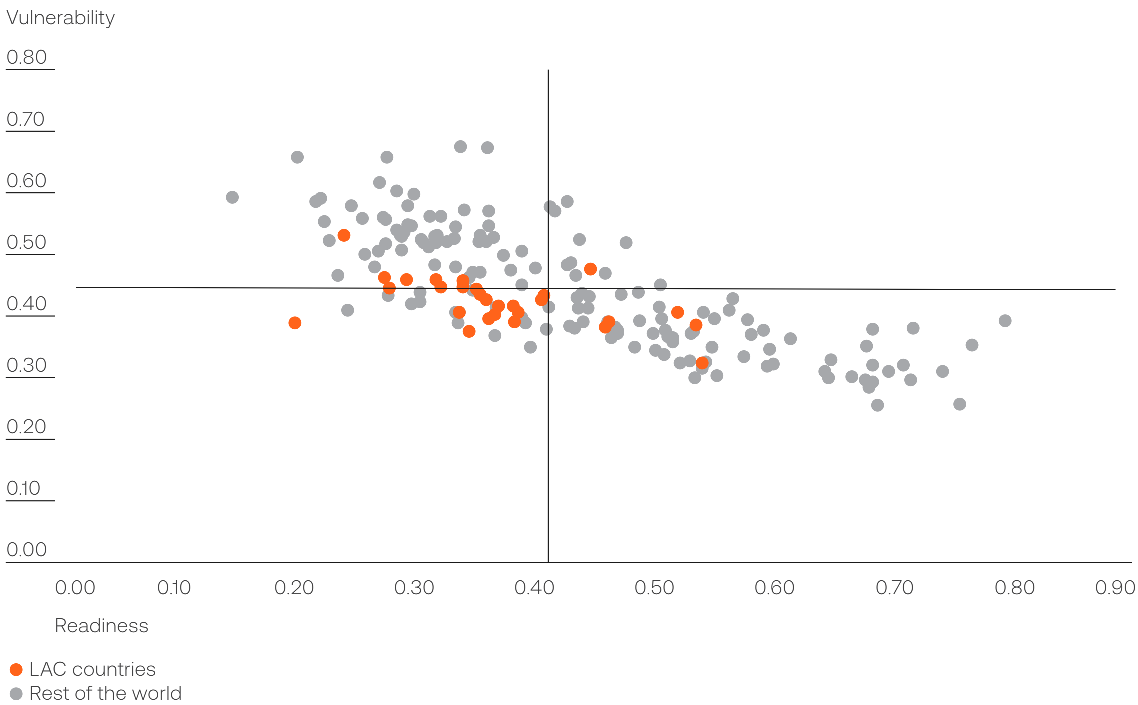
In addition to being vulnerable to the direct impact of climate events in the region, LAC countries are intrinsically vulnerable to the consequences of climate change because of their dependence on natural resources, their geographic location (in particular, the Caribbean and Central America), and their socioeconomic situation. The region has an unmet development agenda, and episodes of economic instability are recurrent. Poverty and inequality levels are high, and some countries are politically and socially unstable.

The University of Notre Dame Global Adaptation Index (GAI) measures the resilience of countries to climate change based on two dimensions: vulnerability and readiness. The vulnerability indicator measures a country's exposure, sensitivity, and capacity to adapt to the negative effects of climate change, focusing on critical sectors for life such as food, water, health, ecosystem services, human habitat, and infrastructure. Exposure to climate change relates to a country's geophysical characteristics, while sensitivity to climate change is measured by the country's dependence on sectors that are sensitive to climate shocks and by the vulnerability of its population. The readiness indicator to face climate change estimates a country's capacity to attract adaptation investment, which depends on economic, social, and governance factors.

Countries in the region classified as highly vulnerable (above the world average) are Bolivia, Ecuador, Guatemala, Haiti, Honduras, and Peru, while countries that are relatively less vulnerable are Argentina, Brazil, and Chile.

Graph 1.4 presents a point cloud that positions countries based on these two adaptation components (readiness and vulnerability). The cluster of orange dots represents LAC countries and the grey dots, the rest of the world.

Graph 1.4
Vulnerability and adaptation to climate change in Latin America in 2020
Source: Authors based on data from the University of Notre Dame Global Adaptation Index (GAI) (2020).



Using average world readiness and adaptation values as a benchmark, the graph identifies high-vulnerability and low-readiness countries (Bolivia, Ecuador, El Salvador, Honduras, Guatemala, and less developed Caribbean Islands), and low-vulnerability and high-readiness countries (Chile, Costa Rica, Uruguay, and more resilient Caribbean Islands) in the region. Argentina, Brazil, and Mexico are some of the low-readiness countries with relatively lower vulnerability than average.

Finally, LAC countries are not more vulnerable to climate change than the rest of the world's countries. However, comparatively, they lack adequate and timely responsiveness. If this trend continues, the region will face greater adaptation challenges. Therefore, making their economic, social, and institutional situations and development agenda compatible with the investments required to face climate change and plan a way forward for sustainable development is increasingly complex.

Ecosystems, biodiversity, and climate

The current negative trend in biodiversity conservation in terrestrial and aquatic ecosystems is an issue associated with sustainable development and climate change. Terrestrial and aquatic ecosystems are a natural source of CO_2 absorption. Their degradation limits their capacity to capture carbon and may sometimes even transform them into sources of net CO_2 emission. In the region, almost 20% of the Amazonia has been affected by deforestation. Deforestation and rising global temperatures have contributed to an increase in dry days. According to several studies, the Amazon is approaching a tipping point beyond which it would begin to transition from a rainforest into a dry savanna (Gatti et al., 2021; Boulton et al., 2022).

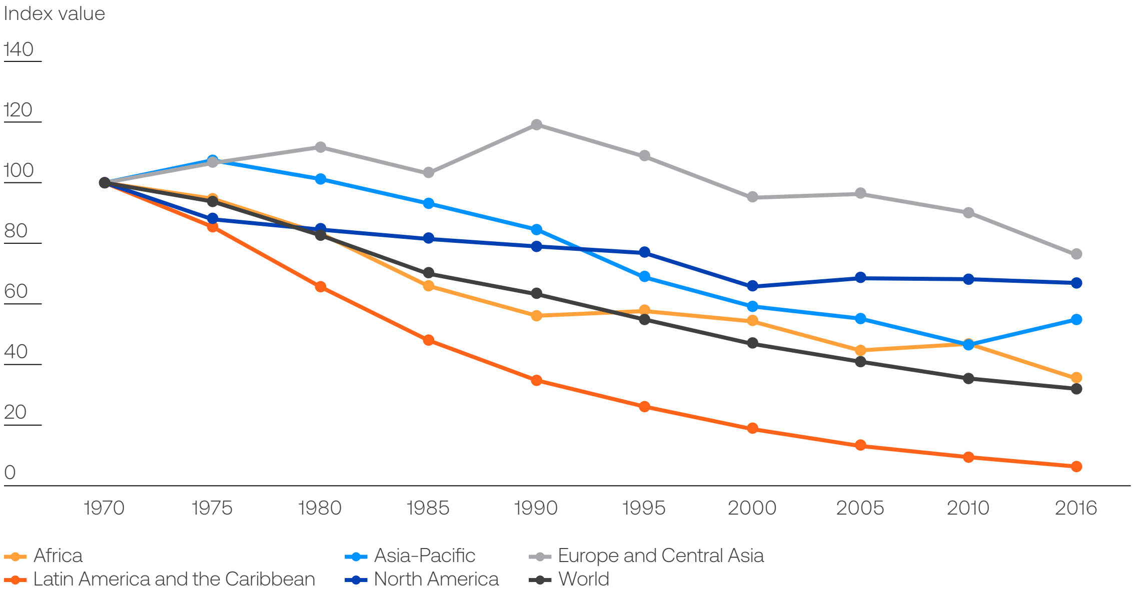
A concrete example of the role of biodiversity in sustainable development—in addition to the protection of animals such as jaguars, turtles, monkeys and other endangered exotic animals—is related to insects and soil-dwelling microorganisms. Crops and fruits need insect pollination but the expansion of areas dedicated to monocultures and the use of pesticides has led to the decline of crucial pollinating insects (e.g., queen bee populations) (Zattara and Aizen, 2021).

To illustrate these findings, the Living Planet Index (LPI) provides a measure of wildlife abundance. Since 1970, it has been measuring the average change in the population size (number of individuals) of a wide range of species (mammals, amphibians, fish, birds, etc.), although it does not include insects, corals, plants or fungi (Graph 1.5).

LAC is a critical hotspot for biodiversity because it hosts many endemic (unique) tropical species, which tend to be adapted to the unique conditions of their habitat, making it difficult for them to survive in other environmental conditions. To this point, Latin America has recorded the steepest decline in average wildlife population size worldwide: a 94% drop from 1970 to 2016.

Maxwell et al. (2016) warn that the biggest threats to biodiversity worldwide include overexploitation (mainly of forests) and agriculture, followed by urbanization, and the introduction of invasive alien species and diseases, among others. In turn, forest exploitation and the advancement of the farming frontier are the main causes of deforestation in the region. Globally, nearly 73% of deforestation is caused by the expansion of pastures for cattle (41%) and croplands for oilseed production (18.4%), and by the invasion of native forests (13%) as part of silviculture (Ritchie and Roser, 2021a and 2021b). Other crops account for the remaining 27%. Considering only these three factors, 73% of deforestation in the region is due to livestock farming, 17% to oilseed production, and 10% to deforestation (Pendril et al., 2019). Graph 1.6 shows that forest area loss in LAC was 13% (vs. 4.2% worldwide), second only to Africa. In Europe and Asia, the trend was positive.

Graph 1.5
Living Planet Index by region for the period 1970–2016 (base year 1970 = 100)
Source: Authors based on data published by OWID (n.d.a).



Note: Living Planet Index data are collected by the World Wildlife Fund (WWF) and the Zoological Society of London (ZSL).

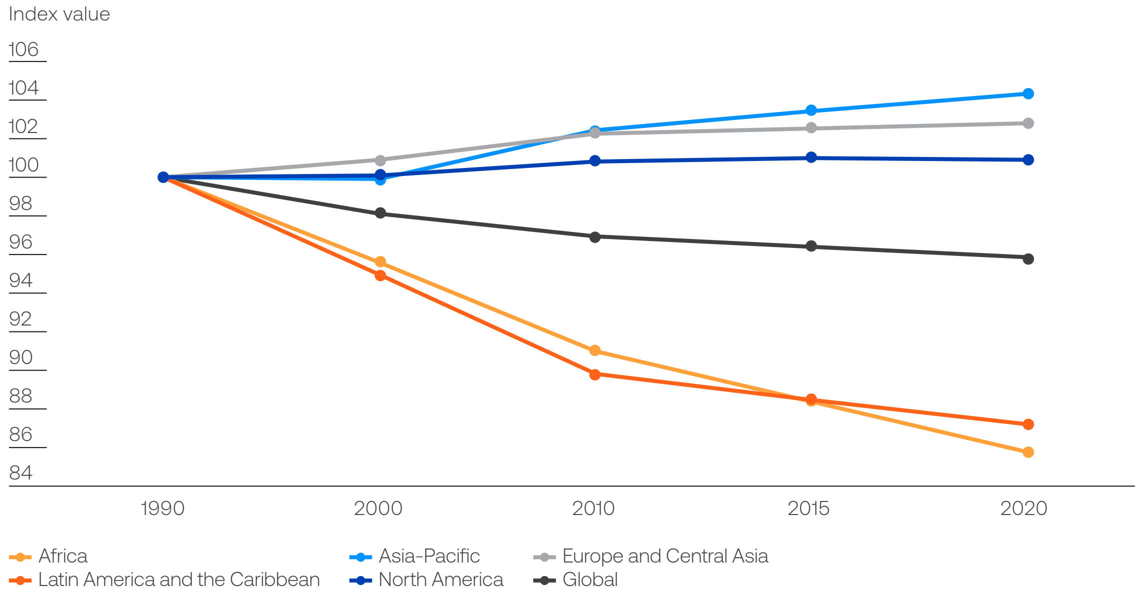
The conservation of natural capital directly involves water—one of the sectors prioritized in this report. Sustainable water withdrawal can be broken down into two main dimensions: freshwater availability and ocean health. In addition, it relates to two broader issues: overexploitation and water pollution. These go beyond the scope of this report but some key aspects should be highlighted as they intersect with the water sector.

First, freshwater availability is essential for the sustainability of the modern economy. In addition to water for human consumption (for drinking, cleaning, washing food, and household chores), production, such as agriculture and industry, accounts for substantial portion of water demand (nearly 80% worldwide and 86% in the region). Water stress disrupts the food supply chain, including intermediate supplies used in production processes. As a freshwater-rich region, Latin America must prioritize strategic and responsible water management within its sustainable development agenda.

Second, sustainable water management includes oceans. Like forests and woodlands, oceans are natural sources of carbon emission absorption and contribute to climate regulation. Oceans sequester from 20% to 30% of CO_2 anthropogenic emissions. Higher emissions are causing ocean water to become more acidic, a process known as acidification. Since the start of the Industrial Revolution, the acidity of the oceans has increased by 30% (NOAA, n.d.).

Finally, linked to the availability and sustainable management of water is the issue of pollution in its two forms: point source pollution, derived from cities and industries, and nonpoint source pollution, mainly resulting from agricultural runoff (e.g., irrigation tailwaters). In the region, point source pollution is a significant issue due to that, on average, only 41% of urban wastewater is treated adequately (see Chapter 3). In addition, fertilizer residues that reach rivers and oceans cause a process known as eutrophication (excess of nutrients in an aquatic ecosystem, which affects its composition and dynamics, generating dead zones). Sewage and plastic pollution is also a major problem of contamination of water reserves.

Graph 1.6
Evolution of total forest area by region for the period 1990–2020 (base year 1990 = 100)
Source: Authors based on data from FAO (2020).



Water, forests, biodiversity, and climate interact to determine the self-regulating capacity of the planet and sustain the modern economy. This is why they are key components of the sustainable development agenda.

Infrastructure in the sustainable development of Latin America and the Caribbean: Sector challenges

Three of the Sustainable Development Goals—SDGs 3, 6, and 7—are specific to the infrastructure sectors prioritized in this report: health, water, and energy, respectively, reflecting the essential role of these sectors in country development. Achieving the established targets in these SDGs requires closing infrastructure gaps in these three sectors and their different dimensions (accessibility, affordability, and quality).

Graph 1.7 shows progress achieved by LAC countries in meeting the 17 SDGs based on scenario and trend simulation exercises for the respective indicators by 2030, conducted by the Statistics Division of the Economic Commission for Latin America and the Caribbean (ECLAC). Each SDG is divided into a set of targets that must be met to achieve the final goal. The targets are measured by indicators. In the graph, the horizontal bar represents the percentage of compliance with each SDG measured as a number of targets, with progress shown over all the targets pertaining to that goal. Good target progress means that the target has been reached or will be reached by 2030 if the current progress rate is maintained. Average target progress means that action is going on the right track but not moving fast enough, and policies are needed to speed it up. Finally, inadequate target progress means that the target presents no progress or is advancing in the opposite direction to reach the goal.

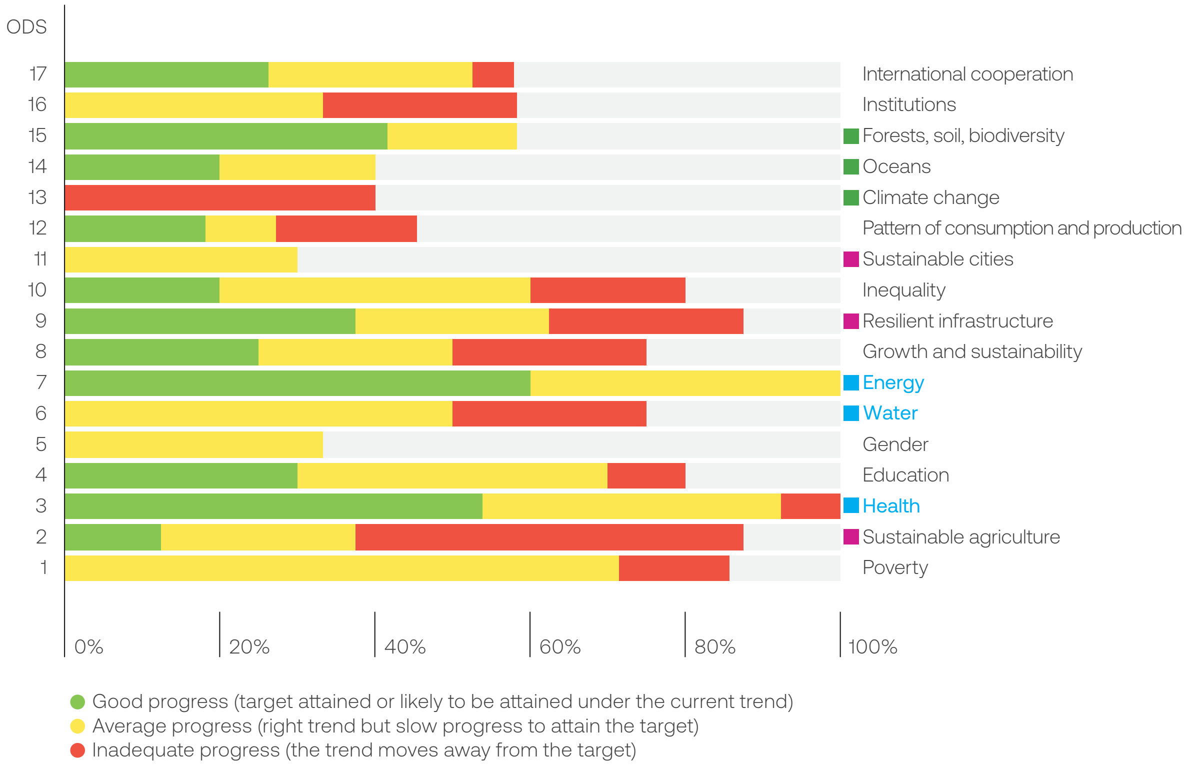
Box 1.4
Infrastructure gaps

Historically, the analysis of infrastructure gaps has focused on monetary investment requirements—often reported as a percentage of GDP—both vertical (supply vs. internal demand) and horizontal (supply vs. benchmark supply or target supply to be reached). However, in recent years, the analysis has been expanded to include development sustainability beyond the monetary investment gap, recognizing that the simple quantification of the monetary gap is not particularly helpful to define what to do. Rather, a more detailed analysis is needed to guide policy actions. Moreover, the monetary gap focus tends to concentrate on the dimension of access—leaving aside other aspects such as cost and quality—resorting to broad assumptions (which sometimes are mistaken) about the future behavior of macroeconomic aggregates such as the GDP (Fay et al., 2017; Cavallo et al., 2020; Cont et al., 2021). This report uses the **service gap approach** to examine infrastructure gaps in the dimensions of access, cost-affordability, and quality of the report's prioritized sectors.

These dimensions are aligned with Sustainable Development Goal targets. For energy, Target 7.1 seeks to ensure universal access (access) to affordable (cost), reliable and modern (quality) energy services. In the water sector, Target 6.1 seeks to achieve universal equitable access (access) to potable water at an affordable price (cost) for everyone. Target 6.2 poses a similar objective for sanitation. Thus, the service gap is not defined as an infrastructure investment need but as an improvement in the relevant dimensions of service supply that can be achieved through investment, public policies, or adaptations to technological or regulatory changes.

These dimensions translate into specific indicators for each sector (Cont et al., 2021). Electricity access is identified as being provided through a connection to an electricity grid. Cost-affordability is estimated based on the final rate paid by users for a reference consumption and compared to some measure of income. Quality is identified by two indicators of interruptions in service supply: the system average interruption frequency index (SAIFI) and the system average interruption duration index (SAIDI). For water, similar access and cost-affordability indicators are used. However, the water quality dimension is identified by the access to a safe water source (provided from an improved source, available when needed, and pollution-free). Chapters 2 and 3 of this report discuss this in greater detail.

Graph 1.7
Progress on SDG achievement in Latin America and the Caribbean
Source: Authors based on data by ECLAC (n.d.a), accessed in April 2022.



The **health** sector shows positive progress in the region, with 54% of the goals achieved or likely to be achieved with the current trend (good progress) and 38% with a correct trend but insufficient to achieve them.

Target progress in the **energy** sector has been good or average. Regarding universal access to energy services, progress has been good. Despite this, the share of renewable energy within all energy sources and the energy efficiency rate have shown average progress and must accelerate if targets are to be reached by 2030.

Assessing sustainable development target progress for the energy sector leads to the identification of environmental challenges 1 and 2 below.

Challenge 1: Renewable energy. To increase the share of renewable energy in total energy sources.

Challenge 2: Energy Efficiency. To improve energy efficiency measured as energy consumption per unit of product.

Progress toward targets in LAC's **water** sector has not been good. In fact, it has been average and must accelerate in almost half of the targets if the sustainable development goals are to be met by 2030. These are associated with universal access to drinking water and suitable sanitation and hygiene services, along with water efficiency when considering water as a resource. Progress is inadequate and moving in the opposite direction to fulfill the sector's sustainability targets according to the indicators of protection and conservation of water-related ecosystems, including forests, mountains, wetlands, rivers, aquifers, and lakes. The indicators that measure local community participation in water management and sanitation activities have also been rated as inadequate. At present, historical data are insufficient to assess target progress on the integrated management of water resources, including cross-border cooperation. Information based on data from 2020 shows that LAC countries have achieved average progress in this respect (see Chapter 3 for detailed information). According to estimates by CAF (Rojas, 2022), regional investments in the sector need to increase threefold compared to historical investment levels if SDG 6 targets are to be met.

Based on Graph 1.7, showing progress on sustainable development goal achievement in the water sector, challenges 3 and 4's trends are moving away from the relevant SDG targets.

Challenge 3: Conservation of water-related ecosystems.

Challenge 4: The role of local communities in water management.

Moreover, the targets in the water sector that show average progress, i.e., those following the right trend but at a slow pace for successful attainment, define additional sector challenges (5 and 6).

Challenge 5: Access to drinking water, and sanitation and hygiene services.

Challenge 6: Efficiency in freshwater use and withdrawal.

Promoting people's health within a framework of wellbeing and healthy lifestyle requires health systems and services that provide universal health care coverage, and access to essential services as well as safe, effective, affordable, high-quality medicines and vaccines. The population also needs to be protected against financial risks resulting from extreme situations (either individual or collective).[10] To that end, health care facilities need good infrastructure, sufficient operational equipment, appropriate supplies, human resources, and funding sources (WHO, 2010).

Within the SDG framework, SDG 3 addresses health and wellbeing directly. Its targets include improving people's wellbeing; promoting a healthy lifestyle; reducing neonatal, child, and maternal mortality; ending epidemics (HIV/AIDS, tuberculosis, malaria); combating communicable diseases; preventing and treating substance abuse; reducing the number of deaths and injuries from road traffic accidents and the number of deaths and illnesses from pollution; ensuring universal access to sexual and reproductive health services; achieving universal health coverage, in particular, financial risk protection; and providing access to high-quality and affordable essential health services, medicines, and vaccines. In addition, links are established with other goals. For instance, access to water and sanitation (SDG 6.1 and 6.2) enables the prevention of diseases such as diarrhea, which is one of the leading causes of death in children under 5 years (Rojas et al., 2019). In addition, according to the latest report from the IPCC Working Group II (2022a), climate change (SDG 13) favors the emergence of communicable diseases, especially zoonosis, and threatens to curtail efforts against other diseases. In addition, extreme climate events caused by global warming can have major effects on the life and health of the population. The higher probability of occurrence of these events could expose the sector to greater stress. Therefore, health action will be vital to minimizing impacts.

Within this framework, the health care system's capacity to handle extreme shocks—pandemics, climate catastrophes—and act promptly to minimize the number of victims and response times is the focus of challenge 7. Along these lines, this capacity may be considered complementary to health system preparedness against the long-term changes expected as a consequence of population aging, as analyzed in the 2020 Report on Economy and Development (RED) (Álvarez et al., 2020).

Challenge 7: Flexible health care systems to adapt to extreme events.

Infrastructure is covered by the SDGs 9 and 11 in the Agenda 2030. However, progress has been insufficient in relation to some of the targets, which involve promoting an inclusive and sustainable industry in the region, as measured by its contribution to the GDP and job creation. This includes developing resilient and sustainable infrastructure and using clean technologies. These dimensions will be reviewed for the sectors prioritized in this report.

Although represented in Graph 1.7, sustainability indicators for the cities in the region are still scarce. This makes it challenging to produce

10 SDG 3 covers a large number of dimensions, in addition to the availability of health systems and services. However, its scope has been restricted to the sector addressed in this chapter. See further details in UN (n.d.).

Adapting to the climate system's inherent inertia is essential, as temperature stabilization doesn't occur immediately even with emission reductions.

statistics for a thorough assessment of the current situation of human settlements and cities. Existing indicators, which show average progress, are associated with access to housing and basic services, the environmental impact of cities, and the number of deaths and economic losses from natural disasters, particularly in low-income and vulnerable populations.

In general terms, although climate change and the conservation of natural capital are cross-cutting issues in the sustainable development agenda, they are also goals in themselves. SDG 13 addresses climate action, while SDGs 14 and 15 deal with the sustainability of oceans, seas and marine resources, forests and soils, and the conservation of biodiversity.

Similarly to urban sustainability, the information available to measure climate action progress in the region is insufficient. Barely 40% of the SDG 13 targets have an indicator that can be followed over time (see Graph 1.7). These targets, showing inadequate progress, are associated with the introduction of climate change measures in national policies, strategies, and plans, and the level of education, knowledge, and human and institutional capacity existing in the countries with relation to this issue (focusing on its effects, mitigation, and possibilities of adaptation).

The Climate Action Tracker—a climate action tracking platform—publishes an indicator produced by an independent agency formed by two cooperating research organizations, *Climate Analytics* and *NewClimate Institute* (both of which are climate science and policy institutes based in Germany). This scientific project tracks government climate action and measures it against the Paris Agreement goal of holding warming well below 2°C. The indicator evaluates a broad spectrum of government targets and actions to reduce carbon emissions. The rating for each country is developed considering government-implemented policies and depends on whether nationally determined contributions are ambitious enough. If relevant, the rating also reflects whether the country's contribution to global financing for lower-income countries is fair relative to global efforts. The overall rating synthesizes all of these dimensions into five groups according to country performance, ranging from critically insufficient to 1.5°C goal compatible. Table 1.2 groups LAC countries according to their degree of compatibility with this goal.

Table 1.2
LAC countries grouped by compatibility with the 1.5°C goal
Source: Authors based on Climate Action Tracker (n.d.).

Critically insufficient	Highly insufficient	Insufficient	Almost sufficient	1.5°C Paris Agreement compatible
	Mexico	Peru	Costa Rica	
	Colombia	Chile		
	Brazil			
	Argentina			

Note: There is no country under the categories 'critically insufficient' or '1.5°C Paris Agreement compatible.' Climate Action Tracker does not provide data for the countries not identified in this table.

The 'Insufficient' rating indicates that a country's climate policies and commitments require substantial improvement to be consistent with the Paris Agreement 1.5 °C temperature limit, while the 'Highly insufficient' rating indicates that a country's climate policies and commitments are not consistent with this temperature limit. For many countries in the 'Highly insufficient' category (e.g., Argentina, Brazil, Colombia, and Mexico), policies and commitments lead to rising, rather than falling, emissions. According to Table 1.2, only Costa Rica is in the 'Almost sufficient' category, which indicates that its climate policies and commitments are not yet consistent with the Paris Agreement 1.5°C temperature limit but could be with moderate improvements. Peru and Chile fall into the 'Insufficient' category.

It is important to highlight that insufficient climate action is not exclusively a problem in LAC; it's global. Until March 2022, the implementation of climate policies and commitments was not sufficient or compatible with the Paris Agreement in any country, according to Climate Action Tracker (n.d.).

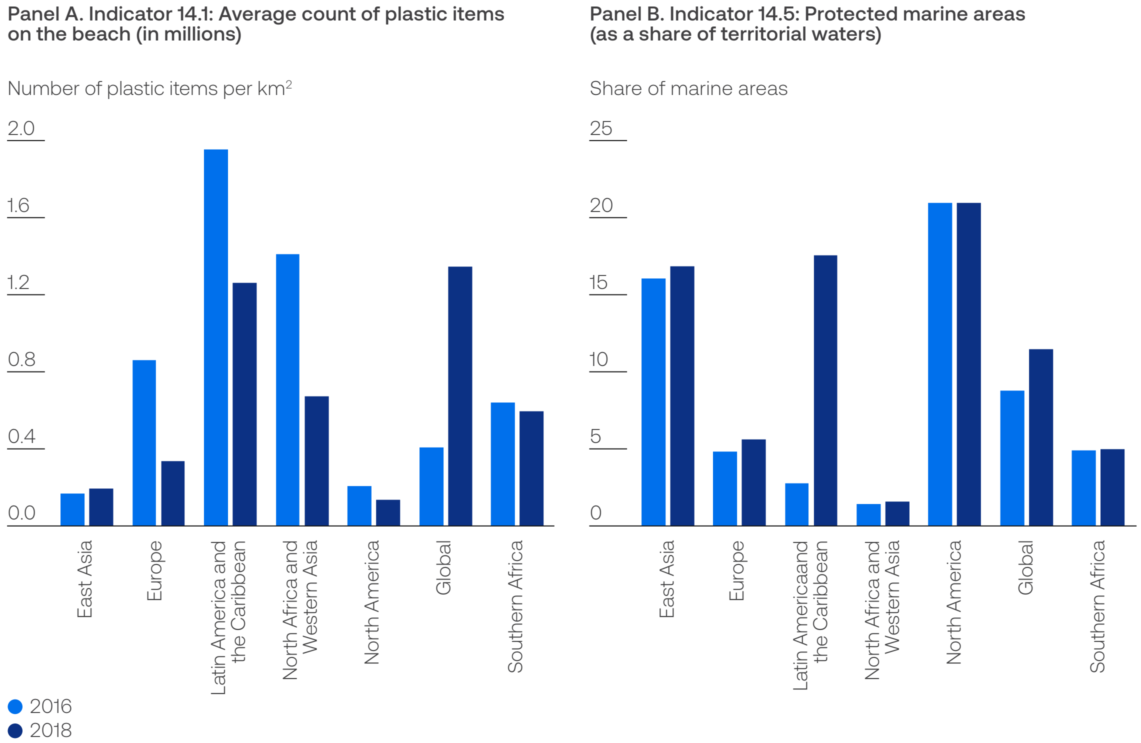
The eighth environmental challenge faced by LAC countries pertains to sustainable development objectives in response to climate change.

Challenge 8: Implementation of climate policy, reducing emissions and promoting adaptation.

Producing information to measure climate action targets accurately in LAC countries is also a challenge. Sixty percent of SDG 13 targets lack indicators for progress assessment. These indicators should be associated with the target of strengthening resilience and adaptive capacity to climate-related hazards and natural disasters, sufficient international finance flows to address the needs of developing countries so that they can adopt mitigation measures, and effective planning and management of climate change impact.

The region has inadequate indicators to measure progress toward the achievement of not only the sustainable development targets but also the conservation of natural capital. Regarding the conservation and sustainable use of oceans, seas, and marine resources, the region shows good progress in reducing plastic pollution in the marine environment (measured by the density of plastic waste) and protecting coastal and marine areas.

Graph 1.8
Progress on SDG achievement against selected natural capital indicators: LAC vs. other world regions in 2016 and 2018
Source: Authors based on data published by OWID (n.d. b; n.d. c).



Note: Groups of countries are classified according to the source and may differ among indicators. Data in panel A were originally collected by the United Nations; data in panel B were processed by the World Bank and taken from the UNEP World Database on Protected Areas.

In contrast, progress is average, and accelerated implementation of measures is needed to attain the sustainability target for the management, protection, and conservation of marine and coastal ecosystems and the management of fishery, aquaculture, and tourism.

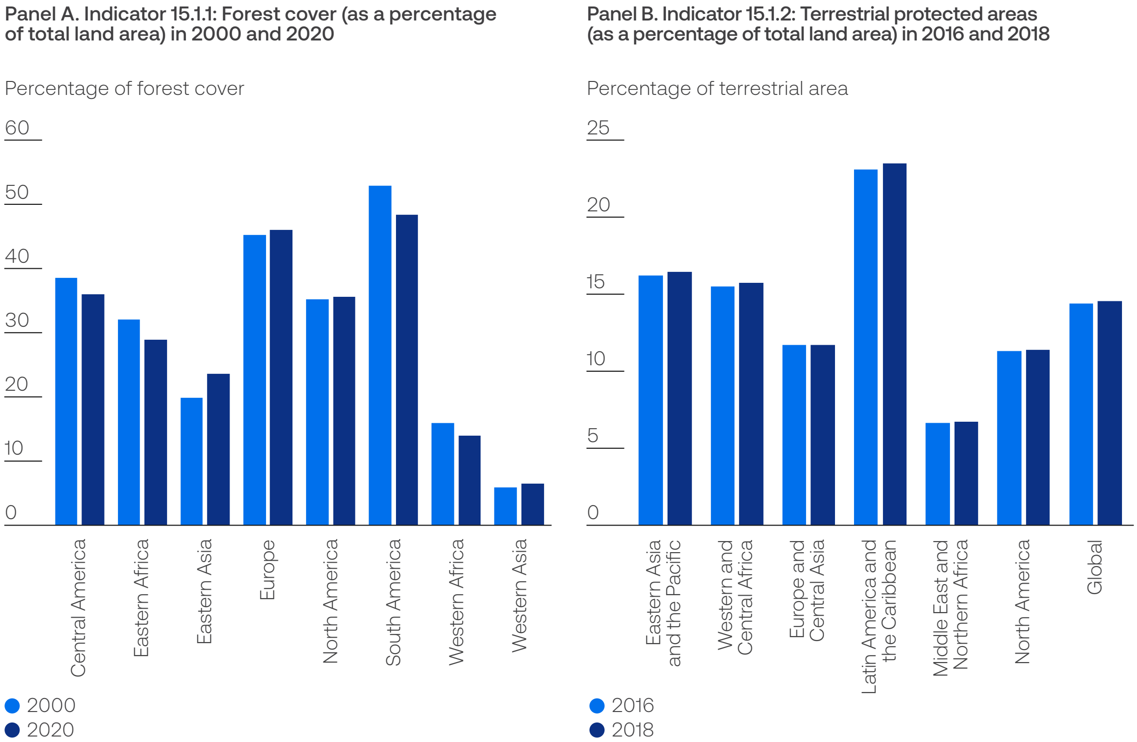
Finally, information is inadequate to assess progress in the region regarding targets associated with the effects of ocean acidification, the regulation of fish harvesting to prevent overfishing and illegal fishing, and plans to restore fish stocks (including bans on certain fisheries subsidies).

Although some of these issues are beyond the scope of this report, the ninth environmental challenge pertains to the sustainable use of water and oceans.

Challenge 9: Management and protection of marine and coastal ecosystems to strengthen their resilience.

The conservation of natural capital includes terrestrial ecosystems, forests, soil, and biodiversity, linked to the targets in SDG 15. In the region, progress toward reaching those targets has been good in the case of 40% of them, as shown in Graph 1.7. Moreover, Graph 1.9 illustrates progress on target achievement to protect, restore, and promote the sustainable use of inland freshwater and terrestrial ecosystems, in particular forests, wetlands, mountains, and drylands. Progress toward these targets is measured by the proportion of forested area relative to the total area, which has shown a slight decline between 2000 and 2020, and the proportion of protected areas with terrestrial biodiversity and freshwater ecosystems, which has shown a slight increase between 2016 and 2018).

Graph 1.9
Progress on SDGs related to forest areas and the protected forest area
Source: Authors based on data from UN (n.d.) for panel A and Ritchie et al. (2018) for panel B.



Note: Groups of countries are classified according to the source and may differ among indicators.

Environmental challenge 10 emerges from the close link between the water sector, prioritized in this report, and the conservation of terrestrial natural capital.

Challenge 10: Conservation and sustainable use of inland freshwater and terrestrial ecosystems.

Impact of the COVID-19 pandemic on SDG indicators

In 2021, upon assessing the global level of progress toward achieving the SDGs globally, Sachs et al. (2021) reported that the score had regressed for the first time since 2015. Most likely, this setback was underestimated in the report as many indicators for 2020 were not yet available at the time of publication. The impact of the pandemic was stronger in developing countries, which generally lacked the fiscal space to implement social policies. In particular, when comparing compliance index scores from 2020 and 2021, Latin American and the Caribbean shows the largest absolute drop (1.8 points). The increased incidence of monetary poverty (SDG 1) was the main driver of this regression.

The negative impact of the pandemic reached all three dimensions of sustainability (economic, social, and environmental). The impact was immediate on the economic and social dimensions, with a substantial increase in poverty and unemployment, and high mortality. In the environmental dimension, at first, there was a positive impact because GHG emissions declined as a result of closed factories and strict lockdowns. However, very quickly, as the lockdown relaxed, emissions recovered their pre-pandemic level.[11] In other words, and in more general terms, the economic and social indicators underwent major decline, but this was not accompanied by an improved environmental dimension.

The drop in CO_2 emissions during 2020 was a compelling indication of the significance of the Paris Agreement goals' being attained by 2030. In 2020, CO_2 emissions declined by approximately 6%—the largest interannual fall since World War II. This decline was associated with an unprecedented halt in economic activity as a result of the mobility restrictions enforced by governments during the pandemic. Meeting the goal of holding the increase in temperature to well below 2°C, as called for in the Paris Agreement, requires that global carbon emissions drop every year by the same amount as they did in 2020 from now until 2030.

Strategies to face climate change and the conservation of natural capital

Mitigation and adaptation

Climate change is caused by an externality: carbon emissions released by economic activities contribute to global warming, but the damage associated with this warming is not borne by consumers and producers. In fact, it is a global externality given that CO_2 emissions by producers and individuals unify and accumulate in the atmosphere, thus contributing to global warming. Global warming, in turn, impacts economic activity and people's wellbeing in different countries around the world, regardless of the place of origin of emissions.

The inter-generational dimension of climate change makes the issue even more complex. The use of fossil fuels or deforestation to expand the farming frontier provides sources of income and drives development in the present but will generate negative production and general wellbeing costs in the future. This tradeoff is crucial for LAC countries, whose development agendas are pending and essential.

Therefore, controlling the rise in global temperature requires a prompt, sustained, and substantial reduction in carbon dioxide and other greenhouse gas emissions.

The conventional economic policy prescription is to put a price on carbon emissions, so that polluters pay for the damages caused by their emissions. Symmetrically, those who undertake activities that absorb atmospheric carbon should receive compensation. However, the implementation of this carbon pricing has presented multiple challenges around the world. In absence of a global policy on pricing emissions, different complementary mitigation strategies can be implemented.

11 Sachs et al. (2021) show the daily CO_2 emissions in China and the United States (Graph 2.14, p. 25). By the fourth quarter of 2020, CO_2 emissions had equaled or exceeded the levels for the same quarter in the previous year (2019).

Mitigation policies aim to encourage the reduction of GHG emissions through the implementation of less intensive or carbon-neutral activities (or activities that have a carbon-neutral trend). Among these, actions to decarbonize the energy matrix—at the origin (renewable sources) or destination (decarbonization of consumption)—and increased energy efficiency stand out. Mitigation also involves actions to absorb emissions that have already been released into the atmosphere by using technologies that allow carbon capture and sequestration and, particularly, by the conservation of natural carbon sinks such as oceans, forests, and soil.

Even if a drastic (significant) reduction in GHG emissions is achieved, temperatures will not stabilize immediately due to the climate system's inertia. For example, if net emissions reached zero within a given time horizon, the combination of GHGs remaining in the atmosphere and the heat stored in the oceans, which would be brought back progressively to the surface during a few decades, would continue to raise the global temperature until it stabilizes (NOAA, 2020). According to IPCC projections, this process could last from 20 to 80 years (IPCC, 2021). Conversely, if the net-zero goal is not attained, the temperature is highly likely to rise by more than 2°C, along with the frequency and severity of natural disasters.

This is why the response to climate change also calls for efforts to **adapt** to adverse impacts of climate variability that cannot be avoided. Adaptation strategies are drawing more and more attention as an essential element of climate policies. NDCs and national adaptation plans in developing countries reflect that the LAC sectors with the biggest financing needs for adaptation are agriculture, infrastructure, water, and natural disaster risk management. Commitments include reducing vulnerability to extreme weather events (especially floods), fostering water resource conservation, improving agriculture efficiency, implementing distributed generation systems, promoting the conservation and sustainable use of biodiversity and ecosystem services, and investing in capacity-building for health systems to respond to climate shocks.

Adaptation to climate change seeks to achieve climate resilience through infrastructure and technological innovations that help buffer regions and communities from the adverse effects of climate change, such as sea level rise, droughts, or extreme storms. It also involves identifying the opportunities that open up in the regions where climate changes have positive effects (e.g., regions with hostile climates that evolve toward milder climates).

Infrastructure plays a key role in any adaptation strategy aimed at making communities less vulnerable to climate change, if it can anticipate, prepare for and adapt to the new conditions (OECD, 2018). Despite this, studies of alternative climate adaptation projects including cost and benefit estimates are limited. In addition, improving the resilience of current systems involves costs (which could be up to 70% higher than in the past decade, according to Brichetti et al., 2021). Therefore, in addition to the lack of information, climate adaptation also presents financing challenges.

Climate **financing** involves two dimensions: one for the decarbonization of economies, and another one for the damages caused by natural disasters which are now considered to be unavoidable. The main financing sources available for both mitigation and adaptation projects are the Green Climate Fund, the Adaptation Fund, and the Global Environment Facility. In addition, financing is provided by multilateral agencies, carbon bonds, and private funds that invest in projects with positive environmental impacts, among others. This financing commitment seeks to ensure that developing countries can implement the necessary mitigation and adaptation actions to honor their environmental commitments.

As stated by the institution responsible for monitoring this goal (OECD, 2021a), in 2019, climate finance provided by developed countries to developing ones was USD 79.6 billion, an increase of 2% from 2018 but still far from the target adopted (20% below). Moreover, of the total financing in 2019, 63% was used for mitigation actions, and Asia was the region that received most funds (43%), far ahead of LAC (which received 17% of the funds). Projections by the Organisation for Economic Co-operation and Development (OECD, 2021b) estimate that the USD 100 billion financing goal will only be met in 2023. Therefore, public financing should increase by 35%, while private financing should rise by 31%, compared to 2019.

According to SDG target 17.2, developed countries undertook to allocate 0.7% of their gross national income to official development assistance to developing countries, and 0.15% to 0.20% to least developed countries (for an aggregate commitment of 0.85% to 0.9%). Only a small group of countries (Luxembourg, Norway, Sweden) currently stay within this target, while the United States has just allocated 0.15% (Sachs et al., 2021). Nevertheless, international negotiations are making progress in favor of greater recognition and commitment by developed countries based on their higher relative climate responsibility. For example, at the United Nations Conference on Climate Change in 2021 (COP 26), formal dialogue began on a new "loss and damage fund" for climate events, reflecting progress in this regard.

Conservation of natural capital

Ecosystem conservation (terrestrial, marine, coastal, and freshwater) is a major environmental challenge for the region (challenges 3, 9, and 10), coupled with efficient water management, access, and use (challenges 4, 5, and 6).

The conservation of ecosystems boosts their provisioning and regulating functions. The services provided by ecosystems include food and clean air and water. At the same time, the water cycle, the climate, the nutrient cycle, soil quality and fertility, and pollination are some of their regulating functions. In addition, ecosystems provide recreational opportunities. Therefore, the conservation of the existing natural ecosystems and their integration with cities helps cool cities, absorb rainwater, filter air and water contaminants, and store carbon in soils and forests, all of which reduce the impacts of climate change.

In response to the challenge of preserving these natural ecosystems, a new form of urban infrastructure has been developed: blue and green infrastructure (BGI). At present, the European Union (EU), the United States, and the United Kingdom, among others, have BGI development plans in place.[12] This infrastructure is intended to be an alternative to traditional grey infrastructure. It is an urban planning strategy that integrates natural and seminatural areas to contribute to water and air purification, along with climate mitigation and adaptation. The blue spaces may be water courses, ponds, and lakes, while the green ones include wetlands, plants, and trees. An example of how blue and green infrastructure complements the traditional grey infrastructure is the role of these spaces as natural drainage systems for stormwater or floodwater.

Actions to promote ecosystem conservation globally also include place-based conservation, such as the creation of protected areas. At present, 15% of the world's land and 7.74% of its oceans are in protected areas (Dasgupta, 2021).

Local as well as state support is of the essence for the proper administration of protected areas. In addition, local communities play a key role, as noted in challenge 4.

Biodiversity is a feature of ecosystems. While there is still no consensus as to biodiversity's productive or enabling role (quality of the asset that increases the value of other assets) (World Bank, 2021; Dasgupta, 2021), there have been attempts to assign a value to it. Dasgupta (2021) distinguishes six potential sources of biodiversity's value: human existence itself; people's health and comfort (these values sometimes intersect); nature's goods and services; the existence of species, and nature's intrinsic value. There are partial biodiversity valuations included in the natural capital (e.g., ecosystems associated with fishing, endangered species, or natural resources). This calculation will improve with future developments.

The conservation of biodiversity considers species variability but also the multiple functionalities and features of each species in the ecosystem. In this regard, biodiversity is particularly threatened by climate change (Dasgupta, 2021). Precipitation and temperature changes alter the distribution of species on the planet, generating consequences that are difficult to anticipate.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) defines species richness as the number of species within a given sample, community, or area (IPBES, 2019). An analysis of projections made using different recognized biodiversity indices (including the LPI) shows that, in all cases, under a business-as-usual scenario, a negative impact on biodiversity is expected

12 See the BGI development plans for the European Union in European Commission (2019), for the United States in EPA (2021), and for London in Mayor of London (2021).

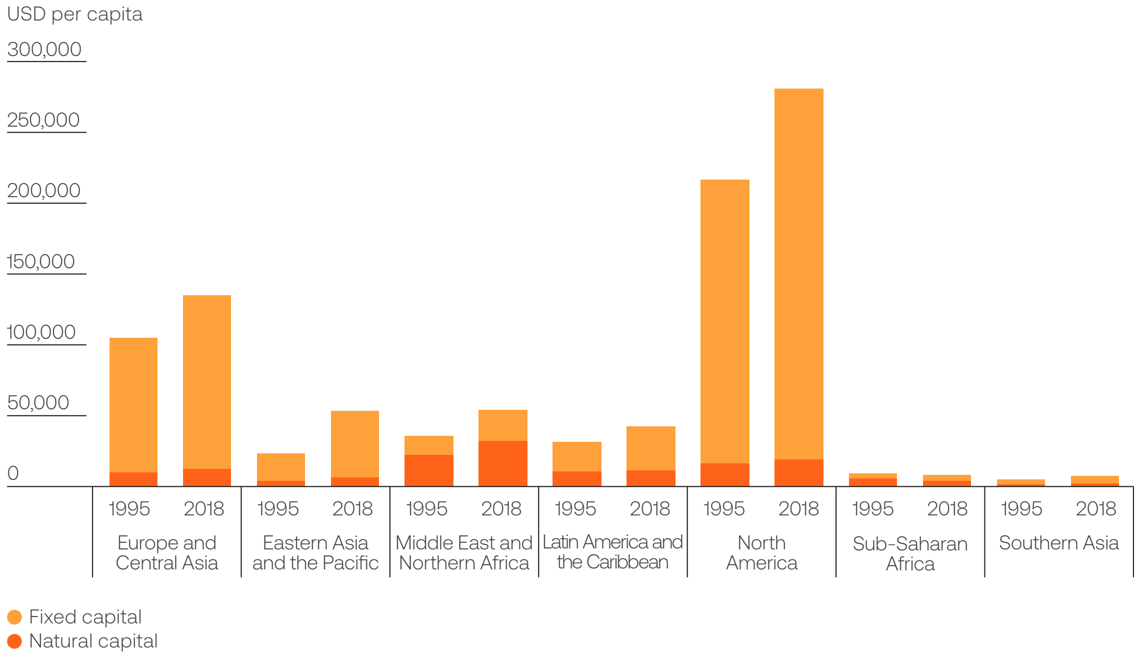
Actions for biodiversity preservation encompass space-based and species-based conservation approaches.

(IPBES, 2019). This report uses multiple models for different global regions to estimate the future impact on biodiversity—understood as a change in species richness (plants and animals) in each region—of different projections of consumption, production, and GHG emissions by 2050. Based on these estimates, the conclusion is that South America, regardless of the scenario being analyzed, suffers the greatest loss of species richness.

In addition to biodiversity, it is important to review the future effects on ecosystem functions, and therefore, on their services to humanity. To do so, IPBES' (2019) models include estimates drawn from two variables in addition to species richness: nature's material contributions to people, and nature's regulating contributions to people. In general terms, the former is anything that ecosystems provide to humanity (with either positive or negative impacts). In particular, material contributions are substances or objects from nature that sustain human life (e.g., food, timber, bioenergy). Regulating contributions, in turn, include any functional and structural aspects of organisms and ecosystems that modify the environmental conditions and regulate the generation of material or non-material contributions, with an indirect effect on the quality of life (e.g., nitrogen retention, soil protection, crop pollination, crop pest control, ecosystem carbon storage and sequestration). IPBES' (2019) projections show that material contributions increase in almost all regions and under almost all scenarios but at the expense of biodiversity and regulating contributions. For these contributions, varied impacts are expected across different regions; in LAC, the least affected area is the Caribbean.

Actions to promote biodiversity preservation include place-based conservation, such as the creation of protected areas, and species-led conservation, such as the conservation of individual species (Dasgupta, 2021). The species-led conservation approach is based on the fact that the habitat where threatened species live is not all under protection, so species conservation needs to be extended even when they are not within protected areas. Species-led conservation usually includes restrictions or bans on hunting and trade. The regulation of animal trade is especially relevant in the current context of increasingly frequent zoonotic diseases. It is important to consider complementary approaches, because biodiversity conservation based on protected areas, in general, has been insufficient to stem the loss of biodiversity, partly due to the low fraction of protected areas worldwide (see Graphs 1.8 and 1.9), and to poorly designed or insufficiently applied protective measures (Pörtner et al., 2021).

Graph 1.10
Natural and built capital by region (USD per capita) in 1995 and 2018
Source: Authors based on data from the World Bank (n.d.a).



A country's **natural capital** consists of all the resources that sustain the life and wellbeing of its population—e.g., plants, animals, water, air, soils, minerals— (Browder et al., 2019), and includes both renewable resources (forests, mangroves, fishery resources, protected areas, crops, and pastures) and non-renewable resources (oil, gas, coal, and other minerals and metals). This kind of capital is particularly relevant for LAC. According to estimates published in a recent World Bank report (2021), the natural capital stock in the region is relatively abundant, comparable to the natural capital in various developed and developing economies. In contrast, built capital stock is relatively limited (compared to North America, Europe, and Central Asia).

Table 1.3 shows that natural capital accounts for about one-tenth of total wealth stock in LAC economies. However, when broken down into renewable and non-renewable assets, natural capital shows great variability. In countries such as Argentina and Brazil, the natural capital consists mainly of renewable assets, such as pastures, crops, and protected areas. In other countries, such as Ecuador and Venezuela, most of the natural capital consists of non-renewable assets, e.g. oil. By contrast, in Chile and Peru, it consists mainly of minerals. Therefore, the natural capital of some LAC countries may be significantly altered: their value can either fall as the demand for fossil fuels drops in the context of the decarbonization of economies (e.g., Colombia, Ecuador, Mexico, and Venezuela) or rise as the international demand for minerals increases, particularly lithium (e.g., Chile).

Table 1.3
Breakdown of natural capital by country in 2018
Source: Authors based on data from the World Bank (n.d.a).

	Argentina	Brazil	Chile	Colombia	Ecuador	Mexico	Peru	Venezuela	U.S.
Percentage of natural capital in total wealth	**10.6**	**12.7**	**10.7**	**8.1**	**10.0**	**7.0**	**13.7**	**10.9**	**1.9**
Renewable	**9.3**	**10.2**	**4.9**	**5.6**	**6.1**	**4.6**	**7.1**	**3.1**	**1.4**
Pastures	3.8	1.9	0.5	1.4	1.1	1.2	1.0	0.4	0.2
Crops	2.3	2.5	1.8	1.9	1.8	1.3	2.3	0.3	0.3
Ecosystem services	2.1	2.2	1.0	1.4	0.7	1.3	1.9	1.5	0.7
Protected areas	0.8	2.4	0.4	0.6	1.9	0.4	1.4	0.9	0.1
Other	0.3	1.2	1.2	0.3	0.6	0.4	0.5	0	0.1
Non-renewable	**1.3**	**2.5**	**5.8**	**2.5**	**3.9**	**2.4**	**6.6**	**7.8**	**0.5**
Oil	1.0	1.1	0	1.2	3.9	1.7	0.6	7.4	0.1
Gas	0.2	0	0	0.1	0	0.1	0.3	0.3	0
Others	0.1	1.4	5.8	1.2	0	0.6	5.7	0.1	0.4

Note: Under renewable assets, the category “other” includes fish and timber. Under non-renewable assets, “other” includes coal and minerals.

The conservation of natural capital is critical for many reasons (Mandle et al., 2016; OECD, 2021d). As mentioned above, natural capital provides ecosystem services (e.g., clean water and air, food availability), and is a contributor to climate regulation and carbon capture. In this regard, the conservation of natural capital can be understood as a climate change adaptation and mitigation action.

The conservation of water as natural capital is challenged by the levels of **global contamination** caused by different productive processes. Climate change aggravates this situation. Rojas et al. (2019) highlight the importance of enhancing the conservation and protection of water bodies against pollution to achieve water security by reducing the wastewater treatment deficit, restoring the quality of water bodies, and promoting the reuse and use of byproducts derived from wastewater treatment. In line with this proposal, the circular economy strategy suggests a sustainable approach to maximizing water efficiency and minimizing production waste (UNEP and Cepei, 2018).

The main cause of water pollution is the discharge of untreated urban sewage (Peña et al., 2019). However, poor management of the productive use of water can also lead to serious consequences. For example, contamination by metals, chemical waste, and antibiotics has a devastating effect on people’s health. In this regard, CAF’s Water Strategy 2019-2022 highlights the importance of access to water services and adherence to international quality standards to ensure that water is clean and safe for human consumption, achieve efficiencies, reduce pollution, and preserve ecosystems.

Natural capital is essential to any country’s development. Despite the many benefits of its conservation, natural capital is subject to multiple market failures: it is a public good, it involves positive externalities, and property rights are not clearly defined. This means that any potential policy recommendations should take this aspect into account to overcome these failures, e.g., by creating protected areas (declaration of protected species would also help), fostering ecotourism as a way to monetize conservation, requiring third-party ecosystem conservation certifications, enforcing taxes on activities that reduce biodiversity (e.g., farming or real estate development), and providing subsidies for activities that increase biodiversity.

Preserving water as natural capital is challenged by pollution levels and consumption patterns and efficiency, exacerbated by climate change.

Within this context, the following chapters explore the **energy**, **water,** and **health** sectors in more detail. In particular, they address the interaction between sectoral challenges and those involved in climate action and the conservation of natural capital. The **energy** sector should prioritize efforts to achieve the transition toward clean (especially solar and wind) energies and reduce GHG emissions to levels compatible with the environmental goal of limiting the temperature rise. In the transport sector, the region needs to promote vehicle electrification, with special emphasis on public transport. This extends to industry, trade, and residential consumers regarding low-emission energy sources used as input or consumed. The **water** sector should promote the integrated management of water resources, particularly focusing on the efficiency, accountability, and monitoring of the multiple uses of water, and circular economy strategies. Adaptation agenda actions for infrastructure resilience also apply to these sectors as complementary initiatives. In addition, the **health** sector should strengthen the system as a whole and system capacities in particular to face extreme events (including biological disasters such as epidemics).

The above is particularly complex when the diverse requirements of each country and the broad heterogeneities across the region are taken into account. However, steps in this direction will cushion the impact of economic shocks from extreme events, making it possible to leverage new investment development opportunities.

2

Energy for a better environment

Chapter 1 highlights the importance of the infrastructure sectors in achieving sustainable development according to the 2030 Agenda, and the interrelation between these sectors with the environment (climate change, and ecosystem and biodiversity conservation). The SDGs set specific targets for water and energy, given that these services largely determine people's economic and social wellbeing, and affect the planet's environmental conditions.

Regarding energy, Chapter 1 identified two specific environmental challenges: increase the share of renewable energy (challenge 1) and improve energy efficiency (challenge 2). Both are relevant to climate change mitigation (challenge 8). This chapter focuses on these challenges and addresses their interaction with the energy sector, the current situation of the energy matrix in LAC, and how the energy transition can be analyzed in the context of climate change. Finally, it summarizes the changes that the environmental situation will bring to the sector.

Climate change and the energy agenda

Over time, the atmosphere, oceans, and earth have warmed as a result of human influence, and the occurrence of extreme events has changed (IPCC, 2021). GHG emissions have played a major role in these effects. Therefore, considering the immediate need to reduce these emissions and their consequences, the decarbonization of economic activities is the goal that needs to be pursued during this century.

In this context, the energy sector plays a vital role worldwide, along with agriculture, land use change, and forestry (ALUCF) in LAC. In 2015-2019, the energy sector generated 76% of GHG emissions and more than 90% of CO_2 emissions worldwide. The LAC region contributed 8.4% of global GHG emissions and 6.8% of global CO_2 emissions (while LAC's GDP and population accounted for 8.3% of the respective worldwide values). Fossil fuels produced 46% of GHG emissions and 66% of CO_2 emissions in the region. Forty-four percent of the GHG emissions came from agriculture and land use (Graph 1.3 in Chapter 1). Over that period, Argentina, Brazil, Mexico, and Venezuela (which account for 65% of the population and 71% of GDP) produced 75% of the energy emissions and 71% of total emissions in LAC.

Although the levels of emissions in LAC are low compared to the global average (e.g., CO_2 emissions per capita versus real income in Graph 2.1) and, in particular, to that of developed countries, the trend over the past 50 years is clear in two aspects. On the one hand, CO_2 emissions per capita show a slightly rising trend in LAC (with a reduction in 2020), whereas they decreased in the European Union and the United States. In this dimension, the emissions produced by China during the expansion period should be highlighted. On the other hand, the marked regional differences in emissions per unit of value added in the economy during the 1970s and 1980s (as shown for selected years in the graph) decreased significantly during the two first decades of the 21st century. LAC stands behind in this respect.

Graph 2.1
Total CO_2 emissions by country and region in selected years from 1971 to 2020
Source: Authors based on data from Ritchie et al. (2020) and the World Bank (n.d. a).

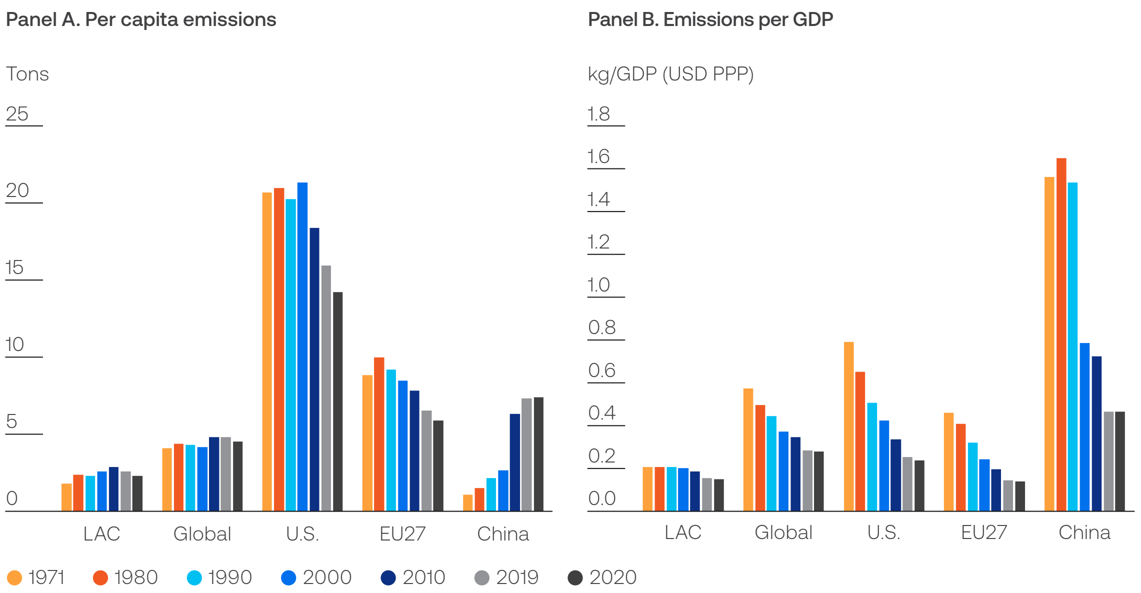
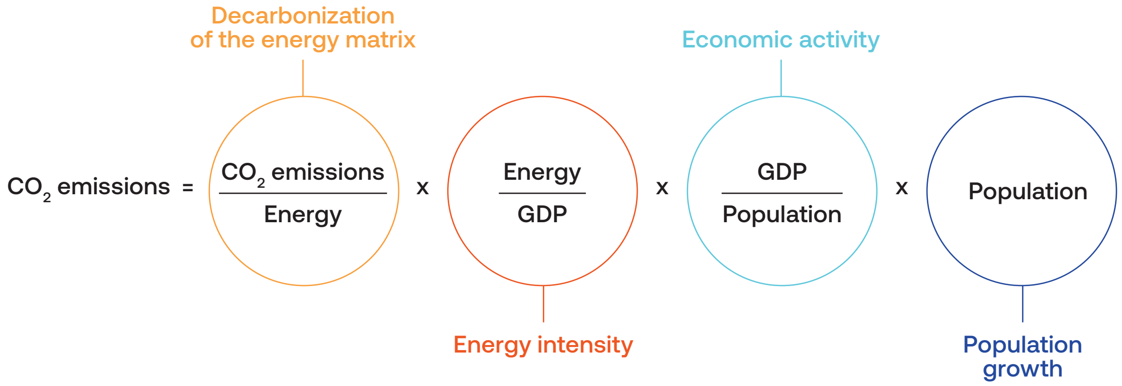


Figure 2.1
Breakdown of per capita emissions using the Kaya Identity
Source: Authors.



The differences in per capita emissions among countries, in turn, reflect differences in technologies (e.g., energy matrix composition, insulation in homes and buildings) and consumption options (e.g., transportation used, distance to work, urban concentrations). One common approach to analyzing per capita greenhouse gas emissions is through the Kaya identity, to break down per capita emissions into three contributions: i) carbon intensity of energy supply (i.e., how clean energy production is); ii) energy intensity of the economy (i.e., how much energy is required to produce the GDP); and iii) per capita GDP (i.e., economic growth). (See Figure 2.1.)

Following this methodology, Graph 2.2 presents a breakdown of the variation in emissions according to the organic growth of the population, economic activity, energy intensity, and the decarbonization of the energy matrix. In LAC, while the 1970s and 1980s were characterized by changes in the energy structure targeting decarbonization, energy efficiency improved during the first two decades of the 21st century.

Graph 2.2 shows that the decarbonization of the energy matrix (related to challenge 1, see Chapter 1) and energy efficiency (challenge 2) reduce pressure on the increase in emissions caused by economic and population growth (as shown for China between decades), and may even bring down emission levels. This was the case in LAC for the period 2010-2019, the United States over 2000-2019, and the European Union during the past four decades. Therefore, in the energy sector, decarbonization[13] involves a set of interventions aimed at achieving four primary strategies. The first is fostering a shift from a fossil-fuel and carbon energy system to one based on primary sources that help reduce emissions (e.g., renewable sources and replacement of coal and liquid fuels with natural gas in the electricity matrix).[14] The second is increasing the share of electricity in the energy matrix by migrating different consumers (electrification of the energy demand, or use of low-emission or zero-emission energies such as green hydrogen). The third is searching for efficiency (e.g., energy efficiency at points of consumption and efficiency gains in different segments of the value chain). Finally, the fourth is developing carbon capture and storage solutions. Institutional and regulatory measures are needed to promote these changes and support the different sectors and stakeholders in adjusting to the new situation (e.g., carbon fees or carbon pricing, or a set of supply and demand measures). However, these measures

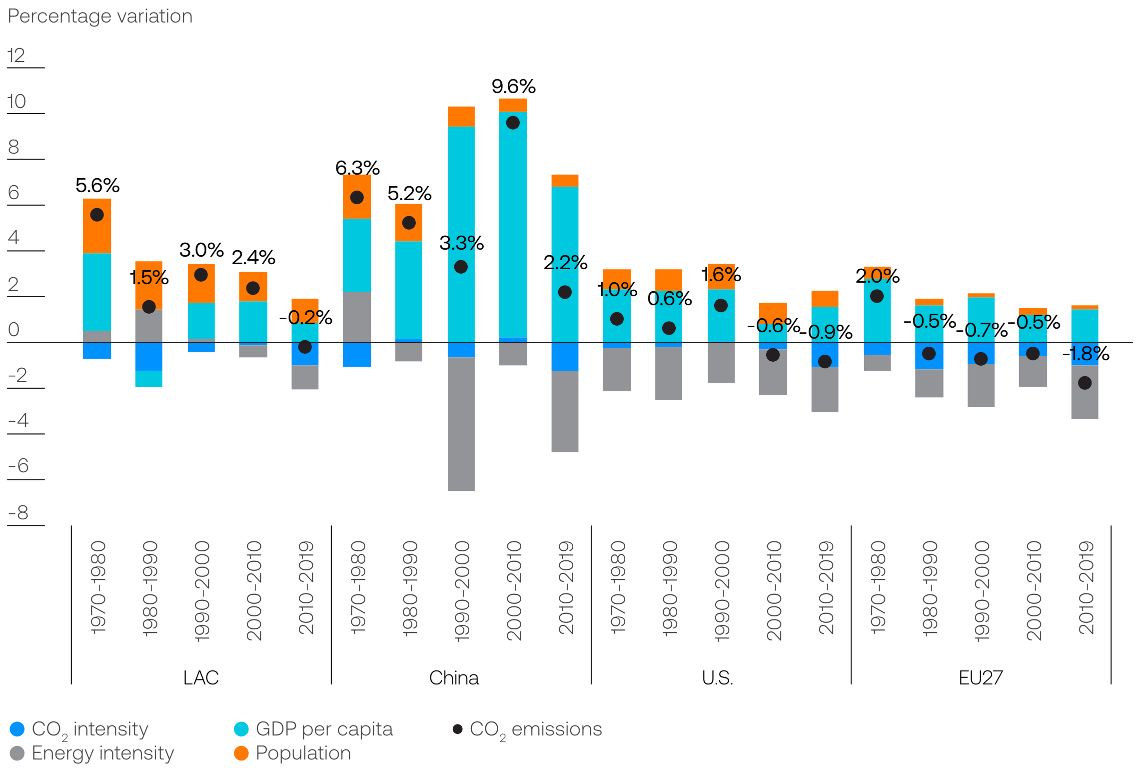
13 Decarbonization of activities related to farming, silviculture and land use are not analyzed in this report. See Bataille et al. (2020).

14 The substitution replacement of coal-fueled fired thermal power plants by with highly efficient natural gas combined cycle plants or combined energy and heat and power generation plants may reduce emissions in the short term (as long as fugitive methane emissions are release is controlled).

The energy sector accounted for 47% of GHG emissions and 62% of CO_2 emissions in LAC.

should take into account local contexts and prioritize each country's capacity to boost sustainable development, i.e., to optimize service accessibility, quality, reliability, and affordability in line with their environmental goals. This process is called energy transition.

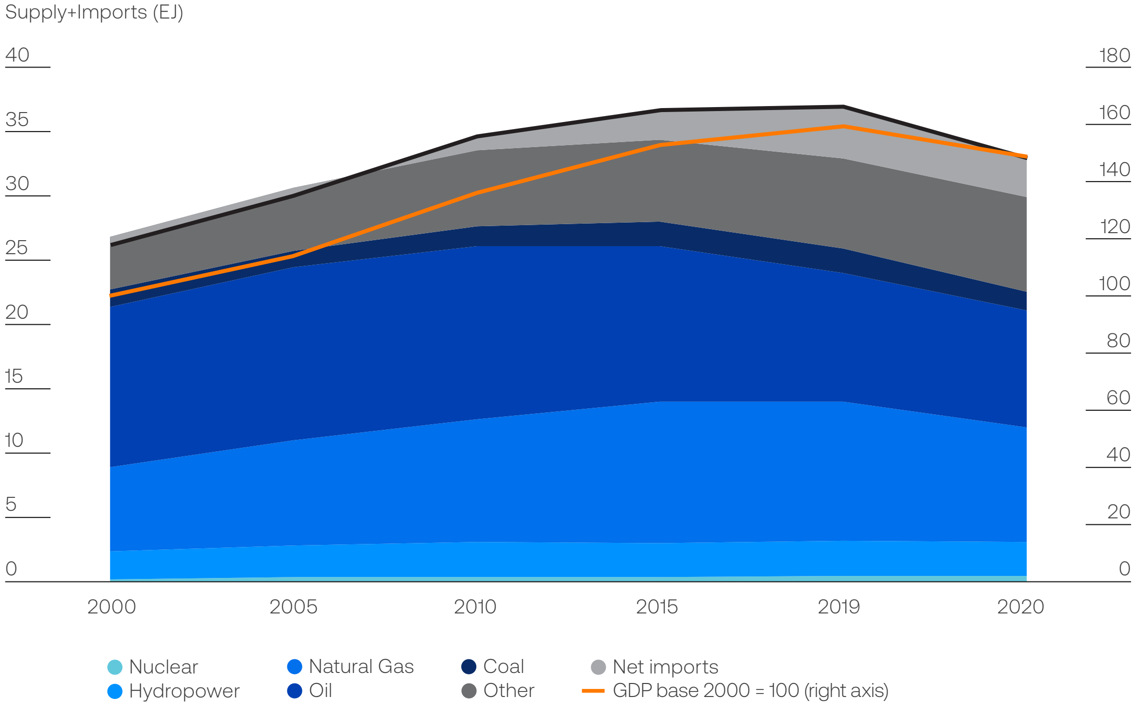
Graph 2.2
Percentage change in CO_2 emissions, population, GDP per capita, energy intensity, and emission intensity (in annual averages per decade)
Source: Authors based on data from Ritchie et al. (2020) and the World Bank (n.d. a).



The energy matrix in Latin America and the Caribbean

Given the importance of the composition of the energy matrix to reduce GHG emissions, this subsection will analyze the evolution and current situation of the energy matrix in the region, broken down by components and countries. Matrices from selected years between 2000 and 2020 are used, based on information available from the Latin American Energy Organization (OLADE). Graph 2.3 shows the evolution of the total supply of primary energy plus net imports of secondary energy in LAC for each year under review, and an aggregate GDP index for the region. The total supply of primary energy and net imports of secondary energy in LAC rose from 26.2 exajoules (EJ)[15] in 2000 (26.8 EJ from production and 0.6 EJ from net secondary energy exports) to 36.9 EJ in 2019 (32.9 EJ from production and 4.0 EJ from net imports). In this period, the region's GDP grew by 59%. Graph 2.3 reflects an apparent shift in the relationship between primary energy and GDP in 2010, as well as a decrease in economic activity and energy needs in 2020 due to the COVID-19 pandemic.

Graph 2.3
Primary energy plus imported secondary energy and GDP in LAC for selected years between 2000 and 2020
Source: Authors based on information from OLADE (n.d.) and the World Bank (n.d.a).



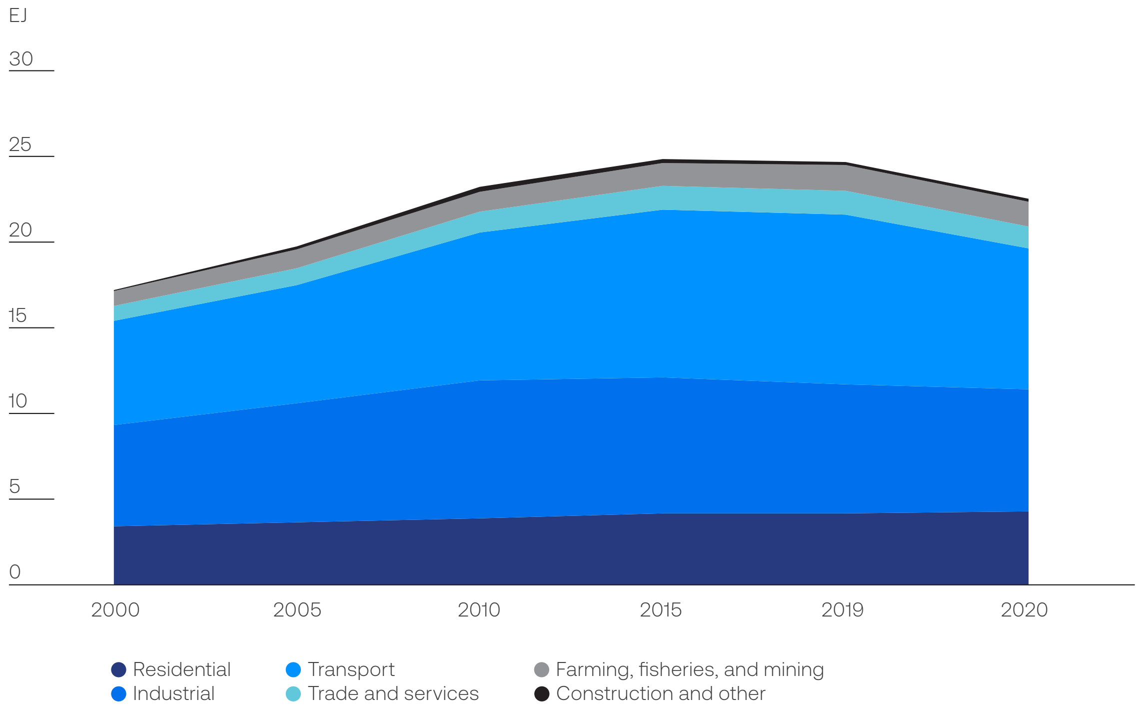
Note: GDP values are expressed in constant currency (constant 2015 USD). GDP base year 2000 = 100.

15 One exajoule is equivalent to one billion gigajoules (one ton of oil equivalent [toe] is equivalent to 41.84 gigajoules, according to data published by OLADE).

Finally, Graph 2.3 also reflects the change in the composition of primary energy sources. From 2000 to 2019, natural gas (up 5.6 percentage points) and other energy sources, including renewables (up 3.9 percentage points) replaced oil (down 16.8 percentage points).[16] Another characteristic of the region is that net imports of secondary sources (mainly oil derivatives) increased by 4.6 EJ. The share of coal rose marginally. In net terms, a slight drop in emissions is observed per unit of energy during the first decade of the period (as illustrated in Graph 2.2).

Final energy consumption increased from 17.3 EJ in 2000 to 24.9 EJ in 2015, and then stabilized at about 24 EJ to 25 EJ up to 2019, falling to 22.6 EJ in 2020 (Graph 2.4). The main change observed in the sectoral composition of domestic energy demand is a drop in the share of industrial and residential consumption (4 points and 3 points, respectively). This is compensated by an increase in transportation (5 points), farming, trade, and service sectors (2 points). In 2020, the transportation sector experienced an unprecedented drop in its relative share of total energy consumption, falling to levels comparable to those seen in the year 2000. This was mainly due to mobility restrictions put in place during the pandemic, which had a significant impact on the sector's energy consumption.

Graph 2.4
Relative evolution and composition of final consumption in LAC in selected years between 2000 and 2020
Source: Authors based on data from OLADE (n.d.).



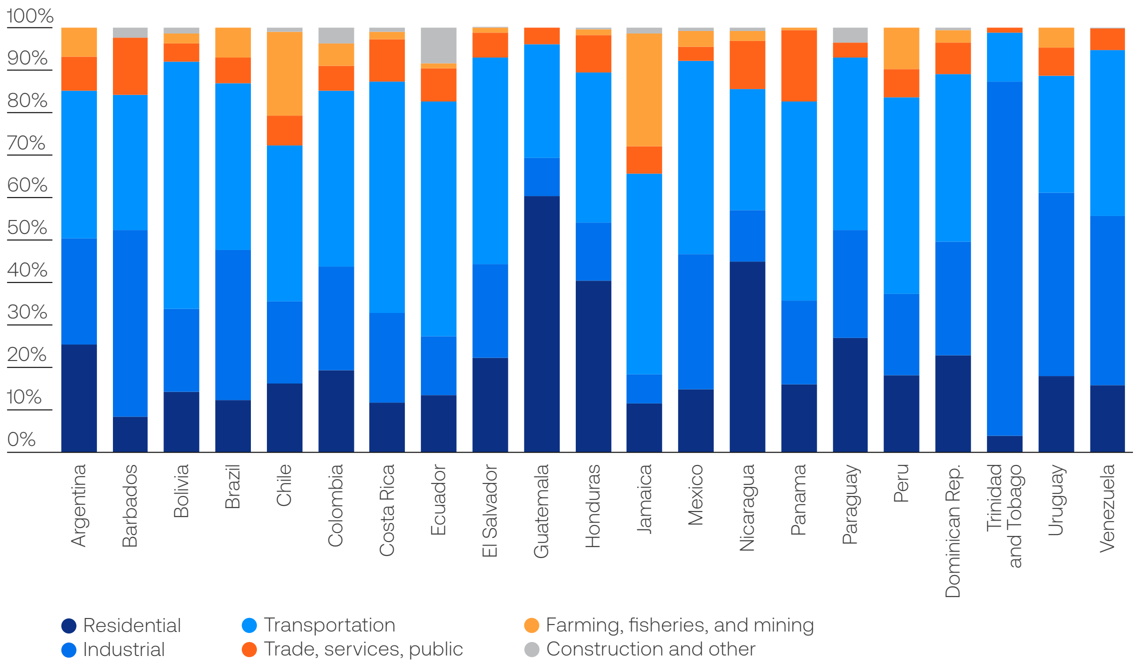
16 The information available from OLADE does not identify renewable energies in detail, as they are grouped under "other primary energies."

In comparing Graphs 2.2 and 2.3, it becomes clear that the region has lost its competitive position in the energy trade. In the year 2000, the region was a net energy exporter (0.6 EJ); ten years later, it had become a net importer, a position it has held since (4.0 EJ in 2019).

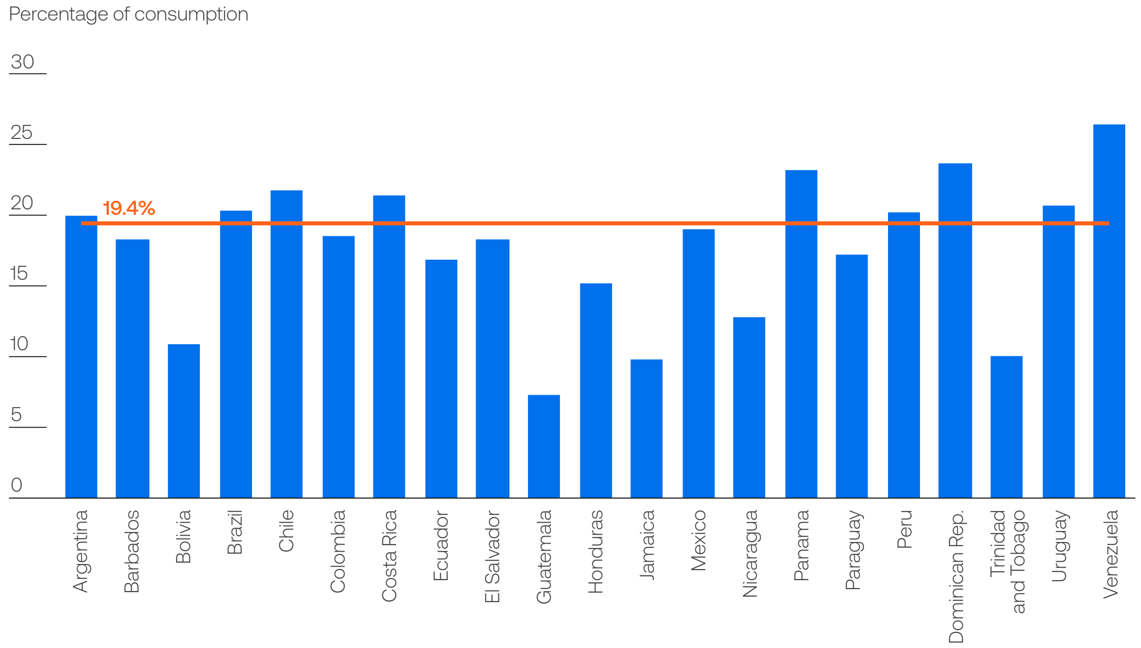
Graph 2.5 illustrates the sectoral composition of consumption in 2019 (the last year with available information before the change in 2020), highlighting the realities of countries that are hidden in the regional average. In some of these countries, the transportation sector accounts for more than 50% of energy consumption (Bolivia, Costa Rica, and Ecuador). In others, the industrial sector represents more than 40% (Trinidad and Tobago, Uruguay, and Venezuela). In the third group, the residential sector is the biggest consumer (Guatemala, Honduras, and Nicaragua). In Argentina, Paraguay, and the Dominican Republic, energy consumption is more balanced among the three sectors.

In LAC, electricity consumption accounts for a little less than 20% of energy consumption (Graph 2.6). In some extreme cases, it can represent more than 23% (e.g., in Panama, the Dominican Republic, and Venezuela), while in others, it is below 10% (Guatemala, Jamaica, and Trinidad and Tobago).

Graph 2.5
Final energy consumption by sector and country in 2019
Source: Authors based on data from OLADE (n.d.).



Graph 2.6
Share of electricity in final energy consumption in 2019
Source: Authors based on data from OLADE (n.d.).

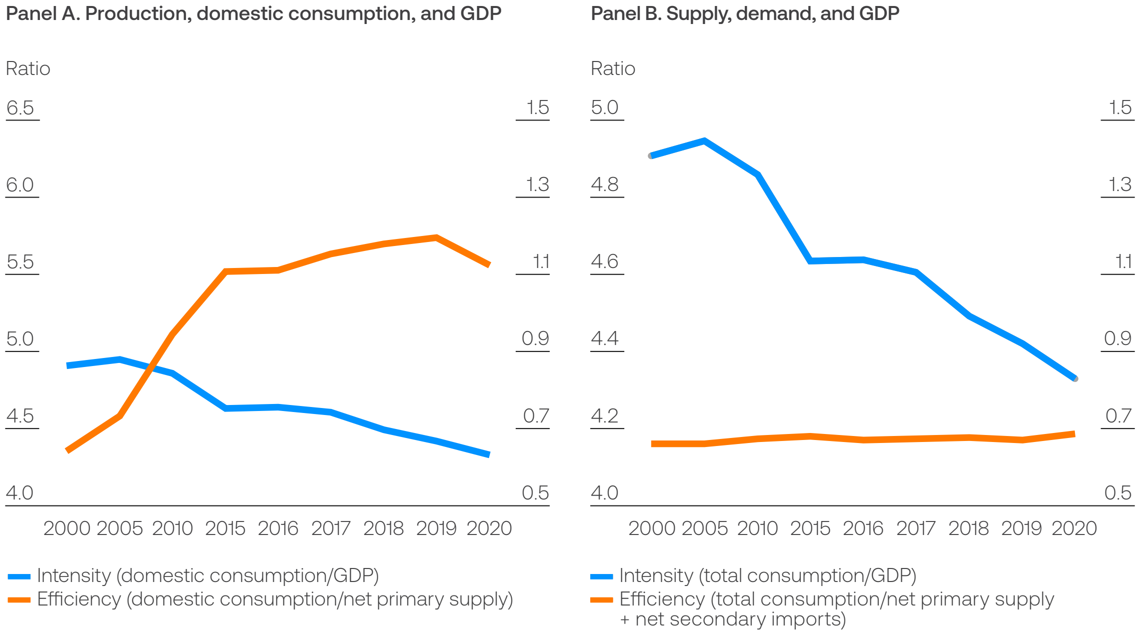


Note: In 2020, the ratio was 21.3%.

In comparing graphs 2.3 and 2.4, how energy intensity and efficiency are measured is particularly relevant when analyzing the region's energy sector. A traditional approach is to compare domestic consumption and primary (net) supply versus GDP. Panel A in Graph 2.7 shows a decrease in the ratio between domestic energy consumption and GDP (9% between 2000 and 2019), indicating an improvement in energy intensity, while the ratio between domestic consumption and primary supply increased (27%). However, this approach conceals the shift in the region's international exposure from a net exporter to a net importer of secondary energy sources. Panel B in Graph 2.7 shows the same relationships for energy intensity and efficiency, adjusting total supply with net secondary fuel imports (necessary for final consumption) and total demand. Under this approach, efficiency—defined as resources necessary to meet consumption needs—has remained constant, while energy intensity (measured as total energy consumption to generate the economy's value added) improved by 10% between 2000 and 2019. Reduced user consumption (i.e., improvements in energy efficiency) is the main contributing factor, more so than production or consumption changes favoring less intensive activities, according to the evidence in the region.[17]

17 Other regions of the world provide evidence of various factors influencing improvements in energy intensity, such as the country's economic structure, climate, economic size, energy prices, energy efficiency measures, and exchange rates (Cornillie & Fankhauser, 2004; Filipović et al., 2015; Sun et al., 2022). However, Jiménez and Mercado (2014) analyze energy intensity by separating it into a pure intensity component and another component related to the country's economic structure, specifically identifying productive activities, and underscore the significance of the former factor.

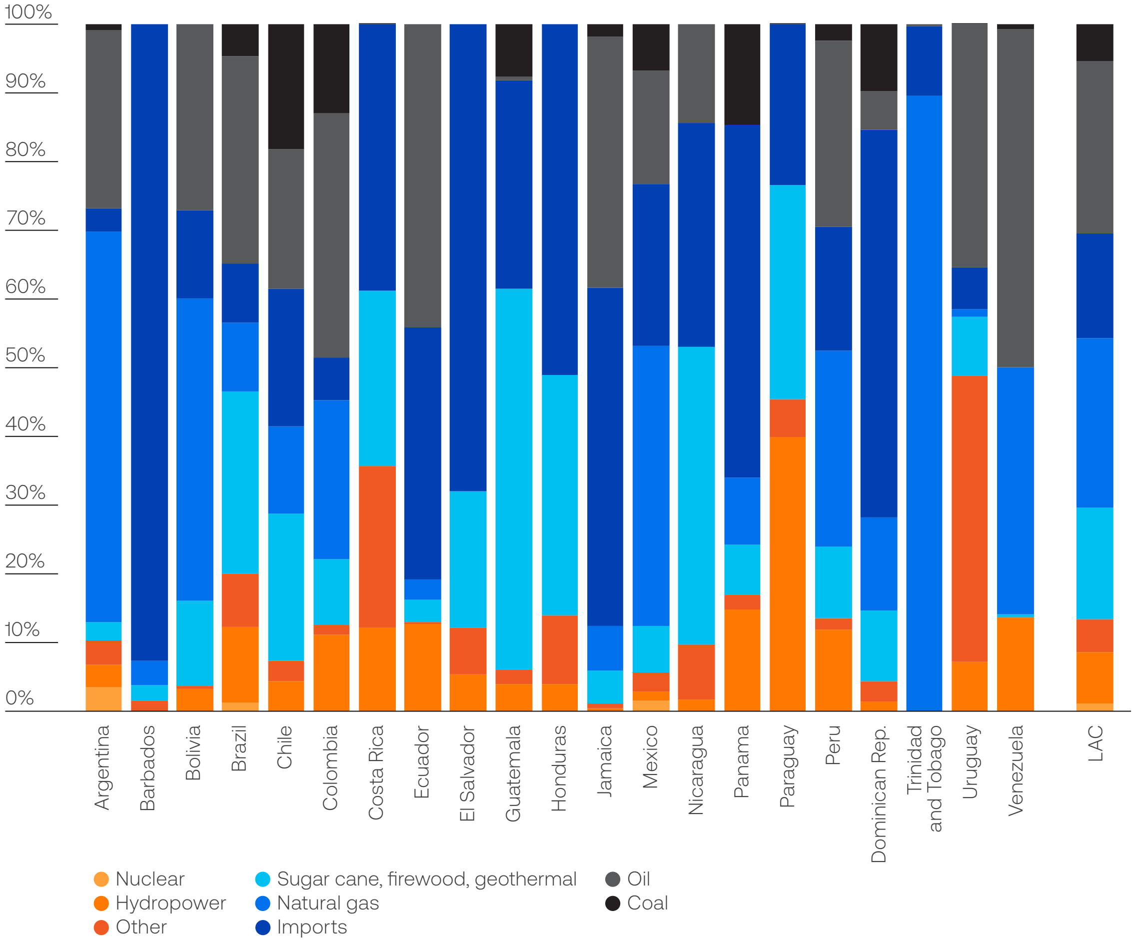
Graph 2.7
Energy intensity and sectoral efficiency
Source: Authors based on information from OLADE (n.d.) and the World Bank (n.d.a).



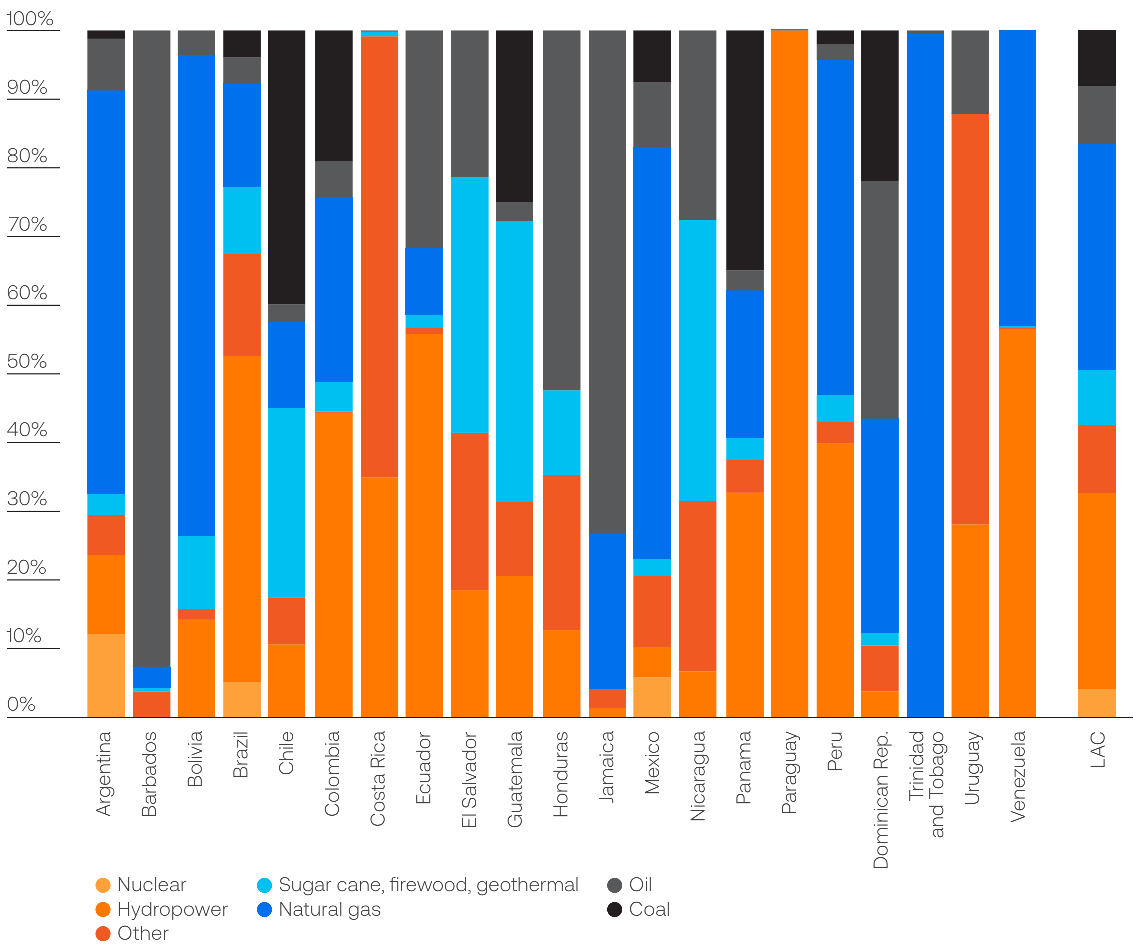
The difference between the energy matrix and the electricity sub-matrix is a key element in understanding energy transition policies. For instance, an electricity matrix in the region may be relatively "green;" however, this does not mean that the energy supply comes from clean sources. There are three reasons for this. First, a significant part of the sources corresponding to the rest of the energy matrix usually come from petroleum derivatives. This is clear in the comparison of Graphs 2.8 and 2.9. For example, 75% of electricity generation in Brazil is from low-emission sources (nuclear energy, hydropower, energy from non-conventional sources, and biomass), but this percentage declines to 50% in the energy matrix. A similar situation is found in Colombia and Ecuador. Second, the analysis can be biased if the primary supply of energy resources is considered in isolation, disregarding imports (which are generally oil derivatives). For example, Costa Rica and El Salvador do not produce oil. Even though their primary supply is completely "clean," they need to import fuels for electricity generation and transportation consumption. Imports account for 39% and 68% of these countries' energy needs, respectively. Third, even if the electricity matrix has a high share of generation from clean sources, any increase in power use (as a result of consumption substitution policies) must be met with new electricity generation under the existing configuration because renewable sources are already being used to almost full capacity. This is clear in Graph 2.9: with the exceptions of Costa Rica, Paraguay, and Uruguay (and Trinidad and Tobago, which uses natural gas), nearly all countries generate electricity from liquid fuels or coal. Indeed, countries such as Chile, Colombia, Guatemala, Panama, and the Dominican Republic still rely heavily on coal. Thus, demand policies involving an increase in electricity consumption will have low or no impact on emissions unless they are complemented by expanding the capacity to generate energy from renewable sources that still have potential (hydropower, wind, solar and geothermal energy).

Electricity consumption in the region represents about 20% of energy consumption. Having a relatively “green” electricity matrix does not guarantee a clean energy supply.

Graph 2.8
Relative composition of primary energy by source and country in 2020
Source: Authors based on data from OLADE (n.d.).

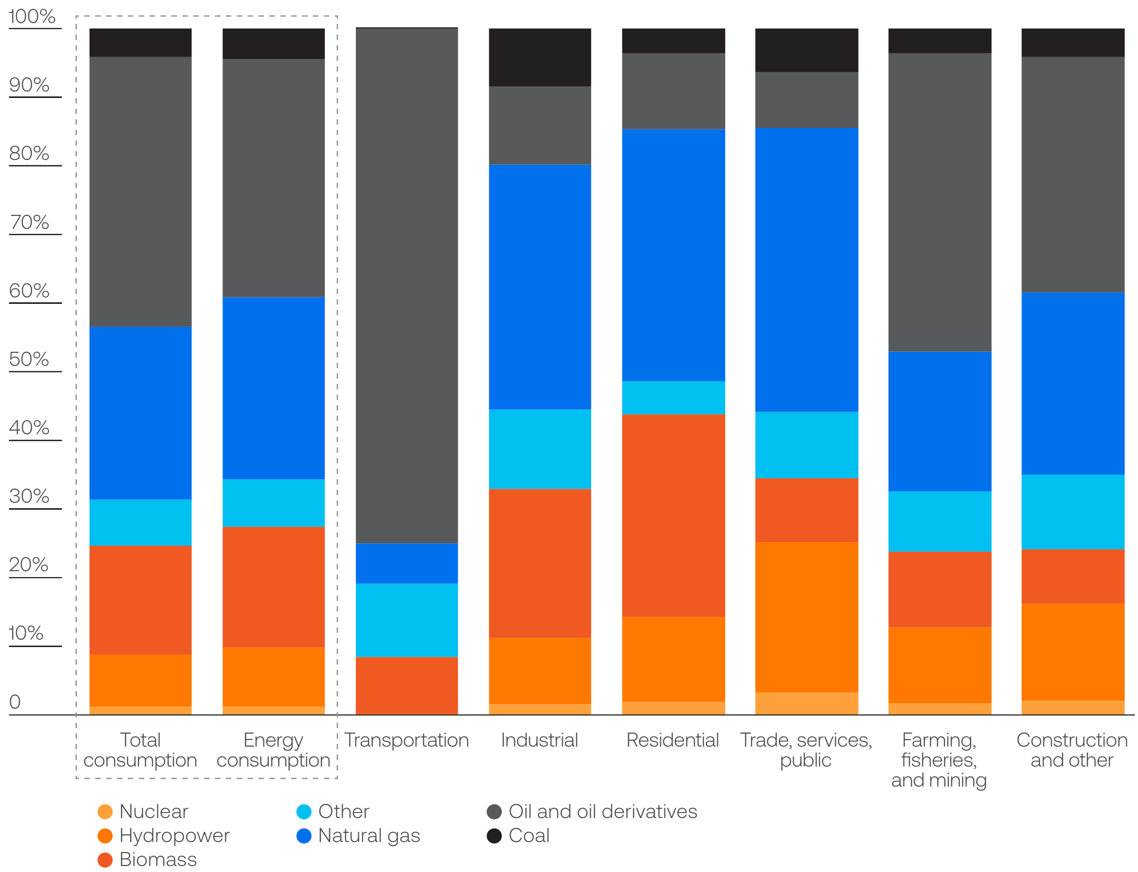


Graph 2.9
Relative composition of power generation by source and country in 2020
Source: Authors based on data from OLADE (n.d.).



Lastly, Graph 2.10 presents an exercise that illustrates the composition of energy sources (primary supply and imports of secondary sources) to meet the final demand in the region in 2020. Although this combination does not differ significantly from the data presented in Graph 2.8 (it simply assigns imports by energy source), fossil fuels have the largest share, particularly oil, oil derivatives, and natural gas, in all sectors of consumption, including transportation, primary activities (farming, fisheries, and mining) and construction. In the transportation sector, oil and oil derivatives accounted for 75% of energy consumption in 2020 (83% in 2019). The industrial, residential, and trade sectors have a high share of natural gas (nearly 40%). Given the differences in sectoral matrices, it is clear that decarbonizing the consumption sectors involves substituting different sources and at different intensities.

Graph 2.10
Relative composition of the energy needed to meet final consumption in LAC by energy source and sector of consumption in 2020
Source: Authors based on data from OLADE (n.d.).



Note: In 2020, the matrix is biased in the combination of energy resources for transportation as a result of the pandemic crisis (in the last year before the pandemic, oil derivatives accounted for 83% of the energy needs for transportation). Moreover, the most up-to-date data are shown for non-conventional renewables as the generation of this energy is highly dynamic.

Heterogeneities in Latin American and Caribbean countries

LAC countries exhibit varying degrees of sectoral progress and sustainable development in their transition toward low-emission energy source adoption.

First, the share of oil, oil derivatives, and coal in the energy matrix has declined (although this has been compensated in part by imports of oil derivatives), while the share of natural gas and renewable energies increased (Graph 2.3).

Moreover, renewable sources account for a significant share of generation in the region's electricity matrix (Graph 2.9). However, this good regional performance hides broad heterogeneities between countries, particularly varying degrees of reliance on coal and hydrocarbons and diverse penetration levels of renewable sources at the sectoral level (Graph 2.9) and by consumption group (Graph 2.10).

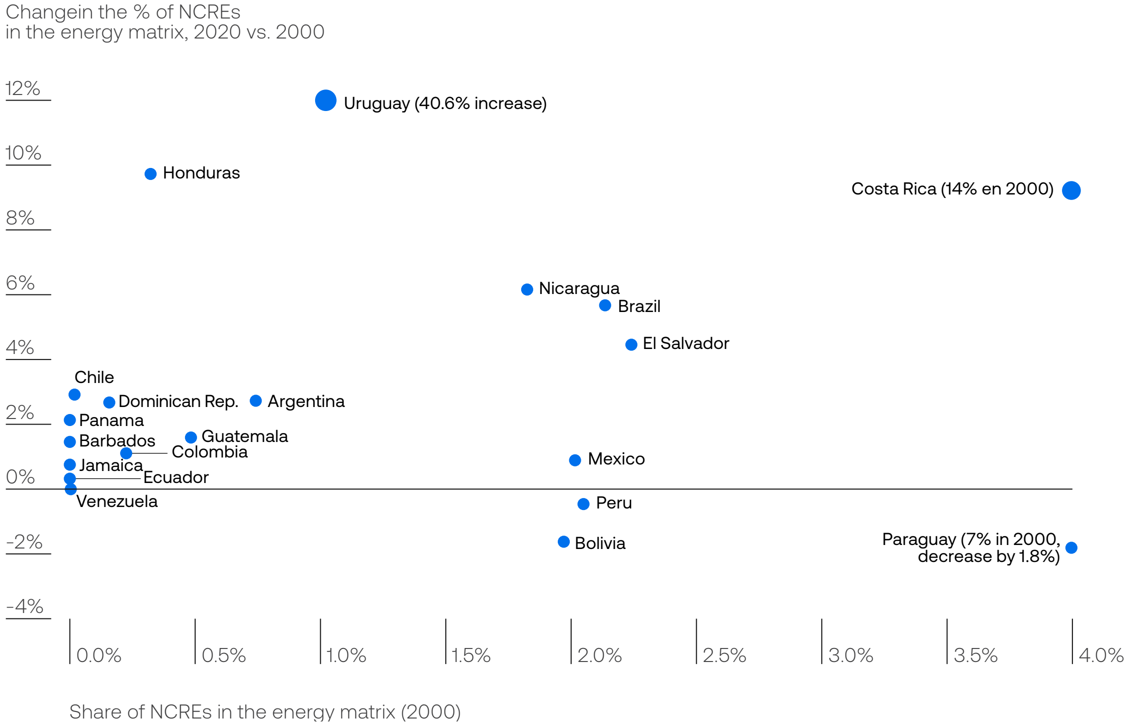
One source of heterogeneity is the introduction of non-conventional sources in the energy matrix. A comparison of the level of penetration of non-conventional renewable energies (NCRE) between 2000 and 2020 reveals the notably strong performance of some countries versus a second group of countries, which have made less progress (Graph 2.11). In the first group, Uruguay stands out, registering a marked increase in NCRE penetration from 1% in 2000 to 42% in 2020. Throughout this transition, NCREs gradually replaced sources of high GHG emissions (the share of oil production declined by 22%, while imports decreased by 4%) and hydropower (whose share dropped by 11%).

Several countries in Central America have performed similarly, with a nearly 5% or higher increase in the share of NCREs (Costa Rica, 9%; El Salvador, 4.5%; Honduras, 10%; Nicaragua, 6%). Within this group, the share of NCREs in Costa Rica already exceeded 14% in the year 2000. At the same time, these countries were the few in the region to have a share of NCREs above 5% in 2020 (Costa Rica, 23%; El Salvador, 7%; Honduras, 10%; Nicaragua, 8%). It is worth highlighting that NCREs competed with other sources while managing to increase their share of the energy matrix in this group of countries (Costa Rica decreased imports; Honduras reduced coal and biomass; Nicaragua and El Salvador reduced the use of oil, but started to import oil derivatives).

In South America, Brazil performed similarly to the group of countries in Central America: the share of NCREs was above 2% in 2000 and increased by nearly 6%, while the domestic supply of high-GHG emission sources (coal and oil) declined.

In contrast, Bolivia, Paraguay, and Peru made no progress in introducing non-conventional renewables. Thus, the uncertainty of their hydropower generation sources has been compensated with imports (mainly oil derivatives), exports (surplus hydropower generation in Paraguay), and biomass.

Graph 2.11
Comparison of NCREs in the energy matrix in 2000 and their growth up to 2020
Source: Authors based on data from OLADE (n.d.).



Note: A comparison of this change in the share of non-conventional renewable energies and the green basis of the energy supply (hydropower, biomass, geothermal energy, etc.) generates the same groupings.

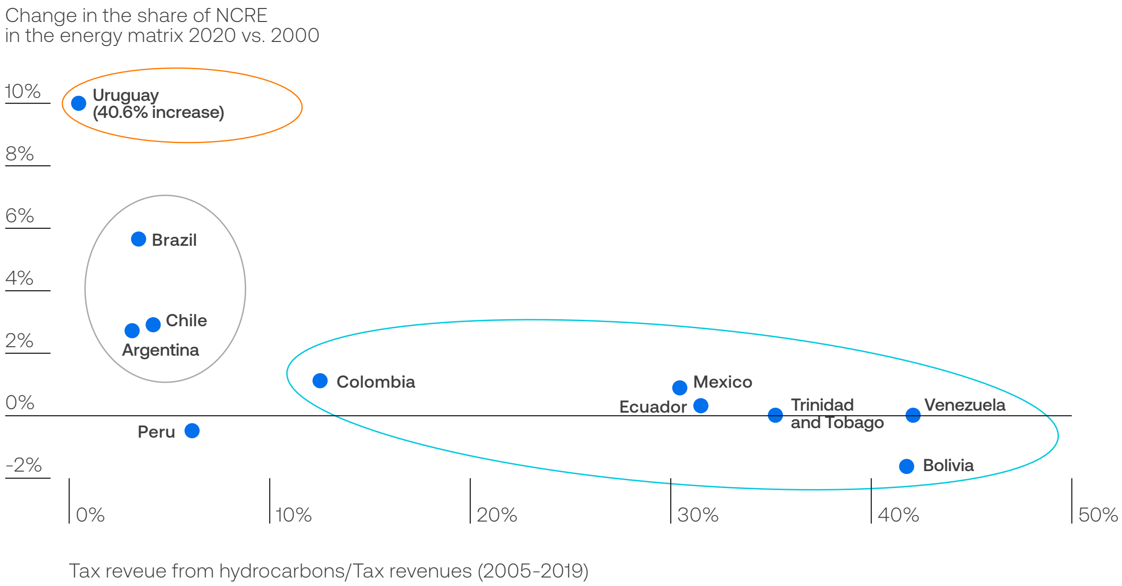
The remaining countries in the region had low levels of renewable energy penetration in the year 2000 (less than or equal to 2%) and limited progress over the last two decades (less than 3%), leading to current levels of renewable energy participation below 4%.

Countries' fiscal dependence on the hydrocarbon sector is a second source of heterogeneity. Building on the previous information, the degree of renewable energy penetration in the energy matrix during the last two decades is compared to the economic and fiscal situation in countries (captured by the weight of tax revenue from hydrocarbons in public accounts).[18] Using data for the countries with available fiscal information, Graph 2.12 reveals three relevant groups of cases. Uruguay has no energy natural resources in its primary matrix, so the growth of clean generation capacity has no impact on its fiscal accounts in this dimension. Another group of countries, including Bolivia, Colombia, Ecuador, Mexico, Trinidad and Tobago, and Venezuela, rely heavily on this source of income, so an abrupt change in the supply matrix could significantly affect them.[19] Finally, countries such as Brazil, Chile, and, to a lesser extent, Argentina have more recently made progress in the incorporation of renewable sources, so their situation could change in the future.

In line with this analysis, promoting certain energy transition policies requiring, for example, certain subsidies, would also meet resistance due to fiscal deficit in most countries.

Graph 2.12
Comparison between NCREs in the energy matrix for the period 2000-2020 and tax revenues from hydrocarbons

Source: Authors based on data from OLADE (n.d.) and information provided by CAF's Direction of Macroeconomic Studies in the Knowledge Department.



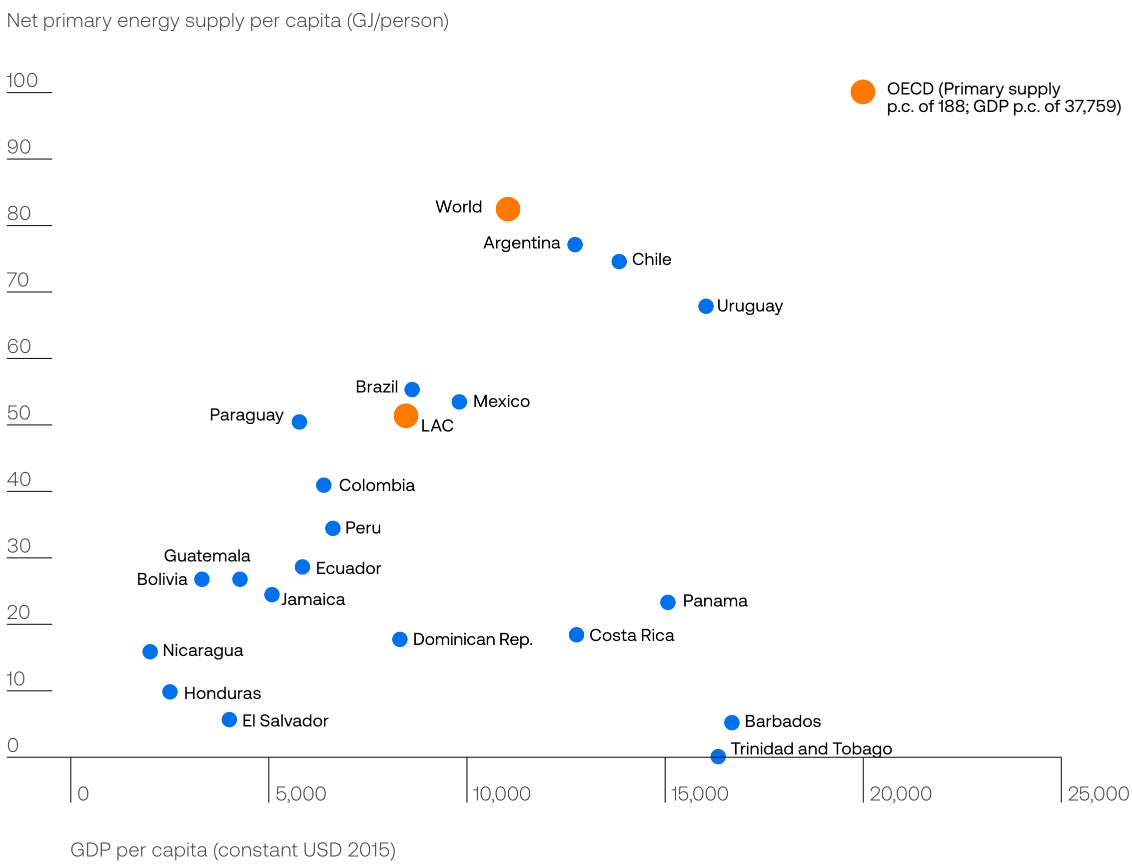
18 The analysis of a country's reliance on tax revenues from the hydrocarbon sector seeks to estimate the economic situation (the importance of the sector and its productive chains) and the fiscal situation (the importance of tax revenues) as a potential source of conflict to adopt low-carbon emission technology. However, this indicator does not capture tax revenues from new sources of energy generation. For example, given the same price of electricity, an NCRE source may contribute more VAT or other sales taxes than a thermal source because it uses fewer energy generation inputs.

19 This situation may change as the share of fiscal revenues from hydrocarbons in public accounts decreases. In several countries, it has dropped sharply from 2015, due not only to the evolution of international prices, but also to falling internal productivity.

A third source of heterogeneity is the economic development path adopted by each country. The literature has studied the relationship between economic development and emissions, suggesting the hypothesis of an inverted U-shaped relationship known as the Environmental Kuznets Curve. There is no clear consensus among studies or data regarding these results (see the review by Kaika and Zervas, 2013). Usually, there is a positive relationship between growth and CO_2 emissions up to a certain level of development, after which emissions decrease with growth. Although this level of detail is beyond the scope of this report, it is worth highlighting that the GDP per capita is much lower in several LAC countries than in developed countries and the global average. Therefore, the region's needs in terms of economic growth and energy consumption (with a positive relationship, as illustrated in Graph 2.13) condition the energy transition.

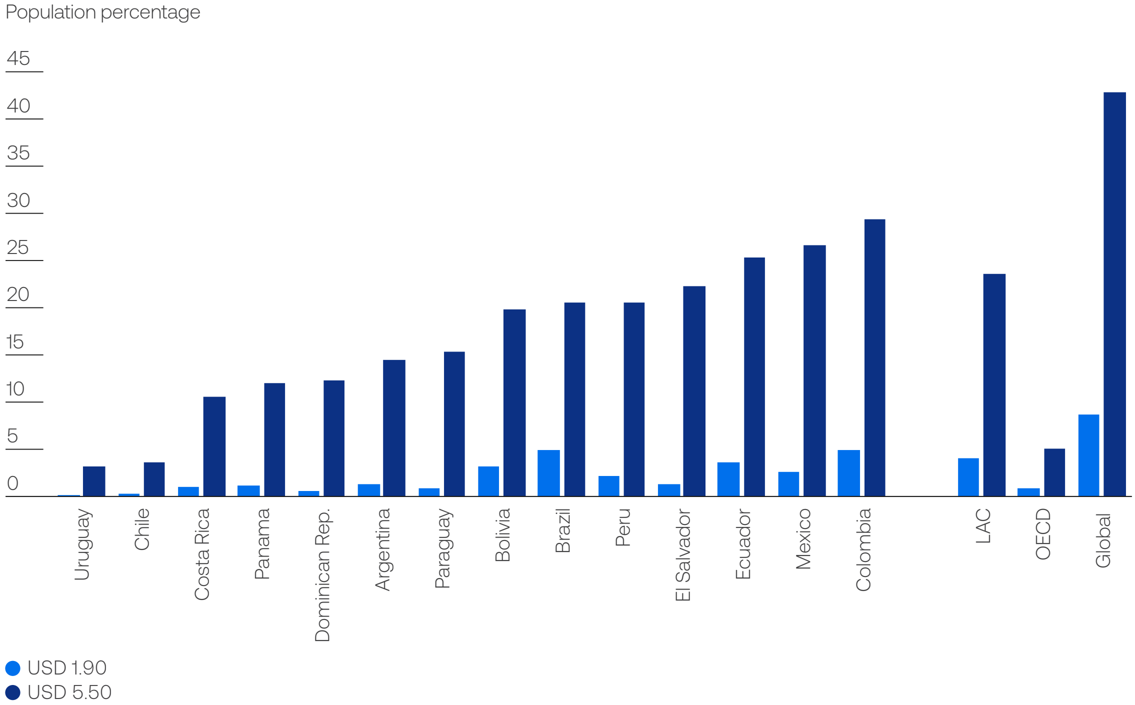
Finally, overall levels of development, inequality, and poverty in LAC countries represent a fourth source of heterogeneity. Graph 2.14 illustrates poverty levels based on two consumption basket thresholds (USD 1.90 and USD 5.50 a day in 2011 purchasing power parity) in 2019 (or the most recent year with available information). This situation has worsened since 2020. Like in the cases of the other sources of heterogeneity, unresolved development dimensions represent an additional constraint for energy transition policies.

Graph 2.13
Comparison between GDP per capita and net primary energy supply per capita in 2019
Source: Authors based on data from OLADE (n.d.), EIA (n.d.), and the World Bank (n.d.a).



Note: Net primary supply p.c. for Trinidad and Tobago is omitted.

Graph 2.14
USD 1.90 and USD 5.50 poverty level thresholds in 2019
Source: Authors based on data from the World Bank (n.d.a).



Note: Percentage of the population that does not have sufficient income or resources to meet their daily expenses (in USD, in 2011 purchasing power parity). Data from 2019 or the most recent year with available information.

These comparisons reveal three main groups of countries based on common characteristics. In the first group, Costa Rica, Chile, Panama, and Uruguay are countries with a high per capita GDP in the region, little dependence on hydrocarbons in public finances, and low to intermediate levels of poverty. A second group consists of Argentina and Brazil, with an intermediate GDP, intermediate to high poverty levels, and relatively low dependence on the hydrocarbon sector in fiscal accounts. A third group includes Colombia, Ecuador, and Bolivia, with a low per capita GDP, higher poverty, and elevated fiscal participation of hydrocarbons. These different realities of the countries in the region allow us to anticipate that the greatest environmental energy challenge is to undertake an energy transition that is committed to the planet and fiscally viable, achieving a balance between the needs (environmental, but also economic and social) and the region's capacities to achieve a certain speed of transition.

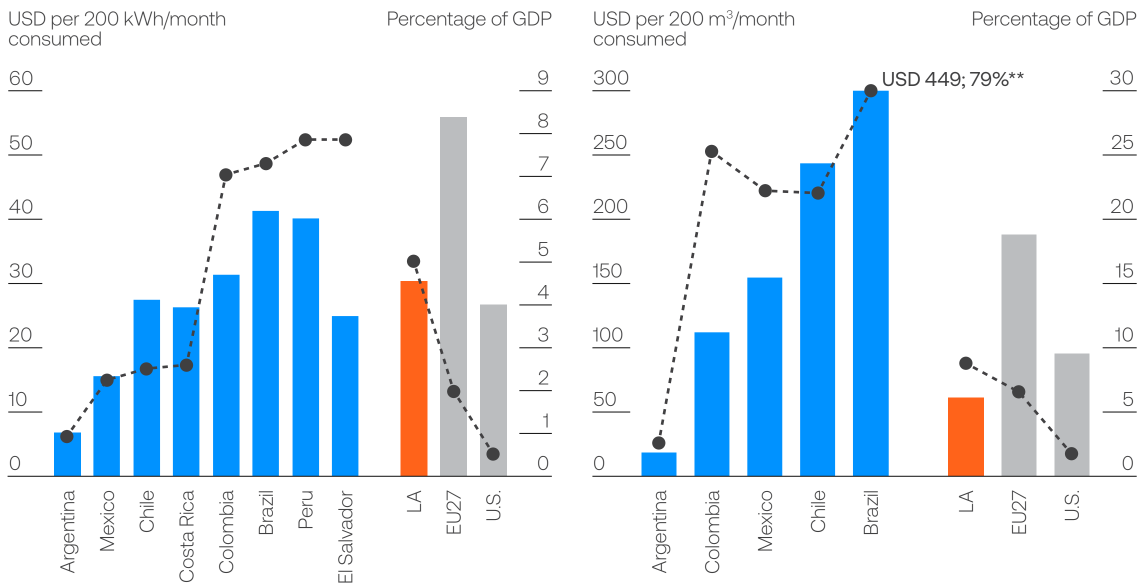
Dimension of service gaps

Based on the above and given the complex situation caused by climate change, the energy sector will face profound changes and challenges in the coming years, which will have to address existing gaps in electricity and natural gas services (Annex 2.1).

The IDEAL 2021 report (Cont et al., 2021) proposed a method to analyze service gaps from the perspective of three dimensions: access, cost-affordability, and quality (see Box 1.4 in Chapter 1 of that report). In the electricity subsector, countries are not far from achieving universal coverage, with the exception of rural access in some of them (e.g., Bolivia, Honduras, and Nicaragua). In regard to costs, electricity rates are low in nominal terms. Average tariffs in the region are similar to those in the United States and approximately 55% of the average tariffs in the European Union, although they are high in terms of per capita income (Panel A of Graph 2.15). For a group of countries, electricity expenditure represents up to 2% of per capita GDP (Argentina, Chile, Costa Rica, and Mexico) whereas it is between 7% and 8% in the case of others (Brazil, Colombia, El Salvador, and Peru).

Graph 2.15
Mean rate and affordability of electricity and natural gas services in 2021
Source: Authors based on data from Annex 2.1.

Panel A. Electricity (USD per 200 kWh/month) **Panel B. Natural gas (USD per 200 m³/month)**



Note: The figure for Latin America is the average of the countries reported in each sector. Natural gas consumed per 200 m³/month is very high for the region (in particular, for Brazil). These values are reported following the comparison presented by *Global Petrol Prices*. Annex 2.1 also reports LPG unit prices.

Table 2.1
Electricity and natural gas service gaps
Source: Authors.

Dimension	Electricity	Natural gas
Access	Levels close to universal access, with some exceptions in rural areas.	Few LAC countries have developed natural gas markets. Less natural gas is consumed compared to developed countries.
Cost/affordability	Disparities between countries and between regions within a country. Low nominal rates, but high relative to income.	The wholesale price is lower than the global average, although this difference has shrunk in recent years. For users, spending on natural gas from the grid accounts for a large portion of income compared to the situation in developed countries.
Quality	Higher frequency and duration of power outages compared to developed countries.	Most countries do not have systematic indicators.

Note: Data presented in the table correspond to the most recent year with available information (from 2019 to 2021, according to the indicator).

However, the biggest challenge is the quality dimension (estimated as the frequency and duration of outages), which is very different from standards in advanced countries. For example, outage frequency in LAC is triple levels in Europe and the United States, while outage duration is 20% longer than in the United States and four times longer than in Europe. Therefore, interventions in the electricity sector, whether sectoral or originating from an energy transition agenda, should consider the need for rural access in several countries and help improve the quality of the electrical service. The impact on system costs will depend on the type of interventions (e.g., technological improvements versus higher costs due to resilience requirements).

The natural gas market does not have the same coverage as the electricity sector. Indeed, only Argentina, Colombia, Chile, Mexico, Peru, and Venezuela have natural gas distribution networks with wide coverage. Capillary distribution has been provided by liquefied petroleum gas (LPG) distributed in cylinders/tanks, which tends to be more expensive than pipeline gas (per calorific unit). Natural gas or LPG indicators are scarcer for a sufficient comparison of countries.

Per capita consumption of natural gas in the region is much lower than in developed countries and the rest of the world (with regional exceptions, such as Argentina).[20] Improved gas availability in recent decades can be explained, in part, by the emergence of liquefied natural gas (LNG). Liquefaction reduced gas volume to transport it over long distances at competitive prices. Therefore, from being a local resource, natural gas became an international commodity. This facilitates gas access to large users (such as the industry or electricity generation) and gas supply to gas pipeline networks when local availability is limited (as in Argentina, Colombia, or Chile; in Chile, the restrictions on natural gas from Argentina limited the availability of this resource). In the past decade, one-third of the global gas trade was in LNG form, driven by the increased gas supply in the United States (Yépez-García and Anaya, 2017).

From a cost perspective, the (wholesale) price dispersion that existed across regions declined significantly in the past decade (see Graph 2.30 in Annex 2.1). However, for natural gas network users, the cost of supply is high relative to income (except in Argentina) compared to developed countries (Panel B in Graph 2.15).

20 Natural gas has had more coverage has been more extensive for industrial uses and electricity generation (see Kozulj, 2004, for historical details data onf the sector in South America, and Annex 2.1 for detailed information on the s of delivery of natural gas by according to user type in LAC countries in the region).

The quality of service dimension presents the greatest limitation, as, usually, representative data are not available either for the region or LAC countries themselves.[21]

The evolution of smart grids

With the advance of digitalization in different sectors of the economy, the electricity sector in particular began to evolve from traditional grids to smart grids (SG), which basically consist of communication infrastructure integrated into power grids. This provides them with more flexibility, better automation, and two-way communication, thereby improving reliability, resilience, and responsiveness in case of faults in the electric system. Smart grids also integrate energy generation from renewable sources and real-time communication with users. According to the IDEAL Report 2021 (Cont et al., 2021), smart meters are an essential component in SGs. Real-time information is made available to manage demand, which optimizes distributed resources, such as distributed generation and storage. Dynamic rates may be applied to improve system efficiency and reduce demand peaks on the grid by shifting part of the demand to off-peak, less expensive hours.

SG deployment requires large infrastructure investments (communication systems integrated into the power grid, data acquisition systems, grid metering and monitoring systems, automation systems, smart meters, etc.). These requirements pose a relevant challenge to developing countries because of potential financial restrictions, a situation that worsened during the COVID-19 crisis, although investments seem to be recovering since 2021 (IEA, 2021f).

21 Contrary to electricity, natural gas supply disruptions can involve safety risks when service is resumed on the distribution network. Therefore, it is usual practice to establish gas rates for can apply to interruptible users that agree to have their service interrupted during a supply shortage versus steady firm users.

Box 2.1
Lessons learned from COVID-19 regarding energy

In Latin America, the coronavirus crisis affected the energy sector, particularly hydrocarbons and, to a lesser extent, electricity and renewable energy. According to Real Instituto Elcano (Escribano, 2020), the impact was stronger on economies with a higher degree of reliance on gas and oil: for the first time in history, oil futures went negative (down to USD -40 per barrel in April 2020).

The plummeting hydrocarbon prices resulting from lower demand reduced the capacity of some LAC countries to address the health crisis. According to estimates by Real Instituto Elcano, Ecuador and Venezuela were the most affected countries, with a decline in tax revenues equivalent to 1% of GDP for every USD 10 drop in the price of oil. The decrease in tax revenues was also significant, though less pronounced, in countries such as Brazil, Colombia and Mexico, which revealed how important it is for LAC countries to uncouple social spending from the price trends of raw materials such as fossil fuels. The situation will be particularly challenging against an energy transition scenario with a sustained fall in hydrocarbon demand.

Electricity demand was also impacted during the pandemic regarding composition and time of use. For example, consumption migrated from companies and offices to homes. In addition, in countries such as Brazil, Chile, and Mexico, midday demand and the consumption peak that used to occur at the end of the workday dropped (Sánchez Úbeda et al., 2021).

The above reflects the importance of a flexible electric system to accommodate changes in demand. In turn, flexibility is key to prices: if seasonal demand declines regarding time of use relative to historical patterns, it would be possible to leverage existing infrastructure and readjust future scheduling. In contrast, more volatility and a higher share of non-conventional renewable sources in energy generation could lead to sudden fluctuations in time-of-use rates.

The COVID-19 health emergency left a valuable lesson: renewable energies help countries guarantee energy security because they make international prices less volatile (Paredes, 2020). This gains further relevance if subsequent events are considered, such as the Russia-Ukraine war starting in early 2022. Renewable energies are an instrument to ensure energy supply, especially in countries that are net oil or gas importers.

Energy transition due to climate change

History has recorded major energy transition periods. For example, replacing firewood with coal in the 19th century was a significant change, and then oil substituted coal in the 20th century. These two changes were brought about by the discovery of transformative uses of new energy sources.

However, concern for the environment and human capacity for life as a result of climate change is behind the current energy transition, including local contexts and sustainable development.

Multiple current perspectives address the meaning and scope of the energy transition, all driven by a broad approach including not only technology and primary energy substitution but also social and institutional aspects. For example, the International Renewable Energy Agency (IRENA) defines a successful energy transition as a road toward "transformation of the global energy sector from fossil-based to zero-carbon sources by the second half of this century, reducing energy-related CO_2 emissions to mitigate climate change" (IRENA, n.d.).

The World Energy Council (WEC)'s proposed approach to energy sustainability is "based on three core dimensions: Energy Security, Energy Equity, and Environmental Sustainability of Energy Systems" (WEC, 2021).

Thus, socioeconomic dimensions (access and affordability) and resilience dimensions (reliability and security) are on top of the reduction of greenhouse gas emissions, giving rise to the concept of an "energy trilemma."[22]

Finally, the World Economic Forum (WEF) promotes energy transition to reflect "an inclusive, sustainable, affordable and secure energy system that provides solutions to global energy-related challenges, while creating value for business and society, without compromising the balance of the energy triangle" [security and access; environmental sustainability; and economic development and growth] (WEF, 2021).

Given the importance of decarbonizing the energy matrix to meet environmental objectives, another relevant dimension is a country's institutional framework and readiness to address the energy transition.

Indeed, although the evolution of decarbonization regulations and commitments has been dissimilar, countries' NDCs suggest that the role of energy transition will increase as regulators, governments, and public and private investors prioritize social, environmental, and governance factors. A country's energy transition readiness depends not only on the transformation of the energy system but also on macroeconomic, political, regulatory, and social factors (WEF, 2021).

The combination of the energy system performance and countries' readiness for energy transition dimensions is reflected in the Energy Transition Index (ETI) developed by the WEF (2021).[23] Table 2.2 presents the index per region, enabling a comparison of LAC's relative performance and evolution from 2012 to 2021.

The Energy Transition Index (ETI), which summarizes the degree of energy transition progress, ranks LAC slightly below the global average (ETI 58.6 vs. 59.3, respectively), far from advanced economies (68.4) and from emerging and developing countries in Europe (61.1). Of note is the low level of CO_2 emissions per capita from energy in the region: 2.4 tons (the second lowest in the world, after Sub-Saharan Africa, with 1.1 tons), approximately half the average global value (see Graph 2.1). Regarding

22 The "energy trilemma" is the name given to the the three-dimensional model that analyzes the balancing of the three system pillars: energy security, equity, and sustainability.

23 Current energy system performance includes security and access, environmental sustainability, and economic development and growth. A country's readiness for energy transition considers regulation and political commitment, institutions and governance, infrastructure and innovative business environment, human capital and consumer participation, energy system structure, and capital and investment. For detailed information on the ETI indicators, see WEF (2021). Given the dimensions it included, in the performance subindex, it is closely correlated to the WEC 's world energy trilemma index (which includesincorporates energy security, equity and environmental sustainability). This indicator is omitted in the analysis, but canmay be explored in WEC (2021).

relative performance, the region has a large hydropower basis installed in the electricity sub-matrix, which, nevertheless, is much smaller in the energy matrix (see Graph 2.8). Moreover, there is room for improvement in energy affordability. Electricity spending based on purchasing power parity remains high: 5% of GDP per capita in LAC in 2021, compared to 2% and 0.5% in Europe and the United States, respectively (see "Dimension of service gaps"). In addition, although the region has achieved almost universal access to electricity, the quality of supply is still a challenge in many countries. Finally, greater diversification of import counterparts and the energy mix could further enhance energy security. These opportunities could be seized if energy market integration is improved across the region (Sanguinetti et al., 2021).[24]

Graph 2.16 shows two ETI dimensions for LAC countries.[25] Panel A illustrates the aggregate index for 2012 and 2021, while Panel B shows the 2021 performance and readiness subindices.

In line with the WEF (2021), sectoral performance in LAC countries is systematically higher than readiness for change. This reflects the region's wealth of natural resources and the relative development of the energy sector. In addition, it shows the big institutional challenges that the region is yet to face. Indeed, the WEF identifies 13 countries that needed to address challenges or risks in 2021. These countries have higher-than-average system performance but lower-than-average readiness for transition, which suggests that efforts need to be redoubled to maintain and improve current performance levels. LAC countries on this list are Argentina, Bolivia, Ecuador, and El Salvador. Another eight are included in the category of emerging countries (below the global average for both indicators): Guatemala, Honduras, Jamaica, Nicaragua, Dominican Republic, Trinidad and Tobago, and Venezuela.

Table 2.2
2021 ETI by region and change since 2012
Source: Authors based on data from the WEF (2021).

Region	Population	CO_2 per capita	ETI	Change 2012-2021
Global	100%	4.7 tn	59.3	1.7
Advanced economies	13%	10.1 tn	68.4	1.6
Commonwealth of Independent States	3%	8.5 tn	56.8	2.7
Asia (emerging and developing)	40%	3.7 tn	54.8	2.8
Latin America and the Caribbean	**8%**	**2.4 tn**	**58.6**	**0.8**
Middle East and North Africa	7%	3.9 tn	53.0	0.9
Europe (emerging and developing)	2%	5.2 tn	61.1	3.0
Sub-Saharan Africa	8%	1.1 tn	50.8	1.1

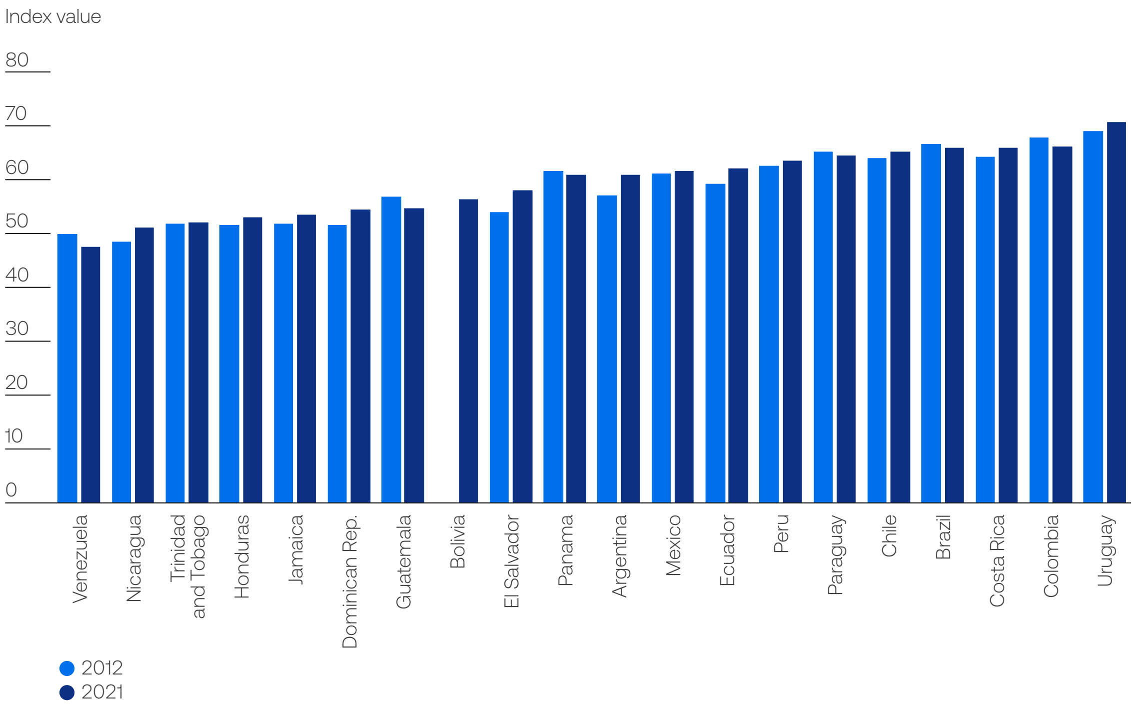
Note: CO_2 measured in tons (tn).

24 These elements have been analyzed by the WEF (2021). Regarding LAC's ETI performance, these elements agree with different dimensions analyzed in other documents published by CAF.

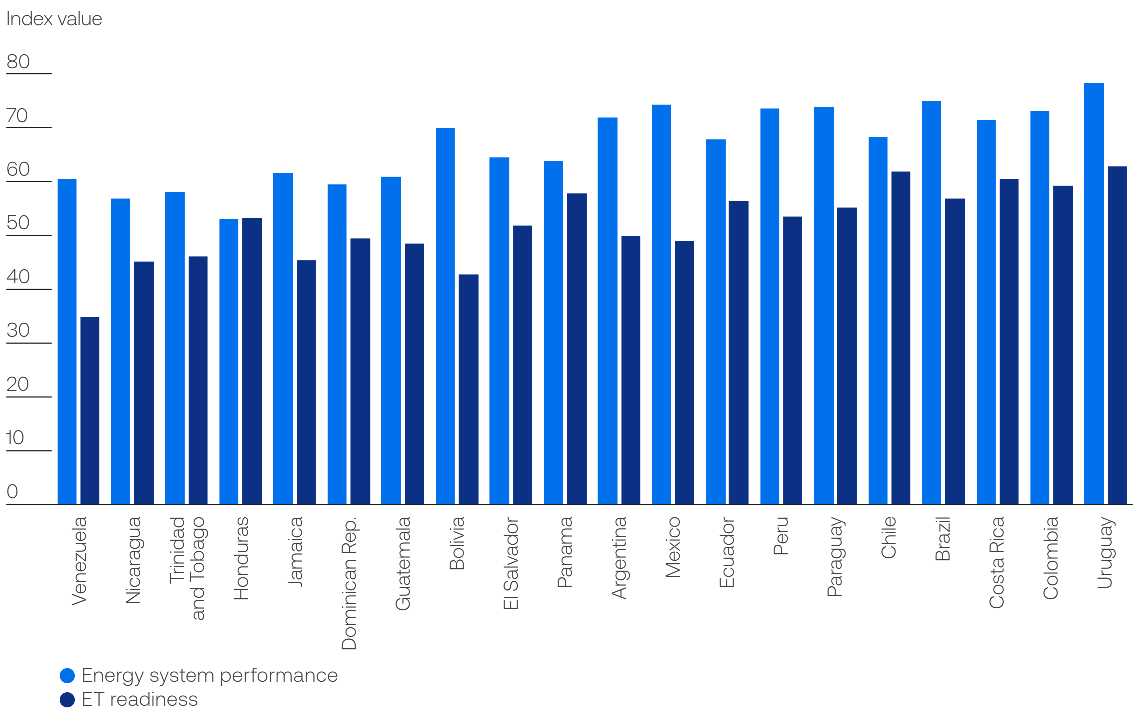
25 The MIT Technology Review (2021) recently presented the Green Future Index (GFI), which ranks countries according to their progress toward a low-carbon future. The dimensions included in the GFI are carbon emissions, energy transition, green society, clean innovation, and climate policies. The GFI for LAC countries has a high correlation with the ETI, except in Paraguay, with average ETI performance and very low GFI performance.

Graph 2.16
Evolution and breakdown of the Energy Transition Index
Source: Authors based on data from the WEF (2021).

Panel A. ETI 2012 vs. 2021



Panel B. ETI 2021 sub-indicators



Mitigation of and adaptation to climate change: Contributions from the energy sector

Energy mitigation policies: decarbonization and efficiency

Energy policy interventions against climate change aim to promote the electrification of consumption, renewable energies, fossil fuel substitution, and a reduction in energy and carbon intensities. These interventions are accompanied by updated regulations and capacities for managing the transition.

Some of these mitigation strategies may be associated with additional sectoral or local benefits such as effects on health as a result of lower local air pollution (decreasing morbidity and mortality indices), availability (in remote areas), and energy security (less reliance on fossil fuel imports).

Changes in primary energies (gas, LNG, renewables, and hydrogen)

Consistently with the growing concern about decarbonizing the energy matrix and the regional averages observed, multiple LAC countries showed changes over the 2000-2020 period. One of the first indicators of this change is the share of renewable sources in the energy matrix (considering hydropower, nuclear, geothermal, and non-conventional sources) (Table 2.3). The trend reflects a growing share of lower GHG emission sources, though not all countries are moving in the same direction (results do not change when biomass is included). In the first place, Uruguay stands out for reversing fossil fuel predominance in favor of renewable energies. Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua are in a similar position from a qualitative perspective, though to a much lesser extent. In Chile, the use of clean sources increased partly to make up for the reduced share of natural gas in its matrix (associated with external factors such as the interruption of exports from Argentina), though the share of high-emission sources (such as coal) needed to be raised. Argentina, Brazil, Colombia, Ecuador, Panama, and the Dominican Republic increased their share of renewable energies and natural gas, though at different levels. Finally, Bolivia, Mexico, Peru, and Trinidad and Tobago recorded a growth in their share of natural gas, but no major initiatives for renewables were launched.

Table 2.3
Changed share of renewable energies and biomass in the energy matrix between 2000 and 2020
Source: Authors based on data from OLADE (n.d.).

	Hydropower + Nuclear + Geothermal + NCREs			Natural Gas		
	2000	2020	Change	2000	2020	Change
Argentina	8%	10%	2%	48%	57%	9%
Bolivia	6%	4%	-2%	32%	44%	12%
Brazil	15%	20%	5%	5%	10%	5%
Chile	6%	7%	2%	23%	13%	-10%
Colombia	9%	12%	3%	18%	23%	5%
Costa Rica	46%	56%	10%	0%	0%	0%
Ecuador	6%	13%	7%	1%	3%	2%
El Salvador	10%	16%	6%	0%	0%	0%
Guatemala	4%	8%	4%	0%	0%	0%
Honduras	8%	18%	10%	0%	0%	0%
Jamaica	0%	1%	1%	0%	6%	6%
Mexico	7%	7%	0%	30%	41%	11%
Nicaragua	4%	14%	9%	0%	0%	0%
Panama	10%	17%	7%	0%	10%	10%
Paraguay	68%	45%	-22%	0%	0%	0%
Peru	14%	13%	0%	2%	28%	26%
Dominican Rep.	1%	4%	3%	0%	14%	14%
Trinidad and Tobago	0%	0%	0%	50%	90%	40%
Uruguay	20%	49%	29%	1%	1%	0%
Venezuela	5%	14%	8%	40%	36%	-4%
LAC	9%	13%	4%	22%	25%	3%

Note: Fossil energy sources include coal, oil, and natural gas. The base is the primary net supply plus imports of secondary energy. Green identifies positive changes between 2000 and 2020; red identifies negative changes, and yellow identifies no change.

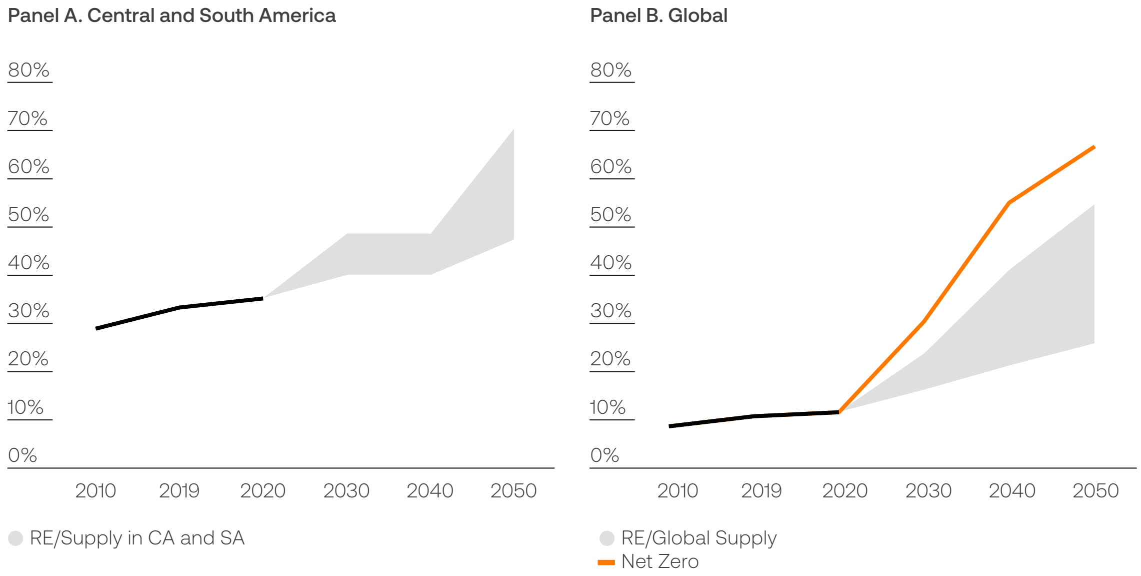
Increased use of renewable energy sources

At the regional level, hydropower accounts for a large share of electricity generation. However, it faces two challenges: one is climate variability, which increases hydrological risk and hinders supply security since climate change can cause more frequent and severe droughts. The other is the obstacles caused by the environmental impact of large hydropower plants.

Renewable energies have now become competitive and, at the same time, more efficient compared to energies that use coal, natural gas, and other fossil fuels (Lazard, 2021). Better competitiveness and efficiency have fostered their growth, especially for land-based wind energy and large-scale solar energy (see Graph 2.11).

Given their quick installation, wind and solar facilities can change their share over a few years. Indeed, according to International Energy Agency projections (IEA, 2021a), renewable energies will meet the increasing global demand for electricity during the next decade by a high share (over 90%), overtaking coal as the main source of power by 2025.[26] By 2050, hydropower will no longer be the main clean source of electricity neither globally nor in the region (in this case, Central and South America), as it will be surpassed by non-conventional sources (see Graph 2.17). The IEA also predicts a slow decline in the share of oil by the end of the forecast period and expects an accelerated penetration of electric vehicles, a slight reduction in the use of natural gas followed by stabilization according to the patterns of demand in the industry and energy sectors, and a smaller share of coal.

Graph 2.17
Projection of the share of renewable energies in the energy matrix in Central and South America compared to the global energy matrix
Source: Authors based on data from the IEA (2021a).



Note: The percentages for Central and South America are consistent with those in Graph 2.3, excluding Mexico. The projection spectrum covers the Stated Policies Scenario (STEPS), the Announced Pledges Scenario (APS), and the Sustainable Development Scenario (SDS). The IEA only includes scenarios to reach net zero emissions worldwide.

26 This is the Stated Policies Scenario (STEPS) projection, in which COVID-19 was gradually controlled in 2021, and the global economy returned to pre-crisis levels in the same year. This scenario reflects all the policy intentions and goals announced at the time of development of the analysis to the extent that they are supported by detailed measures for implementation.

Box 2.2
Distributed generation

The availability of more renewable sources facilitates the expansion of distributed generation, i.e., small-scale generation near or at the point of consumption, mainly from renewable sources. Distributed generation represents a change of paradigm for the electricity sector and, in particular, for the traditional centralized power generation scheme. Grid users then become “prosumers” because they can now inject their surplus energy into the grid.

This process is included within the framework of energy transition and has been taking place around the world for the past two decades. Although its development in LAC is relatively new, it has grown significantly in recent years after new regulatory frameworks and incentives that enable users to integrate these technologies into distribution grids.

According to a survey by OLADE (2020), distributed energy generation has experienced sustained growth year after year. In 2019, installed distributed generation capacity in LAC increased by 125% compared to 2018. In addition, over the period 2015-2019, it grew twentyfold, from 149 MW to 3,332 MW.

Alarcón (2021) notes that the new information and communication technologies (ITC) are transforming the operation of distributed generation from a “fit and forget” concept to an active grid component that can be coordinated with other components in real-time, optimizing the entire system. In more general terms, the possibility of including different storage components and electric vehicles would make “distributed energy resources” available.

Despite the various economic, environmental, and climatic advantages of renewable energies, their effective utilization may depend on certain conditions or even have some adverse consequences. Therefore, it is crucial to heed several warnings regarding their adoption.

First, a high proportion of renewable energies in electricity systems (mainly solar and wind energy) generates different sources of intermittency, primarily due to the lack of large-scale and cost-competitive storage technologies. This necessitates dynamic energy systems with greater operational flexibility. It will require, among other things, increased connectivity, storage capacity, and demand response. These advancements must be accompanied by investments in backup capacity and the grid, posing a significant challenge for the sector, particularly in emerging and developing countries.

Second, the development of these technologies can impact ecosystem conservation. According to Pörtner et al. (2021), while measures such as the development of some renewable resources are effective in mitigating climate change, they can also pose threats to biodiversity. For example, onshore and offshore wind farms alike and dams can interfere with migratory species; solar energy plants need large areas of land, which could have a detrimental impact on natural habitats. Moreover, renewable energy development requires minerals (e.g., for electric vehicle batteries, wind turbines, etc.) obtained from mining activities that can impact ecosystems.

On the other hand, given the evolution and prospects of renewable energy sources, another consequence that will become relevant in the coming decades is the waste derived from discarding photovoltaic panels, wind turbines, and batteries that reach the end of their lifespan or are replaced prematurely. According to IRENA (2016), the disposal of photovoltaic panels could ascend to 78 million tons by 2050 under a scenario where panels are replaced at the end of their lifespan. Atasu et al. (2021) suggest that replacements may occur before the completion of the economic lifespan due to a combination of pricing, fiscal incentives, and panel efficiency improvements. When combined with the insufficient recycling capacity for this type of waste, the costs associated with this technology could be much higher than currently reflected in the market.

A similar situation could arise with the waste generated by wind turbines and electric vehicle batteries. While approximately 85% of wind turbine components—such as steel, copper wire, gear assemblies, etc.—can be recycled or reused at the end of their lifecycle, no viable reuse solution has yet been found for fiberglass blades. Liu and Barlow (2017) estimate that by 2050, blades alone will generate 43 million tons of waste.

Many countries have made progress in the recycling process for batteries. For example, 12 European countries recorded a 45% recycling rate in 2015 (Hu and Xu, 2021). Beyond the benefits and the need to recycle batteries, other challenges hinder recycling expansion: lack or insufficient government regulation and laws, safety issues in battery transportation and storage due to explosion risks, logistical challenges (insufficient points of collection and disposal), high operating costs, environmental damage caused by acid discharge into rivers during leaching, toxicity of solvent extraction processes, air pollution, and high energy consumption during the melting process of battery metals and oxides, among others (Lima et al., 2022).

Lastly, achieving decarbonization goals set by countries under international agreements may also require the early retirement of certain power plants before the end of their lifespan, which can have a substantial impact on service costs (Box 2.3).

Box 2.3
Risk of stranded assets due to energy transition

Estimates of the risk of stranded assets provide an indication of the potential disruption that energy generator owners, sector workers, and communities may face during a clean-technology-based energy transition aligned with the Paris Agreement goals.

Stranded assets are those that prior to reaching the end of their assumed lifespan at the time of investment, no longer yield an economic return (i.e., meet the expected rate of return) due to changes associated with the energy transition to a low-carbon economy (Carbon Tracker Initiative, 2017). According to an analysis by IRENA (2017a), delaying actions to achieve environmental objectives will increase the likelihood of new assets becoming stranded. In fact, the estimated cumulative value of these assets by 2050 could potentially double compared to a scenario where actions are taken immediately.

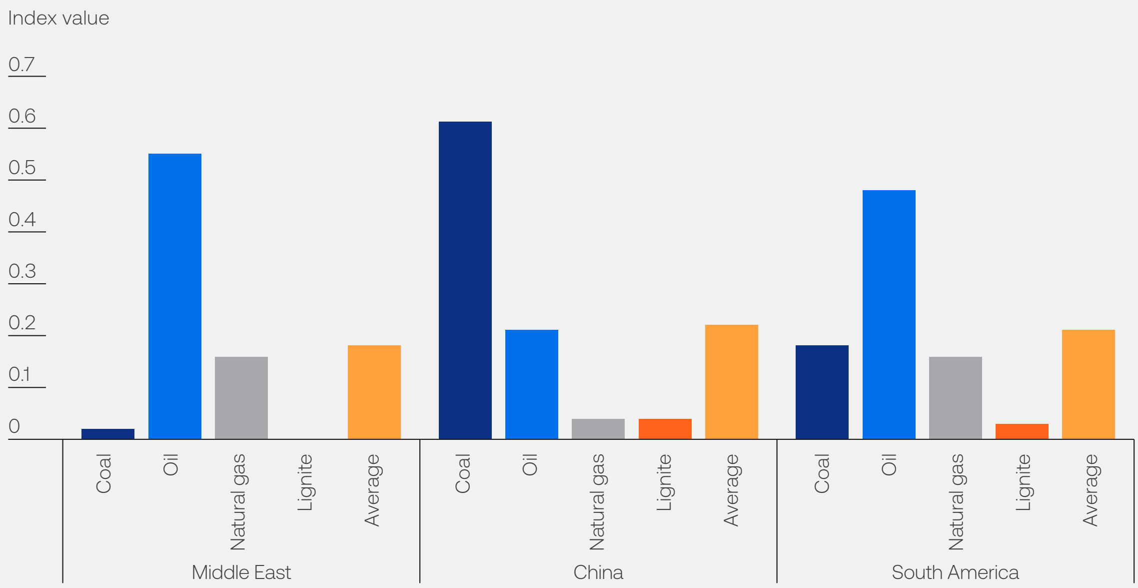
The fossil fuel sector will undoubtedly be the most strongly affected. According to some estimates, 60% to 80% of global public fossil fuel reserves should be classified as unburnable (see Carbon Tracker, 2013) if climate goals are to be met. Kepler Cheuvreux (2014) estimates that the industry would lose USD 28 trillion in gross revenues over a two-decade period compared to a business-as-usual scenario.

According to a report by González-Mahecha et al. (2019), in LAC, existing electricity generation units and planned investments will result in emissions of 6.9 $GtCO_2$ and 6.7 $GtCO_2$, respectively, according to projections. This is double the carbon budget quota permitted for a 2°C temperature rise (6.2 $GtCO_2$), and even more for a 1.5°C increase (5.8 $GtCO_2$). Meeting the more lenient quota would require the premature shutdown of 10% to 16% of existing fossil fuel capacity, respectively, or reducing the utilization rate of existing power plants to achieve the same result and halting all existing thermal energy projects. Moreover, Spavieri (2019) estimates that 94.1% of Venezuela's reserves fall within the 'inappropriate for burning' category in a carbon-neutral scenario

Ansari et al. (2019) created a stranded assets risk index by combining two indicators: (i) the unused generation capacity in a low fossil-fuel production scenario and (ii) the importance of the fossil fuel sector at the regional level (measured as its share in primary energy). The risk is approximately 0.2 for the three regions identified (Middle East, China, and South America). However, the situation varies by resource. In China, coal is the highest-risk resource, whereas, in the Middle East and South America, the highest risk is found in the oil sector, which is more than twice as risky as the coal and natural gas sectors.

Graph 1.
Risk index for stranded assets by sector

Source: Authors based on data from the index developed by Ansari et al. (2019).



Note: On the scale, 0 implies no risk; 1 implies maximum risk.

Natural gas as a substitute for coal and oil derivatives

In the past 20 years, the proportion of natural gas in the region's energy and electricity matrices has increased significantly (Table 2.3). Although natural gas is a fossil fuel, its CO_2 emissions are much lower than those from oil derivatives and coal. For example, on average, replacing coal with natural gas reduces CO_2 emissions by 50% in electricity generation and by 33% in heat production (IEA, 2019). For diesel oil or fuel oil, the reduction is approximately 30% (EIA, 2021).

In addition to its lower CO_2 emissions compared to coal and petroleum derivatives, natural gas offers other significant advantages, particularly in terms of local pollutant generation. Although often overlooked in favor of greenhouse gas discussions, these pollutants have substantial implications for human health and overall quality of life, particularly in urban areas and low-income households. Compared to other fossil fuels, the combustion of natural gas significantly improves air quality by reducing nitrogen oxide emissions by 80% and virtually eliminating sulfur oxide and particulate matter emissions. Moreover, natural gas exhibits superior combustion properties compared to diesel, resulting in lower levels of unburned hydrocarbons. It also serves as a cleaner alternative to firewood for heating and cooking purposes.

Natural gas plays a strategic role in the region. In 2019, it accounted for 36% of electricity generation (Graph 2.9), 24% of industrial energy consumption, 8% of commercial consumption, and 12% of residential consumption. It has not attained representative levels in energy consumption by the transportation sector (2.5%), except in some very specific segments such as taxis.

Setting aside the temporary impacts of the COVID-19 pandemic, annual electricity demand in the region has risen by around 3%, driven by population growth, economic development, and growing middle classes and urbanization. At this rate, the need for power generation will double every 23 years, without taking into account the trend to electrify demand, which increases capacity and infrastructure requirements. Moreover, ambitions to build new hydroelectric dams involve several challenges. In addition, renewable energy sources are intrinsically intermittent (mainly winds and sun hours) and are not manageable. Therefore, electricity systems require reliable backup power sources for their effective integration into the energy matrix.

Table 2.4 compares production, consumption, and natural gas reserves in 2010 and 2020. Over this decade, although production fell (-7%), consumption increased substantially (18%) in the group of countries studied. In several of them, such as Bolivia, Peru, and Trinidad and Tobago, surplus production provided a valuable source of economic and tax revenue.

On the other hand, the availability of proven reserves means that natural gas plays a relevant role in ensuring energy security in the region. The most significant example is Venezuela, which has enough reserves to sustain its energy needs for over two centuries. On the other hand, reserves in countries such as Argentina and Colombia have declined (although in Argentina, these data do not include shale gas).

Global trends in shale gas production, which have led to lower exploration and production costs, suggest a more favorable scenario for sectoral investments in countries that have reserves, such as Argentina. Shale gas extraction, in contrast to traditional oil and gas fields, implies shorter investment and profitability cycles. This reduces regulatory and expropriation risks, given the faster potential contraction of the production supply. In addition, many countries in the region already have extensive gas networks, providing an opportunity for supply expansion by leveraging past investments. In countries without gas networks, LNG has elevated natural gas to a strategic position because it can be delivered to a wide range of sectors without the need to build gas pipeline networks. In addition, costs are competitive, particularly with the availability of large volumes of LNG that can be purchased from US producers as opposed to imports from Asia. Additionally, natural gas has the potential to play a role in the hydrogen business (see next subsection).

Table 2.4
Natural gas production, consumption, and reserves in the region (billion cubic feet) in 2010 and 2020
Source: Authors based on data from the EIA (n.d.).

Country	Production		Consumption		Reserves		R/P Ratio (years)	
	2010	2020	2010	2020	2010	2020	2010	2020
Mexico	1,769	955	2,269	3,041	12,702	6,368	7	7
Argentina	1,416	1,455	1,529	1,747	14,070	13,121	10	9
Bolivia	507	541	96	103	26,500	10,700	52	20
Brazil	523	897	970	1,245	12,862	13,028	25	15
Chile	66	39	187	232	3,460	3,460	53	88
Colombia	398	399	321	413	3,955	3,783	10	9
Ecuador	12	12	12	12	282	385	24	32
Peru	255	427	194	292	11,800	12,880	46	30
Trinidad and Tobago	1,499	1,091	824	574	15,400	10,515	10	10
Venezuela	697	801	748	801	175,970	200,372	253	250

Note: The most current production and consumption data for Mexico, Bolivia, Brazil, Ecuador, and Venezuela are from 2019. For Argentina and Peru, the most current consumption data are from 2019.

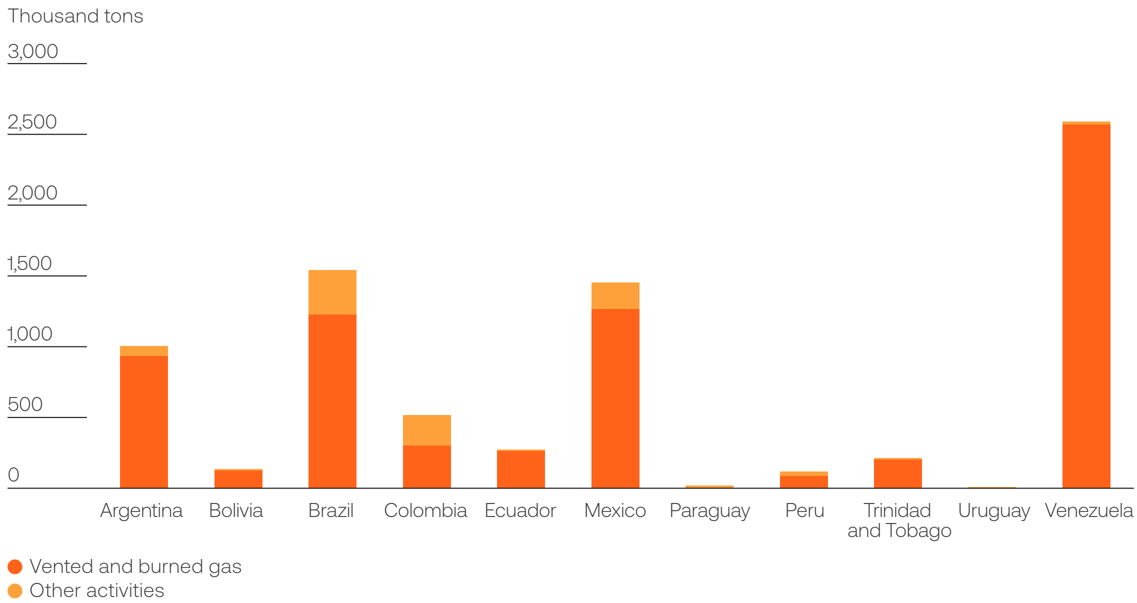
Natural gas has maintained regional relevance in the current context of energy transition. In fact, the Ministerial Declaration by the LI Meeting of Ministers of OLADE (2021) states that, in the context of the region, natural gas "is an important source and a viable, affordable and reliable option to accelerate the decarbonization process of some economies."

Europe, one of the most advanced regions in terms of energy transition, has also recognized the strategic role of natural gas. In February 2022, the European Commission classified natural gas and nuclear energy as "environmentally sustainable" upon including them in the EU taxonomy for sustainable activities (European Commission, 2022), a classification system that helps investors direct capital toward green activities. It goes without saying that, to be considered sustainable, the use of natural gas must meet strict emission standards and replace higher-emission fossil-fuel power generation.

However, unless venting and leaks are controlled during production and transport, natural gas is a source of emissions of methane, which is a type of GHG (Álvarez et al., 2012). In LAC, burning and venting natural gas continues to be an issue of concern. For example, it was strongly controlled in Argentina during the 1990s and in Colombia during the past decade. On the other end of the spectrum, Venezuela is the largest emitter of methane from energy sources in the region (Graph 2.18), ranking fifth in the world in terms of its level of emissions and third in terms of emissions relative to production (World Bank, 2022).

Therefore, natural gas is a reliable alternative that provides energy security and resilience to systems with high intermittency. This entails an opportunity for developing natural gas as a substitute for sources of contamination (provided methane emissions are curtailed) to complement hydropower generation, and to provide solid support for non-conventional renewable energy sources.

Graph 2.18
Methane emissions from energy sources in LAC (thousands of tons): vented and burned gas and other emissions in 2021
Source: Authors based on data from the IEA (n.d.).



Note: Energy emissions account for 18% of total emissions. Other emissions come from farming (60%), waste, and other sources.

The potential role of hydrogen

In the context of a lower consumption of energy from high-GHG-emission sources, and an increased share of renewable sources in the energy and electricity matrices, hydrogen is a fuel with significant potential to contribute to decarbonization in the region. It is the most abundant chemical element in the universe. It is non-pollutant, it does not generate acid rain, it does not reduce ozone, and it does not generate noxious emissions. It becomes stable in the form of a diatomic molecule (H_2).

In 2020, demand for H_2 was 88 million tons worldwide and 4.1 million tons in LAC (IEA, 2021b; 2021c). In the region, it is mainly used in (i) refineries, for hydrotreatments, and for reducing sulfur in fuels in countries where the contents of this chemical element in crude oil tend to be higher than normal (Colombia, Ecuador, and Mexico); (ii) the production of ammonia, which is used in mining as an explosive and in agriculture as a fertilizer (urea); (iii) the production of methanol (as an additive or in fuels); and (iv) in the steel industry, for direct reduction processes of iron (Argentina, Mexico, Trinidad and Tobago and Venezuela). It can also be transformed into several forms of energy, such as electricity, synthetic gas, biomethane, and heat. Hydrogen releases more energy than any other fuel (almost three times that of gasoline or natural gas).

H_2 produced from clean sources (such as water electrolysis) is an attractive alternative to replace fossil fuels, especially in industries that are difficult to electrify, including high-temperature industrial processes (e.g., those used in iron, steel, cement, and chemicals) and long-distance transportation services, including heavy trucks, aviation, and maritime. It can even replace fossil fuels in hydrogen internal combustion engine vehicles, which use fuel cells.

Regarding infrastructure, H_2 requires a storage and transportation system. There are cases of closed networks between producer and purchaser. However, it can also be carried through existing networks, particularly natural gas pipelines,[27] or it can be liquefied and compressed to be transported by ships or trucks (according to the volume in question).

H_2 is obtained from other resources (water, biomass, fossil resources), and to convert these into hydrogen, the transformation process entails consuming some primary energy source (nuclear, renewable, or fossil).

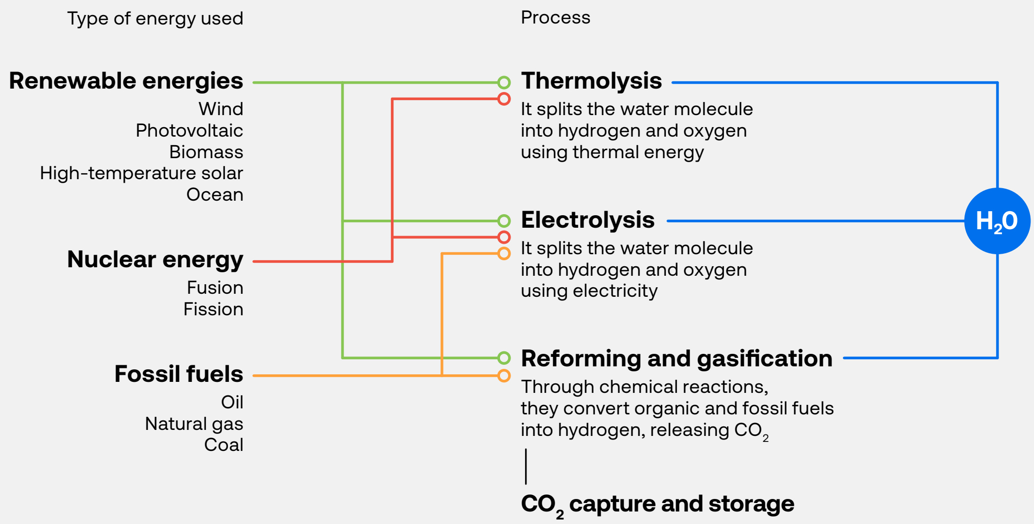
Box 2.4
The hydrogen production process

Hydrogen is an energy carrier, and, like electricity, it must be obtained from other raw materials (water, biomass, fossil resources). Figure 1 shows the H_2 production processes. The conversion of these substances into hydrogen requires transformation processes that consume some primary energy source.

In turn, hydrogen can be converted into electricity and methane (for households and industries), or fuels for transportation. In other words, it can be used in its pure form (gas) or be converted into hydrogen-based fuels such as synthetic methane, synthetic liquid fuels, ammonia, and methanol.

27 This has already been done in Europe (Gasunie in the Netherlands in 2018; see IEA, 2021c).

Figure 1
H_2 production processes
Source: Centro Nacional del Hidrógeno (2019).



The most recent classifications have identified H_2 by colors according to the production process involved; the energy used; the associated emissions; and the capacity for carbon capture, utilization, and storage (CCUS).

Table 1
Classification of H_2
Source: Authors based on IEA (2021c), Florence School of Regulation (2021), and López de Benito (2018).

Color	Energy used	Process	Emissions	Current representativeness
Black	Coal (bituminous)	Gasification	CO_2 and CO released	23%
Brown	Coal (lignite)		CO_2 and CO released	
Gray	Natural gas	Steam methane reforming	CO_2 emitted	76%
Blue		Brown or gray with CO_2 capture		0.7%
Green	Water and renewable sources	Electrolysis with renewable sources (yellow: solar)	No emissions	

Note: There are other colors (turquoise and pink), assigned according to the energy used and the production process involved, which are under development.

At present, H_2 is mainly produced from natural gas (76%) and coal (nearly 23%), so current production processes are GHG emitters. Less than 0.7% of the current hydrogen production comes from renewable energies or fossil fuels with CCUS-equipped plants. In 2019, almost 90% of H_2 demand in the region was from Trinidad and Tobago (over 40% of the total H_2 demand) and the five largest economies (Argentina, Brazil, Chile, Colombia, and Mexico).

Currently, green H_2 generation is not very competitive (Erbach and Jensen, 2021). LAC countries are developing multiple strategies at the national level,[28] with over 25 projects in portfolio, including several on a GW scale. One of the largest projects is the Hychico pilot plant in Argentine Patagonia, which produces around 52 tons of H_2 per year from wind energy. The project features the only H_2 pipeline system in Latin America (2.3 km). In Costa Rica, the Ad Astra Rocket pilot project produces about 0.8 tons of H_2 per year from solar and wind energy. The H_2 is used to power the region's first fuel-cell bus as well as four light fuel-cell vehicles. In Chile, the Cerro Pabellón microgrid initiative in the Atacama Desert is a pilot project that uses solar energy to produce 10 tons of H_2 per year. It provides manageable electricity from renewable sources to meet the needs of a microgrid that serves a community of over 600 technicians working in a geothermal plant (IEA, 2021b).

In the case of Chile, H_2 could also offer a viable alternative in segments with very high power and uptime requirements, including heavy mining trucks. One example is Corporación de Fomento de la Producción (CORFO), a government agency aimed at promoting economic development and fostering innovation that operates as a public-private entity under the Ministry of Economy, Development and Tourism. In 2017, it launched a program called "Development of a dual hydrogen-diesel combustion system for mining extraction trucks" to develop H_2-diesel fuel for mining trucks (OutletMinero, 2017).

Naturally, opportunities may differ among countries, but developing H_2 could contribute to reducing emissions in some of them. Nearly all LAC countries that aim to meet their energy and climate ambitions will need to decarbonize transportation and could find opportunities to implement H_2 technologies in this sector. In contrast, opportunities in heavy industry are limited to a few countries, where current activity is responsible for a large amount of emissions. For example, Brazil and Mexico produced more than 80% of the region's steel in 2019, while the chemical industry in Trinidad and Tobago, which produces and consumes large volumes of H_2 from fossil fuels, accounts for about half of that country's emissions. In Chile and Peru, low-carbon H_2 in mining could become a substitute for large volumes of diesel oil, enabling long-term emission reductions. In fact, Chile has the ambition to produce and export the most competitive H_2 in the world from renewable electricity by 2030, and the conditions in many Latin American countries are apt for developing such processes. In some of them, such as Brazil, the availability of biogenic carbon from existing biofuel and bioelectricity production facilities could also help produce and export synthetic fuels, which require both carbon and H_2. Finally, there are low-carbon H_2 production technologies under development, which will need to undergo learning curves and significant cost reductions before they become competitive.

In this context, natural gas can also substantially contribute to boosting H_2 use. In this regard, several countries are developing a blend of H_2 and natural gas. This mixture is a more competitive fuel than using green H_2 alone and less contaminating than using only natural gas. In the United Kingdom, the blend includes up to 20% H_2, and its share is expected to increase progressively (St. John, 2020; National Grid, 2020). Thus, the use of natural gas as an energy source could be sustained over time because it would help reduce emissions at competitive prices. Moreover, pipeline networks built for natural gas transportation could be readapted for H_2, substantially reducing the risk of higher costs due to stranded assets.

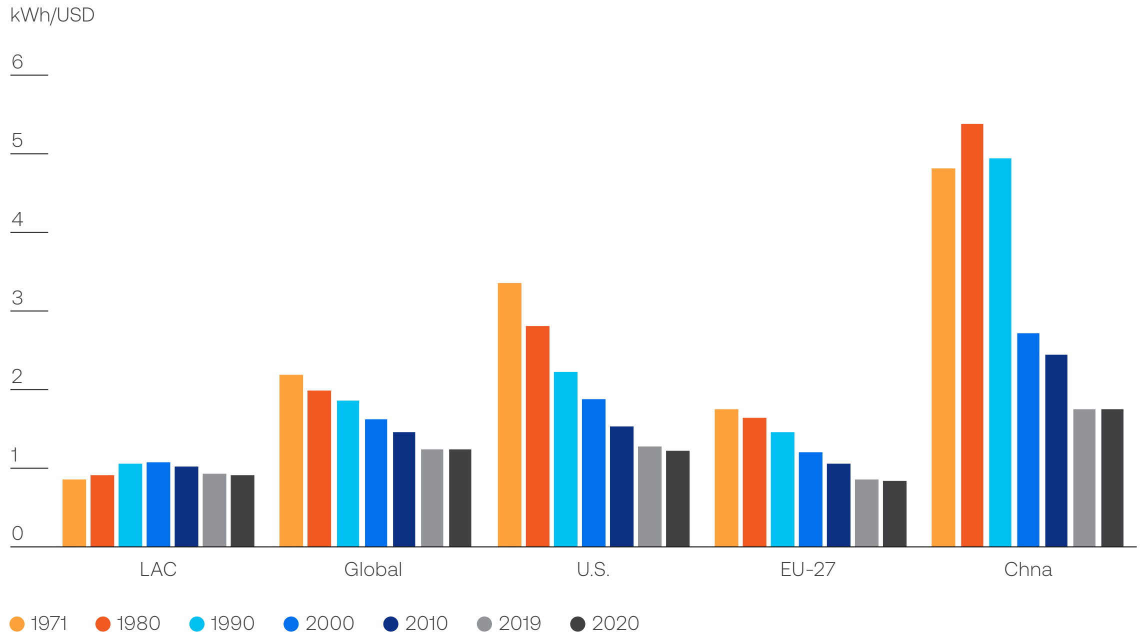
28 In Chile (published), Argentina, Bolivia, Brazil, Colombia, Costa Rica, El Salvador, Panama, Paraguay, Trinidad and Tobago, and Uruguay (in preparation).

Changes in final demand and transformation processes

A second set of actions that contribute to the decarbonization of the energy sector consists of efficiency-improving interventions. The indicator most often used to evaluate a country's overall energy performance is the energy intensity level of primary energy, i.e., the total energy required to achieve the value added of the economy. Graph 2.19 shows this measure for LAC compared to the world, and selected countries and regions (the United States, China and EU-27) from 1971 to 2020. Energy intensity in LAC has been low with respect to comparable countries and regions and has remained relatively stable, while other regions have been consistently active (such as the EU-27, which currently has the lowest intensity among the groups compared), or during the past two decades (the United States and China).

The latest IEA (2021d) yearly update on global developments in energy efficiency reports that the average annual variation in the improved energy intensity level of primary energy worldwide during the 2017-2021 five-year period was less than 2%. This rate is well below the annual variation rate required to meet the global climate and sustainability goals, which is approximately 4.2% in a net zero carbon scenario.

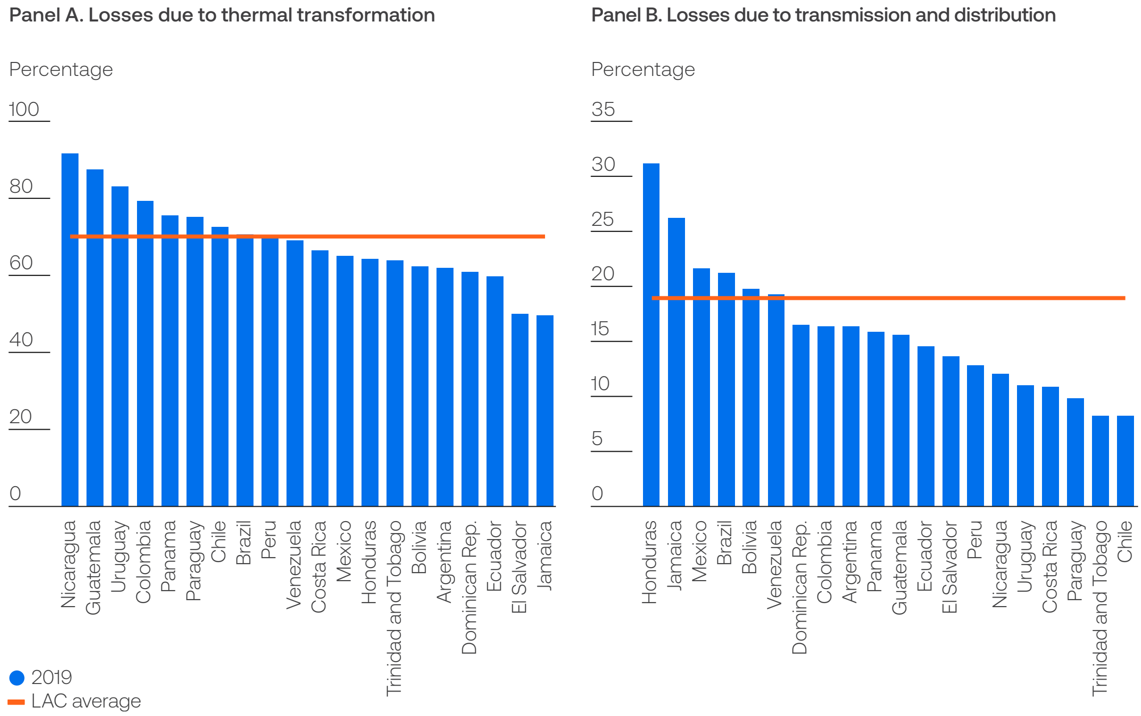
Graph 2.19
Energy intensity level: LAC compared to the world, and selected countries and regions from 1971 to 2020
Source: Authors based on data from Ritchie et al. (2020) and the World Bank (n.d.a).



However, this indicator includes not only energy efficiency but also other factors, such as the economic structure (i.e., the contribution made by different sectors to the GDP), the electricity generation matrix, and the climate.[29] Given the overall lack of information, the energy efficiency analysis tends to focus on two indicators: (i) the difference between the primary energy intended for a transformation process and the resulting secondary energy, which is a measure of mean efficiency in the production process; and (ii) the difference between generated electricity and consumed electricity, which estimates the level of efficiency in the transmission and mainly the distribution process. These two measures of efficiency (related to transformation and infrastructure) become more relevant in scenarios that consider a larger share of the electricity submatrix in the energy matrix.

In the case of LAC 9.6 EJ of primary energy plus 1.1 EJ of secondary energy were used in 2019 to produce 6.0 EJ of electricity, which led to a mean transformation inefficiency of 44%. Energy loss during the transformation process to generate hydropower, nuclear and non-conventional renewable energy is very low or nil, so any loss of energy during transformation is focused on thermal generation. When calculating energy generation with low or no losses, the mean thermal inefficiency in the region amounts to 70%. Panel A in Graph 2.20 shows high heterogeneity in thermal inefficiency by country, with cases such as Colombia, Guatemala, Nicaragua, and Uruguay, with high thermal transformation losses and ample room to reduce them, and others such as Ecuador, El Salvador, and Jamaica, which had met the benchmark energy loss standards in 2019.

Graph 2.20
Energy losses in electricity generation due to transformation in 2019
Source: Authors based on data from OLADE (n.d.).



29 The are other indicators to isolate these factors, such as the ODEX energy efficiency index. However, it requires a large volume of data and is unavailable in most countries. For further information on this index, visit http://www.odyssee-indicators.org/registered/definition_odex.pdf.

Moreover, to generate 6.0 EJ of electricity, the final consumption was 4.8 EJ, which entails transmission and distribution losses of 19%. Panel B in Graph 2.20 also shows high heterogeneity by country for distribution losses, with Honduras, Jamaica, Mexico, and Brazil (in that order) above average, while losses in Chile, Paraguay, and Trinidad and Tobago are lower than 10%.

Sustainable transportation and energy transition

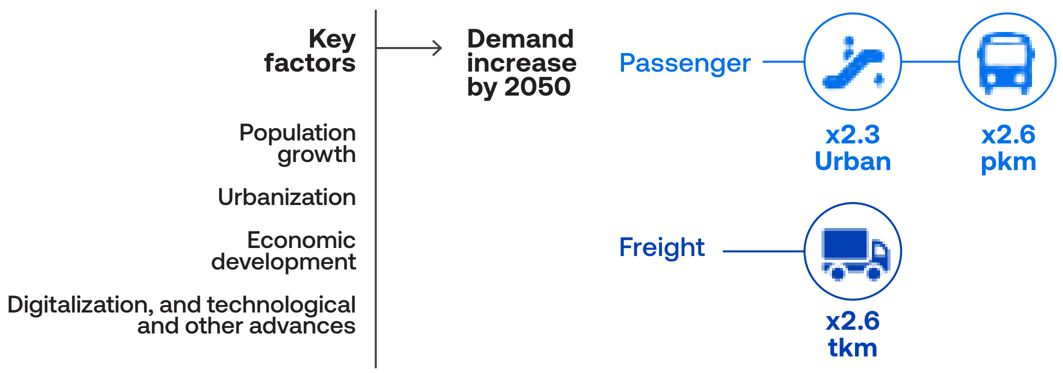
Sector consumption and emissions: current scenario and trends

Transportation continues to be the sector of the economy with the highest reliance on fossil fuels, attaining a regional oil derivative consumption level of 81% and a global level of 91% (data from IEA, 2019). Therefore, this sector is a top emitter, accounting for 15% of GHG emissions and 24% of carbon dioxide emissions in LAC (see Chapter 1). Not only do the intensive use of energy plus the high proportion of carbon-based fuels used by mass transit contribute to the climate crisis through emissions into the atmosphere but also add to local noise and air pollution,[30] which are detrimental to public health.

Planning and implementing a pathway toward zero carbon emissions, thereby limiting global temperature rise to 1.5°C compared to pre-industrial levels, requires considering the sector trends over time. According to the latest report from the International Transport Forum (ITF, 2021), the overall demand for transportation by 2050 will at least double, and the demand for urban passenger transportation will almost triple, driven by key factors such as population growth, urbanization, economic development, and digitalization (Figure 2.2).

Thus, even if the existing commitments to decarbonization are met, an overall 16% increase in direct tank-to-wheel carbon dioxide emissions is estimated for the sector by 2050 (ITF, 2021). This exercise estimates over 8 million tons of emissions by the sector for that year, which exceeds the estimated ceiling of fewer than 3 million tons for that scenario necessary to avoid worsening the climate crisis in the second half of the century.

Figure 2.2
Transportation trends by 2050
Source: Authors based on the *status quo* scenario (ITF, 2021).



30 Local contaminants are particulate matter, nitrogen oxides, sulfur dioxide (SO_2), carbon monoxide (CO), and ozone.

The pathway toward sustainable transportation

To achieve more sustainable transportation, it is essential to align all stakeholders and establish a realistic roadmap. This approach is consistent with all global agendas on sustainable development and the specific efforts geared toward transportation and mobility, which recognize the need for simultaneous action on multiple fronts, including both passenger and freight transportation across different modes and settings: urban, rural, and regional. Although climate change challenges are important on these agendas, they also pose as critical that planning and action should not disregard the social, economic, and wellbeing dimensions of sustainable transportation.

In line with the New Urban Agenda, the avoid-shift-improve (ASI) framework—an action and public policy formulation framework developed in Germany during the 1990s—has been resumed in recent years. ASI focuses on the demand side to develop measures that can reduce the environmental impact caused by transportation, thereby improving the quality of life in cities. The first component aims at **avoiding or reducing** travel needs or travel distances, mainly through land use planning tools and regulations that can integrate the urban fabric and increase combined uses. The second component aims at **shifting** to more efficient transportation modes through improved infrastructure and information on public transportation and active modes, along with economic incentives and regulations on private modes. The third final component focuses on **improving** vehicle efficiency and operations through the use of advanced technologies to reduce reliance on fossil fuels; this includes investing in clean fuels and implementing regulations on fossil fuels to create more environmentally-friendly vehicles. Similarly, the ASI framework groups a wide range of sector strategies against climate change, creating synergies between mitigation and adaptation measures.

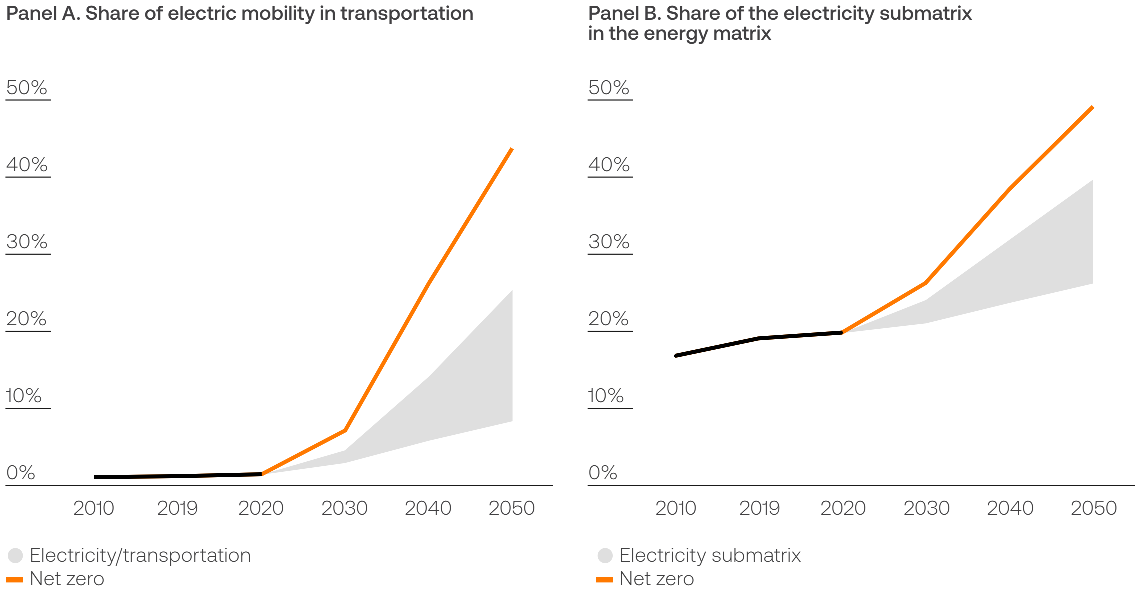
According to the report on electric mobility (MOVE) for the region (UNEP, 2021b), in 2020, several LAC countries updated their NDCs, setting more ambitious goals aimed at meeting the Paris Agreement. Many of the countries (27 out of 33) have prioritized the transportation sector as a key element in achieving the emissions reduction targets in their NDCs.

Decarbonizing transportation: electrification is essential

Replacing carbon-based fuels with clean energies is a critical strategy to limit the transportation sector's contribution to the climate crisis. The use of vehicles powered by low-emission electricity offers the largest decarbonization potential for land transportation based on the entire life cycle (IPCC, 2022b). Within this general consensus, a process marked by the electrification of energy demand will take place in the coming decades. The scenarios based on forecasts by the IEA (2021a), shown on Panel A in Graph 2.21, show that the share of electricity in transportation is expected to increase to values ranging from 8% to 25% by 2050, up from the current 1% (and up to 47% in a zero-carbon scenario). Panel B in the same Graph shows that the representativeness of the electricity submatrix will increase from 20% to values ranging from 26% to 40% (and up to 49% in a zero-carbon scenario) as a result of these and other demand substitution policies.[31]

31 IEA (2021a) projections include information on electricity generation for Central and South America, but do not report electricity consumption. Thus, globally, electricity consumption in 2019 accounted for 17% of energy consumption, while generation to cover electricity consumption accounted for 37% of the energy supply. These percentages were 18% and 24%, respectively, for LAC (according to data from OLADE).

Graph 2.21
Projection of electric mobility and the global electricity submatrix
Source: IEA (2021a).



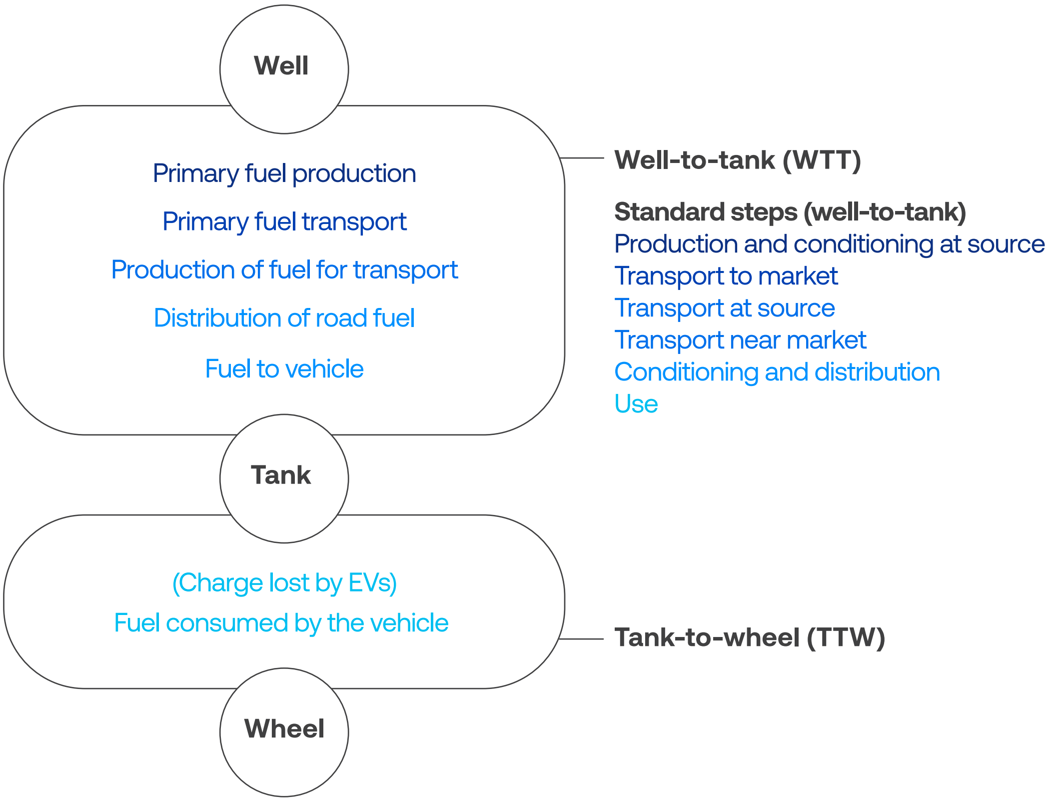
Note: The projection spectrum covers the Stated Policies Scenario (STEPS), the Announced Pledges Scenario (APS), and the Sustainable Development Scenario (SDS). The IEA only includes scenarios to reach net zero carbon emissions globally.

Highly efficient energy consumption by electric vehicles compared to the efficiency of fossil fuel-based systems (60% to 80% difference in consumption) is one of the major advantages of electrified transportation.[32] Second, the reduction of tank-to-wheel emissions (i.e., during electric vehicle operation) will be very significant not only regarding global contaminants such as CO_2 but also local contaminants, such as ozone and carbon monoxide, which greatly deteriorate air quality and, consequently, the health of inhabitants.[33] By promoting renewable energies and expanding their share in the generation matrix, electrified transportation systems can further reduce emissions, i.e., by avoiding the emissions associated with generating the additional electricity needed to meet the new demand (well-to-tank emissions). In this way, considering the well-to-wheel emissions caused by energy use, the decarbonization process may reduce the emissions needed to achieve the climate targets in the countries' NDCs. Figure 2.3 summarizes the well-to-wheel cases that should be considered to calculate the total use of energy and GHG emissions.

32 An automobile with an internal combustion engine uses approximately 0.32 GJ per 100 km, while a battery-powered electric vehicle uses about 0.06 GJ per 100 km.

33 Contamination is estimated to have caused 4.2 million premature deaths per year due to exposure to particulate matter made up of particles measuring 2.5 microns (PM 2.5) which cause cardiovascular diseases, respiratory diseases and cancer (WHO, 2021i).

Figure 2.3
Well-to-wheel emissions
Source: Figure from Prussi et al. (2020).



Transportation electrification should be seen as an opportunity for a holistic approach in which, for example, the improved quality of public transportation can be a complementary contribution to reduced traffic congestion. The adoption of electric buses may provide a broader solution to the extent that renewing the bus fleet can make public transportation more comfortable, therefore more attractive compared to private transportation, fostering the "avoid" and "shift" ASI framework components. Along these lines, in 2019, CAF published a review of the current LAC regulatory and policy framework, including details of the implementation processes conducted in the cities of Bogota, Quito, Montevideo, and Santiago. In addition, within the framework of the Buenos Aires City Government's clean mobility plan known as *Plan de Movilidad Limpia del Gobierno de la Ciudad de Buenos Aires*, CAF (2021) contributed to the assessment and implementation of a pilot test entailing the use of 100% electric buses. This pilot test analyzed the feasibility of integrating this kind of technology to the operation of public transportation, along with the efficiency of vehicles in different traffic conditions. Due to LAC's high urbanization rates, and the increasing urban density and use of public transportation, knowledge improvement on this subject is critical for the region. Many LAC countries, from Mexico to Argentina, have implemented these technologies, whether through pilot programs, operational tests, or massive adoption in public transportation systems. According to the E-BUS RADAR,[34] 3,209 electric buses were operating in Latin America in June 2022, with Santiago and Bogota in the lead. By that date, Bogota

34 Website https://www.ebusradar.org. Accessed on June 23, 2022 had tendered more than 1,500 buses, of which 1,061 were already in operation, and all of which will be in use by late 2022. If this trend continues, it is expected that over 5,000 electric buses per year will be added in Latin American cities starting in 2025 (UNEP, 2021b). Some of these cities, such as Bogota and Santiago, have achieved great progress, and, save for Chinese cities, have the largest number of electric buses worldwide. Panama has enacted the electromobility law which, among other measures, provides for a plan to replace the fleet by 2030 (40% of administrative vehicles and 33% of electric buses) and complementary measures for e-vehicle charge infrastructure. The region can learn important lessons from these experiences, such as the following recommendations: i) uncouple acquisition from operation in tender processes, ii) develop compensation schemes that reflect operational efficiencies in the compensation formulas, and iii) ensure the flow of resources to the financer in independent accounts that are not affected by the operation.

The electrification of urban logistics and last-mile delivery fleets will also be important factors for the decarbonization of the transportation sector. As a result of the high rates of use of digital devices, which increased during the recent pandemic, e-commerce has grown exponentially, and, with it, the demand for delivery logistics systems: delivery vehicles now travel more miles. CAF has launched LOGUS (*Logística Urbana Sostenible y Segura*), a sustainable urban logistics strategy that offers LAC cities a toolset of knowledge, assessment, and action with which to face urban logistics challenges. The LOGUS manuals also include best practices, recommendations for regulations, and new technological advances for decarbonization, especially the electrification of urban logistics.

A similar concept applies to freight transportation systems, which play a significant role in reducing both emissions and logistics costs. In Latin America and the Caribbean, non-urban domestic freight relies heavily on road transportation (89%). Medium and heavy-duty diesel-powered trucks are the mainstay of this mode of transportation, which is responsible for 97% of the CO_2 emissions generated from this sector. In contrast, low-emission rail and maritime-river transportation are efficient modes, but only account for 4.1% and 6.7%, respectively, of ton-kilometers carried across the region. Regarding emissions, for example, rail transportation emits 21 times less carbon dioxide than road transportation per ton-kilometer in LAC.[35] Electrifying trains and barges with clean and renewable energy sources could lead to even greater emission reductions. This is why one of the main lines of action to decarbonize freight transportation is transitioning toward these more environmentally-friendly transport modes, including electrification and the decarbonization of their sources of energy (Sum4All, 2019). In the case of Argentina, the combination of the measures to renovate the fleet of trucks using alternative fuels and the promotion of multimodal transportation to facilitate the transition between modes could half sector emissions by 2050 compared to 2015 (ITF, 2020). Along these lines, many LAC countries, such as Argentina, Bolivia, Brazil, Colombia, and Mexico, have included railways among the pillars of their national logistics policies. However, encouraging a transition toward more sustainable and electric transportation modes presents significant challenges (Calatayud and Montes, 2021).

Electric transportation challenges

Two key factors in the global and, particularly, regional adoption of electric vehicles are reducing battery costs[36] and, in the case of wheeled transportation, deploying infrastructure for electric vehicle charging and discharging. Indeed, as electric vehicle fleets grow, they can offer storage services to the grid (known as vehicle-to-grid) and help regulate frequency to the distribution network, among other benefits. However, one challenge is ensuring interoperability between charge points so that electric vehicle users can charge their batteries at any station, regardless of the service provider or operator. Failure to meet this challenge could hinder the growth and penetration of electric mobility, both nationally and regionally. Suitable interoperability will ensure security, scalability, savings, safety, and simplicity. Countries such as Chile, Peru, Panama, and

35 The percentages and proportions were prepared by the authors based on statistics from the ITF Transport Outlook (ITF, 2021).

36 Europe plans to phase out sales of new combustion engine passenger vehicles and hybrid passenger vehicles as from 2035 to promote the adoption of electric and hydrogen vehicles (European Commission, 2021a).

Paraguay are making progress in reviewing rules and regulations to establish interoperability standards. Interoperability also includes the communication system that enables interaction between charging stations and the grid, as well as managing demand based on grid availability across different countries.

Carbon capture, utilization, and storage (CCUS)

Based on the IPCC's fifth assessment report, Cambridge University and the WEC (2014) reported that reducing emissions to levels compatible with limiting temperature rise to below 2°C requires that the use of fossil fuels without carbon capture is abandoned by 2100 at the latest. The 2022 report by the panel of experts emphasizes the need to reduce GHG by 25% by 2030 to meet this goal, or by 48% to limit the rise in temperature to below 1.5°C (IPCC, 2022b). If fossil fuel production continues, carbon neutrality could be achieved with a complement of carbon capture and storage, especially for emissions generated by the industrial and electricity sectors.

The CCUS value chain has three key links, which are not necessarily integrated: (i) carbon capture, (ii) transporting captured CO_2 to storage sites, and (iii) CO_2 alternative use or storage. There is a broad range of options for reducing the quantity of carbon released into the atmosphere. One of the main recommendations for action in the region, as mentioned in Chapter 1, is the expansion of the forest cover (e.g., reforestation). If, in addition, new crops are planned for biodiversity conservation, the benefit will be twofold (Pörtner et al., 2021).

The most highly developed CCUS applications can be found in the electricity and industrial sectors. Several advances have been made in the power industry in Bioenergy with Carbon Capture and Storage (BECCS) technologies, which contribute to negative emissions.[37] Reconditioning coal or natural gas generators with CCUS reduces emissions and provides the system with a stable source of energy generation having fewer emissions than a conventional plant. Carbon capture technologies have also been developed for oil refineries, natural gas processing (for LNG), and fertilizer production, and progress is being made in carbon capture projects for cement and steel production and other industrial activities. Industrial carbon capture and storage (CCS) is undergoing great development and can capture up to 90-99% of CO_2 emissions from industrial plants (Paltsev et al., 2021). Moreover, it has the potential to recover a portion of the value of energy assets that are stranded during transition processes, given that their impact on the climate would be milder (IPCC, 2005; Clark and Herzog, 2014).

Until 2021, the carbon capture capacity of CCUS projects in operation and underway in the electricity, industrial, and transformation sectors was 41 $MtCO_2$/year, on a pathway to goals of 208 $MtCO_2$ by 2030 in a sustainable development scenario, and 1,578 $MtCO_2$ in a net zero carbon scenario (IEA, 2021a). The largest CCUS project in the region was implemented by the state-owned oil company Petrobras in the Santos Basin to reduce emissions from natural gas extraction. It has been operational since 2013 and has a carbon capture capacity of 3 million tons per year (IEA, 2020b).

A double conditioning factor for the development of these technologies is the measurement of (positive and negative) emissions and the valuation of the activity they perform (CCUS) or replace (renewable sources vs. fossil fuel generation or H_2 production). For these technologies to be economically viable, CO_2 needs to be perceived by investors as having a valuation—at present, it is estimated that at USD 100/tCO_2, CCUS is viable in industries such as cement, iron, steel, and power generation (IEA, 2021e), though implementation at the country level is not uniform—and this valuation should reflect future environmental costs.[38]

Considering the above, it is clear that environmental objectives push for coal, oil derivatives and, to a lesser extent, natural gas to decrease their share in the energy matrix.

37 However, there are also challenges, since BECCSs require a lot of space (affecting cropland and, consequently, food availability, as well as putting biodiversity at risk), and their development takes time. Therefore, BECCs should not continue to be encouraged for climate action (see Vandermel, 2020).

38 Here, it is necessary to consider the so-called "green paradox": the attempt to set a high price for CO_2 to make the CCUS attractive may lead to an increase in current emissions. This would happen if current fossil fuel extraction is accelerated in response to the lower profitability expected in the future.

Transportation remains the sector of the economy with the highest use of fossil energy, with petroleum-derived product consumption levels at 81% and 91% in the region and globally.

Despite their heterogeneity, LAC countries have shown a sustained increase in the share of non-conventional renewable energies and natural gas as a substitute mainly for oil, while the share of coal has remained low (with some exceptions, such as Panama and Chile).

However, this situation presents new challenges, including the intermittency of non-conventional renewable energy sources, and the impact of climate variability on traditional hydropower generation. In this regard, natural gas and renewable energy sources offer interesting complementarities that can be harnessed through their combined development to achieve a more sustainable and stable energy matrix composition. In addition, carbon capture and storage technologies can help the sector achieve carbon-neutrality even if fossil fuels continue to be used. Therefore, there is clearly more than one single combination for meeting the environmental objectives.

Simulations and sensitivities

With the aim of quantifying the impact of different mitigation scenarios on the energy matrix and sectoral CO_2 emissions, Rodríguez Pardina et al. (2022) produced a simplified model in the framework of this report. The model projects the evolution of energy matrices during the period 2021-2030 (with an interim projection for 2025). The model respects the logic of an energy matrix, separating energy supply, transformation, and demand, and is constructed based on the latter. In other words, the sector-specific demand for primary and secondary energy of each country is estimated, followed by the calculation of energy demand and supply in the transformation sector, and finally, the necessary energy supply is estimated. In this way, it is possible to intervene in the energy matrix through different sectoral policies.[39]

First of all, the organic growth scenario (business-as-usual or BAU) is described. The BAU scenario projects the situation of the sector for 2025 and 2030 under the assumption that the energy matrix structure will remain constant (i.e., only macroeconomic growth in the region is considered). The remaining cases will be compared against the BAU scenario. Five scenarios are presented: (A) simulated increased use of non-conventional renewable energies, (B) transportation electrification plus zero-emission energy generation, (C) reduced energy intensity, (D) simulations of natural gas as a substitute for oil in power generation and industrial processes, and (E) improved transformation and distribution efficiency. Scenarios A, B and C are discussed in this subsection, while scenarios D and E are discussed in Annex 2.2. At the end, all the assumptions are grouped under a global

39 See Rodríguez Pardina et al. (2022) for a detailed description of how the model works and the assumptions considered.

scenario. As an initial observation, the BAU scenario assumptions and the simulations are used to compare different scenarios and raise awareness of the potential consequences of inaction or inadequate action.

Status quo scenario and projections for 2025 and 2030

This scenario reflects the situation of the sector assuming that the 2021 structure remains unchanged by 2025 or 2030 (except for nuclear energy, which remains constant and the incremental demand is compensated by maintaining the proportion of the other sources). The level of consumption increases at an annual rate of 2.72% for the period 2021-2025 and 2.28% for the period 2025-2030,[40] while demand from the energy sector grows according to GDP elasticities[41] (the electricity and energy sector) by demand sector inferred based on the information available for the period 2000-2019. This reflects energy intensity improvements achieved so far. According to these values and the assumed growth rates, the total energy demand per sector and the demand per source of energy are obtained. The relative structure by energy source remains practically constant, in line with the assumptions adopted for the design of the BAU scenario.

Table 2.5
Energy demand composition in the base year, and BAU scenario in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Source	P J			Relative structure		
	2021	2025	2030	2021	2025	2030
Oil and oil derivatives	25,134	27,484	29,826	46.6%	45.5%	44.0%
Natural gas	10,526	12,151	14,127	19.5%	20.1%	20.8%
Coal	1,921	2,291	2,764	3.6%	3.8%	4.1%
Conventional renewable energies	8,396	9,190	10,198	15.6%	15.2%	15.0%
Non-conventional renewable energies	1,581	1,727	1,907	2.9%	2.9%	2.8%
Nuclear	419	419	419	0.8%	0.7%	0.6%
Electricity	5,969	7,121	8,576	11.1%	11.8%	12.6%
Total	**53,947**	**60,382**	**67,817**	**100.0%**	**100.0%**	**100.0%**

40 The projection for the first five-year period is taken from the IMF (2020), while, for the following five-year period, the historical growth rate for LAC countries (1990-2021) calculated by ECLAC was used.

41 Elasticity measures the ratio between the percentage change of two variables, e.g., between CO_2 emissions and a policy measure (replacement of fuel consumption for transportation with electricity).

The primary and secondary energy supply required to meet the total estimated demand is calculated under the assumption that technical efficiency (including transformation and distribution) remains constant. The evolution of GDP and different measurements of energy supply associated with the BAU scenario in 2025 and 2030 are summarized in Table 2.6.

The last two rows in Table 2.6 summarize the relative evolution of GDP and the total energy supply, and GDP and total electricity supply. Both remain constant in the BAU scenario, indicating that gains in intensity achieved over the past 20 years are maintained (mainly from 2000 to 2015, with a relatively constant evolution since then).

Finally, total energy supply can be used to estimate CO_2 emissions in 2025 and 2030. Table 2.7 shows the evolution and origin of emissions and GDP for each year for the BAU scenario in 2025 and 2030.

The last two rows in Table 2.7 summarize emissions per unit of energy and per unit of GDP, respectively. Both emissions are constant (reflecting the BAU scenario assumptions). The evolution and composition of emissions in the BAU scenario in 2025 and 2030 are shown in Graph 2.22.

The above means that, if no action is taken to decrease the impact of LAC emissions on the environment, these will be slightly below 2000 $MtCO_2$ in 2025 and 2200 $MtCO_2$ in 2030.

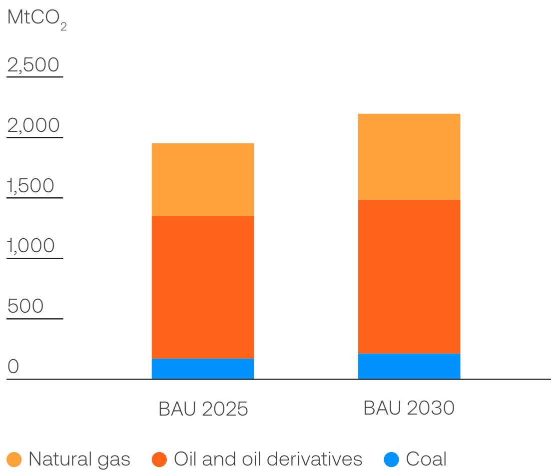
Table 2.6
Evolution of GDP and energy supply indicators
Source: Rodríguez Pardina et al. (2022).

Item	Unit	BAU 2025	BAU 2030
GDP	**MUSD**	5,956,233	6,666,920
Total primary energy supply	**PJ**	36,924	41,554
Total secondary energy supply	**PJ**	24,715	27,613
Total energy supply	**PJ**	41,163	46,122
Total electricity supply	**PJ**	7,120	8,575
Energy intensity	**PJ/MUSD**	0.70%	0.70%
Electricity intensity	**PJ/MUSD**	0.10%	0.10%

Table 2.7
Emissions in the BAU scenario in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	BAU 2025	BAU 2030
GDP	**MUSD**	5,956,233	6,666,920
Total energy supply	**PJ**	41,163	46,122
Total emissions	**$MtCO_2$**	1,954	2,197
Coal	**$MtCO_2$**	165	205
Oil and oil derivatives	**$MtCO_2$**	1,186	1,286
Natural gas	**$MtCO_2$**	603	706
Emissions per unit of energy	**$MtCO_2/PJ$**	0.05	0.05
Emissions per unit of GDP	**tCO_2/thousand USD**	0.33	0.33

Graph 2.22
CO_2 emissions in the BAU scenario in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).



Simulation A: increased use of non-conventional renewable energies (NCRE)

Scenario A, which simulates an increase in NCREs,[42] quantifies the impact on emissions of a larger incorporation of renewable energies into the electricity matrix in LAC. The only change compared to the BAU scenario is the assumption that the share of non-conventional renewable energies in the electricity matrix increases, replacing the assumption that the share of the sources of energy in each country remains constant, but maintaining the relative size of the electricity submatrix within the overall energy matrix.

This assumes that the electricity obtained from non-conventional renewable sources should account for 20% of the electricity produced in each country by 2025 and 30% by 2030. For countries in which these limits have already been reached or exceeded, the current share is maintained.[43] With regard to the rest of the sources of energy, hydropower and geothermal energy increase consistently with the GDP (adjusted by electricity intensity), nuclear energy does not grow, and conventional thermal energy meets the remaining demand. The sources of energy are sorted based on their increasing GHG emissions (biomass, natural gas, oil and oil derivatives, and coal).

As expected, the replacement of thermal generation with NCREs has a direct impact on CO_2 emissions. Table 2.8 shows the evolution and origin of emissions and the GDP for each year for the NCRE and BAU scenarios in 2025 and 2030.

A larger share of NCREs is directly associated with lower emissions. The simulations assume that NCREs replace thermal generation in growing order of contamination (coal ranks at the top, followed by oil and oil derivatives, and natural gas), so the impact necessarily decreases. Graph 2.23 shows CO_2 emissions for different levels of NCRE penetration by 2030.

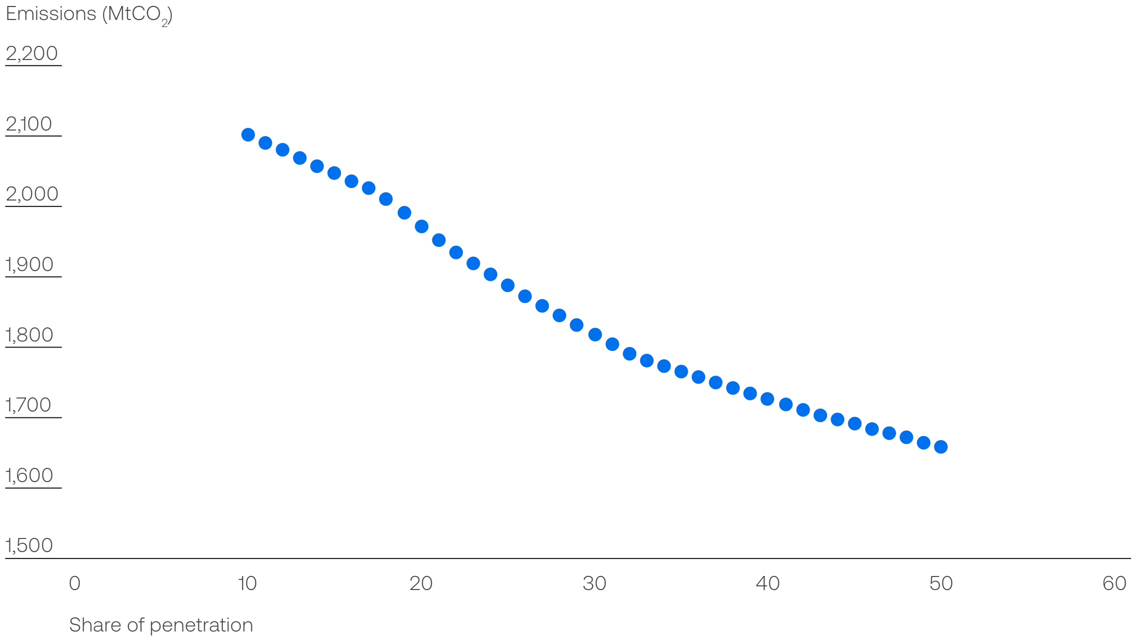
Table 2.8
Emissions in the BAU and A scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	A	BAU	A
GDP	**MUSD**	5,956,233		6,666,920	
Total energy supply	**PJ**	41,163	39,582	46,122	42,463
Total emissions	**$MtCO_2$**	1,954	1,777	2,197	1,818
Coal	**$MtCO_2$**	165	72	205	64
Oil and oil derivatives	**$MtCO_2$**	1,186	1,126	1,286	1,170
Natural gas	**$MtCO_2$**	603	578	706	584
Emissions per unit of energy	**$MtCO_2$/PJ**	0.05	0.04	0.05	0.04
Emissions per unit of GDP	**tCO_2/thousand USD**	0.33	0.30	0.33	0.27

42 In this case, the only NCREs considered are those defined by OLADE as "other primary sources," so geothermal energy is not considered as a NCRE to achieve the penetration goal.

43 The share of NCREs in power generation is over 20% in Honduras and Nicaragua, while it exceeds 30% in Uruguay.

Graph 2.23
NCRE penetration and CO_2 emissions in 2030
Source: Rodríguez Pardina et al. (2022).



Simulation B: Fleet replacement by electric vehicles

Scenario B considers energy consumption replacement in the transportation sector. It quantifies the impact of replacing vehicles (cars and buses) powered by oil derivatives (gasoline and diesel oil, respectively) with electric vehicles on the energy matrix and emissions. Assuming that the need for transportation remains constant (i.e., without considering the promotion of active mobility), replacing the consumption of oil derivatives with electrical energy[44] in a proportion of current consumption equal to 20% in 2025 and 40% in 2030 means that electricity consumption by the transportation sector will increase from 0.2% to 4.3% of total consumption in 2025 and 10.1% in 2030.

In addition, it is assumed that an increased use of renewable energies complements this electrification process. Specifically, for electrified consumption not to generate emissions, the electricity produced by non-conventional renewable sources should account for at least 6.9% of the total electricity produced in 2025 and 9.3% in 2030. If the electricity from renewable sources does not increase, the sequence of installed capacity in the BAU scenario means that a portion of the additional consumption derived from electrified transportation would be from fossil fuels. Table 2.9 (scenario B) shows the decrease in emissions resulting from transportation electrification plus a complementary NCRE penetration.

44 This replacement assumes that a diesel-powered bus consumes 2.1 GJ to travel 100 km, while an electric bus uses 0.43 GJ. This gives a conversion factor of 0.20. Similarly, an automobile uses 0.32 GJ to travel 100 km, while an electric automobile needs 0.06 GJ, with a conversion factor of 0.19. However, the generation of 1 kWh for consumption involves a series of inefficiencies (regarding transformation and infrastructure).

The joint implementation of a package of measures is the most effective way to reduce emissions, creating synergies among various decarbonization assumptions.

Table 2.9
Emissions in the BAU and B scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	B	BAU	B
GDP	**MUSD**	5,956,233		6,666,920	
Total energy supply	**PJ**	41,163	39,792	46,122	43,252
Total emissions	**$MtCO_2$**	1,954	1,820	2,197	1,912
Coal	**$MtCO_2$**	165	142	205	156
Oil and oil derivatives	**$MtCO_2$**	1,186	1,051	1,286	998
Natural gas	**$MtCO_2$**	603	628	706	758
Emissions by unit of energy	**$MtCO_2$/PJ**	0.05	0.05	0.05	0.04
Emissions by unit of GDP	**tCO_2/thousand USD**	0.33	0.31	0.33	0.29

Simulation C: Reduced energy intensity

Scenario C, considering a decrease in energy intensity, quantifies the impact of an improved energy intensity on the energy matrix and CO_2 emissions. This improvement is simulated as a reduction in the historical GDP-energy consumption elasticity (by 20% for 2025 and an additional 30% for 2030). Reducing energy consumption while maintaining the same level of activity also results in a decrease in total energy supply and, therefore, in CO_2 emissions (Table 2.10).

Table 2.10
Emissions in the BAU and C scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	C	BAU	C
GDP	MUSD	5,956,233		6,666,920	
Total energy supply	PJ	41,163	40,882	46,122	45,139
Total emissions	$MtCO_2$	1,954	1,938	2,197	2,141
Coal	$MtCO_2$	165	164	205	204
Oil and oil derivatives	$MtCO_2$	1,186	1,174	1,286	1,243
Natural gas	$MtCO_2$	603	600	706	695
Emissions by unit of energy	$MtCO_2$/PJ	0.05	0.05	0.05	0.05
Emissions by unit of GDP	tCO_2/thousand USD	0.33	0.33	0.33	0.32

Joint scenario analysis (global scenario)

Table 2.11 summarizes the joint effect of the three simulations above plus those discussed in Annex 2.2.

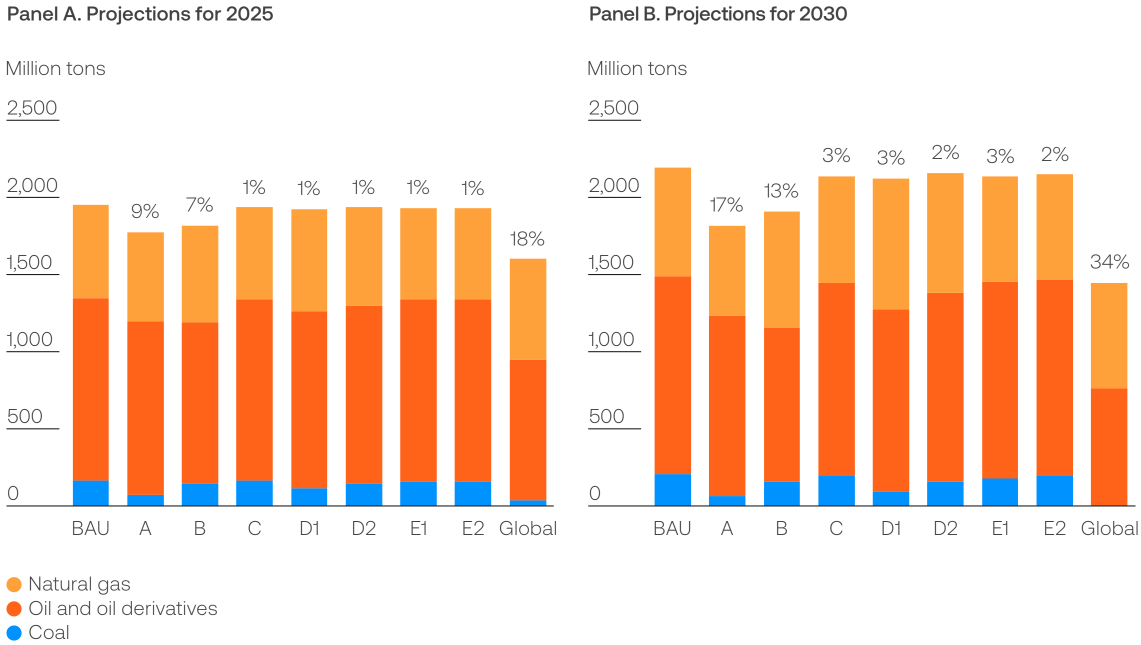
Based on the different proposed scenarios, it is possible to evaluate their environmental impact in terms of emissions and compare them to the BAU scenario. Panels A and B in Graph 2.24 show the projected emissions in each scenario, disaggregated by source, for 2025 and 2030, respectively. In the simulation for 2030, it can be observed that this set of measures (including scenarios A, B, C, D, and E) implies a 34% reduction in emissions, where a global improvement in energy intensity (which reduces emissions by 18%) combines with decarbonization efforts (which decrease emissions by 20%).

Table 2.11
Emissions in the BAU and global scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	Global	BAU	Global
GDP	MUSD	5,956,233		6,666,920	
Total energy supply	PJ	41,163	37,353	46,122	37,639
Total emissions	$MtCO_2$	1,954	1,603	2,197	1,449
Coal	$MtCO_2$	165	35	205	2
Oil and oil derivatives	$MtCO_2$	1,186	916	1,286	765
Natural gas	$MtCO_2$	603	652	706	682
Emissions per unit of energy	$MtCO_2$/PJ	0.05	0.04	0.05	0.04
Emissions by unit of GDP	tCO_2/thousand USD	0.33	0.27	0.33	0.22

Note: the global scenario reflects scenarios A, B, C, D, and E.

Graph 2.24
Projected CO_2 emissions (in million tons) and percentage reduction of emissions with regard to BAU in the different scenarios
Source: Rodríguez Pardina et al. (2022).



Note: The projections in both panels are for scenarios A, B, C, D, and E.

Another useful tool for analysis is estimating the sensitivity of CO_2 emissions to each policy change, approximated through elasticity. Table 2.12 shows the estimates of this elasticity measured between the BAU scenario and each alternative scenario for 2025 and 2030 (for technical details, see Rodríguez Pardina et al., 2022).

Table 2.12
Emission elasticities for different variables in each scenario
Source: Rodríguez Pardina et al. (2022).

Scenarios		Calculated elasticity	2025	2030
A	NCRE	Δ% emissions / Δ% NCRE generation	-0.081	-0.075
B	Replacement by EV	Δ% emissions / Δ% oil consumption by transportation	0.377	0.357
C	Energy intensity	Δ% emissions / Δ% energy supply	1.182	1.179
D1	Replacement with NG-Gen	Δ% emissions / Δ% C&O consumption for generation	0.039	0.045
D2	Replacement by NG-Ind	Δ% emissions / Δ% industrial consumption of C&O	0.026	0.024
E1	Transmission efficiency	Δ% emissions / Δ% thermal generation	0.294	0.327
E2	Distribution efficiency	Δ% emissions / Δ% electricity production	0.383	0.411

For example, if the proportion of NCREs in the electricity matrix rises, elasticity indicates that every 1% increase in generation from these sources results in a decrease of CO_2 emissions by less than 0.1%. For scenario C, the interpretation is that for every 1% decrease in electricity intensity (every 1% reduction in the energy supply required per unit of GDP), CO_2 emissions drop by 1.1%. This enables policy measures to be prioritized according to their sensitivity: among the options with the same percentage effects, energy intensity has the biggest impact, followed by electrification in a sector's consumption (transportation), improvements in the technical efficiency of distribution, and technological improvements in thermal generation. Moreover, transportation electrification, complemented by the penetration of renewable energies for incremental electricity generation, reduces not only CO_2 emissions but also local contaminants such as ozone or carbon monoxide, which degrade air quality and are harmful to citizens' health. Although this effect has not been quantified in this exercise, it is worth mentioning as an additional benefit of transportation electrification.

These impacts could be complemented with a cost approximation of implementing each of the assumptions, to conduct a cost-benefit analysis for each policy or project used in the different scenarios. However, the partial estimates of these simulations (along with their respective sensitivities to CO_2 emissions) provide a first impression of the relative importance of each policy.

Energy adaptation policies: Climate-resilient infrastructure

The warnings issued in successive COPs indicate that even if more ambitious mitigation actions are implemented, they will not be sufficient to avoid the negative consequences of climate change in the coming decades. While the aim is for the energy sector to contribute to mitigating the effects of climate change (e.g., through a greener energy matrix or greater efficiency), it is undeniable that the sector must be prepared to withstand these expected consequences. Some of these consequences are: [45]

- Extreme climate events pose a major threat to all power plants because they could disrupt the operation of critical processes and equipment essential to safe operation.

- It is highly likely (over 80%) that the changes in regional climate patterns will affect the hydrological cycle on which hydropower generation is based. This could lead to reduced or more intermittent power generation capacity.

- It is moderately likely (at least 50%) that the consequences of global warming and changing climate patterns will have a negative impact on agriculture, affecting production and biomass availability for both energy generation and biofuel production.

- Extreme weather events, especially strong winds, are expected to affect power transmission and distribution networks, with an impact on service quality (University of Cambridge and the WEC, 2014).

- Several of these effects impact countries' energy reliability and security. They also directly affect access to service and service quality (considering that quality is a dimension that demands the most attention in this sector), leading to more frequent and longer service interruptions.

It is moderately probable (probability of at least 50%) that the consequences of global warming and climate change, and related environmental objectives make transformation imperative in the energy sector. Given the sector's share in total emissions, decarbonizing the energy matrix is fundamental. However, mitigation actions alone are insufficient: achieving climate neutrality (in terms of GHG emissions) by 2050 appears to be a challenging objective for the region, and even if it were achieved, the negative effects of climate change will persist for decades to come. Therefore, decarbonization clearly needs to be complemented with adaptation actions, not only in the energy sector but in all infrastructure sectors. At the same time, it is vital to enhance

45 See, for example, the University of Cambridge and the WEC (2014), and The Energy Ministry of Chile (2018).

the resilience of energy infrastructure to climate change.[46] Mitigation measures have received stronger commitments than adaptation actions to address the expected impacts. However, the following are some specific adaptation strategies that have already been identified:[47]

- Build underground electricity transmission lines, relocate substations and implement stricter design standards for power transformers to reduce risk during extreme events.

- Reduce water usage in cooling systems of thermal solar power plants located in regions with water scarcity.

- Improve vegetation management (pruning, controlled burning) near distribution and transmission networks.

- Diversify the energy matrix to reduce the risk of supply shortages during extreme events (e.g., low river flow rates, limited sunlight, disruptions in fossil fuel supply chains due to wars, epidemics or climate events).

- Incorporate into energy demand projections the implications of global warming on heating and cooling demands.

- Conduct hydrological basin studies to assess the effects of different climate change scenarios on future power generation and develop contingency plans accordingly.

- Perform comprehensive assessments of climate risks in the electricity sector, including potential impacts on hydropower, solar, and wind generation under different scenarios (see Box 2.5).

- Foster technological advancements to enhance the resilience of solar technologies and wind turbines, making them more capable of withstanding extreme weather events.

- Draft new land zoning codes for duct and pipeline operators, and implement design and construction standards for new pipelines, as well as structural improvements for existing infrastructure, based on climate change risks. Similar approaches can be taken for electric transmission lines.

- Promote public-private cooperation to exchange adaptation experiences and define specific actions.

- Develop smart grids (SG) that provide greater adaptability and resilience to transmission and distribution infrastructure during extreme events.

- Promote complementary adaptation or mitigation policies. For example, non-conventional energy sources (wind, solar, geothermal, tidal, etc.) not only contribute low-emission resources to the energy supply but also enable diversification of the energy mix, reducing dependence on water resources in scenarios with predicted increased duration and frequency of droughts and heatwaves.

46 The IPCC defines resilience as the capacity of a system and its components to anticipate, accommodate, adapt to and recover from disruptions in a timely, efficient manner, e.g., by ensuring the preservation, reestablishment or improvement of their basic essential structures and functions.

47 See Tall et al. (2021), Islamic Development Bank (2019), Rodríguez Pardina et al. (2022) and Ministerio del Medio Ambiente de Chile (2020).

Box 2.5
The Climate Atlas of Chile

An initial step in assessing climate risks can be the development of an atlas, such as the ARClim platform (https://arclim.mma.gob.cl/). The platform presents the Climate Risk Atlas for Chile, a project of the Ministry of the Environment, developed by the Climate and Resilience Research Center and the Center for Global Change (Catholic University of Chile), in collaboration with other national and international institutions.

The overall objective of ARClim is to create a set of risk maps related to climate change, using a common conceptual framework and a consistent database. ARClim covers various sectors with national coverage and community or specific details, including the electricity sector. It serves as an important tool for designing public policies and implementing adaptation measures. As an example, Figures 1 and 2 display maps that capture risks associated with decreasing water resources and increasing temperatures.

Figure 1
Risk maps showing the impact of the decline in water resources
Source: ARClim website (accessed June 2, 2022).

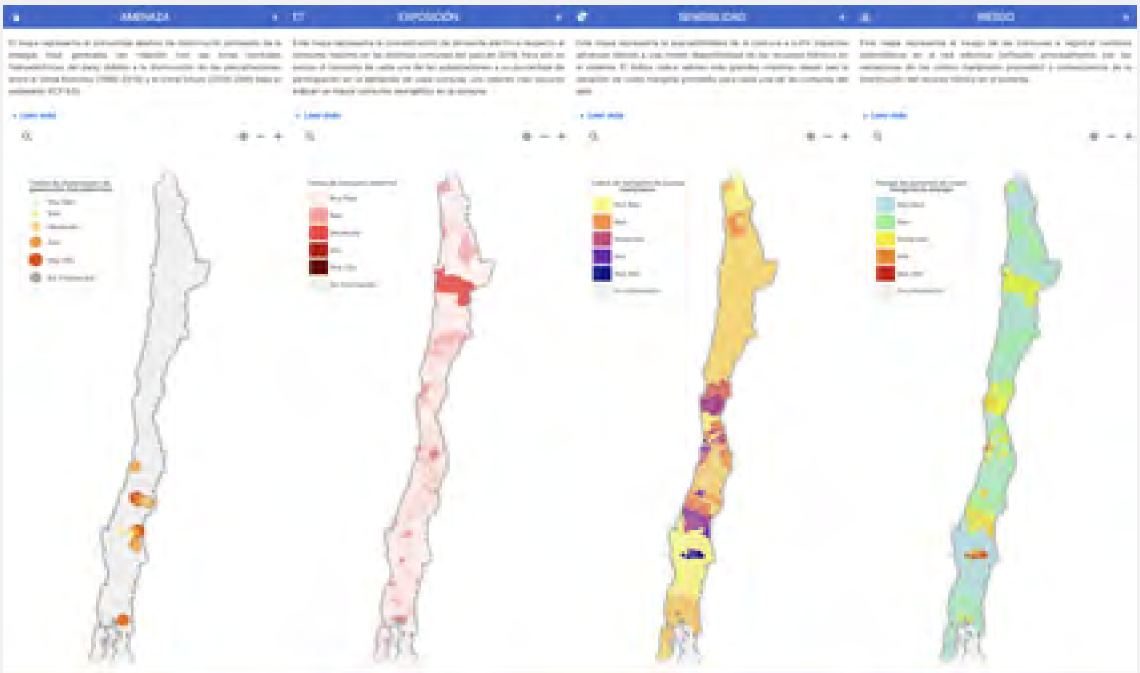
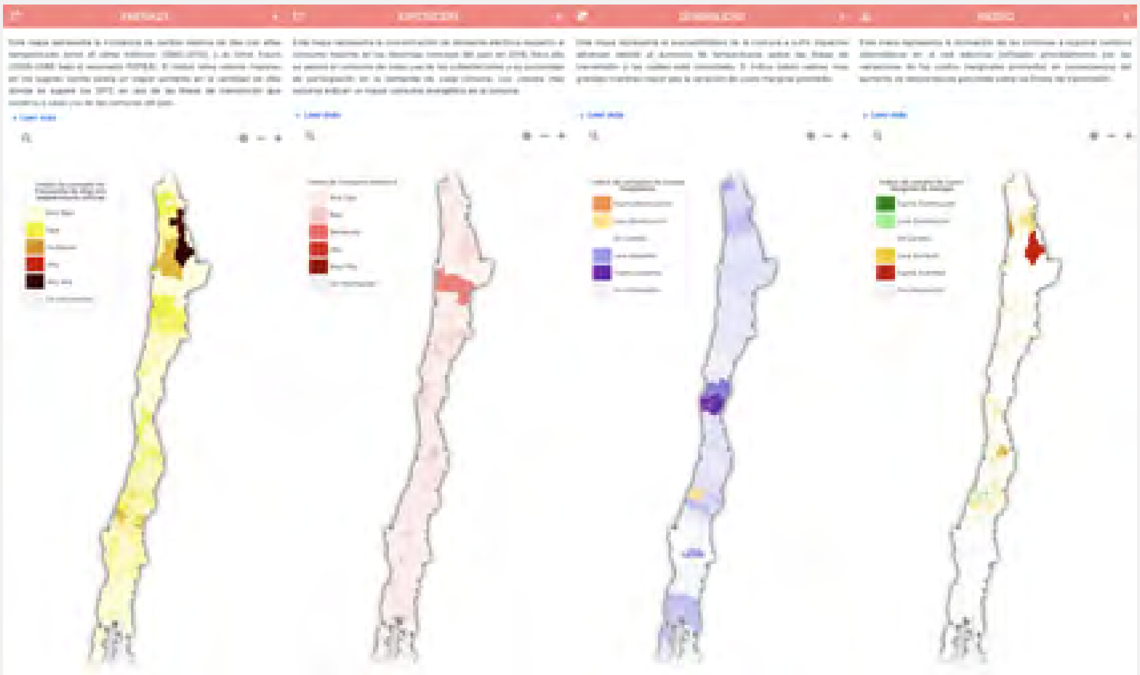


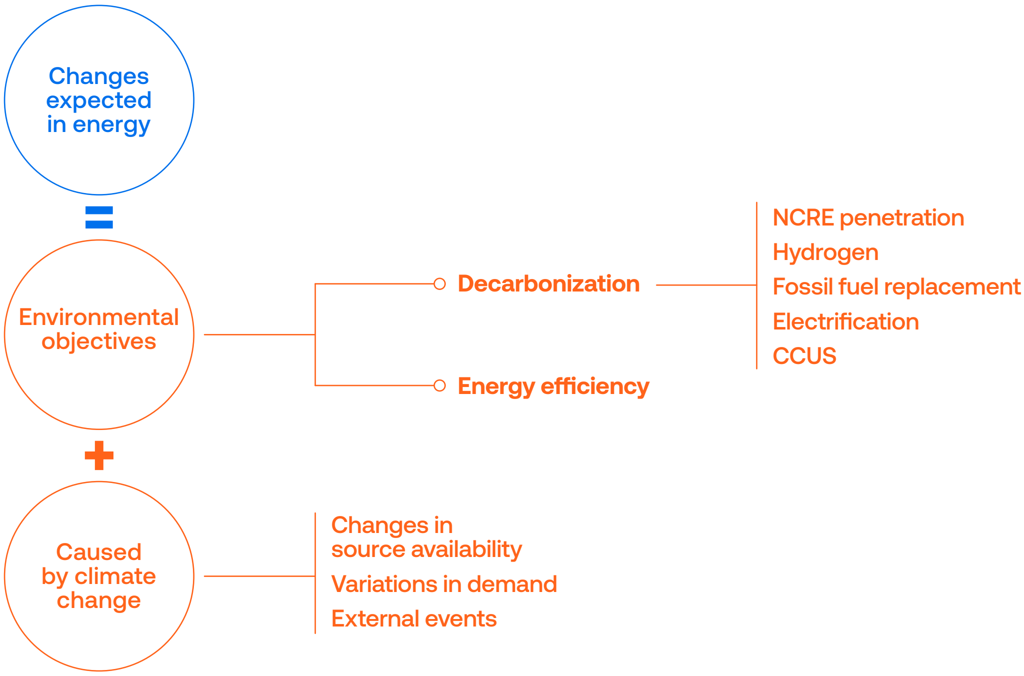
Figure 2
High-voltage power line risk maps related to rising temperatures
Source: ARClim website (accessed June 2, 2022).



Changes expected in response to environmental challenges

Based on the analysis in this chapter, it is possible to identify some of the changes and relevant challenges that the sector will have to address in the future. These changes, shown in Figure 2.4 and explained below, stem from the environmental objectives envisaged to address environmental issues and those imposed by climate change.

Figure 2.4
Diagram of changes expected in the energy sector
Source: Authors.



- **Increase in the share of NCREs.** The penetration of non-conventional renewable sources (solar and wind) brings the challenge of how to resolve their intermittency in electricity generation cycles. In response to this challenge, greater connectivity, storage, and demand response will be required, which will necessitate increased investments in backup capacity and grid infrastructure. Moreover, the installation of new generation sources located far away from the existing grid will require extensions of transmission networks (or reinforcement if they already exist).

- **Development and inclusion of hydrogen in the energy matrix.** Hydrogen can involve major changes to the sector's production processes (low-emission hydrogen production processes, transport and storage systems, etc.). Moreover, transformation processes (from raw material into hydrogen) may be inefficient or costly and thereby reduce its potential. Currently, the generation of green hydrogen is generally not competitive, although some options are emerging if mechanisms are included to internalize the environmental benefits of this source compared to more polluting versions.

- **Replacement of fossil fuels with less polluting sources.** Beyond NCREs and hydrogen, natural gas may be useful in this substitution process because in some cases it produces up to 50% less GHG emissions then other hydrocarbons (as long as methane emissions are contained), in addition to contributing to lower local pollution. Moreover, the availability of natural gas reserves in the region highlights its importance in ensuring energy security (especially in contexts with high penetration levels of renewable energies and the issue of intermittency). The challenge here is to keep natural gas venting and leaks (which are its main source of emissions) under control.

- **Electrification of energy consumption.** Transport electrification faces three main challenges. First, the high cost of batteries; second, the deployment of infrastructure for connection to the grid for charging and discharging; and third, the interoperability of charging electric vehicles. There are also electrification alternatives for certain industrial, commercial and residential uses.

- **CCUS.** The main factors conditioning CCUS technologies are the measurement and assessment of emissions (which, in fact, also apply to other GHG emission capture activities). In order for CCUS technologies to be economically viable, investors need to perceive their environmental benefit as a financial benefit.

- **Energy efficiency.** Improving energy efficiency requires three major changes. First, the infrastructure needs to be improved in order to make the transformation and distribution processes more efficient, with fewer losses. Second, it is important to assess instruments enabling the alignment of incentives in order to foster efficient use of energy by consumers. Third, investment in research and development must be encouraged to continue to improve the transformation and consumption processes through new technologies.

- **Changes in availability of sources due to climate change.** The greater frequency of extreme events, particularly droughts, may affect hydroelectric generation capacity, suggesting the need to diversify the energy matrix. Relying heavily on this source puts the system at risk in the face of projected water shortages. Likewise, biomass production and availability may be affected by the adverse impact of climate change on agricultural activity.

- **Variations in demand.** Rising global temperatures due to climate change can have profound impacts on consumption patterns, thus altering energy demand levels. Additionally, the electrification of various sectors such as transportation and industry will bring about changes in the composition of the energy sources demanded. Accurately projecting these changes is crucial to determine the necessary investment requirements to meet this evolving demand.

- **Extreme events.** With climate change driving an increase in extreme events, power plants, refineries, pipelines, and transmission and distribution networks are at greater risk. These effects undermine energy reliability and security, exacerbating access and quality gaps. The sector's challenge is to provide resilient services that can respond swiftly to disruptions caused by extreme events, minimizing the number of affected individuals and the service restoration time.

- **Regional integration.** In response to issues like renewable generation intermittency and resource scarcity, regional integration emerges as a potentially viable solution for increasing countries' energy security. However, it poses major challenges regarding coordination and cooperation among the different States (a topic analyzed in detail in Chapter 5 of RED 2021).

- **Distributed generation.** Increased availability of renewable sources also facilitates the expansion of distributed generation, posing a new challenge. This paradigm shift is driven by improved technology efficiency and reduced costs, primarily in solar photovoltaics, which constitute nearly 98% of distributed generation installations in the region due to their characteristics and urban integration capabilities. Implementing such systems entails multiple considerations, including compensation schemes (energy or cash-based), minimum technical requirements to ensure the quality of distributed generation, the rate at which credits are exchanged with the grid, financial mechanisms (if any), and how to finance them.

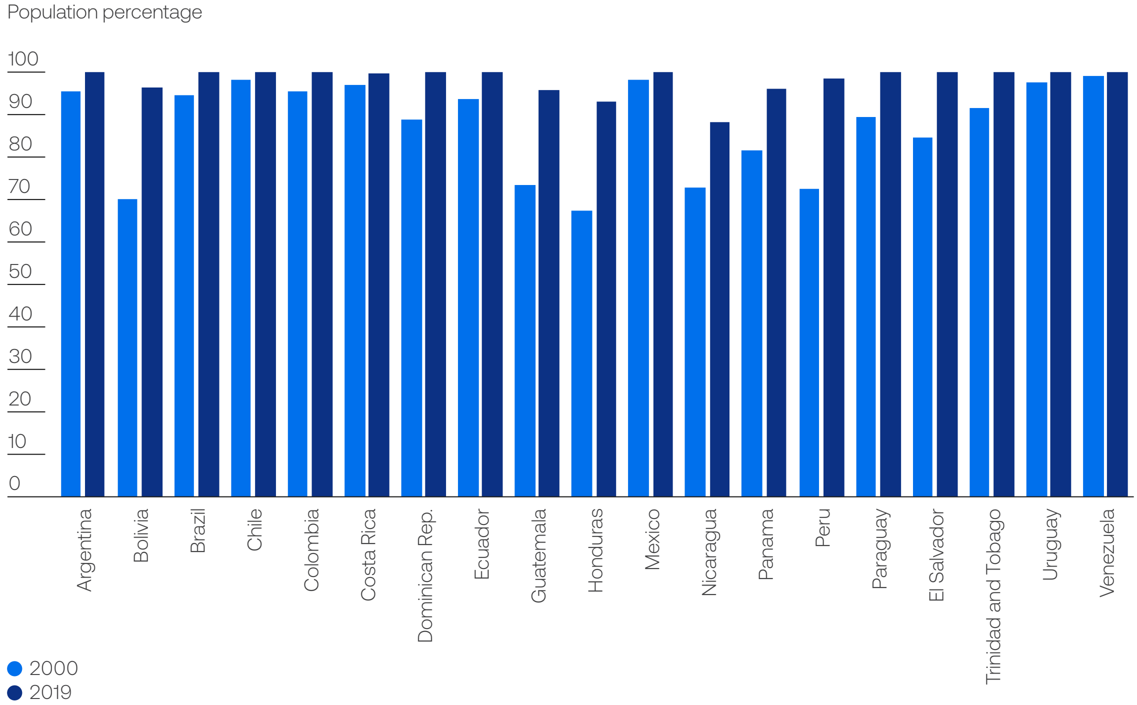
Annex 2.1 Service gaps in energy: Electricity and natural gas

This annex analyzes service gaps in electricity and natural gas markets in LAC, emphasizing three dimensions: access, cost, and quality of the service (Cont et al., 2021).

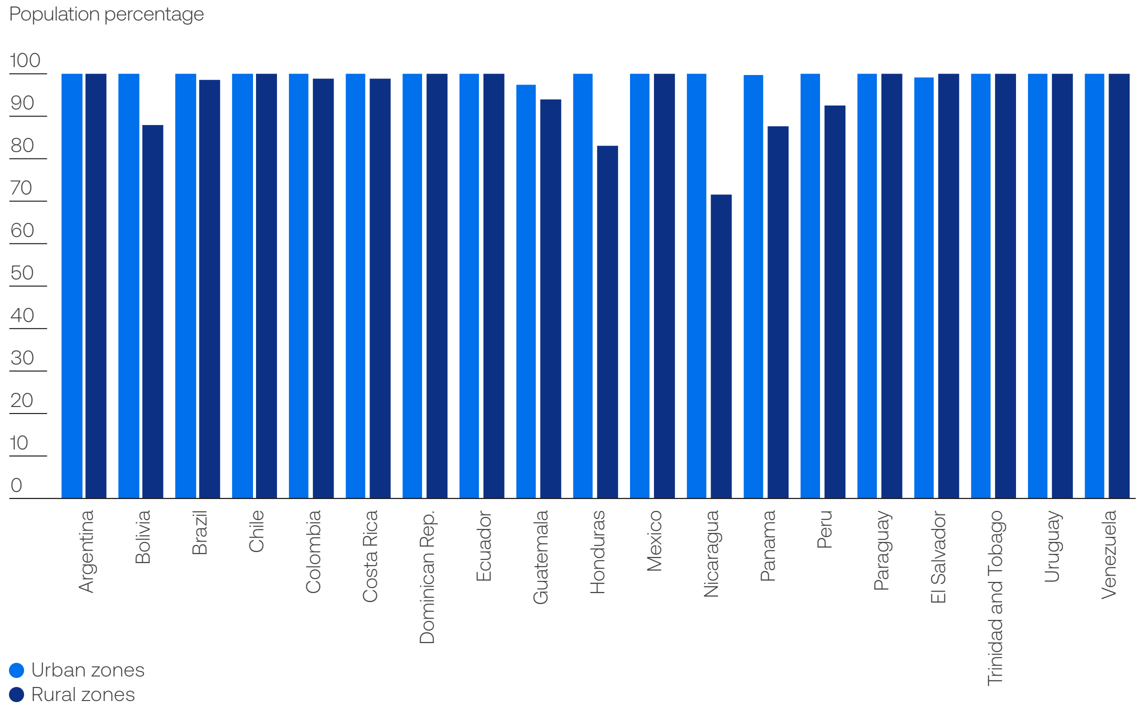
First, the electricity market in the region is characterized by high levels of access. According to the latest data available (2019), most countries in the region have attained universal access (100% of the population with access to electricity) or are close to achieving it (Graph 2.25). During 2000-2019, Bolivia and Peru achieved the highest increases in access (close to 26 percentage points).

However, this obscures major differences between urban and rural zones. Graph 2.26 shows that, in general, people in rural zones have less access to electricity than in urban zones. Clearly, countries in the region must make bigger efforts in rural settings. Several countries, including Nicaragua (where nearly 30% of the rural population has no access to energy), Bolivia, and Honduras still have plenty of room to expand coverage for this population segment.

Graph 2.25
Percentage of the population with access to electricity
Source: Authors based on World Bank (n.d.a).



Graph 2.26
Percentage of urban and rural population with access to electricity in 2019
Source: Authors based on the World Bank (n.d.a).

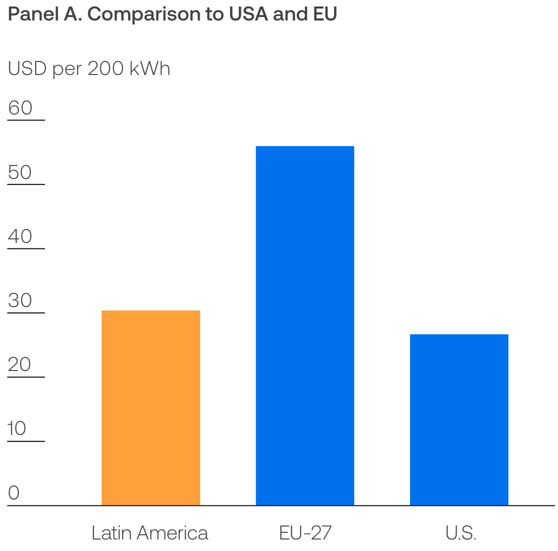


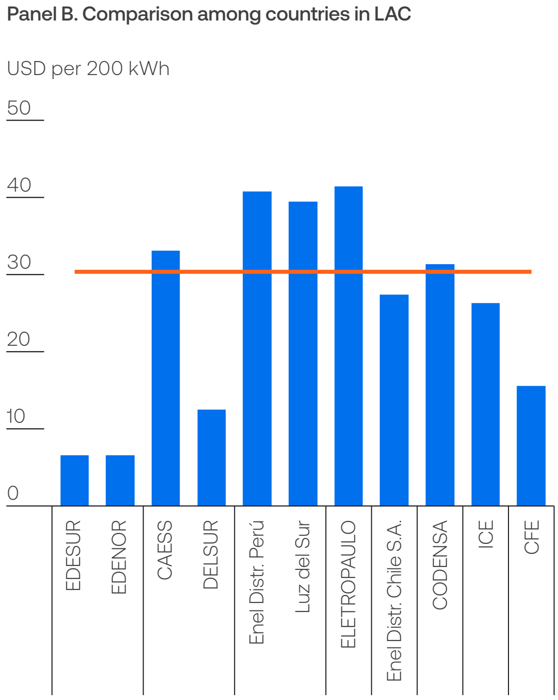
There are marked differences in residential electricity costs (rates). Overall, the region has similar rates to the United States, which are substantially lower than in Europe. However, within the region, even though the weighted average for household expenditure on a reference consumption of 200 kWh is USD 30.4, rates in Argentina are significantly lower (USD 6.7), while at the opposite extreme, rates in Brazil and Peru are much higher (close to USD 40).

The fact that the rates in the region are similar to those in the United States is cause for concern regarding the affordability of the service for households in the region. A person in the United States had to spend, on average, 0.51% of their income on electricity over a year (12 months with average monthly consumption of 200 kWh), whereas a European had to spend 1.97% of their income. A Latin American, on the other hand, had to spend 5% of their income to cover annual expenditure on electricity.[48] This shows that, despite paying a lower rate in absolute terms, the relative cost of the rate for households in the region is 2.5 to 10 times higher than in Europe and the United States.

48 Data on income from the World Bank refer to the GDP per capita in current values: https://datos.bancomundial.org/indicador/NY.GDP.PCAP.CD?locations=ZJ-AR-PE-EU-US

Graph 2.27
Residential electricity rate: Monthly expenditure in USD for 200 kWh consumption in 2021
Source: Authors.





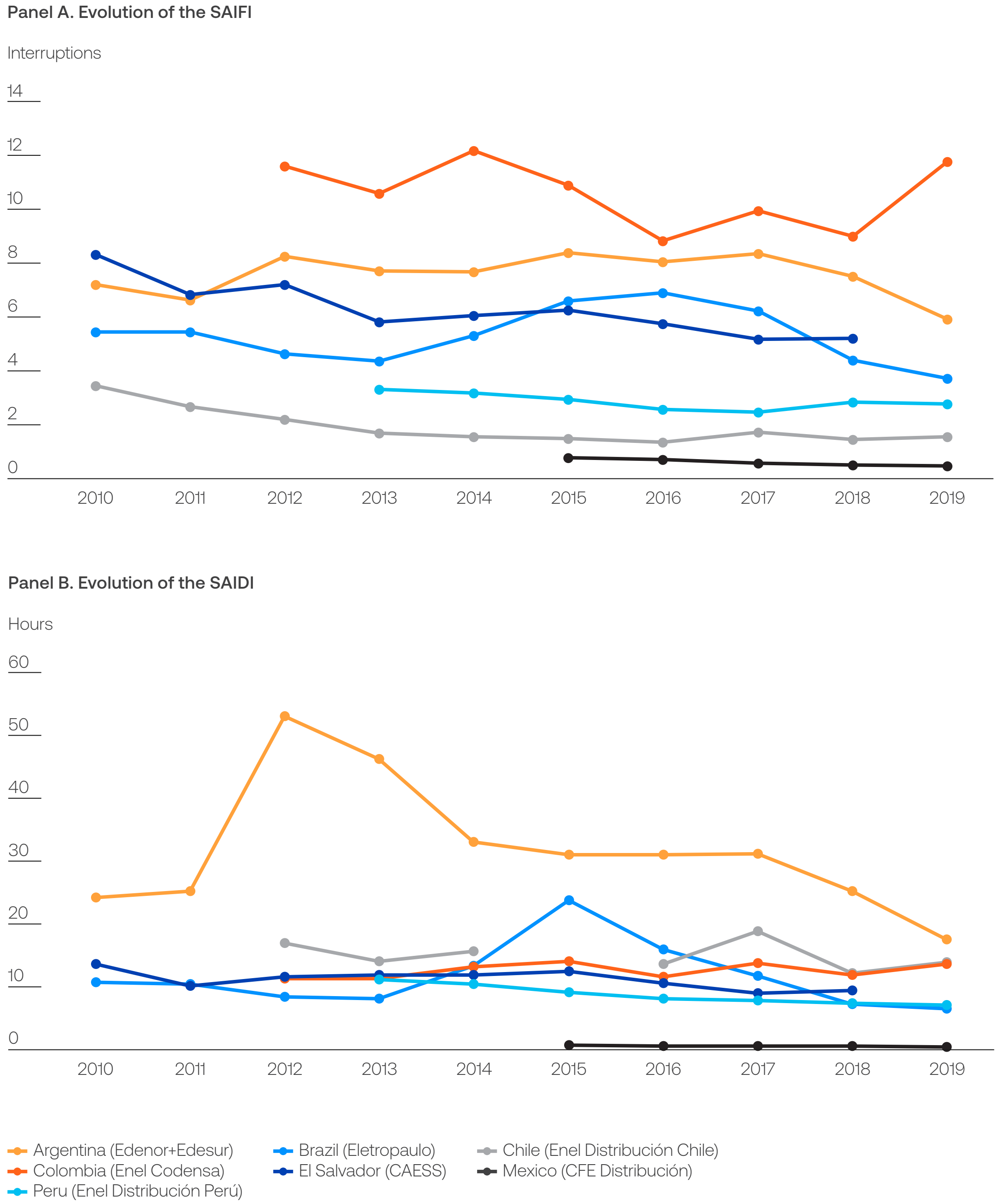
Note: The data for LAC in Panel A correspond to December 2021, and include Edenor and Edesur in Argentina, Eletropaulo in Brazil, Enel in Chile, Codensa in Colombia, ICE in Costa Rica, CAESS and Delsur in El Salvador, CFE in Mexico, and Enel and Luz del Sur in Peru; the data for EU-27 correspond to the second semester in 2021; the data for USA are the average price in December 2021.

Two indicators are often used for analyzing service quality: the System Average Interruption Frequency Index (SAIFI), usually over a year, and the System Average Interruption Duration Index (SAIDI). Graph 2.28 shows the evolution of these indicators for countries in the region. Some countries, like Argentina and Colombia, have a high service interruption frequency. Argentina is also the country with the longest average duration for those interruptions. Mexico has the best quality indicators, with the lowest interruption frequency and lowest average duration.

More generally, the region is lagging in terms of quality. Thus, for the latest year with available data, while the frequency of interruptions was 3.6 in LAC (2019), it was 1.2 and 1.3 in Europe and the United States, respectively. The region is also lagging in terms of the duration of interruptions, with an average duration of 6.8 hours (2019) versus 5.7 in the United States (2018) and 1.7 in Europe (2016). It is thus clear that the whole region needs to increase efforts to improve the electricity service quality.

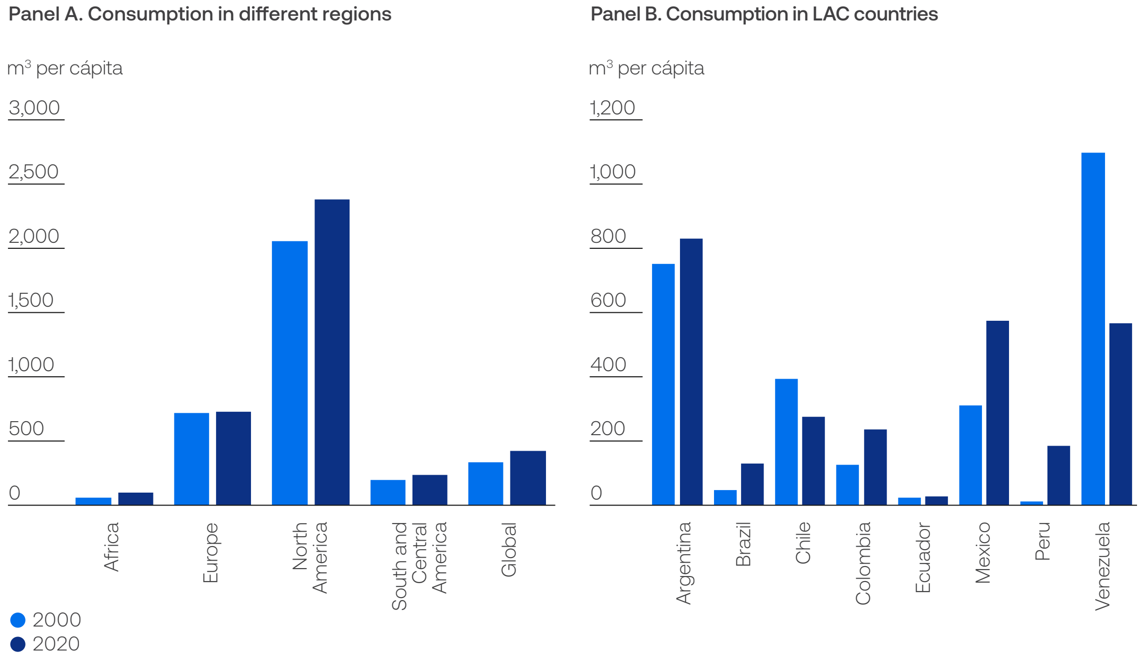
For a number of countries, there are not as many indicators available for the natural gas market, compared to the electricity market. This variation depends on the development of natural gas markets in each country. The main limitation lies in the aspect of service quality, for which representative data for the region's countries, except for Argentina, were not found (see Table 2.13). However, an approximation of access to natural gas can be calculated based on consumption per capita in the countries (Graph 2.29). Consumption is lower in the region than in developed countries and the rest of the world. In analyzing individual countries, significant differences emerge: while Argentina's consumption is similar to that of European countries, Brazil and Peru consume less than a quarter of Argentina's figure.

Graph 2.28
Quality of residential electricity service
Source: Authors.



Note: For LAC, reference values are the SAIDI (System Average Interruption Duration Index) and the SAIFI (System Average Interruption Frequency Index) of the main distributors in each country, except in the case of the SAIDI in Chile (national datum).

Graph 2.29
Natural gas consumption in m³ per capita
Source: Authors based on OWID (n.d.d) and the World Bank (n.d.a).



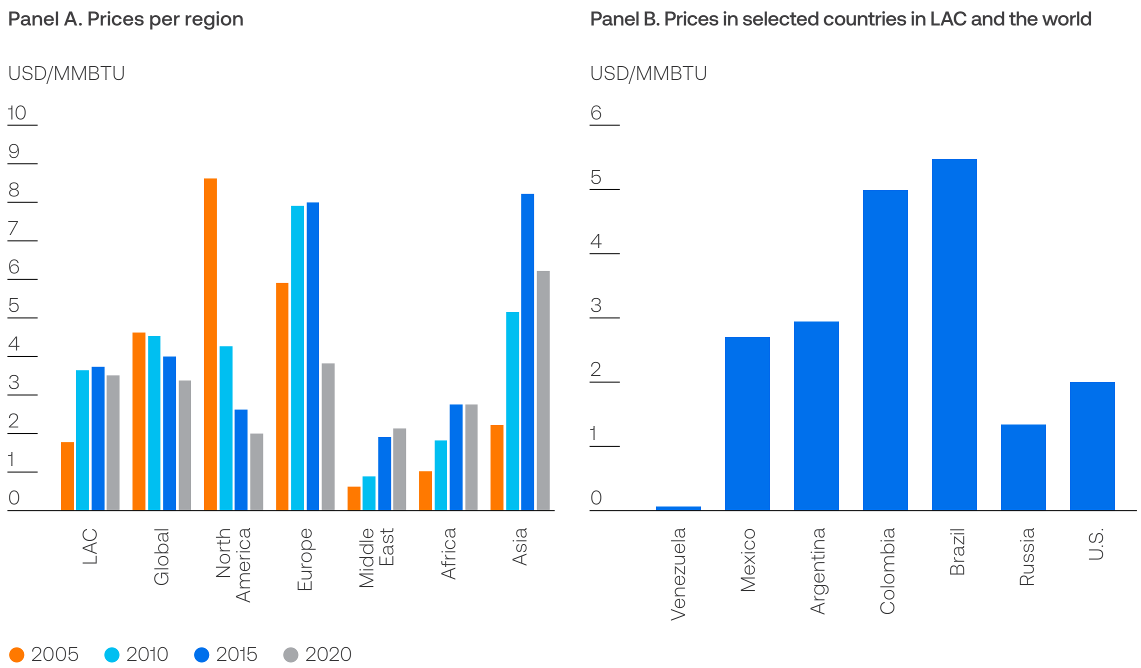
Note: The OWID data used come from the Statistical Review of World Energy.

Part of the improvement in access to gas in recent decades can be attributed to the emergence of liquefied natural gas (LNG). The liquefaction process reduces the volume of natural gas, allowing it to be transported over long distances at competitive prices. This facilitates access to this resource in areas without a gas pipeline network, or if such a network exists, it can help alleviate domestic scarcity. LNG can be transported over long distances in LPG tanker ships. The main limitation of this alternative is the high cost of building and operating gas liquefaction plants (at the source) and regasification (at destination). In the past decade, one-third of the international gas trade was LNG, mainly due to the expansion of its supply in the United States (Yépez-García and Anaya, 2017).

In response to the gas surplus, US producers are increasingly turning to LNG to find new markets for their production. This is an opportunity for the region because transport from the United States to other countries in the Western Hemisphere costs less than shipments from Asia.

In terms of costs, the countries in the region for which data is available show that the wholesale price of natural gas (in dollars per million BTU) is lower than the global average. However, this difference has considerably narrowed in the past decade. This can be attributed to the persistent decline in prices in North America and the one-off drop in Europe in 2020. The breakdown by country shows broad heterogeneity in the region: while prices in Venezuela are less than USD 0.10, in Brazil they are higher than USD 5.

Graph 2.30
Wholesale natural gas prices in USD per million BTU
Source: Authors based on the International Gas Union (2021).

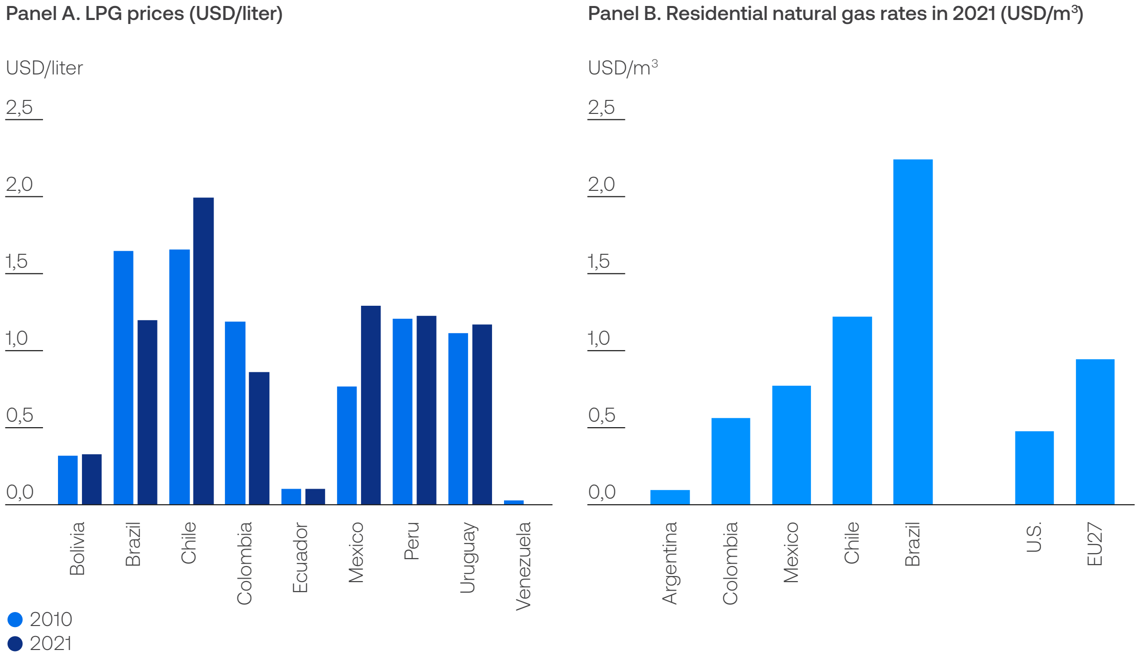


Note: Panel B shows the prices for the last year with available data (2020).

Graph 2.31 shows LPG prices and natural gas rates. In the case of LPG, there is wide heterogeneity in LAC: while the rates in Venezuela are near 0; in Chile and Brazil, they are well over one dollar per liter. In comparing five LAC countries, there is also a wide variation in residential natural gas prices. Regarding affordability, there are also surprising results for the region: for an annual consumption of 2.500 m^3, an average US household spends just over 2% of its income, similarly to Argentina at 3%, whereas in Chile, it is 22%. This simple comparison overlooks the climatic and regional lifestyle differences but serves to highlight the critical situation regarding affordability of the resource in the region. However, tariff differences partly explain the consumption variations among countries (Argentina and Brazil are clear examples).

Natural gas quality depends on local regulations and has not been systematized like in the electricity sector. The clearest case of quality regulation is Argentina, where the national gas regulatory entity ENARGAS publishes natural gas quality indicators, classifying technical service and commercial service. Table 2.13 shows these indicators for the average of distributors in Argentina, along with reference values.

Graph 2.31
LPG prices and residential natural gas rates in countries in the region
Source: Authors based on ECLAC (n.d.b) and Global Petrol Prices (2022).



Note: the latest information available for Venezuela is for 2020, and is USD 0.00 (rounded to two decimal places). In panel B, expenditure per m^3 was estimated for an annual consumption of 2,500 m^3.

Table 2.13
Natural gas service quality indicators in Argentina
Source: Authors based on data from ENARGAS (n.d.).

	Indicator	Reference Value	Distributors Average
Technical service - operation and maintenance indicators (2019)	Cathodic protection	100%	100%
	Leaks per kilometer	95%	100%
	Average time to repair grade 2 leaks	80%	91%
	Reserve capacity in regulator plants*	100%	100%
	Interruption of supply	80%	99%
Commercial service (2021)	Invoicing management	Maximum 1.01	0.39
	Problems in residential gas supply	Maximum 1.23	0.60
	Service management	Maximum 0.09	0.04
	Claims to licensees	Maximum 2.33	1.03
	User satisfaction	Minimum 0.95	0.97
	Delay in telephone customer service	Minimum 90%	84%
	Delay in resolving claims		13%

Note: The average corresponds to the simple average for distributors in the country. * Includes regulating plants for isolated and connected systems.

Annex 2.2 Complementary energy policy simulation scenarios

Scenarios D (natural gas substitution) and E (electricity system technical efficiency), mentioned in the main body of the chapter, are discussed below.

Simulation D: Replacement of oil and coal by natural gas

Simulation D1: Replacement in the electricity mix

Scenario D1, replacement in the electricity mix, quantifies the impact on CO_2 of replacing coal, oil and derivatives with natural gas. The only change with respect to the BAU scenarios is the drop in the share of coal, oil and derivatives in the electricity mix (5% per year from 2021 to 2025, and 10% per year from 2025 to 2030), being replaced by natural gas if necessary.

The increase in electric generation with natural gas to replace generation out of coal and oil produces a substantial change in the structure of energy sources for energy generation.[49] Moreover, it has a direct though small impact on CO_2 emissions due to (i) the electricity mix share in the energy matrix and (ii) the magnitude of replacement. Table 2.14 shows the evolution and source of emissions for the BAU and D1 scenarios in 2025 and 2030.

Table 2.14
Emissions in the BAU and D1 scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	D1	BAU	D1
GDP	MUSD	5,956,233		6,666,920	
Total energy supply	PJ	41,163	41,105	46,122	45,988
Total emissions	$MtCO_2$	1,954	1,925	2,197	2,126
Coal	$MtCO_2$	165	118	205	90
Oil and derivatives	$MtCO_2$	1,186	1,145	1,286	1,183
Natural gas	$MtCO_2$	603	662	706	852
Emissions per energy unit	$MtCO_2$/PJ	0.05	0.05	0.05	0.05
Emissions per GDP unit	tCO_2/thousand USD	0.33	0.32	0.33	0.32

49 Given the information available in the OLADE, this simulation underestimates one of the benefits of replacement by natural gas, which is the improvement of transformation efficiency (which is greater for generation with natural gas than with coal or oil derivatives). In the statements a single transformation efficiency value was used as an average for all thermal energies.

Simulation D2: Replacement in industrial consumption

Another possibility is to replace coal and oil in the final demand, in particular the demand from industrial users. Scenario D2 assumes that the industrial sector reduces coal consumption by 50% and consumption of oil and derivatives by 25% by 2025 compared to consumption in 2021. By 2030, the reduction should reach 100% of coal and 50% of oil and derivatives.

These sources are replaced by natural gas. This change signifies an increase in natural gas share in the demand from industry which, in BAU, would go from 23.2% in 2025 (22.5% in 2030) to 33.5% in scenario D2 (39.2% in 2030). The impact on CO_2 emissions is summarized in Table 2.15.

The global scenario in Table 2.11 includes both simulations, D1 and D2, as scenario D.

Table 2.15
Emissions in the BAU and D2 scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	D2	BAU	D2
GDP	**MUSD**	5,956,233		6,666,920	
Total energy supply	**PJ**	41,163	41,126	46,122	46,049
Total emissions	**$MtCO_2$**	1,954	1,937	2,197	2,163
Coal	**$MtCO_2$**	165	142	205	159
Oil and derivatives	**$MtCO_2$**	1,186	1,155	1,286	1,223
Natural gas	**$MtCO_2$**	603	640	706	781
Emissions per energy unit	**$MtCO_2$/PJ**	0.05	0.05	0.05	0.05
Emissions per GDP unit	**tCO_2/thousand USD**	0.33	0.33	0.33	0.32

Simulation E: Improvements in efficiency

Simulation E1: Improvement in transformation efficiency

The production of secondary energy, particularly electricity and oil derivatives, involves transformation processes (electricity generation and distilleries) which entail energy losses. Scenario E1 assumes that by 2025, countries' losses due to thermal transformation should achieve a 50% reduction in the gap between their current level and the losses from an internal combustion generator powered by oil derivatives (67%, as illustrated in Graph 2.20), and by 2030, they should achieve a 50% reduction with respect to the losses from an internal combustion generator powered by natural gas (61.7%) (EIA, 2019). Countries with values lower than this in 2019 do not undergo any modifications (Ecuador, El Salvador, Jamaica and the Dominican Republic).

Under the assumptions established, mean transformation efficiency in 2025 goes from 53.2% in the BAU scenario to 54.9% in the E1 scenario (from 51.2% to 55% in 2030), wherefore the energy supply to cover the same demand is lower. The improvement in efficiency also leads to changes in the relative structure of primary share, with reductions in the use of thermal sources (coal, oil and derivatives, and natural gas) compensated by relative increases in the use of other sources. The net effect is an improvement of transformation efficiency on CO_2 emissions, as illustrated in Table 2.16.

Table 2.16
Emissions in the BAU and E1 scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	E1	BAU	E1
GDP	MUSD	5,956,233		6,666,920	
Total energy supply	PJ	41,163	40,752	46,122	44,956
Total emissions	$MtCO_2$	1,954	1,934	2,197	2,138
Coal	$MtCO_2$	165	155	205	182
Oil and derivatives	$MtCO_2$	1,186	1,182	1,286	1,275
Natural gas	$MtCO_2$	603	596	706	681
Emissions per energy unit	$MtCO_2$/PJ	0.05	0.05	0.05	0.05
Emissions per GDP unit	tCO_2/thousand USD	0.33	0.32	0.33	0.32

Simulation E2: Improvement in distribution efficiency

Energy losses are common in electricity transmission and distribution, mainly in the final segment of the grid. The efficiency of this process is measured as the difference between electricity generated and electricity used by consumption centers. Scenario E2 analyzes the impact of distribution efficiency improvements on the energy sector and particularly on CO_2 emissions. Assuming that distribution losses gap between their current level and the efficient minimum (defined as 10%) must decrease by 50% by 2025 and another 50% by 2030,[50] the mean loss during distribution would descend from 15.3% to 12.4% in 2025 and 10.9% in 2030 (Scenario E2). This implies less electricity generation to meet demand, and, as a result, lower emissions by reducing generation based on the pollution level of fuels (Table 2.17).

The global scenario in Table 2.11 incorporates both simulations, E1 and E2, as the E scenario.

Table 2.17
Emissions in the BAU and E2 scenarios in 2025 and 2030
Source: Rodríguez Pardina et al. (2022).

Item	Unit	2025		2030	
		BAU	E2	BAU	E2
GDP	MUSD	5,956,233		6,666,920	
Total energy supply	PJ	41,163	40,621	46,122	45,162
Total emissions	$MtCO_2$	1,954	1,929	2,197	2,152
Coal	$MtCO_2$	165	161	205	197
Oil and derivatives	$MtCO_2$	1,186	1,179	1,286	1,274
Natural gas	$MtCO_2$	603	589	706	680
Emissions per energy unit	$MtCO_2$/PJ	0.05	0.05	0.05	0.05
Emissions per GDP unit	tCO_2/thousand USD	0.33	0.32	0.33	0.32

50 In Chile, Colombia, Nicaragua and Trinidad and Tobago, distribution losses do not require adjustment according to the criterion established.

3

Environmental challenges for water resources

This chapter focuses on the importance of water conservation as a key element of biodiversity, taking into account the significance of infrastructure sectors in achieving sustainable development as set out in the Agenda 2030 and their interrelation with the environment, including climate change and ecosystem conservation. It assesses the situation in the region in terms of water availability, pollution, and sustainable use. It also analyzes some of the proposed solutions to address the challenges such as integrated water resource management (IWRM) and the circular economy. It also explores possible impacts of climate change and the changes that environmental problems impose on the sector.

Water is a fundamental resource to sustain life on Earth. Access to affordable, quality water (free of contamination) affects basic aspects of human welfare, such as health, sanitation, nutrition, and housing. Moreover, water is used for productive purposes in different stages of the economy's value chains: in the primary sector, it is essential for activities such as agriculture, forestry, fishing, aquaculture, and mining; in the secondary sector, water is a basic input in product transformation processes, manufacturing, and power generation; and in the tertiary sector, it is a key element for tourism and the provision of various public services (Rojas et al., 2019).

In the case of Latin America and the Caribbean (LAC), the region is highly dependent on water for electricity generation, with 25% of electric energy sourced from hydropower (with extremes such as Paraguay at 100% and values close to 50% in Brazil, Colombia, Costa Rica, Ecuador, and Uruguay). Thus, water plays a crucial role in the energy sector (challenge 1) and climate change as part of mitigation policies. Additionally, water availability is vital for maintaining species diversity in ecosystems.

Despite progress toward meeting the sustainable development goals (SDGs) (Chapter 1), LAC's water sector is lagging across all the targets. The region must make greater efforts to achieve them by 2030.

The challenges highlighted in Chapter 1 emphasize the central role of water in achieving sustainable development in all three dimensions—economic, social, and environmental—of a country. Therefore, a major objective of the sector should be the preservation and conservation of water resources to ensure their availability in both quantity and quality, promoting their sustainable use,[51] and reducing pollution in their natural sources (challenge 6) to conserve the ecosystems related to water (challenges 3, 9, and 10), as well as ensuring access to safe drinking water and sanitation (challenge 5).

Countries have already evaluated two approaches, in particular, to address the considerable challenge of conserving water resources and related ecosystems. First, proper management of the resource is essential. The multiple uses of water—from agricultural and energy to human consumption—can create competition for this scarce resource or produce sectoral, territorial, or temporal externalities. To address these effects, integrated management is needed. However, water management is especially challenging due to geographical factors (sources far from urban areas), economic factors (activities such as mining and agriculture that demand water) and demographic factors (large metropolitan areas and high urbanization) (Cavallo et al., 2020). Within this context, challenge 5 highlights the importance of the role of local communities in water conservation. The second approach is the circular economy strategy, which can help maximize water use efficiency and minimize water cycle waste. Although the implementation of circular economy strategies has been explored in water-related industries (mining and extractive activities, waste management and recycling, and the bioeconomy), applying this approach to the water sector presents additional challenges. They include regulatory, institutional, financial, and environmental hurdles, particularly when promoting the reuse of water resources. This chapter provides a detailed discussion of both approaches.

Climate change is also a major threat to water conservation and future availability. Global warming has a significant impact on freshwater systems and their management. Most of the effects caused by climate change will be observed through modifications in the hydrological cycle, including the overall availability of water resources, water quality, and the frequency of extreme weather events (e.g., floods and droughts). In this context, under the Paris Agreement, water also appears in the **nationally determined contributions** (NDCs) as one of the sectors to be considered in the context of climate change, mainly in adaptation policies According to a 2020 UN study, 70% of NDCs reported by 80 countries already included water management or governance tools, such as water pricing, infrastructure protection, desalination, and others, within their adaptation policies. Likewise, the resource can contribute to climate change mitigation mainly through its use in hydropower generation. According to Rojas et al. (2020), this type of action is proposed in three LAC countries (Bolivia, El Salvador, and the Dominican Republic).

This chapter analyzes these environmental challenges and their corresponding coping strategies in detail.

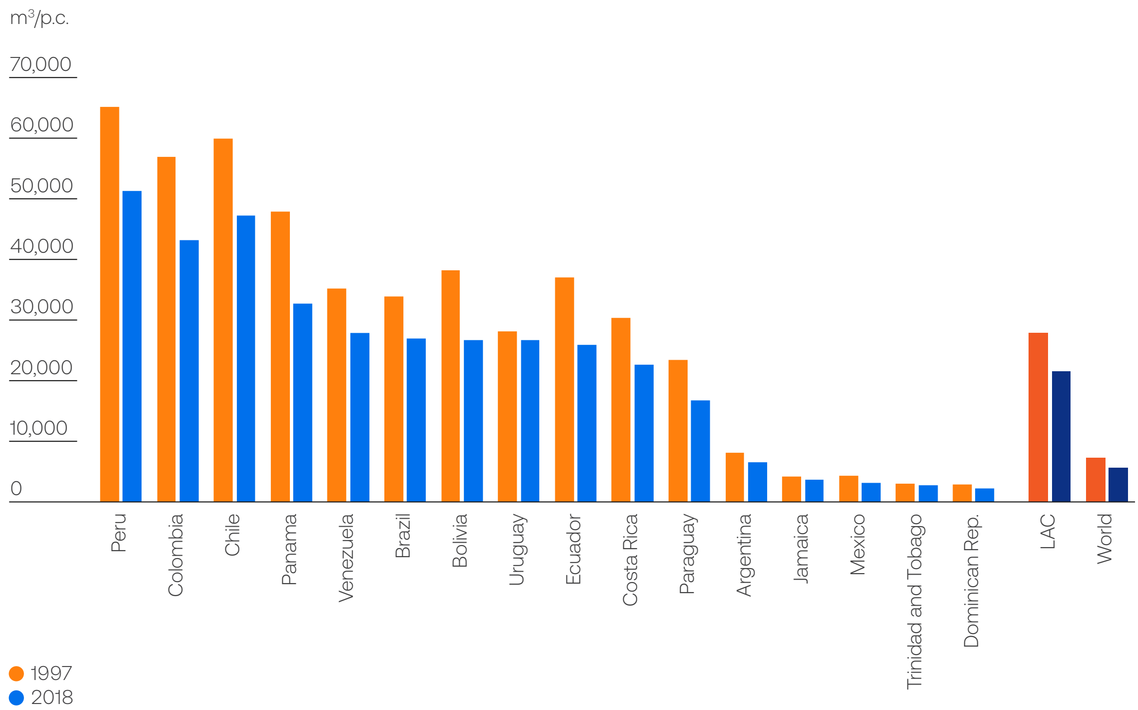
51 Achieving sustainable use of water involves using this resource for various productive and social wellbeing activities, while preserving the natural processes that enable its availability in both quality and quantity (CLAC, 2017). (CLAC, 2017).

Conservation of water resources and related ecosystems

Starting point: Resource availability in Latin America and the Caribbean

The region possesses about one-third of the world's freshwater resources and is home to about 8.5% of the world's population. However, the distribution of these resources is unequal within and among countries. Graph 3.1 shows that there are countries that had low per capita freshwater availability (less than 10,000 m^3) in 2018, namely Argentina, Mexico, Jamaica, Dominican Republic, and Trinidad and Tobago. In the first two countries, although they are continental, the lack of availability was caused by overexploitation, pollution, or misuse of water sources.[52] On the other hand, when comparing the 2018 values with those of 1997, water availability has decreased by more than 20% (in some countries, such as Bolivia, Ecuador and Panama, it has fallen by more than 30%).

Graph 3.1
Freshwater availability per capita by country in m^3 in 1997 and 2018
Source: Authors based on FAO data (n.d.).



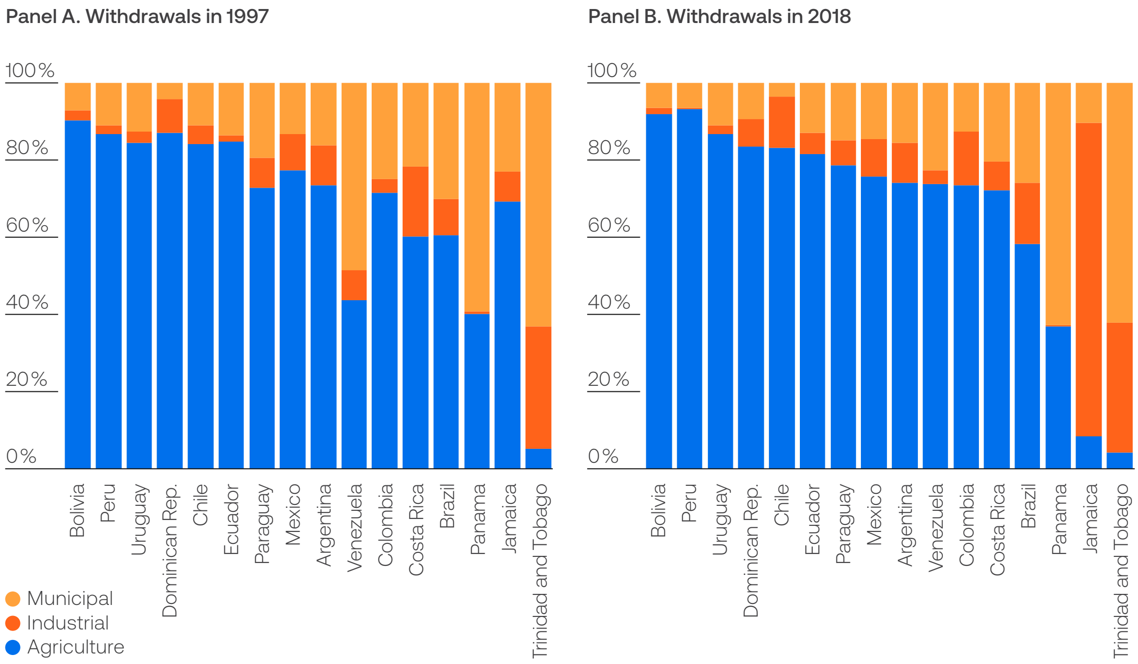
52 See National Water Commission (2018) for the Mexico case and OECD (2018) for the Argentina case.

Water use increased globally by approximately 1.1% per year between 1970 and 2010 (FAO, n.d.). This steady increase is mainly due to growing demand in developing countries and emerging economies, resulting from a combination of population growth, socioeconomic development, and evolving consumption patterns (WWAP, 2016). In the region, agriculture (including irrigation, livestock, and aquaculture) is by far the largest consumer of water, using 80% of annual withdrawals regionally (vs. 67% globally), followed by households (14% vs. 20% globally) and industry (6% vs. 13% globally).

Graph 3.2 illustrates the regional disparities between countries with almost entirely agricultural use (such as Bolivia) and those with a higher share of industrial use (such as Jamaica). Panama has the highest share of domestic water use, although this may include industrial or agricultural establishments connected to the local network.

The withdrawal of water for productive or economic purposes has exerted strong pressure on the availability of water resources, provoking increasing conflicts over its use for different purposes (Martín and Justo, 2015). According to Pacific Institute records (2022), there have been about 1,051 episodes of water-related conflict in the last two decades.[53] Of these, almost 10% have occurred in LAC. Some of the most recent include protests against the expansion of mining activity in Chubut (Argentina) for fear of a reduction in the availability of the resource; protests in Chile over improved access to the resource and the installation of a hydroelectric plant; and disputes between farmers and mining companies over the use of the resource in the Arque River (Bolivia). These situations highlight the need to preserve this natural capital to ensure economies' sustainable development and the conservation of ecosystems related to this resource.

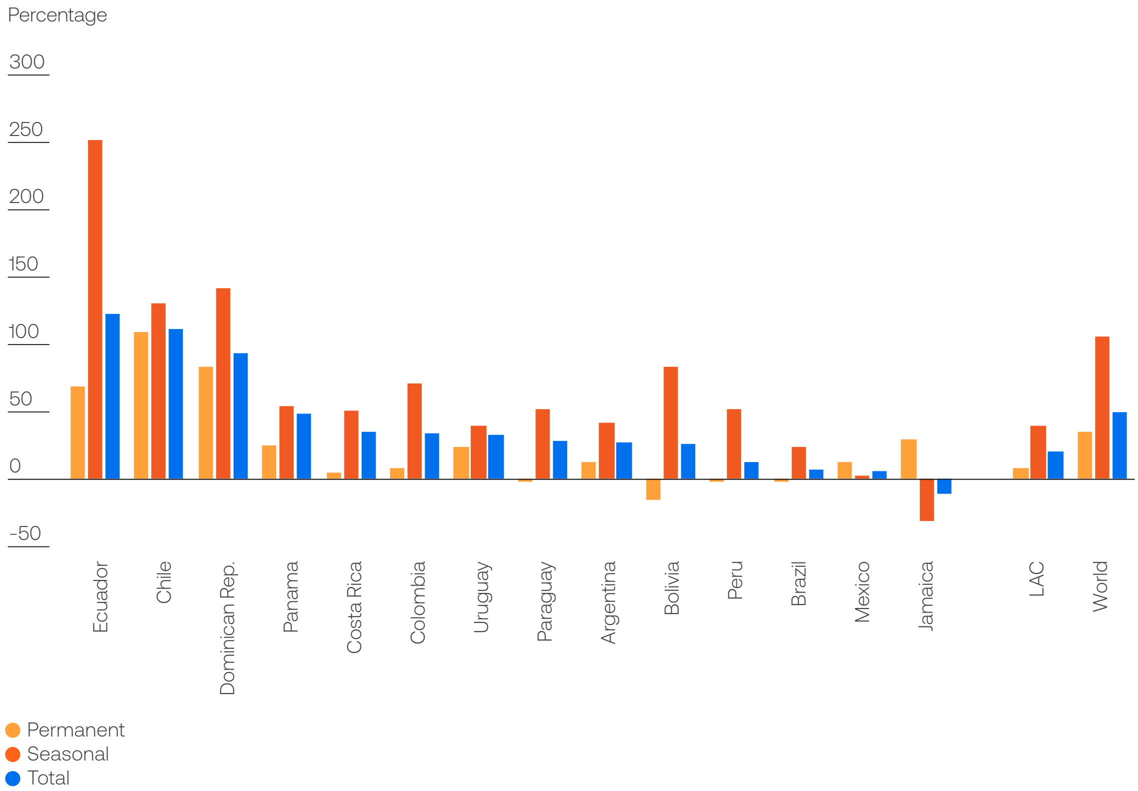
Graph 3.2
Agricultural, industrial and municipal (households) water withdrawals as a percentage of total water withdrawals
Source: Authors based on FAO data (n.d.).



53 Datos accedidos en julio de 2022.

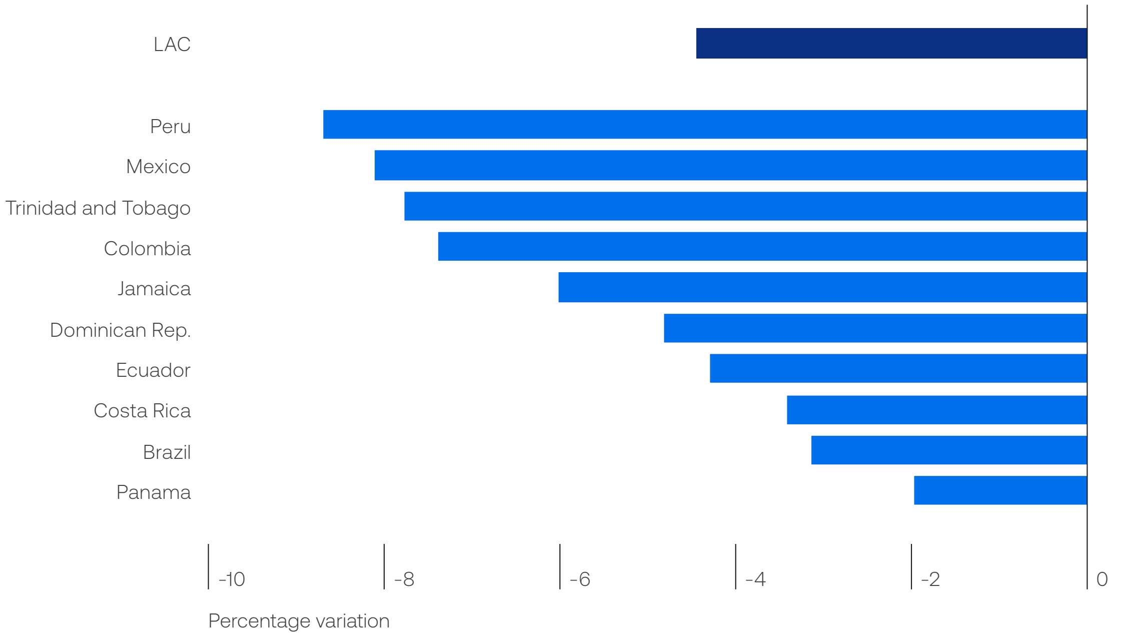
On the other hand, there are disparate experiences among countries in terms of the protection and conservation of water-related ecosystems, particularly the water area of lakes and rivers. In Bolivia, there has been a sharp drop in permanent areas and a sharp increase in seasonal areas between 2000 and the average for 2020 and 2021; in Chile, Ecuador, and the Dominican Republic, there has been a sustained increase; while in Jamaica, the permanent area has increased, but the seasonal area has decreased (Graph 3.3). Graph 3.4 shows a drop in total mangrove cover reported in all the countries, and Graph 3.5 shows the area of wetlands as a percentage of the total land area as of 2017, with a greater concentration in the Mediterranean countries of South America.

Graph 3.3
Percentage change in the permanent and seasonal water area of lakes and rivers between 2000 and the 2020-2021 average
Source: Authors based on UN data (n.d.) for SDG indicator 6.6.1.

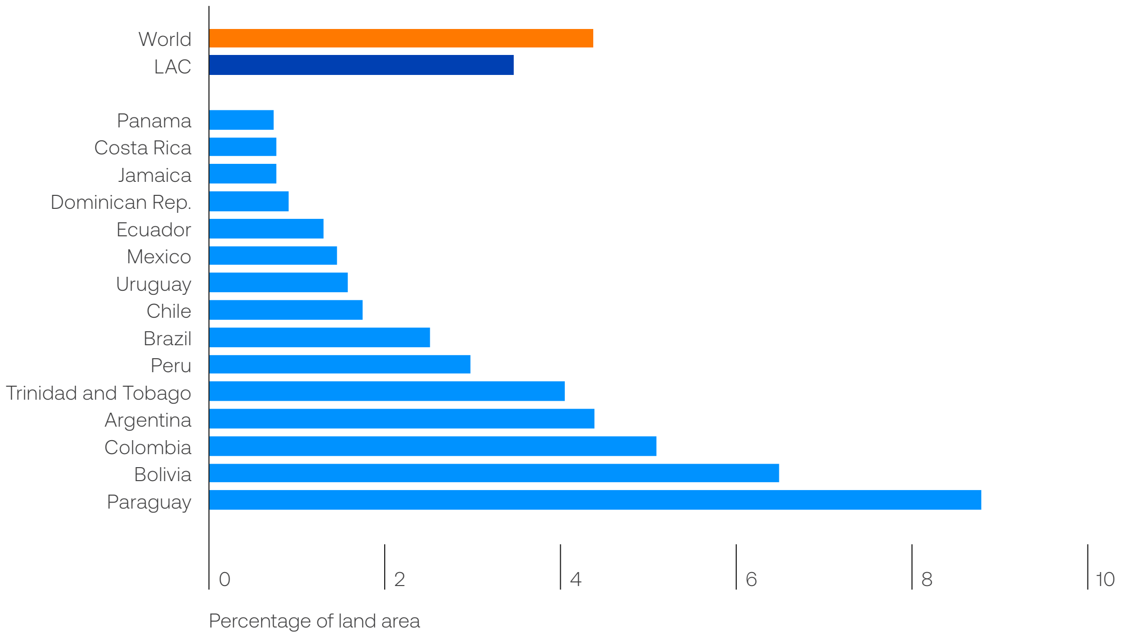


Note: Values for 2020 and 2021 are averaged to control for seasonality between the two years.

Graph 3.4
Percentage change in total mangrove area between 2000 and 2016
Source: Authors based on UN data (n.d.) for SDG indicator 6.6.1.



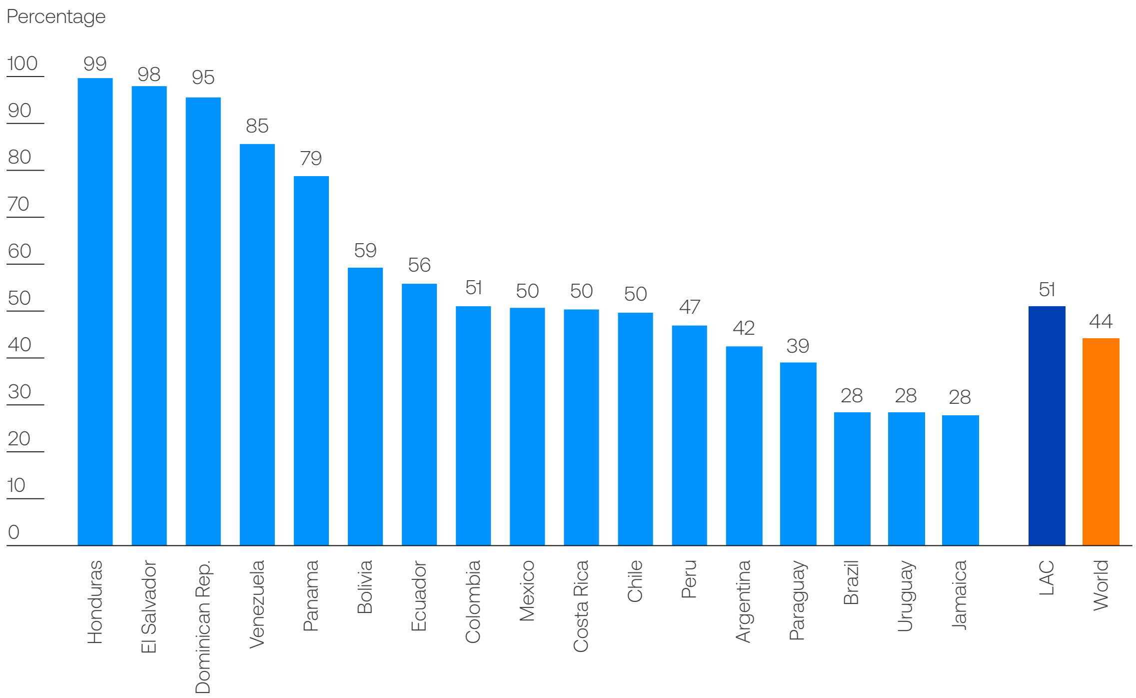
Graph 3.5
Wetland area as a percentage of total land area in 2017
Source: Authors based on UN data (n.d.) for SDG indicator 6.6.1.



Water is an essential natural resource for economic development, and its conservation is vital for the well-being of current and future societies.

In line with ecosystem conservation, a fourth indicator measures the average proportion of Freshwater Key Biodiversity Areas (KBAs) covered by protected areas. Honduras, Dominican Republic, El Salvador, Panama, Panama, and Venezuela have 80% or more of such areas covered by protected areas. In Brazil, Jamaica and Uruguay, coverage drops to 28% (Graph 3.6).

Graph 3.6
Average proportion of Freshwater Key Biodiversity Areas (KBAs) covered by protected areas in 2021
Source: Authors based on UN data (n.d.) for SDG indicator 15.1.2.



Pollution reduction

The main externalities that impact water bodies are pollution and overexploitation. These problems can destroy entire ecosystems, eliminating their benefits (freshwater and food supply, climate regulation, and cultural services) and hindering their sustainability (Saravia et al, 2020).

In many countries of the region, the availability of usable water is compromised by pollution, which is mainly caused by the dumping of untreated urban wastewater (Peña et al., 2019). Wastewater from mining and industrial activities also poses a significant pollution threat and requires specialized treatment to prevent severe damage to ecosystems and biodiversity (Rojas et al., 2019). For example, mining activities can pollute water sources with chemicals, acid mine drainage, higher soil salinization, and waste production (Martín and Justo, 2015). In agriculture, poor water management practices can contaminate water sources with metals, chemical residues, and antibiotics.

In view of this situation, a major environmental challenge related to the conservation of natural capital is to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" (SDG 6.3). To analyze the region's status in regard to this challenge, the UN reports two indicators: the first refers to the proportion of safely treated domestic wastewater flow and the second to the proportion of bodies of water with good ambient water quality.[54]

With respect to the first indicator, the region lags behind the world average (in LAC, 41% of wastewater is safely treated, compared to 60% globally). At the country level, the situation varies dramatically (Graph 3.7). At one extreme, Chile (91%) and Mexico (60%) are the only countries in the region with a treatment percentage above the world average (Bolivia is slightly below); and at the other extreme, El Salvador (12%) and Colombia (21%), the countries with the lowest levels of wastewater treatment.

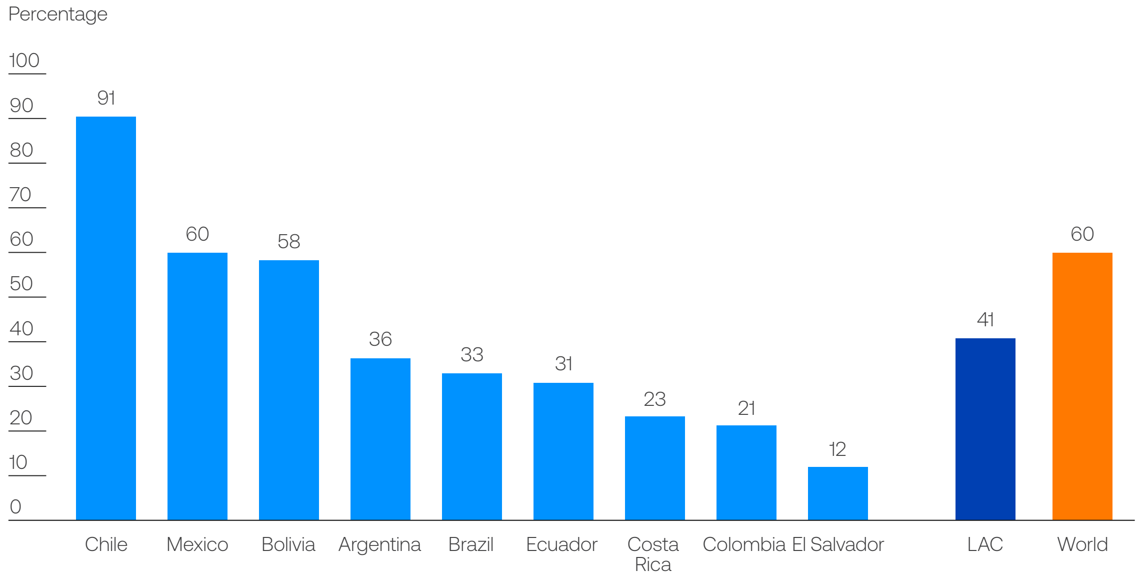
In terms of the proportion of bodies of water with good ambient water quality, the region again lags behind the world average (57% vs. 72%, respectively). That said, several countries perform above this global average (Graph 3.8): Jamaica (92%), Trinidad and Tobago (88%), Chile (84%) and Uruguay (76%). At the other extreme, in Peru and Argentina, bodies of water with good ambient water quality represent only 25% and 18%, respectively.

According to the UN (2022), countries such as Argentina, Brazil, Mexico, Paraguay, and Peru face the challenge of reducing groundwater contamination from natural substances (arsenic and fluoride), anthropogenic pollutants (nitrates, pesticides, etc.), industrial compounds and emerging pollutants (cosmetics, antibiotics, hormones, etc.). In part, this implies resolving the conflicts that arise over the use of and access to the underground resource as a result of careless exploitation and contamination. In this regard, between the first two decades of the 21st century and the last two decades of the 20th century, the number of new conflicts over groundwater depletion and contamination has more than quadrupled. It also highlights the importance of managing the resource under an integrated approach (an aspect that will be addressed later in this chapter).

In short, the contamination of water sources affects not only the availability of the resource but also its quality. In this regard, situations vary greatly among the countries of the region. However, in general, they have low levels of domestic wastewater treatment.

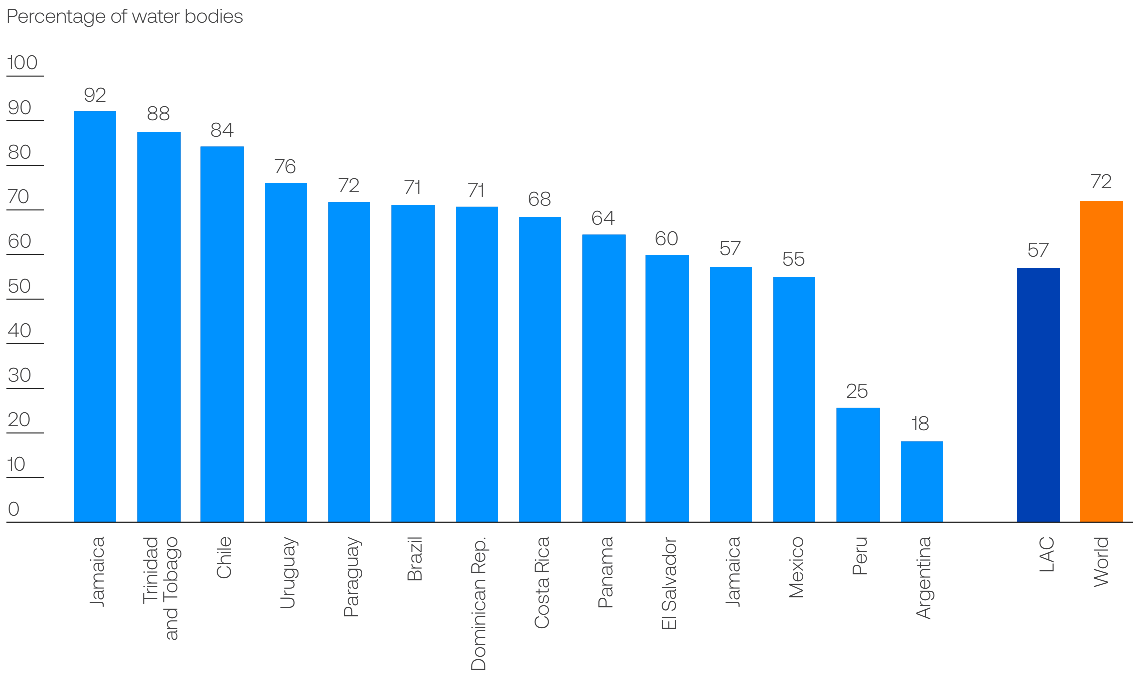
54 Good quality water refers to the resource in bodies of water such as rivers or lakes that, under normal flow conditions, does not pose a threat to human health or the ecosystem. However, measuring it in practice poses challenges due to the changing conditions within the same body of water. (Warner et al., 2020).

Graph 3.7
Proportion of safely treated wastewater in 2020
Source: Authors based on UN data (n.d.) for SDG indicator 6.3.1.



Note: Data for 2020 or the closest year with available information. The figure reported by the United Nations for Bolivia seems high given the characteristics of treatment in the country (water in La Paz is not treated and in the cities of El Alto and Cochabamba treatment is partial).

Graph 3.8
Proportion of water bodies with good ambient water quality in 2020
Source: Authors based on UN data (n.d.) for SDG indicator 6.3.2.



Note: Data for 2020 or the nearest year with available information.

Sustainable use

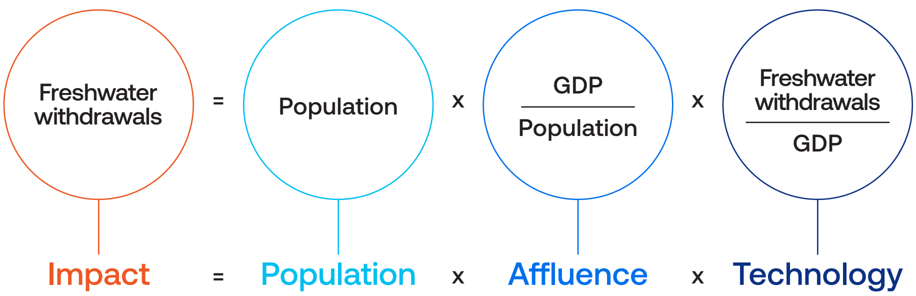
One of the challenges highlighted in the SDGs is the efficient use and withdrawal of freshwater (challenge 6). Using a similar approach to the one used in the chapter on energy, freshwater extraction can be broken down using an approach that disaggregates the human impact on the environment (I) based on population (P), level of activity or affluence (A), and the technology employed for production (T). This framework was developed in the early 1970s by biologists Commoner (1972a and 1972b) and Ehrlich and Holdren (1971; 1972).[55] More recently, UNEP and the International Resource Panel (2019) have modified this approach to analyze the impact of each of the factors (population, inflow/influx and technology) on the demand for natural materials. With this framework, the adapted IPAT formula for the case of water is presented in Figure 3.1.

Panel A of Graph 3.9 applies this formula to the percentage change in freshwater withdrawals in LAC, the European Union, China, and the United States between 2002 and 2017, disaggregated by the different factors explaining that change. Panel B of the same graph does the same for the countries in the region.

LAC has increased its withdrawals (impact) more than comparable countries and regions (1.2% compared to -1.3% for the European Union, -0.5% for the United States and 0.5% for China). The difference with China is remarkable given that this country was an engine of world growth in the comparison period. On the other hand, in all cases, more efficient water use made it possible to compensate to a greater or lesser extent (China, on the one hand, and the European Union, the United States and LAC, on the other) for population and economic growth. Complementary sources confirm the existence of efficiency gains in different sectors: agriculture, services and, most importantly, industry (FAO and UN-Water, 2021).

In LAC, Paraguay (with an annual increase of 7.4% in withdrawals between 2002 and 2017), Colombia and the Dominican Republic (both with rates above 3%) stand out at one extreme, while at the other extreme are Uruguay, Ecuador, Bolivia and Nicaragua (with withdrawal variation rates below 0.5% per year). No country reduced the nominal withdrawal of the resource in the period analyzed. However, with the exception of Paraguay, all of them made efforts to compensate for the level of economic activity and population growth with greater withdrawal efficiency. In four counties—Bolivia, Ecuador, Nicaragua, and Uruguay—efforts represent a reduction in withdrawal per GDP of more than 3.5%.

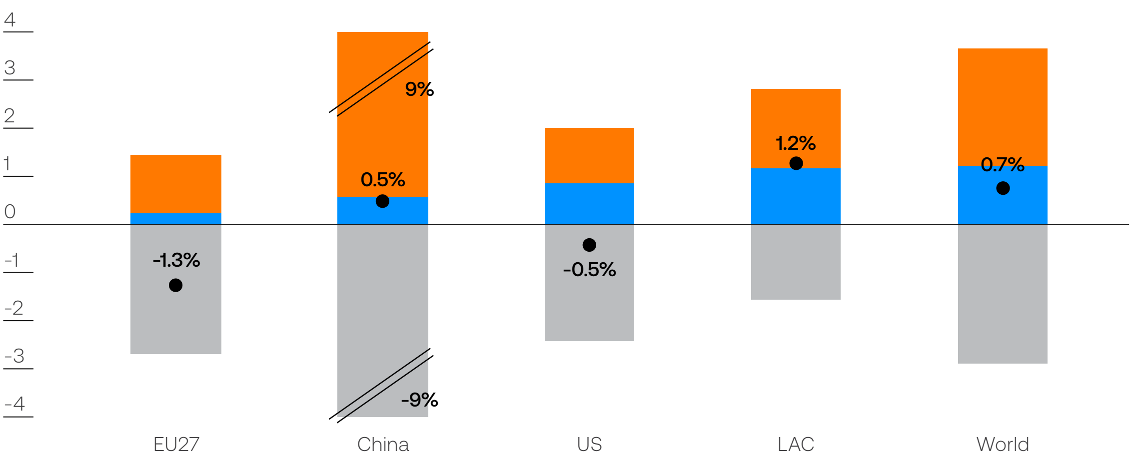
Figure 3.1
IPAT approach for freshwater withdrawal
Source: Authors.



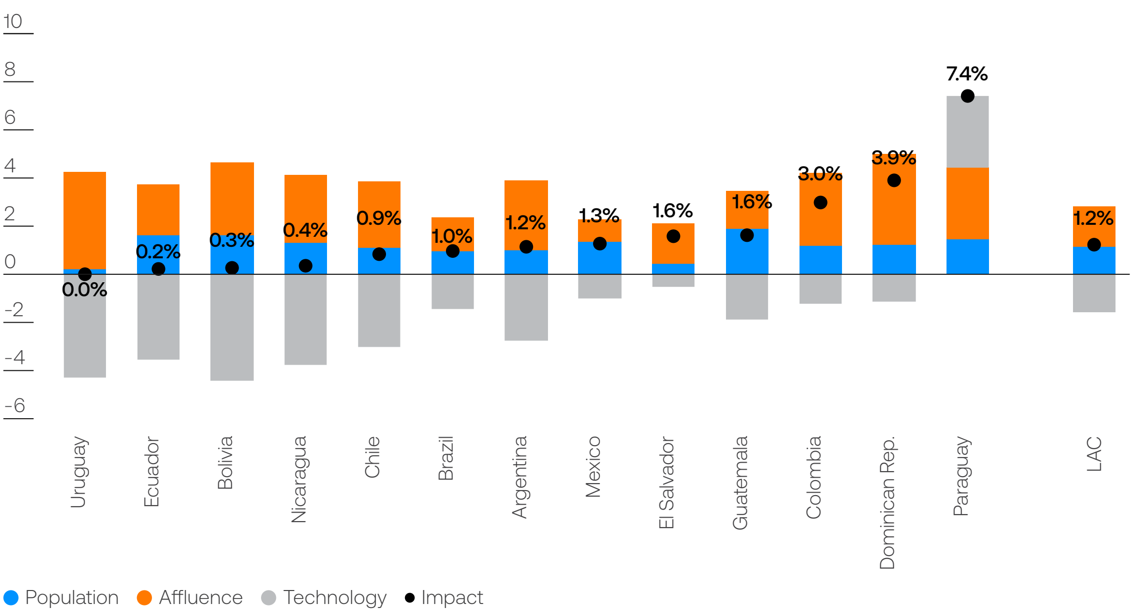
55 The original formula considered some measure of pollution as the environmental impact variable. However, the simplicity of the equation allowed for its easy adaptation to the development of subsequent approaches such as the Kaya identity.

Graph 3.9
Annualized percentage change (2002-2017) of the factors analyzed in the IPAT formula for selected regions and countries inside and outside Latin America and the Caribbean
Source: Authors based on World Bank data (n.d.a).

Panel A. Variation for LAC and other selected countries and regions



Panel B. Variation for LAC countries

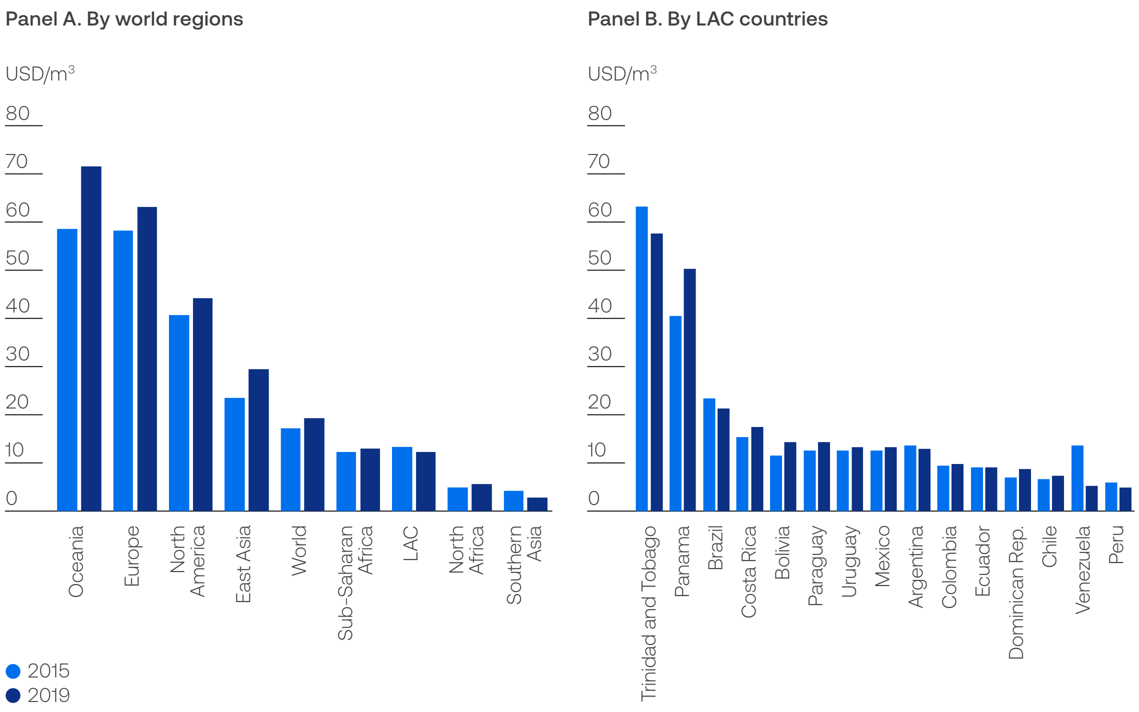


Water use efficiency is usually measured based on the ratio between value added and the unit of water used by all sectors (which is the inverse of the concept of technology in the IPAT approach). Latin America and the Caribbean (LAC) generates less GDP per m^3 of water than the rest of the regions (Graph 3.10). In 2019, the average water use efficiency worldwide was USD 19/m^3 compared to USD 13/m^3 in LAC, a value that exceeds only that of North Africa and South Asia.[56]

The efficiency indicator for the region again presents regional disparities. On the one hand, Panama and Trinidad and Tobago have high levels of value-added, above USD 50/m^3. In the former case, this is mainly due to the value contributed by the activity of the canal. They are followed by Brazil, with USD 21/m^3, while Costa Rica registers an efficiency of USD 17/m^3. At the other extreme are Chile, Ecuador, Jamaica, the Dominican Republic, and Venezuela with values below USD 10/m^3.

Efficiency values are strongly influenced by the main economic activities carried out in each country and how they are distributed among services, industry, and agriculture, among other factors. In particular, primary activities—which demand large volumes of water for production—are the most developed in LAC. A big primary activity in the region is irrigated agriculture,[57] with an average water use efficiency of USD 0.3/m^3 in LAC in 2019, compared to USD 0.6/m^3 worldwide (Graph 3.11). Only Ecuador and Trinidad and Tobago rank above the global average, while countries such as Colombia, Paraguay, and Venezuela generate a sectoral value added below USD 0.2/m^3.

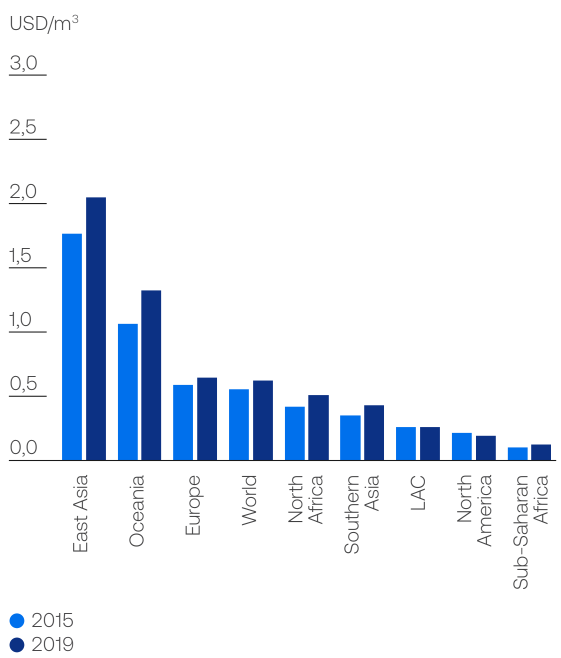
Graph 3.10
Water use efficiency by region and LAC countries (USD/m^3) in 2015 and 2019
Source: Authors based on FAO data (n.d.) for SDG indicator 6.4.1.

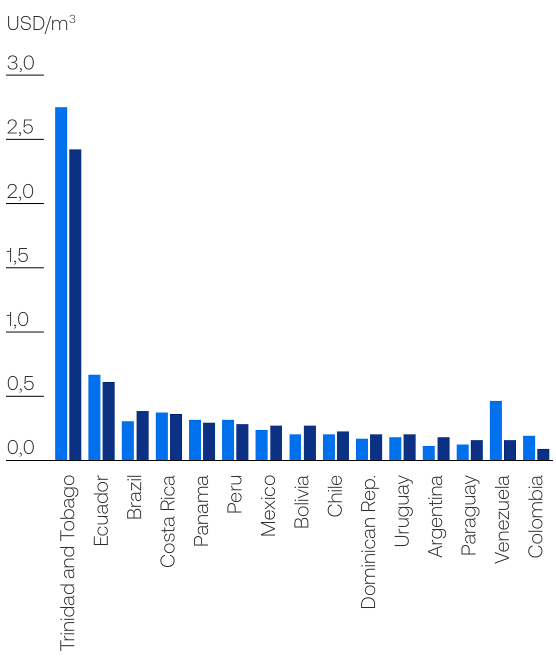


56 This indicator should be used as a proxy for water use efficiency, which shows significant regional disparities (such as differences in development levels, productive structures, and water scarcity between Europe and LAC).

57 Forestry and fishing are also included in this category. The detailed methodology for constructing the indicator can be found in FAO (2019). However, the available information does not allow for inferences to be made about the determinants of water use efficiency, such as specific water usage, factor allocation, other components of the value chain (distribution to the agricultural sector, irrigation practices, crop utilization), heterogeneity between activities (composition effects), among others.

Graph 3.11
Water use efficiency in irrigated agriculture (USD/m³) in 2015 and 2019
Source: Authors based on FAO data (n.d.).





The agricultural sector must increase production by 50% in the next 30 years (FAO, 2017). This challenge aims to increase water use efficiency and, for countries with low water availability, to promote its sustainable use.

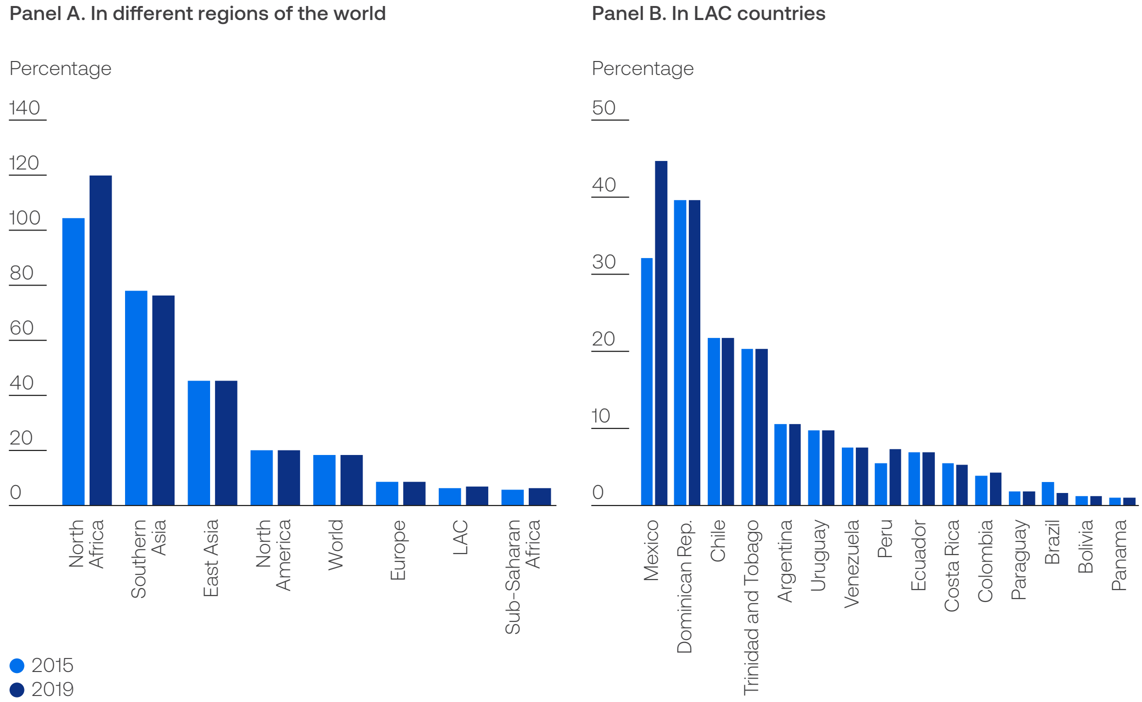
Efficiency technologies have been developed to optimize water usage in agriculture. One example is hydroponics, which has evolved to incorporate closed recirculation systems, reducing water needs to match evapotranspiration levels. Another system that has shown promise in Europe and the United States is the use of closed and semi-closed greenhouses, which result in considerable water and energy savings.[58] By combining these technologies, water usage can be reduced to half or less than the water loss through plant transpiration, making it a viable solution for water-scarce regions. For instance, high-tech greenhouses in Mexico feature fully enclosed spaces with automated irrigation that allocate water based on plant needs using precision dosing, drip irrigation, micro-sprinkling, pumping, and sensor technologies. These features result in minimal evaporation and water loss. However, implementing these technologies requires significant investments, and therefore, they are mainly focused on export crops that can provide a return on investment (Pratt and Ortega, 2019).

Water stress is an important indicator for evaluating the sustainable use of water resources. It is approximated by the ratio of water withdrawal to available renewable water resources. Graph 3.12 presents this indicator for different regions for the years 2015 and 2019. According to the graph, Europe, LAC, and Sub-Saharan Africa had the lowest levels of water stress, ranging from 6% to 8%. At the other extreme, North Africa had the highest levels of water stress, with water abstraction rates exceeding 100%, highlighting the urgent need for more sustainable water management practices in regions that are facing water scarcity.

58 In this type of system, it is possible to recover the water transpired by plants through condensation and use it for irrigation purposes.

Graph 3.12
Level of water stress (percentage of renewable water resources withdrawn in the year) by region in 2015 and 2019

Source: Authors based on FAO data (n.d.) for SDG indicator 6.4.2.



Note: Renewable water resources are the difference between total water resources and the freshwater flows needed to sustain freshwater ecosystems and the human livelihoods and well-being that depend on them.

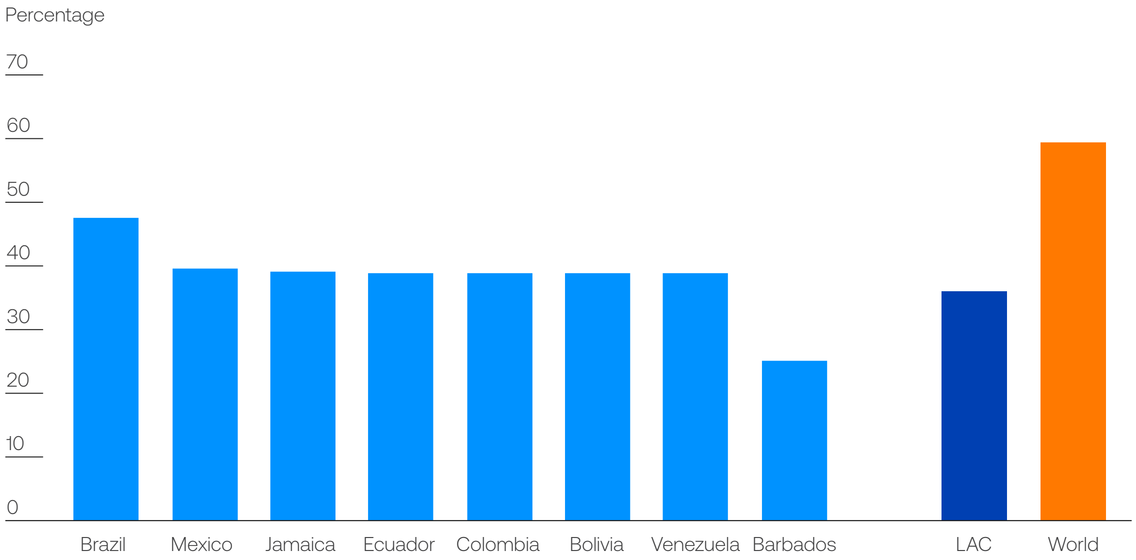
Despite the low relative withdrawal value for the Latin America and the Caribbean (LAC) region, certain countries such as Mexico and the Dominican Republic exhibit high withdrawal rates (above 40%), while others like Bolivia and Panama have withdrawal rates in the order of 1%. Furthermore, Mexico's withdrawal rate has increased relative to the stock between 2015 and 2019. This indicates a potential future water stress issue if the trend continues.

One of the major obstacles to improving efficiency rates in the water sector is the significant water losses in drinking water systems or production processes. In the LAC region, unaccounted drinking water in urban systems in most countries exceeds 35%. This high level of water loss is due to the poor condition of networks and bad business practices such as clandestine connections and vandalism of micro-meters (Rojas, 2014). This situation also exists in the agricultural sector, affecting the sustainability of water resource use. On average, the percentage of water withdrawn in relation to irrigation requirements is 36% in LAC, which is much lower than the world average.

In summary, the expansion of the agricultural sector in LAC has contributed to low efficiency indicators compared to other regions. However, there are opportunities to enhance efficiency, such as the development of new technologies and reduction of water losses. Over the last two decades, water stress has increased considerably, highlighting the need to alter this trend and achieve sustainable development of the economies.

In the majority of LAC countries, unaccounted water in urban systems surpasses 35%, with an average of only 36% of extracted water being utilized in productive processes.

Graph 3.13
Ratio (percentage) between irrigation water requirements and abstraction in 2018
Source: Authors based on FAO data (n.d.).



Dimensions of service gaps and other strategic sector challenges

In addition to the environmental situation, the region still faces challenges specific to the sector, such as addressing inequalities in access to and quality of drinking water and sanitation.

For water and sanitation services, the SDGs emphasize the need to guarantee universal access at an affordable price adhering to quality standards. These objectives are reflected in CAF's Water Strategy 2019-2022 (Rojas et al., 2019) and in the recent document on water security (Lentini, 2022). Several objectives stand out. They include guaranteeing access to these services and compliance with international quality standards so water is suitable and safe for human consumption; achieving water use efficiencies and protecting water bodies from contamination; ensuring water availability for the promotion of sustainable productive development; conserving ecosystems; and reducing risks associated with lack or excess of water.

Service gaps in water and sanitation can be measured in multiple dimensions: access, cost/affordability, and quality (Cont et al., 2021). Appendix 3.1 presents an analysis of service gaps for the sector, concluding that LAC still needs to make significant efforts to close these deficiencies that affect the quality of life of its population.

Specifically, the region shows good performance in drinking water coverage, as of 2020, 97% of the population had access to at least a basic service (with a backlog in rural populations). This proportion indicates that the region is close to achieving universal service coverage (100%). The cost for users (average tariff) varies greatly across countries in the region. In 2021, the average tariff for the combined service (water and sanitation) ranged from USD 0.53/m^3 in Mexico and Peru to USD 2.11/m^3 in Chile. Finally, the most pronounced gap is in the quality dimension: in 2020, only 75% of the population in the region had access to a quality service, measured as access to water managed safely (from an improved source, available when required, and free of fecal and chemical contamination). This percentage contrasts with that of developed regions, such as Europe (98%) and North America (97%).

Table 3.1
Drinking water and sanitation service gaps for LAC
Source: Authors based on information in Appendix 3.1.

Dimension	Drinking water	Sanitation
Access	Levels close to universal access to basic drinking water service. At the rural level, there are still deficits.	Basic access: 88%, far from universal access.
Cost/affordability	Heterogeneity between and within countries. Rates range from USD 0.53/m^3 to USD 2.11/m^3. Low or medium affordability (the share of income allocated to this service doubles that in developed countries).	
Quality	Only 75% of the population has access to safely managed water, far below developed countries. This deficit is even more evident in rural areas.	One in three people has access to quality sanitation services in the region.

Note: The data on which this table is based correspond to the most recent year available (between 2019 and 2021, depending on the indicator).

In terms of basic access to sanitation, the region is still far from achieving universal access (average coverage of 88%), although several countries have values close to 100% (Argentina, Chile, Costa Rica, Uruguay and Venezuela). This gap widens even further when analyzing access to quality sanitation services. In 2020, barely one in three people in the region had access to quality sanitation facilities at home (34%), with extreme cases such as Colombia (17%). In rural areas, only three countries report this dimension.

On the other hand, the challenges in the water sector were affected by the shock caused by the COVID-19 pandemic. In this regard, as documented by Rojas (2020), operators were exposed to both operational difficulties and challenges (due to demands and requirements regarding water quality and the rehabilitation of service to disconnected users) and financial ones (in the context of increasing payment defaults). In light of all this, the authorities had to resort to different policy measures in order to preserve the capacity of users, especially the most vulnerable, to meet their basic needs in relation to water, sanitation and hygiene; raise awareness among citizens on hand washing with soap and water and efficient use of water in the home; ensure the continuity and safety of water and sanitation services; and provide technical and financial support to service providers (SIWI, 2020).

Box 3.1
Lessons learned from COVID-19 in the water sector

Water supply and sanitation services have played an essential role in the context of the COVID-19 pandemic, given the importance of the resource in health measures (e.g., frequent hand washing with soap and water). This has highlighted the importance of ensuring universal access to safe drinking water in the countries of the region.

Mobilizing private capital is key to closing the infrastructure financing gap in the sector, especially since the COVID-19 pandemic has further limited government investment capacity. Therefore, it is crucial to have flexible legal and institutional frameworks that promote alternative sources of financing, especially in emergency contexts.

Furthermore, the arrival of COVID-19 has put the digital infrastructure of the region's countries to the test. Governments must strengthen digital resilience since other crises caused by viruses or natural disasters are likely to arise, which could jeopardize not only technological infrastructure but also critical infrastructure such as telecommunications networks, energy networks, airports, etc. This would have a severe impact on the provision of essential services to the population. Therefore, the lesson learned is that the sector's digitization can contribute to ensuring continuous access to the resource, reducing the exposure of workers and users (via remote leak detection solutions and even service billing) and detecting new diseases early and monitoring them (Matheri et al., 2022).

In summary, based on the lessons learned from COVID-19, the sector must intensify its efforts to ensure universal access to quality service, particularly in dispersed and rural populations, develop emergency plans for extreme events, and promote digitalization in all stages.

Ways of approaching water management with a sustainability focus

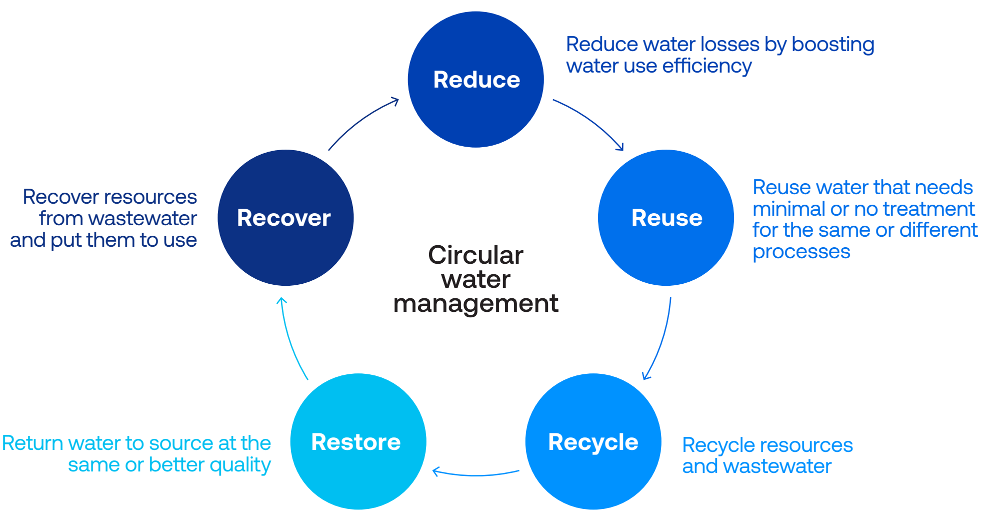
SDG 6 is about ensuring water availability and its sustainable management (including sanitation). Two important concepts for water management are the circular economy and the integrated approach to the resource, which are discussed below.

Circular economy

As part of the environmental challenge of sustainable resource use, pollution reduction and ecosystem conservation, it is important to increase and improve recycling and reuse practices. These practices incorporate the circular economy into the sectoral policy for the integral use of water flows. Thus, they help to meet the objectives of containing demand by increasing flows in the hydrological cycle (reclaimed water), reducing pressure (less water exploitation) and reducing discharges into the environment (Figure 3.2 outlines the circular economy process in the water sector).

In recent years, the circular economy has gained importance as an approach that favors sustainable development. LAC countries have implemented or are planning new policies, public initiatives and roadmaps linked to the circular economy. The most visible example is wastewater treatment plants. Once treated, wastewater can be reused in agricultural and industrial activities, while treatment byproducts can be used for energy generation and soil improvement. In fact, as of 2021, 11 LAC governments were working to include the circular economy in their NDC guidelines (Argentina, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Mexico, Nicaragua, Panama and Paraguay). Another example is the "Roadmap towards Sustainable Management of Plastics in the Pacific Alliance Countries" published in December 2020 and adopted by Chile, Colombia, Mexico, and Peru. Another important area of action is the adoption of circular economy models (Circular Economy Coalition, 2022). However, these technically attractive models face various regulatory, institutional, financial, and environmental challenges (CONAMA, 2019).

Figure 3.2
Circular water management
Source: WBCSD (2017).



As noted in CAF (2018), in the case of reuse for irrigation, technical discussions make it difficult to create adequate regulations and mechanisms to ensure compliance, especially in developing countries. Some problems are the non-existence of accredited laboratories and the current incapacity of the entity in charge of irrigation surveillance or control. Others have to do with the investment requirements for appropriating the benefits of treated water for different uses (e.g. irrigation or electricity generation). Another case is the use of biosolids as soil conditioners for crops. In many countries, sludge is considered hazardous waste and, as such, must be confined in special landfills. The reuse of biosolids implies revising and complementing regulations, but, above all, it imposes a paradigm shift on institutions, farmers and individuals. Moreover, the preservation of nutrients in biosolids that provide value entails a risk that bacteria (coliforms) or parasites (helminths) that are harmful to human health may also be preserved in that process.

Water recycling has evolved in recent years, incorporating strategies that distinguish potable and non-potable water reuse and centralized versus decentralized systems (CUWA, 2019). Figure 3.3 illustrates these different strategies and their interaction.

Box 3.2
Circular economy: The Cerro Verde case in Arequipa (Peru)

Source: Proactive (2019).

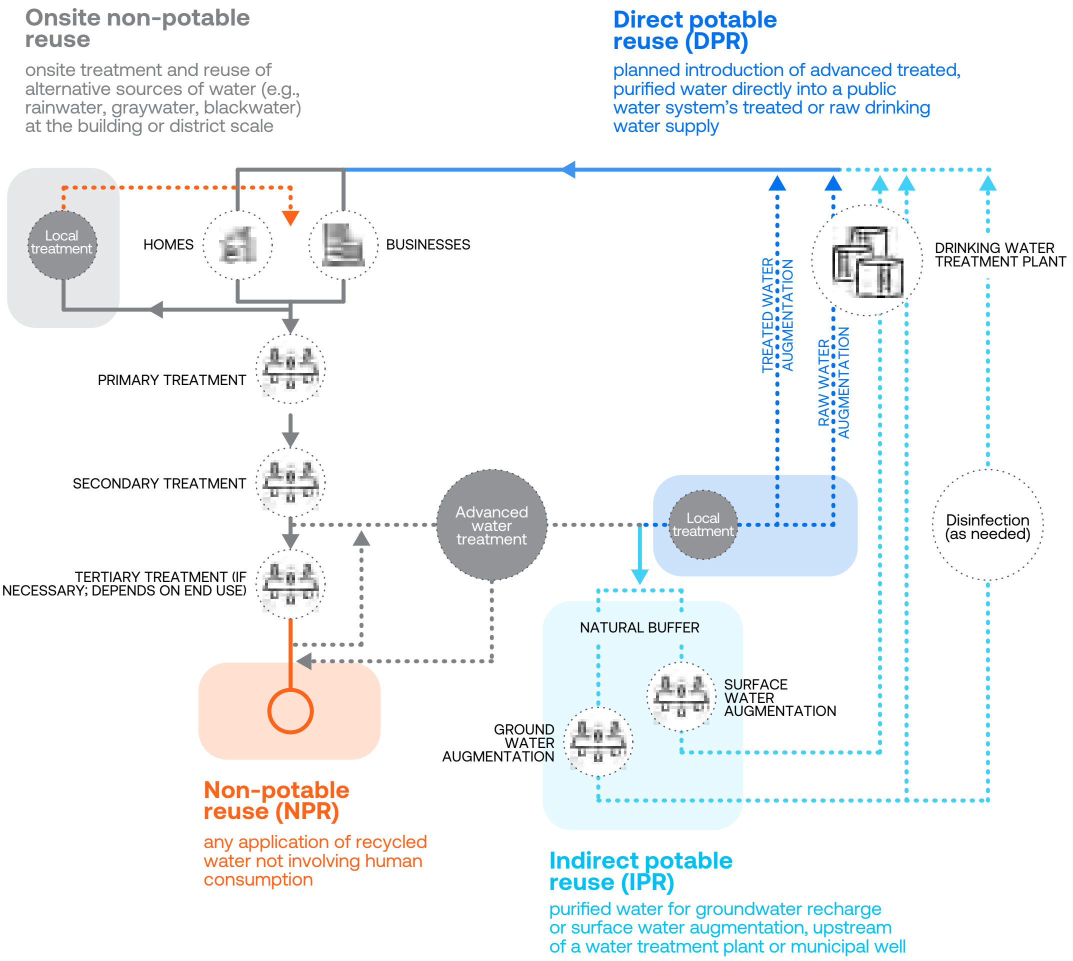
Discharges into the Chili River, in Arequipa, Peru, can be traced to as many as 35 sources along its waterway, from industrial (3%), agricultural (32%) and domestic (65%) activities. This means that almost two-thirds of the river's sources were Arequipa's untreated sewage, contaminating downstream the main source of this resource, and impacting the health and quality of life of the entire population. This contamination resulted in significant damage to the agricultural sector and producers were unable to export their products, which failed to meet minimum quality and health standards.

To address this issue, the Cerro Verde Production Unit expansion project presented a solution. Through a framework agreement and seven specific agreements signed with the Peruvian Potable Water and Sewage Service, the mining company Sociedad Minera Cerro Verde agreed to cover the cost of the construction, operation, and maintenance of the "La Enlozada" Wastewater Treatment System. In exchange, its operations would be able to take an annual average of 1m3/s of treated wastewater, returning the surplus to the Chili River with water suitable for agriculture.

The project's benefits are two-fold. On the one hand, it improved the viability of the Cerro Verde Production Unit expansion, including an increase in the production of copper (more than 270,000 tons per year) and molybdenum (6,800 tons per year), leading to an increase in the amount of product sold. On the other hand, it had multiple social impacts, particularly in the agricultural sector, where the improved quality of irrigation water led to a significant increase in the value of agricultural land.

In the United States, decentralized reuse systems have emerged. For example, the Solaire building in New York City has a wastewater treatment system that reuses treated water for cooling towers and toilet drainage, thereby avoiding transportation costs and associated energy use. The building also has a roof garden with a rainwater retention system. These strategies, combined with the use of water-efficient appliances, reduce the building's potable water use by up to 43% (Epstein, 2008), serving as an example of a distributed systems approach for wastewater treatment and capture.

Figure 3.3
Water reuse strategies
Source: CUWA (2019).



Integrated water resources management

In a context of increasing scarcity due to demographic and climate factors, (public and private) management of water resources entails new challenges in terms of water allocation, highlighting the need for an integrated approach. According to the Global Water Partnership, Integrated Water Resources Management (IWRM) is a process that promotes the coordinated development and management of water, land, and related resources, seeking to maximize social and economic wellbeing without compromising the sustainability of aquatic ecosystems (GWP, 2000, p.22).

This conceptual management framework includes key concepts such as integration, decentralization, participation, and sustainability. In particular, integration should be twofold: horizontal, involving all sectors that use or affect water resources, and vertical, coordinating efforts among local, regional, national, and international institutions (Xie, 2006). In fact, a particularly critical dimension in terms of competition for water resources and their availability or quality is that of transboundary basins, which involve two or more countries or subnational jurisdictions. In this regard, the concept of an integrated basin governance system seeks to promote coordination among the different actors involved (OECD, 2015).

Coordination among different sectors (and even among different countries) is essential to achieving the other SDGs related to water. In addition to its environmental objective, this goal has an economic component, as it is the key tool for addressing the challenges related to the multiple uses of this scarce resource, which in turn generate externalities. Thus, all water uses should be considered in an integrated way for their management, use, and conservation, under a logical unit of the hydrographic basin (GWP Central America, 2013).

In the context of the SDGs, two indicators point to IWRM dimensions. First, the degree of implementation of IWRM is tracked based on the existence of policies, laws, institutional frameworks, and adequate financing for this purpose. Countries report every three or four years on the results of this indicator, which arise from a survey covering the four main dimensions of IWRM: (1) enabling environment (laws, policies, and plans); (2) institutions and participation; (3) management instruments; and (4) financing. Each question is scored on a scale of 0 to 100, guided by specific threshold descriptions (UN-Water, 2021). Table 3.2 illustrates the levels considered for implementing IWRM.

Currently, most countries in the region have implemented the foundations for IWRM. However, the regional level of progress is considered medium-low in the latest measurement (2020), behind the rest of the regions of the world (panel A of figure 3.14), registering a slight improvement compared to 2017.

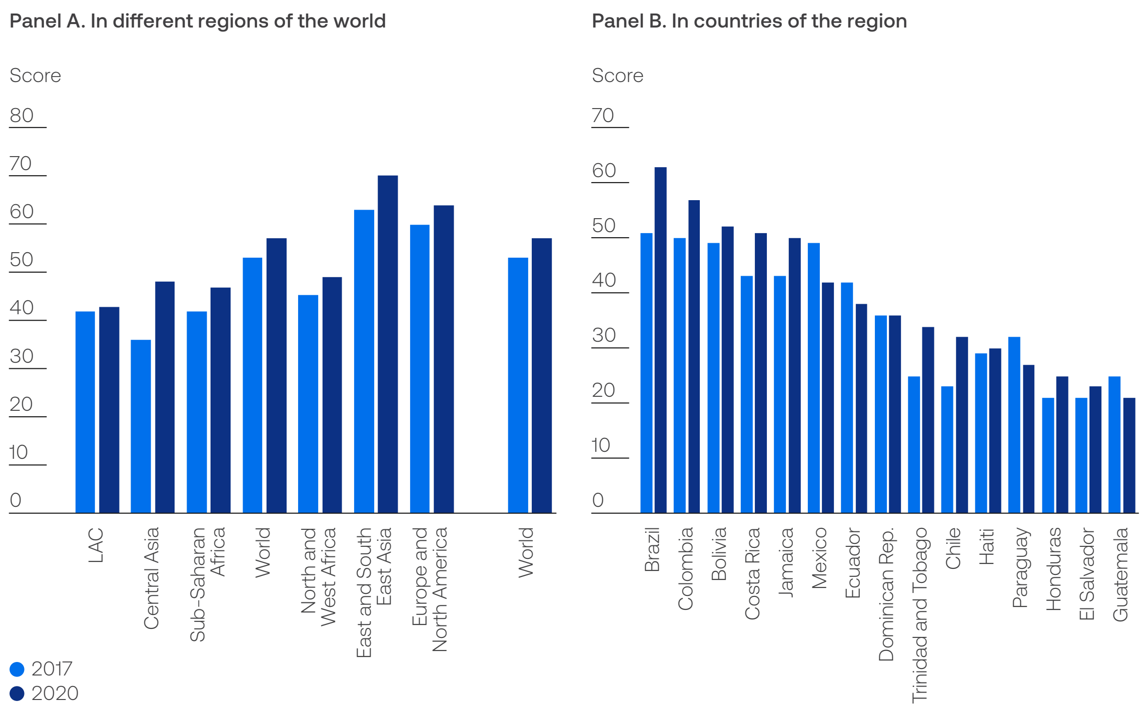
Table 3.2
Levels of implementation of IWRM and their interpretation
Source: UN-Water (2021).

Level	Score range	General interpretation of scores
Very low	0-10	The development of elements of IWRM has generally not started or has stalled.
Under	11-30	Implementation of elements of IWRM has generally begun but with limited acceptance across the country and potentially low participation of stakeholder groups.
Low medium	31-50	The elements of IWRM are generally institutionalized and implementation is underway.
Medium-high	51-70	The capacity to implement elements of IWRM is generally adequate and the elements are generally implemented in long-term programs.
High	71-90	The objectives of the IWRM program and plan are generally met, and geographic coverage and stakeholder participation are generally good.
Very high	91-100	The vast majority of IWRM elements are fully implemented, objectives are consistently achieved, and plans and programs are periodically evaluated and reviewed.

The percentage of properly treated water (41%) in the region lags compared to the global average (60%), which is the main cause of contamination.

At the individual level (panel B of Graph 3.14), four countries are in the medium-high category (Brazil, Colombia, Bolivia and Costa Rica, in that order), and only Brazil is considered potentially capable of meeting this target by 2030 (UN Environment and Cepei, 2018).

Graph 3.14
Degree of IWRM implementation in 2017 and 2020
Source: Authors based on UN data (n.d.) for SDG indicator 6.5.1.



Box 3.3
IWRM in Brazil

Source: UNEP-DHI (2021).

Brazil represents the most successful case of IWRM implementation in Latin America and the Caribbean. In 1997, Federal Law 9433 established the National Water Resources Policy. A National Water Resources Plan was later launched in 2006 to monitor and review the policy's objectives and implementation, which was valid until 2020. In 2021, a new plan for 2022-2040, covering the first dimension of the indicator (enabling environment), came into effect.

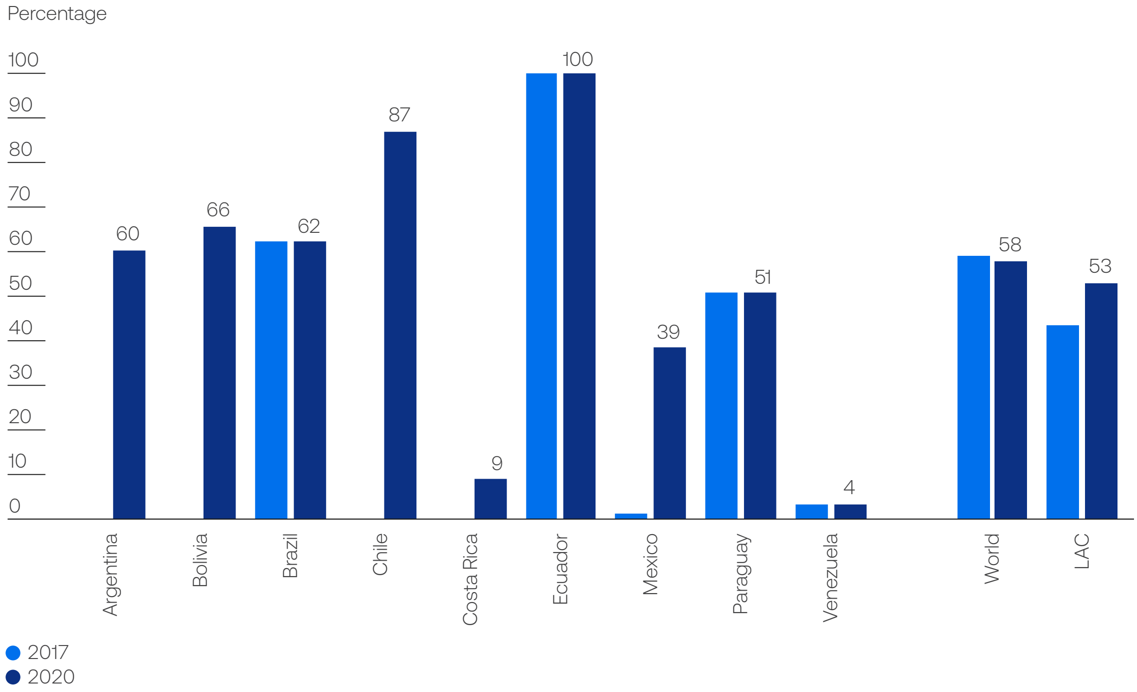
Regarding the second dimension, which concerns institutions and participation, Brazil's water sector has a consolidated regulator in the National Water Agency (ANA) with excellent technical personnel for water resource management. The sector also has consolidated ministries and sectoral agencies. The ANA works together with other ministries, regulatory agencies, environmental agencies, and other sectors to implement IWRM. Interministerial committees are created as needed to discuss water-related issues. Finally, basin committees serve as mechanisms for collaboration and citizen participation.

The third dimension concerns management instruments. Brazil has a national network that provides good spatial coverage for monitoring the flow of surface water masses. The network includes telemetric stations, whose data is systematized and made available to the general public. Brazil also implemented a specific national program (situation room) in all units of the country. Situation rooms are integrated with agencies that already work on the prevention and occurrence of disaster situations.

In the fourth dimension, which concerns financing, the ANA has significant financial resources, partly from the hydroelectric sector's financial compensation, which has majority participation in the country's energy matrix. Some basins have their own financial resources (revenues) as they charge users for water use. According to the National Water Resources Policy, this type of revenue should be applied to improve IWRM in the basin where the charge is made. It should also be noted that in Brazil's transboundary agreements, the country is one of the main funders, and the resources for the Amazon and Plata basin agreements predominantly come from Brazil.

In Central and South America and the Caribbean, there are 97 transboundary hydrographic basins (69 river basins, six lake and reservoir basins, and 22 aquifer basins; ILEC et al., 2016a and 2016b). Three large basins (Amazon, Plata, and Orinoco) account for 92% of the total area of these basins (Unesco and CODIA, 2022). Graph 3.15 shows the proportion of water basins subject to cooperation agreements.

Graph 3.15
Percentage of transboundary water basins subject to operational arrangements for water cooperation
Source: Authors based on UN data (n.d.) for SDG indicator 6.5.2.



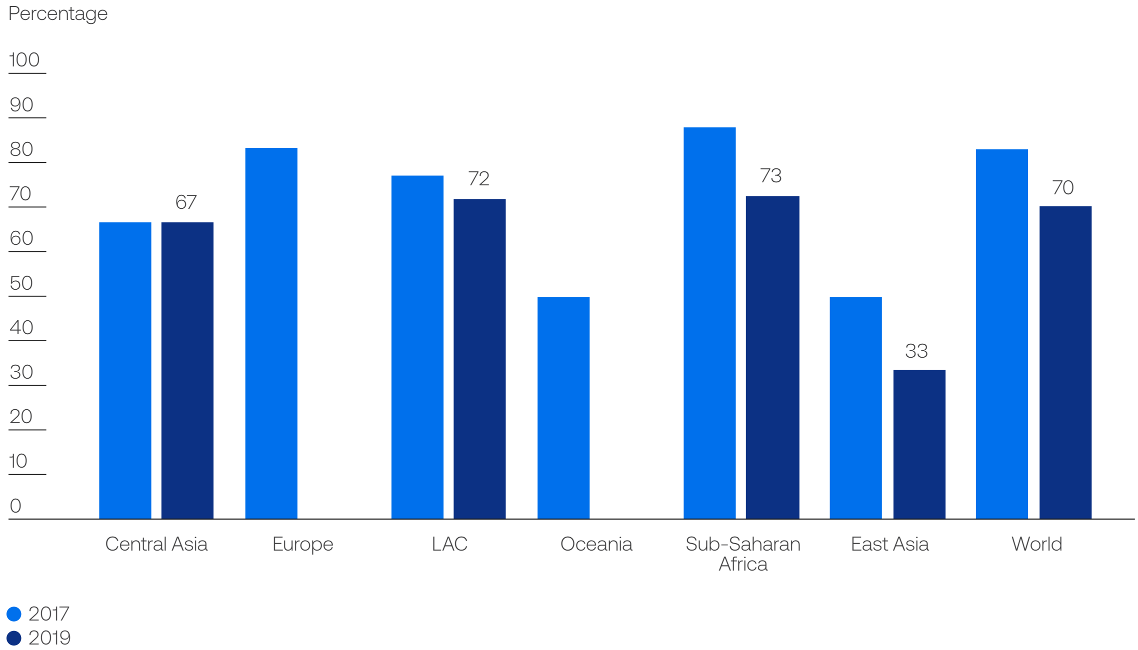
Note: The LAC value corresponds to the simple average of the countries that reported information in the corresponding years.

Finally, in the framework of IWRM, local communities have a fundamental role in the conservation and management of water resources, mainly in those actions that must be carried out on a small scale. Beyond the promotion of management at the national and multinational levels, monitoring and management at the local level have a high potential (Bunclark et al., 2011).

LAC has extensive experience in community management of the resource (which is led by local actors and provides services on a small scale). Community organizations play an important role in water resource management in the region; they provide water services and are led by local actors who have created their own rules and rights under principles of self-management, collective work and local democracy. In more general terms, community management facilitates the incorporation of a "common good" vision that takes into account private and social costs and promotes transparency in resource management (Acosta Maldonado et al., 2019).

The target of SDG 6.b recognizes this potential and seeks to "support and strengthen the participation of local communities in improving water and sanitation management." Progress toward this target is monitored through the tracking of established policies and procedures that are operational for the participation of local communities in water and sanitation management (Graph 3.16). In this regard, the proportion of Latin America and the Caribbean countries promoting the participation of local communities is high, similar to Europe.

Graph 3.16
Percentage of countries with procedures in place for local community participation in water and sanitation management by world region
Source: Authors based on UN (n.d.) for SDG indicator 6.b.1.



The region still has a long way to go to achieve IWRM, which is essential for the proper use of water resources. UN-Water surveys (2021) consistently reveal challenges related to policy coordination and alignment, weaknesses in institutions responsible for enforcing legislative frameworks, delayed regulatory frameworks, lack of funding and capacity to execute projects, and lack of control and information. All of this points to the need for improvement in policy and regulatory frameworks, management arrangements, and financing.

Water and climate change

Climate change has a considerable impact on freshwater systems and their management, affecting their availability, quality and quantity, and jeopardizing human well-being and the world's economies. On the one hand, climate change contributes to increased demand for the resource due to higher temperatures and lower humidity and, simultaneously, to population growth in the region. On the other hand, greater variability in precipitation (e.g., droughts), together with extreme events of different types, can reduce supply (both due to lower availability of the resource and to the destruction of the sector's infrastructure). Rainfall variability becomes especially critical for countries highly dependent on hydropower generation. In this regard, the LAC region has 20% of the world's installed hydroelectric capacity and in some countries, namely Colombia, Ecuador, Paraguay and Uruguay, it is the most important source of electricity generation. Thus, the consequences of climate change on the resource extend beyond the water sector. In addition to affecting the energy sector, there are negative effects on human health, via an increase in the incidence of diseases transmitted by vectors, food or water, deaths from extreme events or malnutrition due to food shortages. It also has an unfavorable impact on agriculture, which will have to prepare, depending on geographical location, for scenarios with increasing scarcity or excess of the resource, and human settlements, where spatial planning will have to be improved to cope with greater variability in precipitation and create the associated infrastructure.

In turn, climate change affects wetlands, drylands and hydrological areas differently. Changes in climate variability and extreme events have already affected the region, especially in the Caribbean area (UN-Water, 2020). For his part, Peña (2016) already indicated that computational modeling showed an increase in air temperatures and a reduction in precipitation in arid and semi-arid areas of LAC. He also pointed out that climate change would have a greater impact on extreme hydrological conditions (especially those related to the La Niña and El Niño phenomena), which have a greater effect on the hydrology of the region's arid and semi-arid zones.

Schewe et al. (2013) studies water availability trends due to climate change and projects an increase in evaporation on the earth's surface as a consequence of the increase in air temperature, with a consequent decrease in the availability of the resource. In this regard, UN-Water (2020) estimates that 685 million people could face an additional decrease of at least 10% in water availability by 2050. In the region, peaks of decline are projected for central Chile, western Argentina and northern Venezuela.

Climate change also negatively affects water quality. Increased temperature decreases the amount of dissolved oxygen in water and this can reduce the self-purification capacity of freshwater reservoirs. In turn, floods and droughts (through the concentration of pollutants) can increase the risk of water pollution and pathogenic contamination (UN-Water, 2020).

As mentioned in Chapter 1, the main strategies to address climate change include mitigation and adaptation. The relative importance of these two types of actions varies according to sectors, countries and time periods. In general, mitigation measures are applied more to the energy sector, while in the water sector, the adaptation actions outlined in the NDCs by countries are prioritized (Graph 3.17).

Key adaptation actions for the sector include climate-proofing infrastructure, digitalization, early warning systems, nature-based solutions (NBS) and insurance against extreme events.

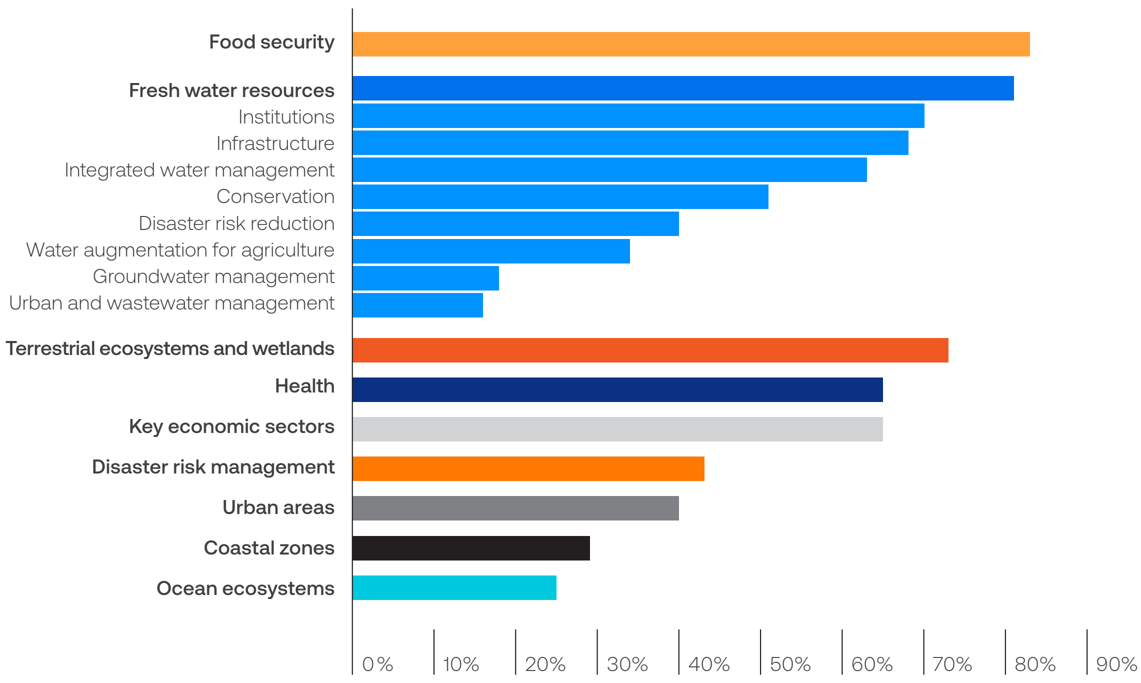
Climate change-proofing infrastructure refers to the consideration of the risks and opportunities that different climate scenarios impose on the sector. One action along these lines is the development of dams. This infrastructure helps to store water for periods of scarcity, but also allows for the absorption of excess water during floods. For example, while in Mexico a dam is being built to reduce the impact of droughts (Presa Libertad, in Nuevo León), in Argentina another is being developed to minimize the impact of floods (Presa del Arroyo Pergamino). This line of action includes technologies that allow water harvesting, i.e., the capture of rainfall for later use. As previously mentioned, there are buildings with this type of technology on their rooftops, which retains rainfall and then distributes it throughout the building.

Adaptation actions for the sector include climate-resilient infrastructure, digitalization, early warning systems, NbS, and insurance against extreme events.

Graph 3.17

Percentage of the adaptation component of the NDC that refer to the priority on adaptation in specific areas or sectors

Source: Authors based on Figure 10 of UNFCCC Secretariat (2021) and Figure 4 of GWP (2018).



A second set of adaptation actions has to do with digital innovations, which play an important role in processes such as infrastructure controls (hydrometric districts for loss measurement, geographic information system for georeferencing the pipeline network, etc.), customer portfolio management (advanced metering infrastructure, data acquisition control, etc.) and service quality controls (remote quality monitoring, etc.) (Cont et al., 2021). A recent IDB report highlights some of the innovative digitalization experiences in the sector that have been successful (Stankovic et al., 2020). These include the use of robots (WatchTower Robotics project) and drones (Anglian Water project) for leak detection in pipeline networks and three-dimensional (3D) mapping. These tools make it possible to substantially reduce water losses.

Development of prediction and early warning systems—another adaptation measure—ensure households, businesses, and governments can take timely action in the case of extreme events to reduce their negative consequences and improve the anticipation of the lead time (time that elapses between the warning and the materialization of the event). Some developments in the region include the Early Warning Center in Chile, which monitors the evolution of hazard manifestations, vulnerability conditions, and the occurrence of destructive events; the mechanism managed by the National Center for Risk and Disaster Management in the State of Paraná (Brazil) to inform the population at risk (due to floods, storms or landslides), which is implemented through cell phone communications; or the Early Warning System of La Plata (Argentina), to report situations of high flood risk.

NBS use or mimic natural processes and can contribute to improved water management while providing ecosystem services and a wide range of co-benefits. Healthy wetlands, an example of an NBS, can store carbon and reduce flood risk, improve water quality, recharge groundwater, support fish and wildlife, and provide recreational and tourism benefits. In many cases, they can also lead to cost savings compared to built infrastructure solutions. Afforestation and reforestation—a second example of NBS—produce beneficial hydrological and mitigating effects but with their own water needs (Schwärzel et al., 2018). A third example consists of the conservation and balance of groundwater bodies (UN-Water, 2022), which can store excess water (seasonal or episodic) and suffer less evaporation than surface reservoirs. For the region, of the more than 150 projects reviewed by Ozment et al. (2021), at different stages of progress, more than half include water and sanitation as the primary sector and involve reforestation, agroforestry and good agricultural practices, among others. Examples include the miPáramo projects in Bogotá (Colombia); Sustainable Urban Drainage in Mérida (Mexico); and NBS for hydroelectric power generation in Yauyas (Peru), which also extends to the energy sector.

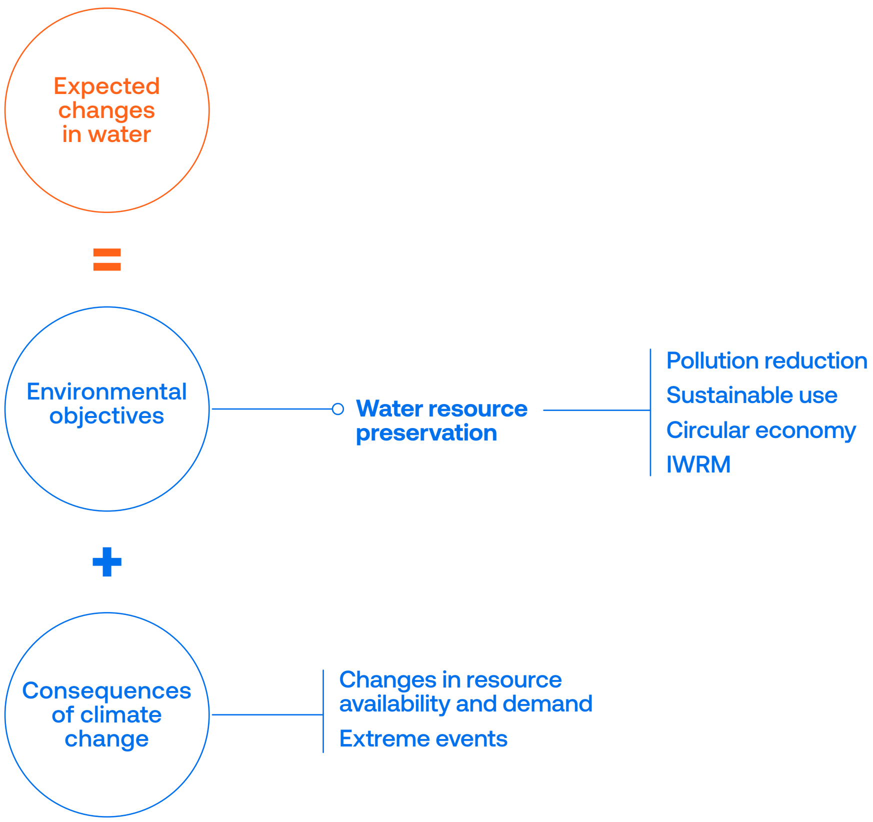
Finally, the development of flood and drought insurance markets is another important adaptation strategy. Most of the damage caused by natural disasters occurs to assets that are not insured. Therefore, improving access to climate insurance makes it possible, on the one hand, to strengthen resilience to disasters by providing timely payments for damages suffered and, on the other, given the direct relationship between risk and premium, it provides incentives for investment in infrastructure improvements in the sector.

While it is essential for water management to adapt to climate change, it can also play a very important role in mitigating it. Energy and water use efficiency measures contribute to energy savings (drinking water production processes consume energy), which can lead to reductions in greenhouse gas (GHG) emissions. Specific water management interventions, such as conservation agriculture, wetland protection, and other NBS, have the potential to sequester carbon in biomass and soils. Finally, advanced wastewater treatment can help reduce GHG emissions while supplying biogas as a renewable energy source (UN-Water, 2020).

Expected changes in response to environmental challenges

In view of what has been discussed throughout this chapter, it is possible to identify the changes that the sector will have to face in the future and their corresponding challenges. These changes, represented in Figure 3.4 and explained below, stem from the environmental objectives related to water resource conservation and the challenges imposed by climate change.

Figure 3.4
Diagram of expected changes in the water sector
Source: Authors.



- **Pollution reduction**. The great challenge in the region is to improve the levels of domestic wastewater treatment and reduce pollution from productive activities.

- **Sustainable use**. Recognizing the importance and scarcity of the resource is the first step in encouraging its sustainable use. In the different sectors that use water, it is important to develop technologies to increase efficiency in its use (mainly in the agricultural sector) and reduce existing losses in the processes of production and distribution of the resource (productive use and consumption).

- **Circular economy**. This model is becoming more widespread in the region, but still faces regulatory challenges since in many countries sludge is considered hazardous waste and must be confined in special sanitary landfills; therefore, the reuse of biosolids involves revising and complementing regulations. There are also institutional challenges, due to the lack of accredited laboratories and the inability of the entity in charge of monitoring or controlling irrigation; investment challenges, including who carries it out and who finances it; and environmental challenges, which require the definition of quality standards.

- **IWRM.** This conceptual framework of governance suggests intersectoral and international cooperation and coordination, considering management by basins or ecosystems rather than by administrative units (municipalities, sectors, countries). The great challenges in several countries of the region lie in developing regulatory and institutional frameworks that encourage this joint work and in achieving consensus among the different parties involved.

- **Changes in resource availability and demand.** Climate change will negatively affect the availability, quality and quantity of the resource. In turn, high temperatures and possible droughts will mean changes in demand. In this context, the challenge is to be able to forecast requirements and thus plan the optimal allocation of the resource, investment needs and the incorporation of alternative sources in the face of extreme shortages.

- **Extreme events**. Their frequency increases with climate change. Given the indispensability of the resource, it is important to develop a resilient water service with a rapid infrastructure response.

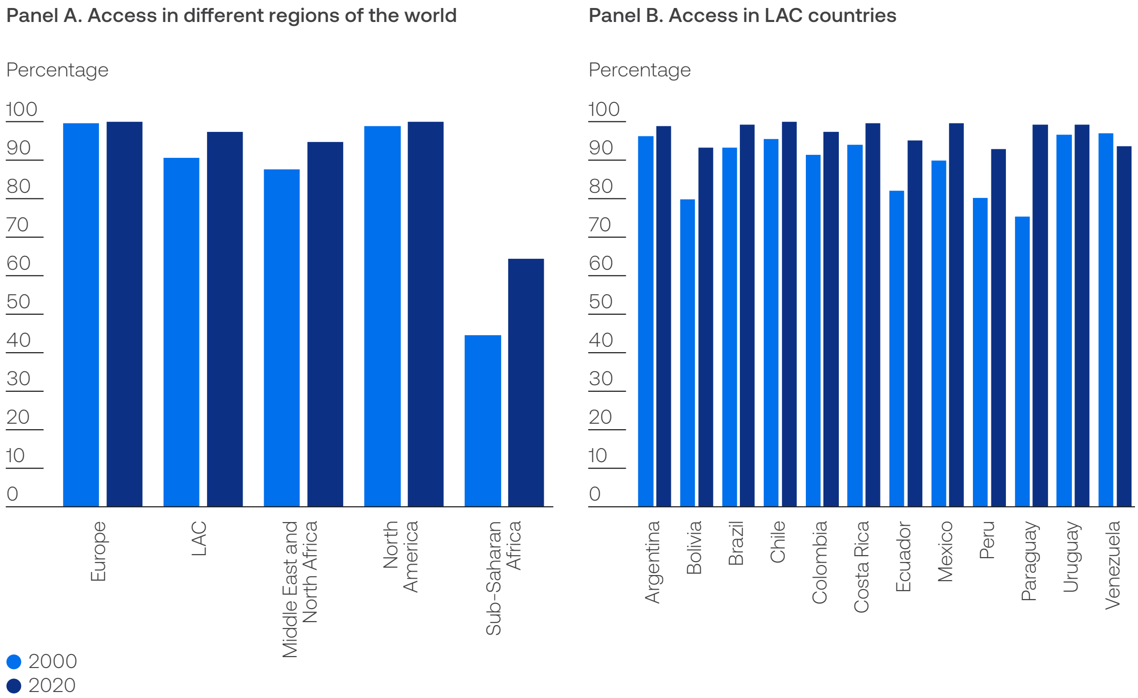
In the last two challenges, NBS can contribute to improved water management, provide ecosystem services and provide a wide range of co-benefits.

Annex 3.1 Gaps in drinking water and sanitation services

This Appendix examines the existing service gaps in the water and sanitation sector and their recent evolution in LAC countries. The analysis focuses on three main dimensions: access, cost/affordability, and quality.

Firstly, in terms of access, the region is performing well. In 2020, 97% of the population had access to at least a basic water supply service, indicating that the region is close to achieving universal coverage (100%). When disaggregated by country, some notable trajectories are observed, such as Paraguay's, which increased access from 75% to 99% during the analyzed period. Venezuela, on the other hand, is the only country in the region that experienced a decline in access to the service (-3.5 percentage points).

Graph 3.18
Percentage of population with access to potable water
Source: Authors based on World Bank (n.d.a).



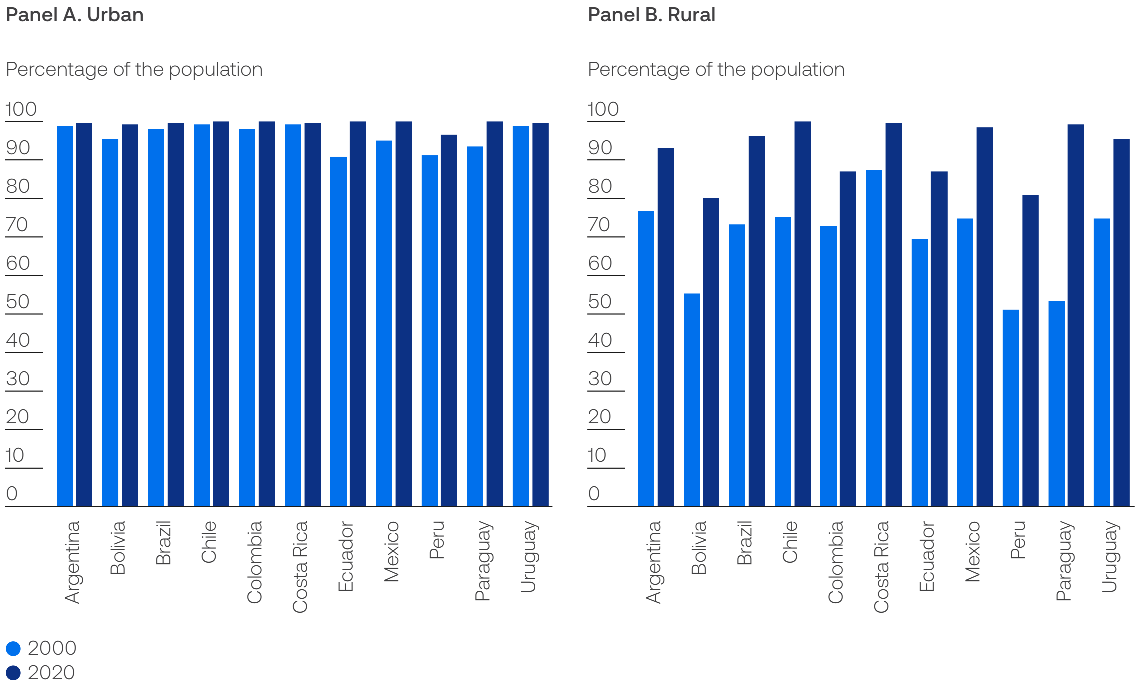
Note: In panel A, the first data for North America refers to 2005, while in panel B the latest data for Argentina refers to 2016.

When disaggregated by area, it is evident that the countries of the region have achieved or are very close to universal access in urban areas (panel A of Graph 3.19). However, as with electricity, the greatest deficits are in rural areas (panel B), especially in countries like Bolivia, Colombia, Ecuador, and Peru. That said, over the last 20 years there has been an increase in rural drinking water coverage in the region (Paraguay being the example of the greatest progress).

Furthermore, LAC is still far from serving 100% of its population with safely managed water (from an improved source, available when needed, and free of fecal and chemical contamination). In 2020, 75% of the region's population had access to a quality service, considerably lower than developed regions such as Europe (98%) and North America (97%). A breakdown by country shows that Mexico and Peru are those with the greatest deficits in achieving quality service (Graph 3.20).

In addition, access to quality water is substantially lower in rural areas than in urban areas. In 2020, only rural areas in Costa Rica reached the level from which most urban areas started twenty years earlier (80% of the population with access to a quality resource). Thus, it is clear that the region's rural areas face a double lag: less access and, to an even greater extent, poor water quality (Graph 3.21).

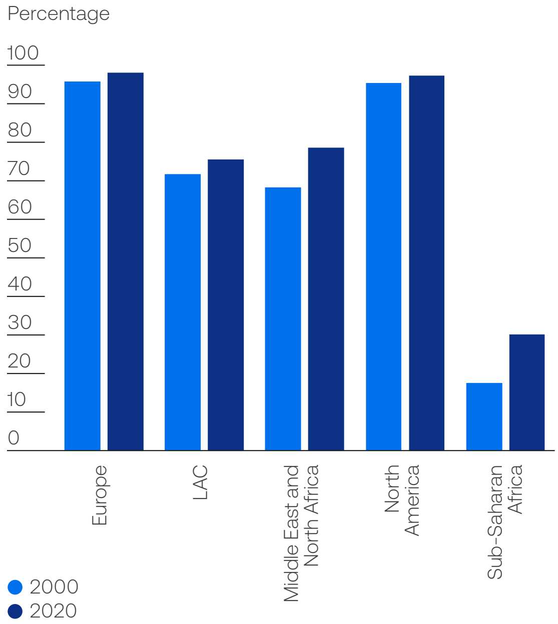
Graph 3.19
Percentage of population with access to potable water in urban and rural areas in LAC countries
Source: Authors based on World Bank (n.d.a).



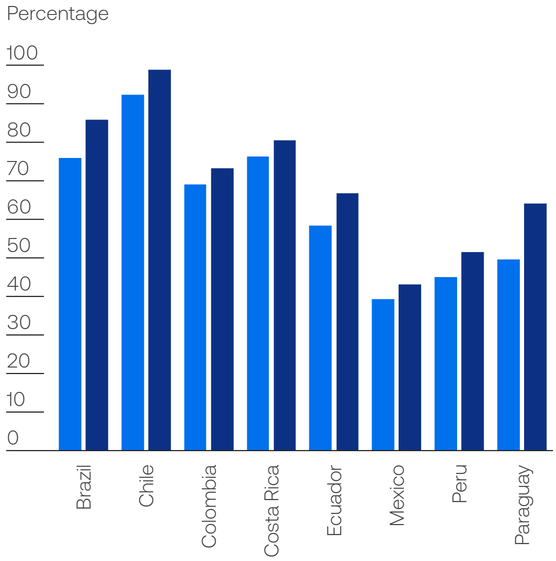
Note: The latest data for Argentina in panel B refers to 2016.

Graph 3.20
Percentage of population with access to safely managed water
Source: Authors based on World Bank (n.d.a).

Panel A. Access in different regions of the world



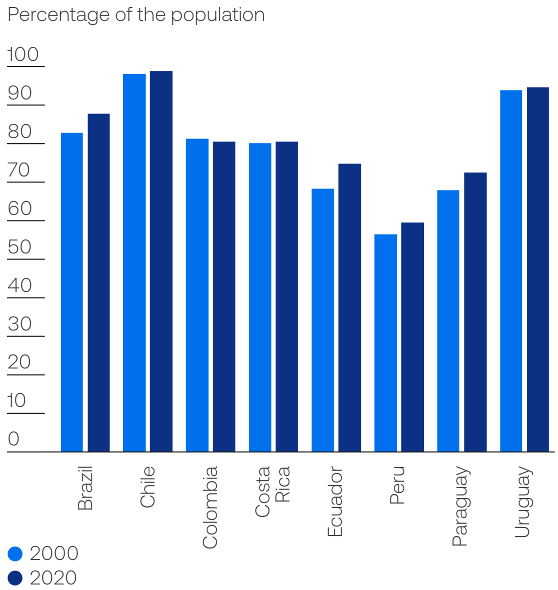
Panel B. Access in LAC countries



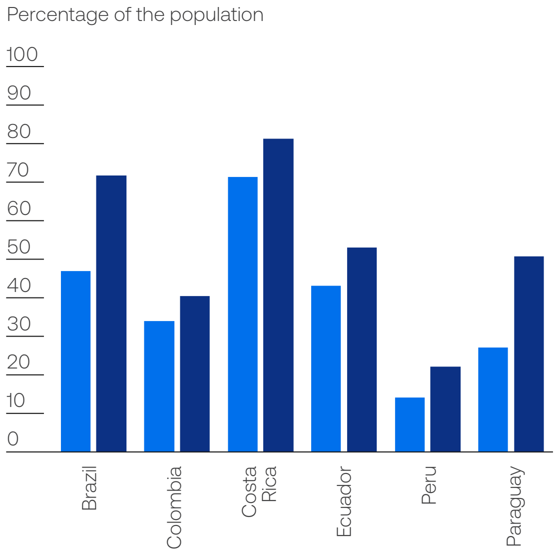
Note: The first value for North America refers to 2005.

Graph 3.21
Percentage of population with access to safely managed water in urban and rural zones
Source: Authors based on World Bank (n.d.a).

Panel A. Urban



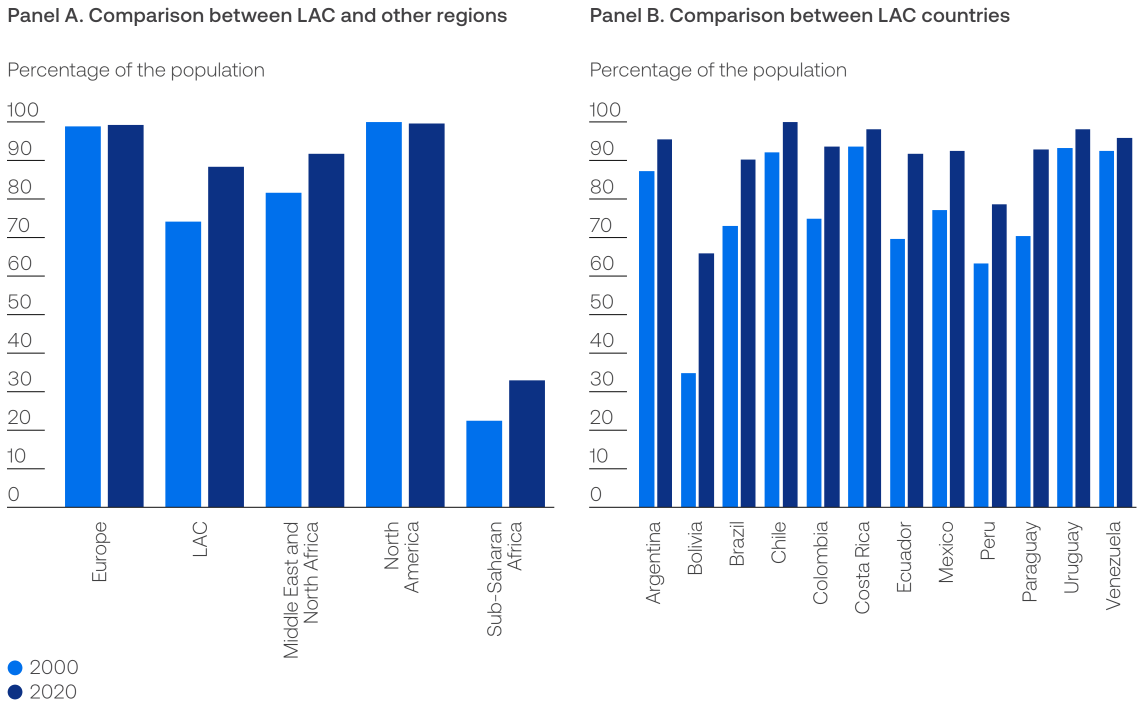
Panel B. Rural



The region is still far from achieving universal access to sanitation.

In contrast, the region is still far from achieving universal access to sanitation (Graph 3.22). In 2020, 12% of the population still lacked access. The countries with near universal coverage are Argentina, Chile, Costa Rica, Uruguay and Venezuela. Bolivia is the country with the greatest lag in this dimension.

Graph 3.22
Percentage of population with access to sanitation
Source: Authors based on World Bank (n.d.a).



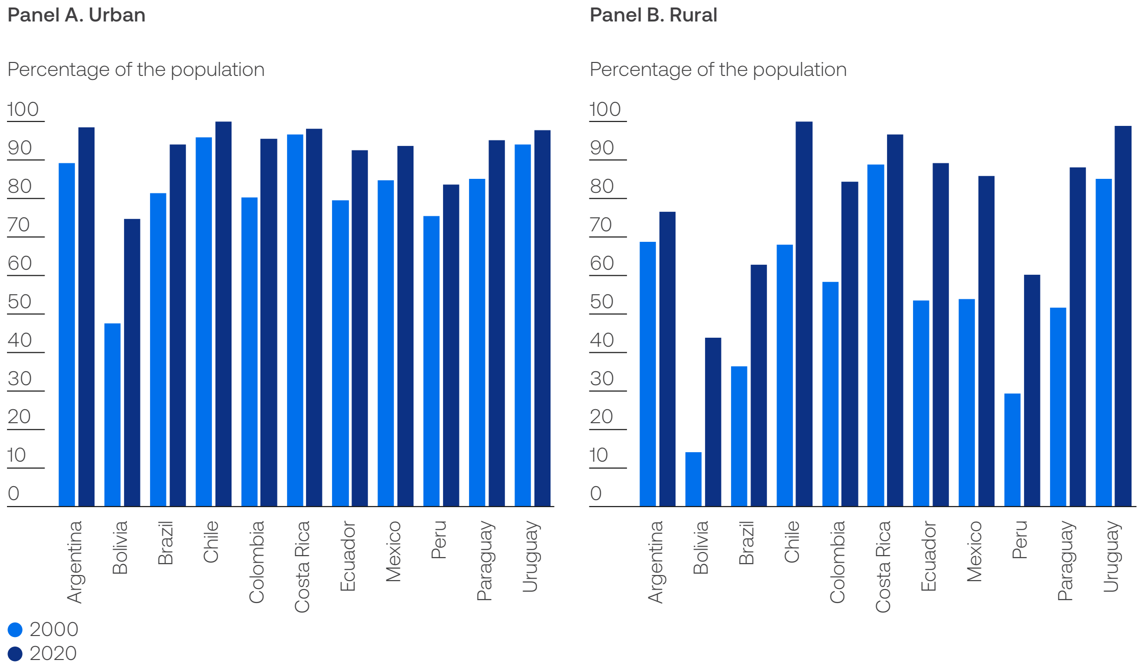
Note: The last value for Argentina in panel B corresponds to 2016, while the first value for Venezuela is from 2005.

When disaggregating between urban and rural areas, it is again clear that rural areas have greater needs. While many countries are close to achieving universal access in urban areas (Argentina, Brazil, Chile, Costa Rica, Ecuador, Mexico, Paraguay, and Uruguay), only a few are in the same situation in their rural areas (Chile, Costa Rica, and Uruguay). The worst positioned country in 2020 is Bolivia (Graph 3.23).

In terms of access to quality sanitation (approximated by exclusive sanitation facilities with safe excreta disposal), the gaps are even wider. Indeed, in 2020, barely one in three people in the region had access to quality sanitation facilities at home (34%). When disaggregated by country, none is close to universal quality coverage. In Chile, the best positioned country, barely 80% of its population has coverage. At the other extreme, only 18% of Colombians have access to quality sanitation.

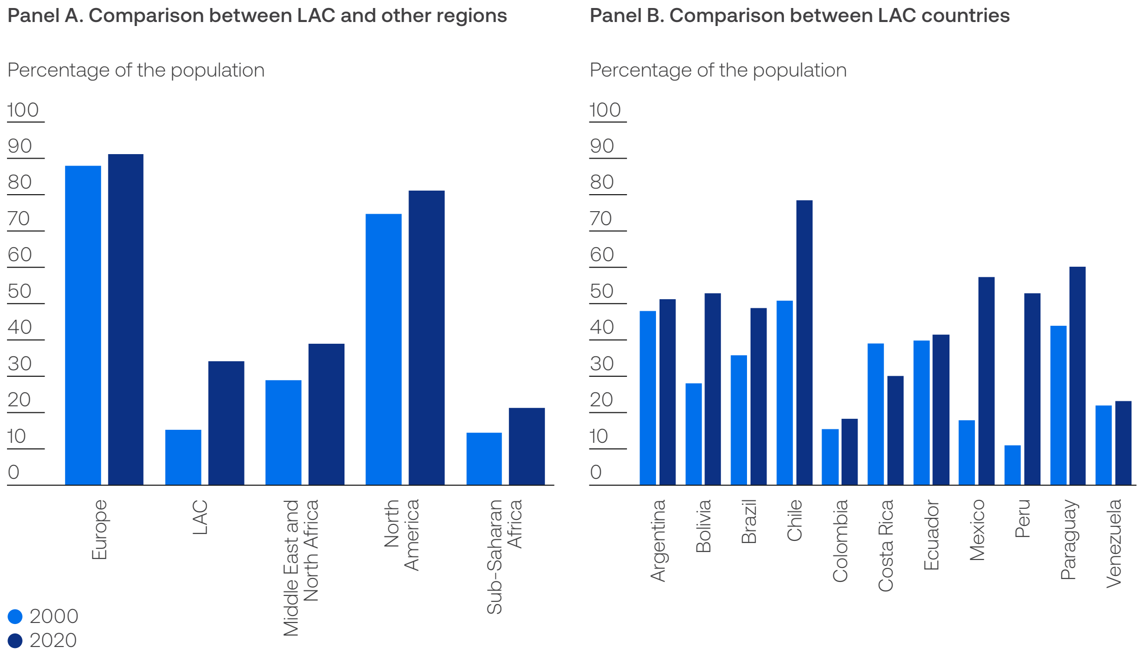
When disaggregated by urban and rural areas, a significant limitation emerges: only three countries report disaggregated information for rural areas (Graph 3.25). In this group, the case of Paraguay stands out once again: during the period analyzed, it managed to increase access to sanitation with safe disposal in its rural areas by 34 percentage points, which represents a doubling of the coverage that existed in 2000.

Graph 3.23
Percentage of population with access to sanitation in urban and rural areas in LAC countries
Source: Authors based on World Bank (n.d.a).



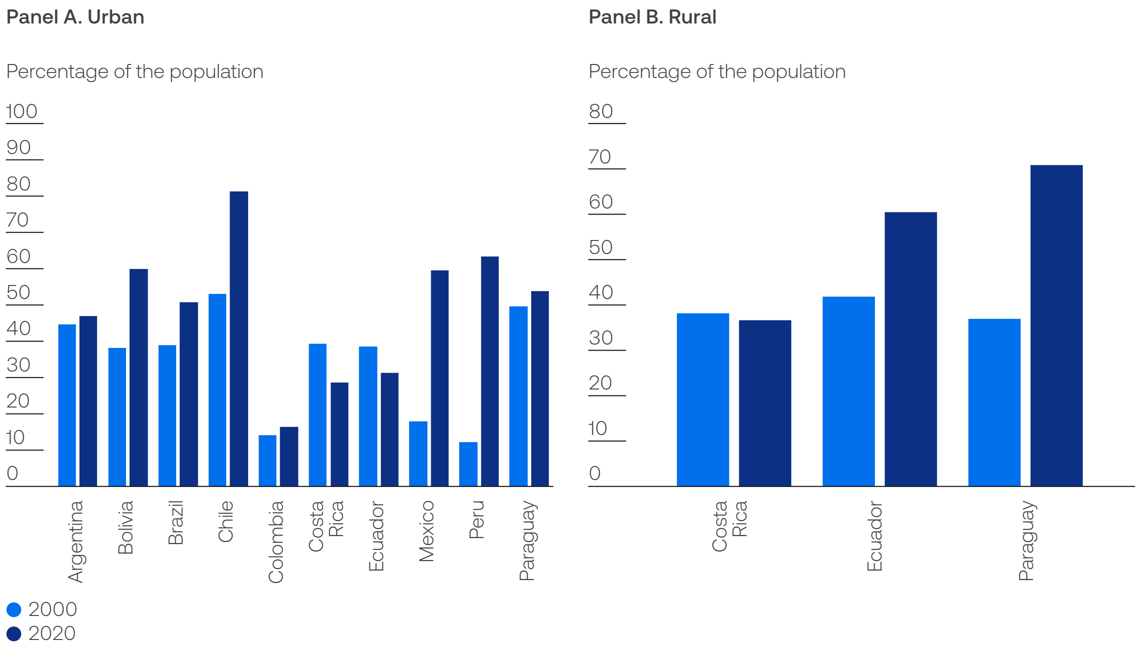
Note: In panel B, the latest value for Argentina corresponds to 2016.

Graph 3.24
Percentage of population with access to non-shared sanitation facilities and safe excreta disposal
Source: Authors based on World Bank (n.d.a).



Note: The first value for the Middle East and North Africa refers to 2009, while the first value for Venezuela refers to 2005. The last value for Argentina refers to 2016.

Graph 3.25
Percentage of population with access to non-shared sanitation facilities and safe excreta disposal by zone
Source: Authors based on World Bank (n.d.a).

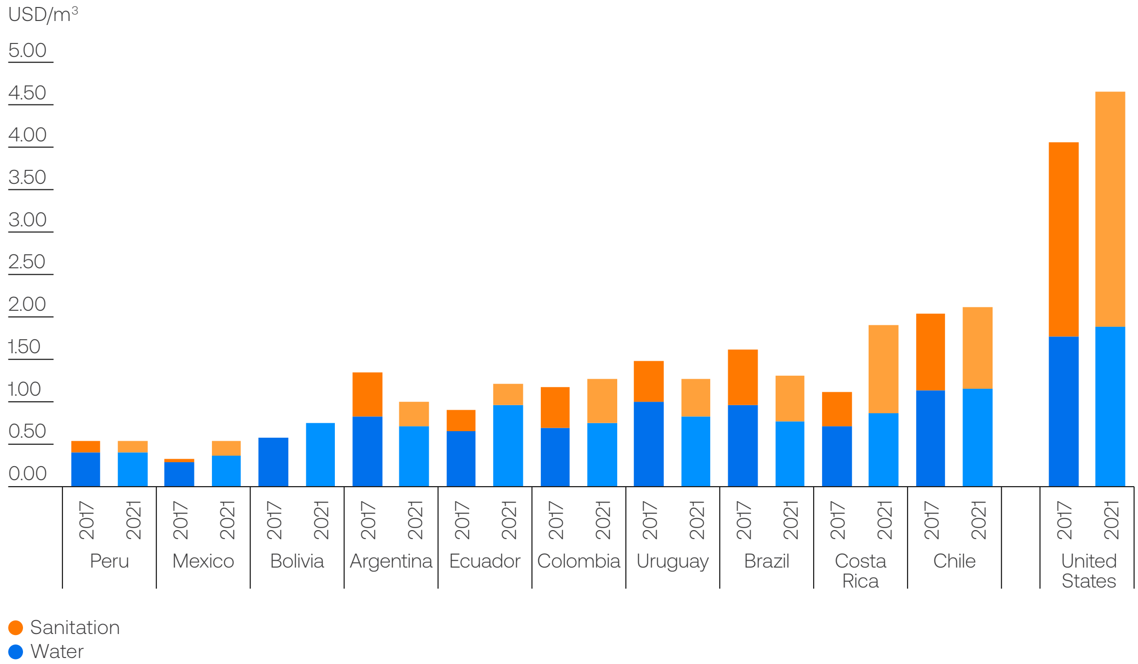


On the other hand, the average service tariff paid by users varies across countries (Graph 3.26). While the average combined service tariff in Mexico and Peru was USD 0.53/m³ in 2021, in Chile it rose to USD 2.11/m³. Graph 3.26 also illustrates an average increase between 2017 and 2021 (with the exception of Argentina, Brazil, and Uruguay). In all cases, however, the region's tariffs are substantially lower than those of developed countries like the United States.

These values also reveal affordability issues with water and sanitation services in the region.

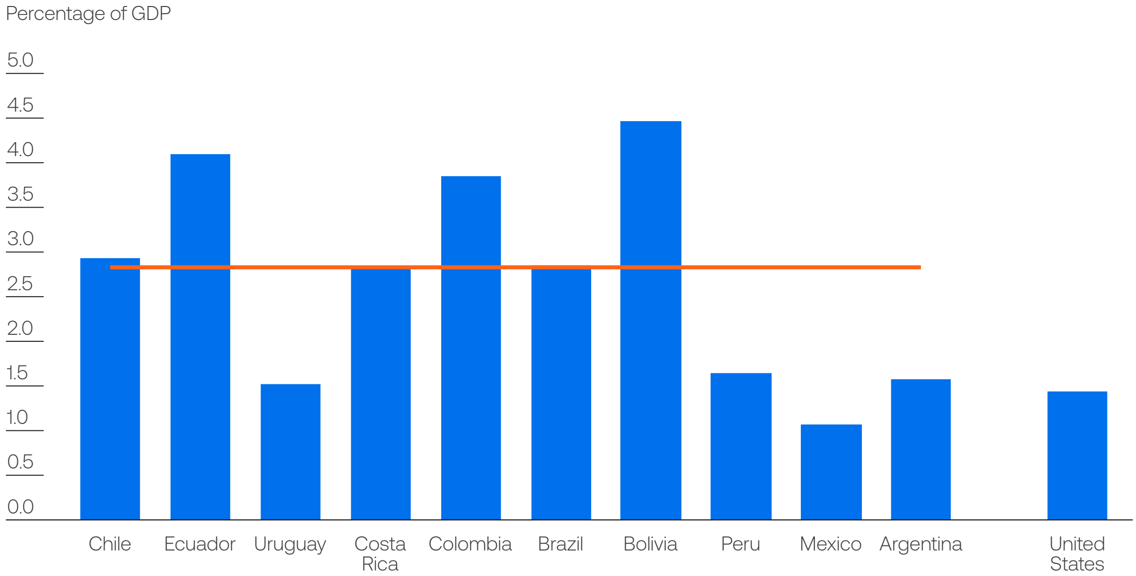
In 2021, while an individual in the United States spent on average 1.4% of their income to pay for water and sanitation services for a monthly consumption of 15 m³, a Latin American spent 2.8% of their income for the same services (over 4% in Bolivia and Ecuador, less than 1.5% in Uruguay and Mexico). Although the differences are smaller than those for electricity services, this still highlights a relative affordability gap for households in Latin America compared to their counterparts in a developed country like the United States.

Graph 3.26
Water and sanitation tariffs in countries of the region and the United States for a consumption of 15 m³ in 2017 and 2021
Source: Authors based on IB-NET (n.d.).



Note: The tariffs for each country indicate (in USD/m³) the weighted average per population served by each provider.

Graph 3.27
Affordability of water and sanitation services in countries of the region and the United States for a consumption of 15 m³ measured as a percentage of GDP in 2021
Source: Authors based on IB-NET (n.d.) and World Bank data (n.d.a).



4

Resilient health systems

The Context of the COVID-19 Pandemic

Chapter 1 proposed to analyze the preparedness of health systems to respond in the short term to large-scale shocks (such as pandemics or climatic catastrophes), minimizing casualties and response times. The analysis in this chapter complements that carried out by RED 2020 on the long-term changes expected due to population aging (Álvarez et al., 2020).

The pandemic caused by severe acute respiratory syndrome (SARS CoV-2), responsible for COVID-19, produced a disruption in the health sector and in economies and societies in general.

In December 2019, a cluster of viral pneumonia cases was detected in the city of Wuhan in China. The World Health Organization (WHO) declared that it was due to a new coronavirus and, given its nature and epidemic behavior, constituted a public health emergency of international concern (PHEIC) and, therefore, all countries in the world were alerted to prepare for and detect early cases (WHO, 2021b). Although more than a decade ago, WHO and other scientific institutions formulated alert and response mechanisms for health emergencies based on the experience of the 2009 influenza pandemic (see Box 4.1 and the historical review in Guibovich, Zamora and Castillo, 2022), modern history has never before recorded the unfolding of a pandemic of such magnitude in such a short period of time, affecting all spheres of society. In its annual report first published in 2019, the Global Preparedness Monitoring Board (GPMB) had already stated that the world was at serious risk of a pandemic because of the “novel convergence of ecological, political, economic and social trends including population growth, increased urbanization, a globally integrated economy, widespread and faster travel, conflict, migration and climate change" (GPMB, 2019).

From the outset, the pandemic was marked by high levels of uncertainty and the absence of evidence that would allow us to know precisely how the virus is transmitted, its mechanisms of action in the body, as well as effective measures to control its spread and contagion. At the beginning, without specific and effective pharmacological weapons, the world deployed a series of non-pharmacological measures with two main objectives: to reduce the number and speed of contagion and to reduce fatality.

During the first months of 2020, all governments implemented fairly traditional and recognized public health measures, of proven efficacy, but some took actions of relative effectiveness: quarantines, social distancing, reduction of crowds, ventilation, contact tracing and isolation, hand washing, and border closures, among others. Health personnel were primarily responsible for timely and reliable diagnosis and for encouraging the above-mentioned non-pharmacological measures; however, decision-makers and society also played, to a greater or lesser extent, a relevant role. All these measures had, and still have, a transcendental objective: to reduce COVID-19 fatalities. Subsequently, with the arrival of vaccines in early 2021, countries carried out strategies to distribute vaccines and immunize people, initially high-risk populations and later the general population almost in its entirety, as a complement to the measures previously implemented.

With the increase in vaccination coverage, particularly of the complete vaccination schedules, the pandemic evolved in an undulating manner, with periods of outbreaks of infection and even of fatalities, sometimes with accelerated drops. It was evident that, with the passage of time and the presence of the various variants of the virus, the consequences of the disease were less severe in terms of loss of life, either because of the immunity achieved through natural immunity, previous exposure to the disease, or vaccination.

The pandemic has left its mark on LAC, just as it has on every other region of the globe. By December 31, 2021, among the 10 countries with the highest number of COVID-19-associated deaths, there were three Latin American countries: Brazil, Mexico, and Peru.[59] However, beyond its negative impact, the health crisis has provided insight into the changes needed to develop a health system that is better prepared for events of this magnitude that put it under stress, whether epidemiological or climatic. In other words, this pandemic has left lessons to be taken into account in the design and development of a resilient health system.

The following sections analyze the condition of the sector in institutional terms and in service provision before and after the COVID-19 pandemic, especially assessing how flexible the system was in responding to this emergency; the future health needs that the effects of climate change on population health will demand; and what lessons can be drawn from the recent pandemic to design a resilient health system.

59 Within the framework of the "leave no one behind" objective of the 2030 Agenda, the pandemic has exposed the sector's deficits in the social dimension. For example, in Mexico, municipalities with greater marginalization or indigenous population had more severe forms or more deaths from the disease by mid-2020 than the rest (Ortiz-Hernández and Pérez-Sastré, 2020), while in Peru, mortality in the poorest districts of Lima and Callao doubled mortality in the least poor districts (Mújica and Pacheco, 2020).

Box 4.1
Pandemics of the 21st century

Source: Guibovich, Zamora and Castillo (2022).

In the 21st century, there were three pandemics caused by zoonoses (natural transmission from vertebrate animals to humans) that did not reach the LAC region: severe acute respiratory syndrome (SARS) pandemic, originating in China in 2002 and transmitted to humans through civets; Ebola hemorrhagic fever, originating in Africa between 2014 and 2016, probably transmitted by bats; and Middle East Respiratory Syndrome (MERS) transmitted by camels to humans in 2014. Both Ebola fever and MERS were classified as PHEICs and triggered emergency response plans in LAC.

In contrast, the pandemic caused by the influenza A H1N1 strain in 2009 spread to more than 180 countries, including all LAC countries (in the year of the pandemic, it is estimated that between 11% and 18% of the world's population was infected and caused between 150,000 and 575,000 deaths).

Three arbovirus diseases (arthropod-borne viruses) are currently relevant in LAC: dengue, chikungunya and Zika virus infection, all of which are transmitted by mosquitoes of the *Aedes* genus. Apparently, dengue was introduced to the Americas in the 18th century and produced several epidemics throughout the continent, until the eradication of the mosquito and control of the disease was achieved in 1965. However, it resurfaced years later becoming hyperendemic by 2017 (more than 2 million cases and 1,000 deaths by 2020). Chinkungunya started a pandemic in 2005 in Comoros and India and reached LAC in 2013, spreading to all countries in the region (more than 100,000 cases by 2020). In 2014, Easter Island reported an outbreak of Zika virus infection, which had originated in Uganda. It then spread throughout the Americas in 2016 (producing more than 700,000 cases in that year).

In December 2019, a cluster of severe viral pneumonia cases associated with a fish market in Wuhan, China, was reported. The agent was a novel, possibly zoonotically transmitted coronavirus, which was later named SARS-CoV-2 and the disease produced was labeled COVID-19. Since then, there has been an increase in cases and deaths worldwide, in successive waves that have not yet ended. As of July 2022, more than 561 million cases and 6.4 million deaths had been reported worldwide, of which 73 million cases and nearly 1.7 million deaths occurred in LAC.

Health systems: Characterization and response to an extreme event

This section breaks down health systems' analysis in the following dimensions: governance and management; organization and functioning; health financing; and pandemic management. Within these dimensions, it examines aspects of epidemiological surveillance, public health laboratories, digital health, health infrastructure, human resources, and health inputs, including medical equipment or drugs, among others. For each dimension, it presents a state of affairs prior to COVID-19, how it was affected and the responses to the new scenario.

Institutional framework, financing, and public health

Governance and management to implement health policies

In the region, countries with unitary (although with varying degrees of decentralization) and federal forms of government coexist, with different resources (political, institutional, financial, technological, human and socio-cultural). In these countries, the collective action processes that organize the interaction between actors, the dynamics of the processes and the rules of the game (informal and formal) that regulate the interests of the stakeholders involved in the health system and that influence decision-making and its implementation in the health sector (its governance) are mediated by the interdependence between national and subnational government actors and by the capacity for intergovernmental coordination. In addition, there is the interrelationship with the various social actors at all these levels (Guibovich, Zamora and Castillo, 2022). The degree of decentralization, together with the levels of fragmentation of health systems, explain an important part of the weakness in the steering role in LAC countries (PAHO, 2020c).

In this context, the response of the region's countries to the multiple challenges presented by COVID-19, of which the preservation of health stands out, without destroying the economy or guaranteeing the effectiveness of the measures and preserving freedoms and human rights as much as possible, can be organized at four levels: supranational, national, planning and management.

First, governments faced difficult decisions during the COVID-19 pandemic. They had to make choices based on limited information and with little support from international organizations that could have helped them better navigate the high levels of uncertainty and evolving scientific evidence. This all happened in an environment of widespread mistrust. The pandemic highlighted the need for greater cooperation between countries, which was one of the great lessons of this pandemic.

Secondly, at the country level, two large groups of measures were implemented, with a third group to be added in 2021, with different levels of performance. The first consisted of traditional public health and health promotion measures; these were aimed at preventing the virus from continuing to spread (use of masks, frequent hand washing, social distancing voluntary or mandatory, and mandatory isolation of infected persons).[60] The second consisted of strengthening their capacity to treat patients who developed moderate and severe disease; that is, hospital beds, including

60 Mandatory isolation measures were implemented through strict or targeted quarantines (by territory, age, time, or activity). In the case of quarantine measures, the countries mobilized other State actors outside the health system; for example, the police and military forces to adequately control the measures; the economic sectors to guide and evaluate the impact on the productive and employment sectors; and other social sectors, in order to ensure the protection of the most vulnerable populations, especially with regard to the implementation of emergency vouchers, stimulus payments, and cash transfers and food distribution or, in the case of the Ministries of Education, to minimize the impact on the education of children and adolescents.

The experience of COVID-19 provides some lessons about the necessary changes to develop a health system better prepared for events of this magnitude.

critical care services, adequately supplied with the necessary equipment, drugs and protective measures, and staffed with sufficient numbers of personnel with the required skills to perform the function, components that are detailed below. Vaccination campaigns were subsequently added to these measures. All these measures were implemented in conditions of scarce financial resources and in a context of economic, political and social vulnerability (Merke et al., 2021),[61] facing a dilemma between allocating greater resources to the primary level or strengthening hospital and high complexity care systems.

Third, countries utilized existing structures, designed both for regular operations as well as emergency and disaster situations, with special or *ad hoc* bodies. These bodies took the form of special interministerial teams to strengthen multisectoral coordination, analysis and guidance, coordination of response operations at different levels of government or manage strategic resources (such as vaccines, personal protective equipment, personnel, etc.).

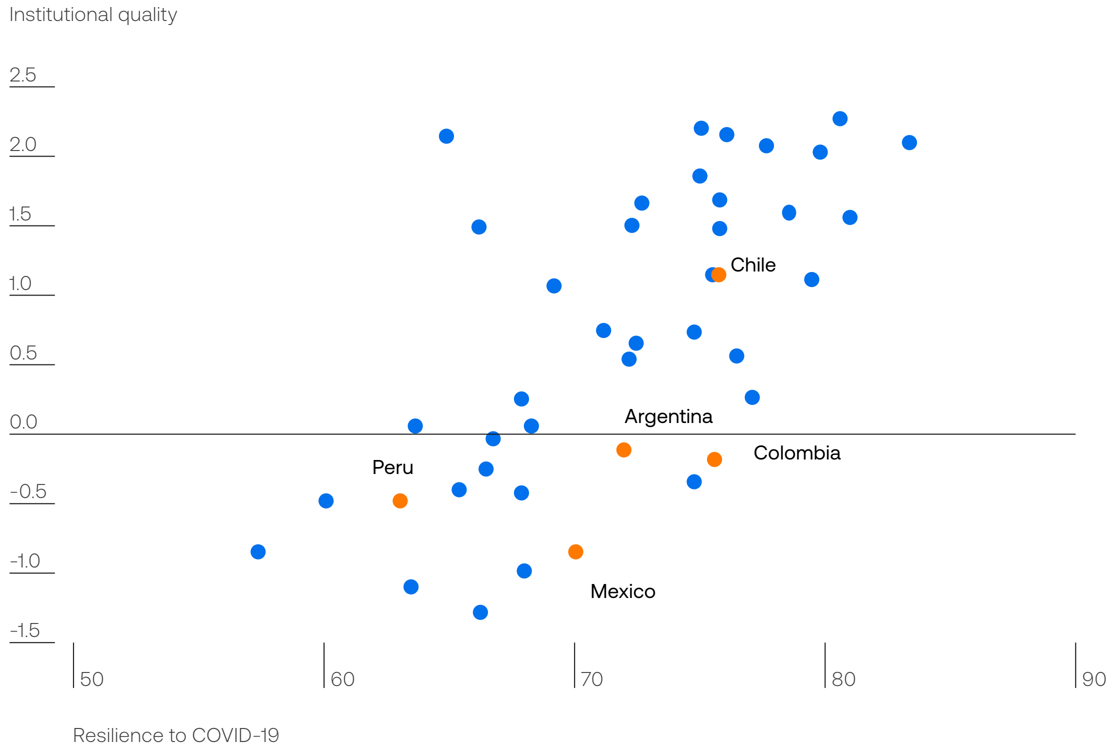
Finally, the countries developed national and subnational sectoral plans (health, education, social protection, etc.) to reduce the impact of the pandemic and maintain basic services through social protection mechanisms. These plans were accompanied by special laws, decrees, sectoral resolutions, and other management documents to ensure plans were financially and operationally viable (Enriquez and Saenz).

It will take time to draw definitive lessons from the pandemic in terms of government action to contain the virus, provide quality health care, including broad, rapid and safe vaccination coverage, reduce lethality and ensure a return to economic activities (including resumption of travel).

61 By the beginning of 2020, the region had already been suffering from the sustained fall in commodity prices since 2014 (Merke et al., 2021) and was facing severe restrictions on financial transfers to vulnerable individuals. With quarantine measures being implemented, it was hard for many to sustain precarious jobs or replace them with remote jobs, given that quality connectivity covered only 20% of existing positions, compared to 40% in the more advanced economies (see Pienknagura et al., 2020). On the other hand, in 2019 alone, Bolivia, Chile, Colombia, Ecuador, Haiti, and Venezuela were facing massive popular protests, in most cases related to the price-quality ratio of public services and economic inequalities.

The analysis conducted by the Lowy Institute (2021) on pandemic management in 102 countries compared epidemiological and response indicators (confirmed cases, deaths, and detection capacity) with country characteristics (regions, political systems, population size, and economic development). While no definitive patterns were identified, performance varied among countries. Uruguay ranked 12th, followed by Trinidad & Tobago and Jamaica in the 20th to 30th positions. However, Argentina, Bolivia, Chile, Colombia, Ecuador, Mexico, Panama, and Peru ranked below 90th. Additionally, Bloomberg's COVID-19 resilience ranking classified 53 countries based on a measure that placed Chile and Colombia in the top 20, Argentina and Mexico in the 20th to 30th positions, and Brazil and Peru below the 40th position (Bloomberg, 2022). As shown in Graph 4.1, there is a clear association between institutional quality (vertical axis) and resilience to the COVID-19 pandemic (horizontal axis).

Graph 4.1
COVID-19 resilience and institutional quality
Source: Authors based on Bloomberg (2022) and World Bank (n.d.a).



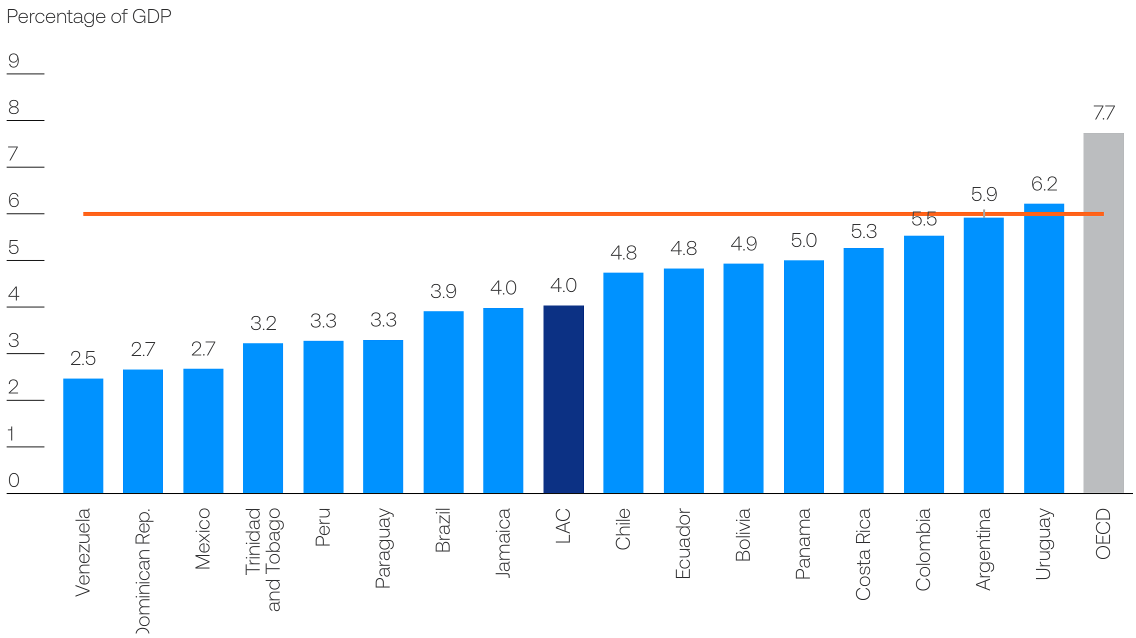
Note: Institutional quality refers to control of corruption and the indicator ranges from 2.5 (strong control) to -2.5 (weak control).

Organization: Fragmented health systems

Latin American systems were created and developed to serve specific segments of the population. As noted by the RED 2020 report, most Latin American countries have built health systems in which different subsystems coexist to provide coverage to different segments of the population (Álvarez et al., 2020). These systems are characterized by varying levels of fragmentation and segmentation[62] among the public system (for general care, as in Bolivia, Brazil, Ecuador, Jamaica, Mexico, Panama, Paraguay, Peru, and Venezuela, and for poor and vulnerable populations in mixed systems), funded through taxes; the social security system, financed by employer and employee contributions as well as government funds (for formal workers and their families, as in Argentina, Colombia, and Costa Rica, including prepaid medical schemes, depending on the country); and the private system (for healthcare services paid for out of pocket by individuals). In addition to this, there are a large number of other public services for the armed forces, police forces, and other corporate groups. This situation is the result of a historical process and the convergence of multiple factors, including ideological, political, economic, health, and even technological transitions (Atun et al., 2015; Cotlear et al., 2015; Marquez & Joly, 1986), which have resulted in a segregation and stratification of the population regarding their access to healthcare (Giovanella et al., 2012).

Although some countries have made progress toward integrating their subsystems in recent decades, fragmentation and segmentation still persist (Guibovich, Zamora & Castillo, 2022). These two dimensions generate differences in coverage, quality, and quantity of healthcare services received by different segments of the population. Additionally, most countries in the region allocate a low percentage of public funds towards healthcare. Only Uruguay spends more than the WHO-recommended threshold of 6% of GDP for healthcare spending (WHO, 2010).

Graph 4.2
Public expenditure on health as a percentage of GDP in 2019
Source: Authors based on data from World Bank (n.d.a).

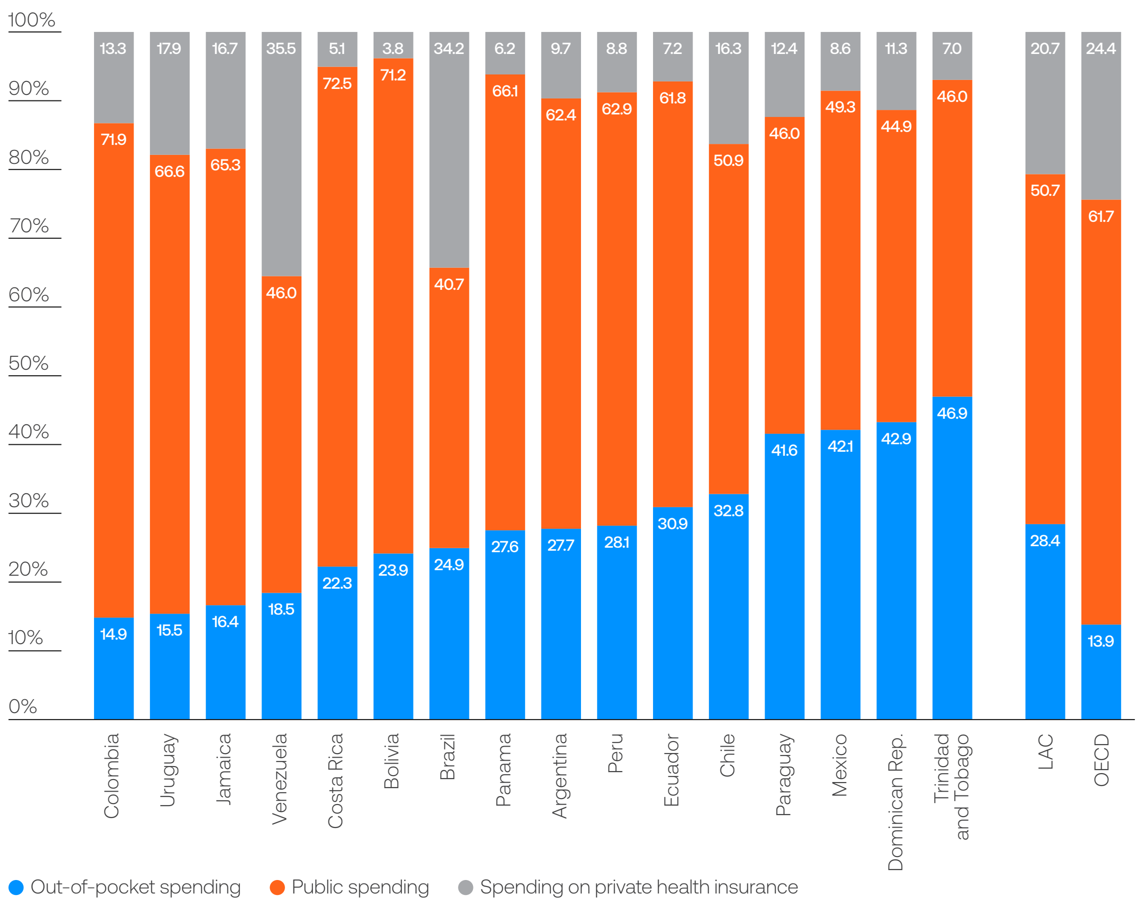


62 Segmentation is the coexistence of subsystems with different modalities of financing, affiliation and provision of health services, each of them "specialized" in different segments of the population according to their labor insertion, income level, ability to pay, and social position. Fragmentation of the system is the coexistence of several non-integrated units or facilities within the health care network. Fragmentation leads to increased transaction costs and an inefficient allocation of resources in the overall health system.

In addition, in general, systems in the region offer little or no financial protection, so the population must resort to private outlays, which represent, on average, 28% of total health spending (with the exception of Colombia, Uruguay, Jamaica and Venezuela, according to 2019 data), well above the threshold of 20% recommended by WHO (2010). Addressing these issues is crucial to achieving universal health coverage and meeting SDG 3.8.

In response to COVID-19, the two main objectives set by national and subnational governments were to reduce the number and speed of infections and to lower the fatality rate. One key element to identify, monitor, and evaluate non-pharmaceutical actions to reduce transmission was improved diagnosis capacity and timeliness so individuals in contact with the sick could be tracked and isolated. During 2020, with the support of information and communication technologies (ICTs), improvements were made in the use of data (for the control of infections and their spread), and various platforms were implemented to monitor the mobility of people in public spaces (for example, in Argentina, Brazil, and Colombia), as well as tracking or traceability systems for cases (Peru and Uruguay). The other element was to improve the existing installed capacity, which was and continues to be deficient in all countries. To achieve both objectives, plans focused on hiring additional temporary staff, building new infrastructure (mostly temporary or adapted), and acquiring essential medical equipment, drugs, and supplies.

Graph 4.3
Health financing profile in LAC countries in 2019
Source: Authors based on data from World Bank (n.d.a).



The health systems were forced to make substantial modifications to the traditional organization of services, such as converting some hospitals for chronic patients (e.g., psychiatric hospitals or rehabilitation hospitals) into COVID-19 hospitalization sites. In other cases, entire hospitals were converted to attend only COVID-19 cases. The pandemic forced services to adapt their organization to the changes occurring in population needs.

The collateral impact of these decisions occurred in people with basic or complex "non-COVID" service needs. Many patients suffered postponed or suspended check-ups or treatments or received care under very restrictive conditions (Barriga et al., 2021; Gómez Rincón, 2021; Union for International Cancer Control, 2020; Vela-Ruiz et al., 2020), using basic telemedicine tools, often without prior training. Although there are still no studies to date that have measured all the dimensions of this impact, the pandemic has led to longer waiting times for elective surgeries. Difficulties in receiving emergency treatment increased, and the quality of cancer care deteriorated, as did surgeries for cardiovascular diseases (Iacobucci, 2021). In the case of mental health, services for neurological conditions and care for substance abuse—already deficient before the pandemic—further declined in the face of increasing demand as a result of the pandemic (Guibovich, Zamora y Castillo, 2022). Similarly, well-established services or those in a process of sustained improvement, such as reproductive health, micronutrient supplementation and immunization, among others, were also affected. During the critical months of the pandemic, pregnancy and newborn care was interrupted in almost half of the countries of the region (PAHO, 2021a).

In the case of chronic patient monitoring, countries promoted mitigation strategies through the development and use of digital health. Legal instruments allowing their development were approved in a short period, as well as the enabling of new digital and administrative tools that facilitated registration, financial transfers, and storage and transmission of sensitive data (see Box 4.2). Progress in this area was also diverse and, naturally, dependent on previously developed substrates.

Health financing

Health systems have different sources of financing, among the most important of which are public and private financing. Public financing can be divided into financing from general or specific taxes, as well as mandatory contributions to a public insurance scheme (social insurance). Private financing, on the other hand, can be subdivided into financing for the purchase of private health insurance and financing from direct payment or out-of-pocket expenditures.

The sources of financing and organization of spending in the health sector are factors that have an impact on the financial sustainability of health systems and access to services (Perea Flores, 2018). In particular, while a certain financing model may be effective in generating revenue, it may also constitute a differentiated access factor for different population groups (see "Gaps in health sector services"). Given the fragmented and segmented nature of LAC health systems, each country has a unique financing profile, the main components of which are illustrated in Graph 4.3.

When the pandemic stuck, the region's countries were struggling high financing needs and low investment in the health sector, so in response to the health emergency, budgets had to be prioritized or new sources of resources had to be obtained (debt or contingency funds).

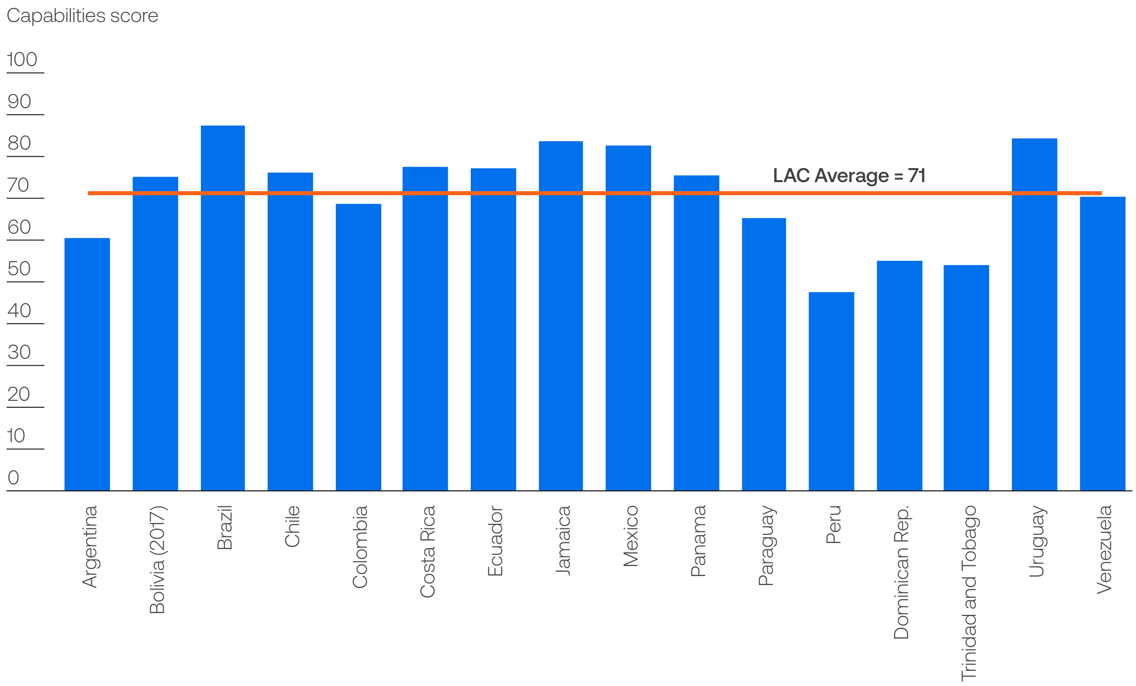
For example, the arrival of the pandemic in Peru forced the country to allocate resources to increase its hospital capacity in infrastructure and equipment, resulting in a higher health expenditure as a percentage of GDP to address COVID-19 (IPE, 2021). In Mexico, the Coordinating Commission of National Health Institutes and High Specialization Hospitals anticipated a 500% increase in its budget, from USD 58.5 million in 2020 to USD 371.9 million in 2021 (CANIFARMA, 2020). In fact, Mexico's Health Welfare Fund provided flexible and timely financial support during the pandemic. This fund for protection against catastrophic expenses was an important support for buying personal protective equipment, replenishing medication supplies, and, in general, responding to the urgent need to keep hospitals functioning during the crisis (Institute for Global Health Sciences, 2021). Finally, in the case of Uruguay, the amounts allocated in 2020 to building improvements, maintenance, repairs, remodeling and equipment of various health centers almost quadrupled with respect to the values executed in 2017 (USD 18.8 million, according to a report by Uruguay's Office of the President, 2018), which allowed for the completion of multiple hospital infrastructure works and equipment of the State Health Services Administration.

Public health and pandemic management

Responding appropriately to a public health problem, particularly an event that could potentially become an epidemic, requires mechanisms for timely detection, identification of its causes and risk factors, and the implementation of effective interventions to control it.

The adoption of the International Health Regulations (IHR) by WHO member states in 2007 reflected their commitment to improve their capacities for implementing surveillance and response to potential events that could constitute a public health emergency of international concern. Accordingly, the WHO established a conceptual framework for monitoring IHR implementation in general and countries' core capacities for surveillance and response. Countries report annually to the WHO on the status of IHR implementation. For the report corresponding to 2019 (WHO, 2021c), few countries in the region (Ecuador, Jamaica, Panama, and Uruguay) presented levels between 60% and 100% for all their indicators, while Argentina, Peru, Dominican Republic, and Trinidad and Tobago reported percentages between 0% and 40% for a significant number of indicators. Graph 4.4 illustrates the simple average of the indicators for the countries in the region.

Graph 4.4
Basic public health emergency surveillance and response capabilities in LAC countries in 2019
Source: Authors based on data from WHO (2021c) and Guibovich, Zamora and Castillo (2022).



Note: The indicator is constructed from 13 capabilities (each identified with between 1 and 3 indicators), with five performance levels (in multiples of 20%). The indicator is presented as a percentage on a scale of 100.

Once the cases of severe pneumonia in Wuhan were characterized as a Public Health Emergency of International Concern (PHEIC), countries were alerted through their respective National Focal Points for International Health Regulations. This alert triggered the revision and adaptation of their epidemiological surveillance methods and tools to detect, investigate, diagnose, report and control cases of the disease caused by this new virus.

COVID-19 surveillance, implemented by countries within the framework of their health information systems, had the general objective of monitoring the spread of the disease in order to identify patterns and apply prevention and control measures. Table 4.1 summarizes some of the surveillance methods used in the countries of the region in 2020 and 2021.

A common denominator of these countries was the formulation or permanent updating of their standards and procedures for COVID-19 surveillance and control of entry points into the countries (ports and airports), health facilities, businesses, educational and work centers, prisons and others. At the global level (in Europe and Central Asia), countries recognized that their surveillance systems needed to be updated and reorganized to keep pace with the dynamics of the pandemic (Negro-Calduch et al., 2006). However, the alert and response systems of the countries did not prevent the pandemic from acquiring global reach. In fact, with some specific exceptions, no significant relationship has been observed between surveillance capacities and COVID-19 cases registered by country (both in terms of infections and deaths).[63]

Table 4.1
Types of surveillance used globally during the COVID-19 pandemic
Source: Translated and adapted from Khamis Ibrahim (2020).

Type of surveillance	Description
Indicator based	Periodic collection, analysis and interpretation of structured data (indicators elaborated from periodic information provided by health facilities).
Clinical syndromic	Surveillance based on clinical manifestations and classification into suspected, probable or confirmed.
Active	Active case finding and contact tracing.
Laboratory-based	Investigation of suspected or probable cases with molecular and serological tests, culture and genomic characterization.
Sentinel	Through healthcare providers with high demand and installed capacity to report comprehensive and robust data.
Mortality	Reporting of deaths in hospitals and other health care facilities.
Health care	Availability of hospital and ICU beds, ventilators, personal protective equipment, human resources and vaccines.
Digital	Using applications or mobile devices for fully or partially automated tracking or tracing of cases and contacts (Braithwaite et al., 2020).
Event-based	Organized collection and evaluation and interpretation of unstructured information on events that may represent an acute risk to human health.

63 This assessment arises from comparing the indicators in the Graph 4.4 and the cases and deaths registered per thousand inhabitants (at the end of 2021). Only Peru stands out, with the lowest indicator of capacities and response in the region in 2019, suffering the highest number of deaths per capita.

The region faces several challenges in health provision, which can be analyzed in three dimensions: access, cost, and quality.

Gaps in health sector services

As in other infrastructure sectors, it is possible to approximate the gaps in health sector services, defined as deficits in the provision of services that can manifest themselves through user dissatisfaction in three dimensions: access, cost-affordability and quality (Cont et al., 2021). Analyzing the pre- and post-pandemic situation of these gaps will provide insight into the impacts that COVID-19 had on these gaps and identify effects that similar future events may have.

Access

The supply of health services is sustained or supported by the existence of qualified health professionals (personnel), health infrastructure and equipment (including medical supplies and medicines). Therefore, access to health services must take into account the availability of these three elements.

Human Resources

One of the main conditions for progress toward the achievement of SDG 3 is to ensure a sufficient number of health workers, adequately trained and equitably distributed so that there are no inequalities in access to health services (Poz y Roberto, 2013; OMS, 2008b; OMS, 2013; Girardi et al., 2013). In this regard, WHO (2016) warns that the incorporation of 14.5 million more health workers will be necessary to reach the institution's most demanding threshold—compatible with the fulfillment of the SDGs—in terms of availability of professionals (44.5 per 10,000 inhabitants). Most of the new professional additions must be in Africa (6.1 million) and Southeast Asia (4.7 million) and, to a lesser extent, in Latin America and the Caribbean (0.6 million).

To measure access to an adequate number of health personnel, one can use the health professional density indicator (HPD), whose formula includes the combined number of physicians, nurses and midwives or midwives per 10,000 population. Initially, in the 2006 World Health Report, WHO stated that countries with HPD indices below 22.8 were probably unable to provide 80% coverage of the most basic health services (WHO, 2006). A minimum threshold of 25 professionals per 10,000 population was then established, which was subsequently increased to 44.5 as a condition for achieving the SDGs by 2030 (WHO, 2016).

According to the data presented in Table 4.2, only Jamaica has an indicator below 25. Bolivia, Costa Rica, Dominican Republic, Paraguay, Peru, Peru and Venezuela have an indicator between 25 and 45. The rest of the countries in the region already exceed the minimum threshold established for 2030 (HPD of 45). In addition, the ratio of at least one qualified nurse to one qualified physician is largely being met in the region.

On the other hand, at the regional level, the countries have steadily increased human resources training. The HPD in LAC has doubled in the last two decades. This growth has been greater for nurses and midwives than for physicians (Table 4.3).[64]

Table 4.2
HPD indicator in LAC in 2020
Source: WHO (2020).

Country	Physicians (per 10,000 inhab.)	Nurses and midwives (per 10,000 inhab.)	Physicians, nurses and midwives (per 10,000 inhab.)
Argentina	39.9	25.9	65.8
Bolivia	10.3	15.6	25.9
Brazil	23.1	74.0	97.1
Chile	51.8	133.2	185.1
Colombia	38.4	13.9	52.4
Costa Rica	28.9	8.9	37.9
Ecuador	22.2	25.6	47.8
Jamaica	4.5	9.4	13.9
Mexico	48.5	23.6	72.2
Panama	16.3	32.1	48.4
Paraguay	13.5	16.6	30.1
Peru	8.2	29.8	37.9
Dominican Republic	14.5	14.6	29.1
Trinidad and Tobago	44.7	40.7	85.5
Uruguay	49.4	72.2	121.6
Venezuela	17.3	20.7	37.9

Table 4.3
Evolution of the HPD in LAC for the period 2000-2018
Source: Guibovich. Zamora and Castillo (2022).

Year	Physicians (per 10,000 inhab.)	Nurses and midwives (per 10,000 inhab.)	Physicians, nurses and midwives (per 10,000 inhab.)
2000	16.2	21.1	37.3
2010	19.1	40.8	59.9
2018	22.8	50.6	73.4

64 Unfortunately, the data provides an approximation but not necessarily a complete representation of the national reality due to the great fragmentation of health systems. Not all health subsystems record their data in unified platforms, a situation that is further complicated by the multiple contractual conditions of health workers, which generates duplications in accounting. All these factors suggest that special studies should be carried out to assess this area, which, due to their cost, are not carried out in all countries or are not done regularly.

While these indicators have been favorable in addressing a critical situation in the health sector before the pandemic hit the region, it should be noted that this average may hide large differences between countries and, in turn, these differences are repeated within each country. In this regard, the commitments set goals on the equitable distribution of human resources in different geographical areas. Thus, the WHO (2016) also establishes that by 2030 "no less than 80% of countries [should] have halved the gap in the density of health professionals between urban and rural areas."

However, a comparative analysis of Colombia, Costa Rica, Jamaica, Panama, Peru, and Uruguay, published in 2015, confirmed this concern about the geographic distribution of human resources. Systematically, in all the countries studied, large cities concentrated the largest proportion of resources to the detriment of rural areas (Carpio and Santiago Bench, 2015).

Other cases analyzed individually provide similar evidence. In Argentina, which has an HPD of 65.8, the difference in distribution between urban and rural areas is significant. For example, in 2019, the number of physicians reached 166.3 per 10,000 inhabitants in the City of Buenos Aires, while the provinces of Misiones and Chaco had 18.1 and 19.4 physicians per 10,000 inhabitants, respectively (Ministry of Health of Argentina, 2018). Mexico reflects similar regional disparities. Mexico City has three times more physicians than the State of Mexico and ten times more specialists than the State of Chiapas, one of the poorest in the country (González-Block et al., 2020). For the case of Brazil, municipalities with less than 5,000 inhabitants had one doctor for every 3,000 people in 2018, while this indicator was one doctor per 230 people for municipalities with more than 500,000 inhabitants (The Commonwealth Fund, 2020).

The pandemic exposed a shortage of specialized healthcare professionals in areas required for the management of COVID-19: epidemiologists, intensive care specialist and pulmonologists, among others. This situation, in view of the unequal territorial distribution of human resources, was even more pronounced in rural areas. This was the case in Argentina, where only 8% of the country's 181,189 active medical professionals work in specialties relevant to COVID-19 treatment (Silberman et al., 2020).

In order to counteract this situation and increase the number of health care workers, countries implemented policies aimed at socially protecting health care personnel who care for COVID-19 patients and providing them with incentives like the provision of life insurance (Chile, Peru) or a temporary economic bonus (Argentina, Chile, Colombia, Paraguay, Peru) (SELA, 2021). Other actions implemented included offering the possibility of early graduation or incorporating students in the last years of health careers (Brazil, Chile, Colombia, Uruguay); the exceptional authorization for the practice of health professionals with degrees abroad (Argentina, Chile, Peru); the reconversion of human resources to address the gap of specialists in critical patient units (Bolivia, Chile, Peru); the flexibilization of licensing, contractual regimes and payment of incentives for overtime (Peru); and, finally, the increased use of digital health tools to maintain the supply of services, especially for the medical care of patients (Brazil, Chile, Ecuador, Paraguay, Peru, and Uruguay), as well as the training and monitoring of personnel (PAHO, 2020a).

In summary, although most of the countries studied had already met the minimum HPD value established by the WHO, the distribution within countries is a further reflection of a geographic gap in health resources in general. In addition, the supply of health professionals does not necessarily ensure that the needs of the population can be met in terms of the required specialties.

Box 4.2
Digital health

In 2011, the Pan American Health Organization (PAHO, 2011) proposed an eHealth Strategy and Action Plan, synonymous with cyberhealth, and defined it as:

> "The support that the cost-effective and safe use of information and communication technologies offers to health and health-related fields, including health care services, health surveillance and documentation, as well as health education, knowledge and research on health."

In 2018, the Final Report of the eHealth Strategy and Action Plan highlighted the main achievements and some pending challenges, which were consistent with the results of the WHO's Third Global Survey on eHealth (PAHO, 2016). For countries in the region, they could be summarized as follows:

- Most countries were in the process of formulating a national *eHealth* policy or strategy with clear objectives, goals and priorities.
- Few countries had funding to develop and support electronic health record programs and appropriate legislation to support their use.
- Only one-third of the countries referred directly to telehealth in their national health policies or strategies, although many used telemedicine and teleradiology services.
- All countries had mHealth programs, although few programs were government-sponsored and far fewer had an entity responsible for overseeing their quality, safety and reliability.
- The vast majority of countries used digital learning in the training of health sciences students and continuing professional education.
- Not all countries had legislation protecting the privacy of health-related data or allowing individuals to access their own data electronically.
- Although not all countries had a strategy on the use of social networks in health, in almost all of them social networks were used by the population to learn about health.

In 2020, the 73rd World Health Assembly approved the Global Strategy on Digital Health 2020-2025, which defines digital health as "the field of knowledge and practice associated with the development and use of digital technologies to improve health," including digital consumers, with a broader range of connected smart devices. It also refers to other uses of digital technologies for health, such as the internet of things, advanced computing, big data analytics, and artificial intelligence, including machine learning and robotics (WHO, 2021f).

The COVID-19 pandemic accelerated the need to implement digital solutions to strengthen epidemiological surveillance capacity, increase care capacity (because health personnel were insufficient, sick or confined) and inform policy makers, researchers and the population. Thus, policies and standards were formulated, applications and digital tools were developed for traceability, case tracking and contact identification, to provide care through telemedicine, to inform the population about prevention and to make open data on the pandemic available to all, trying to close the gaps mentioned above.

For example, in Bolivia, self-diagnosis was carried out and recommendations on the management and prevention of COVID-19 were provided through a mobile application called *Unidos Contra el Covid* [United against Covid]. Likewise, in Argentina, the CUIDAR application facilitated self-diagnosis and case follow-up; in addition, Law 27.553 enabled the prescription and dispensing of medicines by means of electronic or digital prescriptions (Congreso Argentino, 2020). In Ecuador, a call center and a mobile application "SaludEC" were assigned to provide information, self-diagnosis, telemedicine, appointment scheduling, patient registration and emergency management (CAF, 2020b; Moller, 2020).

Authorities responsible for telemedicine management in Argentina, Brazil, Colombia, Costa Rica and Uruguay have identified great benefits and opportunities, but also challenges[a] as a consequence of the application of this type of care during the COVID-19 pandemic, which put its post-pandemic sustainability at risk. These challenges are:

- An insufficient or inadequate legislative framework to enable teleconsultations by physicians to patients and ensure quality, safety and confidence in the service.
- Insufficient or incomplete digital infrastructure due to low funding and deficiencies in connectivity and devices.
- Poor culture and training of health professionals, especially due to the lack of undergraduate and in-service training.
- The need to ensure continuity between virtual and face-to-face care.
- The need to inform and educate citizens about the advantages of telemedicine, but also about respect for their rights.

In general terms, countries with greater broadband infrastructure were able to partially counteract the negative effects at the onset of the pandemic; the pandemic led to an increase in network traffic, the effect of which on health has not been determined. In addition, unequal digital access affected the receipt of health information and other services (CAF, 2020a).

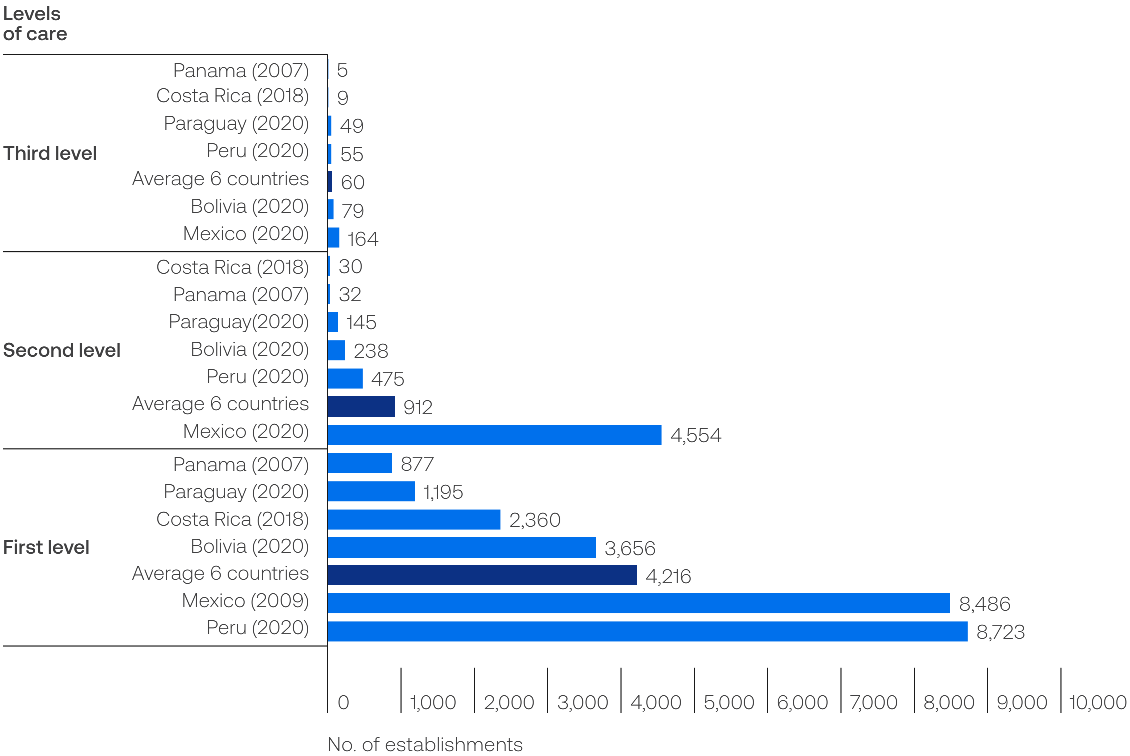
a. Raised during the PAHO/IDB webinar "Telemedicine during the COVID-19 pandemic: Lessons learned one year later," held on May 12, 2021.

Sanitary infrastructure

The availability of health infrastructure is analyzed according to the classification by levels of care formulated by the WHO in 1986.[65] Table 4.5 shows the number of facilities according to these levels.

Another indicator that complements the information on the availability of health infrastructure is hospital density or concentration of hospitals per 100,000 inhabitants in a territory (Table 4.4), based on the concept that a higher density indicates closer proximity of health services and effectiveness in meeting demand. However, this will also depend on the real existence of the resolution capacity in health facilities, the development of primary care models and integrated networks, and the presence or absence of barriers that prevent their use.

Graph 4.5
Number of health facilities by levels of care in LAC
Source: Guibovich, Zamora and Castillo (2022).



Note: Paraguay has a fourth level of care that covers specialized hospitals.

65 The classification of health infrastructure according to levels of care, as formulated by WHO in 1986, is a technical and administrative concept based on the organization of individuals' and communities' contact with the health system. The three levels of care are each assigned specific objectives based on their location, level of complexity, and specialization. The first level of care comprises health promotion, prevention, medical care, early detection of diseases, and recovery and rehabilitation procedures. This level caters to around 85% of basic needs and the most common health demands (Ministry of Health of Peru, 2022), and includes medical offices, health posts, and centers, among others. The second level encompasses hospitals and facilities that provide services related to internal medicine, pediatrics, gynecology and obstetrics, general surgery, and psychiatry. Up to 95% of the population's health problems can be resolved between the first and second levels (Vignolo et al., 2011). The third level is reserved for less common problems or complex pathologies requiring specialized and high-tech procedures. Its coverage should span the entire country or a significant portion of it, and approximately 5% of the population's health problems are addressed at this level.

Table 4.4
Density of health facilities per 100,000 inhabitants in LAC in 2013
Source: WHO (2021g).

	Hospitals			Health centers	Health posts
	Total	Third level	Second level		
Bolivia	1.1	n.a.	0.8	8.8	13.8
Chile	1.0	0.1	0.6	0.1	10.7
Costa Rica	0.8	0.3	0.3	0.7	2.1
Ecuador	0.3	0.2	0.1	0.4	2.9
Mexico	3.5	3.5	n.a.	n.a.	102.1
Panama	0.9	0.3	0.4	10.0	12.4
Paraguay	2.4	0.1	2.0	1.7	9.7
Uruguay	3.9	3.5	n.a.	1.2	17.6

Note: Third level includes regional, specialized, teaching and research hospitals. Second level includes provincial hospitals; n.a.: data not available.

During the health emergency, the most vulnerable populations in several countries of the region had difficulty accessing hospitals. For example, in Mexico in 2020, there was a bias in care and resources toward the center of the country, as 33% of third-level hospitals are concentrated in Mexico City (52% if the State of Mexico and Jalisco are included), and 35% of second-level hospitals are located in that same city, as well as Guanajuato, Puebla, and Michoacán. In some affected inland areas, there was less availability of hospitals and beds for severe or complicated cases, but most cases occurred in states with better accessibility to infrastructure (Campos and Balam, 2020). In other words, while some areas had less access to healthcare resources, the majority of COVID-19 cases occurred in regions that had better healthcare infrastructure.

According to the OECD, governments in the region redirected public resources to close gaps in health services and increased their capacity to care for COVID-19 patients. This included the expansion of health infrastructure (OECD, 2020). For example, in Ecuador, ten field hospitals were installed in some of the most affected neighborhoods in Guayaquil, seeking to alleviate the overflow of its health infrastructure. Colombia and Peru proposed a territorial management strategy that consisted of extending part of high-complexity hospitals' services to institutions such as hotels, closed clinics, and field hospitals. In Panama, the accelerated construction of the Integrated Panama Solidarity Hospital, with state-of-the-art technology and a biosafety system, and the habilitation of the old Figali Convention Center are two examples of these measures. Additionally, the Ministry of Health of Panama enabled 15 Community Operations and Traceability Centers in each health region of the country, where a team composed of joint task forces, local governments, civic clubs, chambers of commerce, and religious groups worked. Their objective was to locate and georeference each positive case, their contacts, and family members to establish, from each community, the necessary medical and social follow-up (Enríquez and Sáenz, 2021).

Although most countries strengthened and expanded their health infrastructure, it was insufficient for the number of affected populations in their countries (Enriquez and Saenz, 2021), especially at the peak of the pandemic.

Sanitary equipment, supplies and medicines

Countries use different indicators to analyze the availability of health equipment; some use the operational status of equipment, others classify it by level of investment, type, age or according to the complexity of the service provided. For the purpose of comparing countries, the indicator of availability of equipment considered key for providing health services during the health emergency imposed by the pandemic has been selected, taking into account, essentially, that the equipment is operational or suitable for use. This indicator can be applied to hospital beds, beds in intensive care units (ICUs), mechanical ventilators, and some diagnostic support equipment (Jaldin and Marquez, 2017). According to WHO, the minimum number of hospital beds should be between 2.4 and 4 per 1,000 inhabitants; ICU beds, between 6 and 8 per 100,000 inhabitants, and mechanical ventilators, between 6 and 8 per 100,000 inhabitants.

In all the countries of the region, with the exception of the Dominican Republic and Trinidad and Tobago, the number of hospital beds did not exceed the minimum defined by the WHO. Paraguay and Venezuela had the lowest availability (Graph 4.6)

As for ICU beds, which are a better approximation of the equipment required in life-threatening hospitalizations (a prevalent situation during 2020), six of the countries studied exceeded the WHO's minimum standard, but most were far from the average number of ICU beds available in OECD countries (12 per 100,000 inhabitants). Uruguay and Argentina had notably higher numbers of ICU beds, and Peru had the lowest (Table 4.5).

In response to the health emergency, most countries, except Trinidad and Tobago, increased the number of ICU beds. This increase was also evident in Argentina, Brazil, Chile, Colombia, and Uruguay, which before the pandemic exceeded the WHO suggested standard of six ICU beds per 100,000 inhabitants—although there are some experts like Torres (2020) who believe it should be ten ICU beds per 100,000 inhabitants in cases like the COVID-19 epidemic.

Graph 4.6
Hospital beds in LAC countries in selected years
Source: Guibovich, Zamora and Castillo (2022).

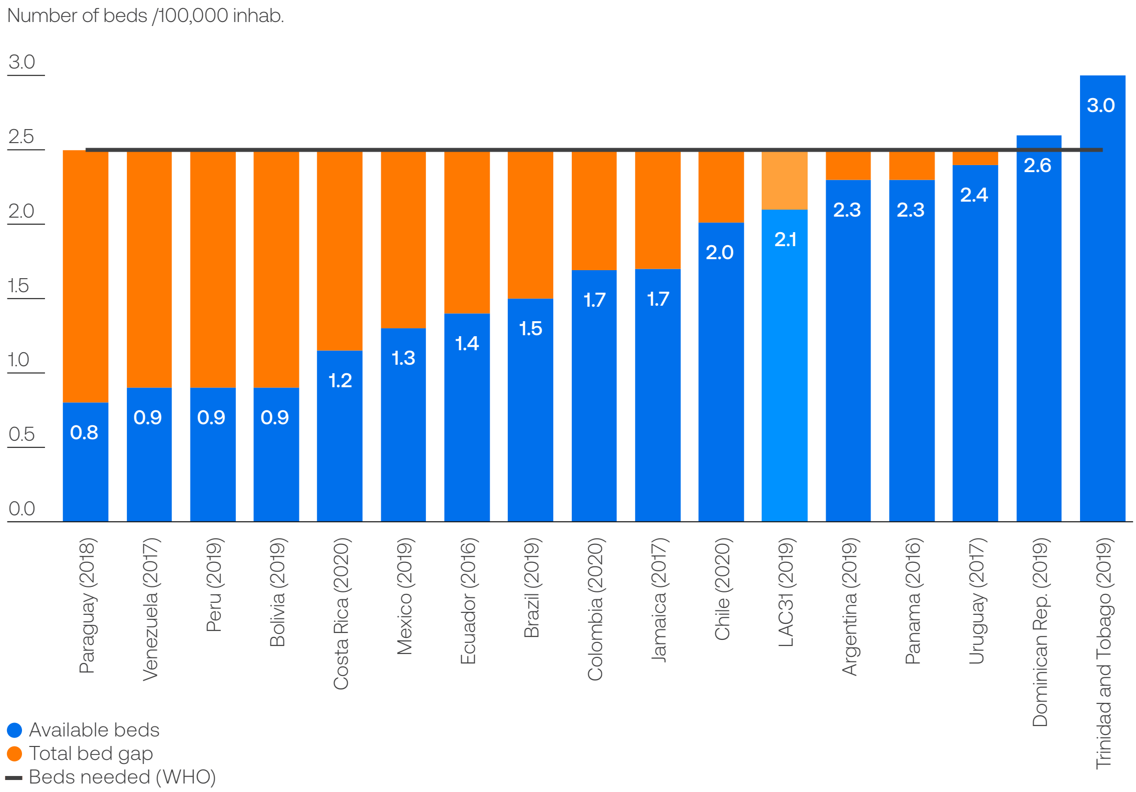


Table 4.5
Number of ICU beds per 100,000 inhabitants before and in response to the pandemic
Source: Guibovich, Zamora and Castillo (2022).

Countries	Before the pandemic (2019)	During the pandemic (2020-2021)
Trinidad and Tobago	2.1	2.1
Costa Rica	n.a.	2.7
Ecuador	1.5	2.7
Bolivia	2.2	4.2
Venezuela	1.2	4.3
Dominican Rep.	n.a.	5.5
Peru	0.4	6.2
Panama	8.1	n.a.
Paraguay	n.a.	10.3
Chile	7.0	12.0
Brazil	8.0	20.6
Uruguay	19.9	23.2
Colombia	11.2	23.7
Mexico	2.0	24.8
Argentina	19.0	25.8
Average	**7.5**	**15.2**

Note: In some cases, the data corresponds to the closest year for which information is available; n.a.: data not available.

In nine of the countries analyzed, the number of mechanical ventilators was above the WHO minimum standard. Brazil and Uruguay had the highest and Peru the lowest (Table 4.6). All of them increased the number of ventilators during the pandemic. The increase averaged more than 53%, reaching almost three times the WHO standard, with the exception of Peru, which, despite having increased the number of mechanical ventilators by more than 500%, did not reach the standard of one ventilator per ICU bed.

In some cases, such as Mexico, these significant increases were not sufficient to meet the demand at the worst point of the pandemic. According to data from the General Directorate of Epidemiology of the Mexican Ministry of Health, between April 12 and July 9, 2020, only 16.9% of persons who died from COVID-19 who needed a mechanical ventilator actually had access to these devices. During the onset of the pandemic, at a COVID-19 referral center in Mexico City, 45% of patients who did not survive failed to be admitted to an ICU bed due to a lack of space, despite justified admission (Olivas-Martínez et al., 2021).

In the wave corresponding to March 2021, ICU bed occupancy collapsed in several LAC countries. Paraguay reached 100% occupancy and there were still patients waiting, according to the country's health authorities. Chile and Peru were also in a critical situation, with hospitals in both countries reaching 96% occupancy. Uruguay recorded 70% occupancy of its beds and Argentina between 56% and 60%, with the highest in Buenos Aires, with 61%. In Quito, occupancy reached 97%; in Bogota, 65%, and finally, in 18 of the 27 states of Brazil, occupancy exceeded 90% (in only one state was less than 80%) (SRALA, 2021).

With respect to the supply of other medical equipment during the pandemic, there were international bottlenecks for some products, such as facemasks and mechanical ventilators. These became very scarce goods during periods of greatest need and high demand (Enriquez and Saenz, 2021).

Table 4.6
Mechanical ventilators per 100,000 inhabitants, before and during the pandemic
Source: Guibovich, Zamora and Castillo (2022).

Countries	Before the pandemic (2019)	During the pandemic (2020-2021)
Peru	0.8	5.1
Trinidad and Tobago	4.7	6.5
Paraguay	4.8	9.0
Panama	11.6	12.0
Colombia	12.7	13.0
Argentina	12.9	19.3
Uruguay	18.6	23.0
Mexico	13.4	24.8
Chile	9.2	26.6
Brazil	25.1	28.0
Costa Rica	5.9	n.a.
Bolivia	6.6	n.a.
Dominican Rep.	12.4	n.a.
Average	**10.7**	**16.7**

Note: In some cases, the data corresponds to the closest year for which information is available.

The global pharmaceutical industry is characterized by a small number of players specialized in the research and development of innovative drugs. As patent laws have gained ground worldwide, this characteristic extends to commercialization during periods of protection. LAC participates marginally in this market (4%) and has a similar situation in the field of research and development (1%), according to ECLAC (2021). The region is a net importer of pharmaceutical products, mainly innovative finished products and inputs for the local production of generics. Argentina, Brazil, Colombia and Mexico are the largest markets and, in turn, are involved in intra-regional exports. Ecuador, on the other hand, is the largest importer of manufactured products in the region.

In the particular case of vaccines, their development, production and marketing are not substantially different or even more precarious than that of drugs because the major supply centers for these products are located in the United States, Europe and Asia.

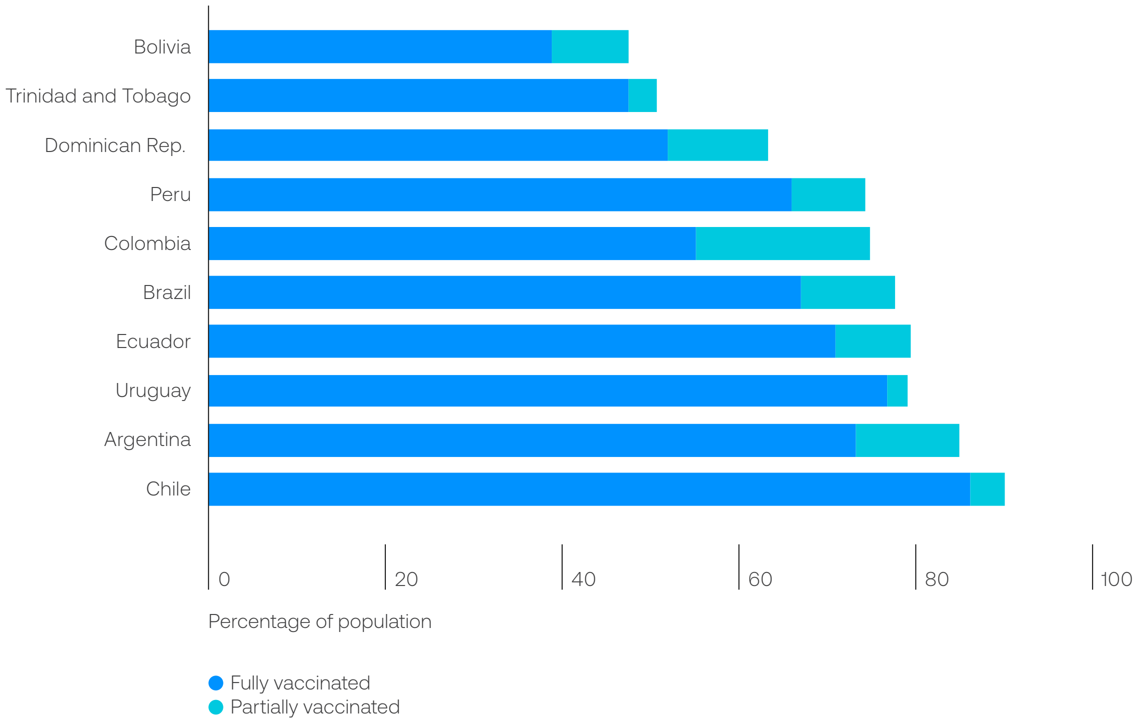
The pandemic has served to highlight the dependence of the countries of the region on the production of inputs, medicines and technology by multinational companies and, therefore, on their importation (ECLAC, 2021). Being net importers, the countries were forced to develop other strategies that would allow better access to markets, such as authorizing national health authorities to purchase equipment, goods and services for the actions planned to combat COVID-19; adopting provisions for the acquisition, manufacture and modification of ventilators; issuing import and export permits for all health inputs; active ingredients for the production of medicines, as well as food and other products for human consumption and medical devices required to combat the pandemic.

Without having developed a vaccine of their own and with local capacities under development, the route taken by almost all countries to access vaccines was to purchase what was available on the market, even considering some that did not have emergency approval from regulatory agencies. On different dates, between

December 2020 and May 2021, vaccination campaigns were launched in the region. The first to implement their vaccination strategy were Chile, Costa Rica and Mexico, all on December 24, 2020. On the other hand, in order to guarantee sufficient volumes to vaccinate their entire target population as soon as possible, the countries diversified their negotiation strategies and sources of vaccine supply. The mechanisms used were: country-to-country, country-to-company, direct donations and, secondarily, through the Global Access Fund for Vaccines COVID-19, better known as COVAX, promoted by WHO with the support of the Global Alliance for Vaccines and Immunizations. The latter mechanism quickly demonstrated its own limitations to supply in the required volumes and with the expected timeliness.

It is noteworthy that, after different starting speeds and different strategies carried out by the countries, by December 31, 2021, on average, 76% of people in South America had received at least one dose of a vaccine and 64% had completed the full schedule, above Europe (66% and 62%) and the United States (74% and 62%). In other words, despite their dependence on international trade, in the case of vaccines, LAC countries were able to find negotiation mechanisms that enabled them to achieve high levels of vaccination. Thus, the wave that took place during the first months of the year 2022 had a much greater impact in terms of infections than in cases of hospitalization or deaths (compared to the first wave that began two years earlier).

Graph 4.7
Percentage of population vaccinated with one and two doses of COVID vaccine- 19 in LAC countries by December 31, 2021
Source: Authors based on data published in OWID (n.d.e).



Note: The OWID data used are from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) of the Johns Hopkins University.

Quality

The health services offered differ from one country to another and even between different systems within a country. However, regardless of these aspects, in any properly functioning health system, the service delivery network has defined the following aspects as essential attributes to take into account in order to achieve accessibility, timeliness, and quality (WHO 2010):

- Continuity of care through a referral and counter-referral system.
- Typification of the health services that make up the integrated health networks (high complexity hospitals, general hospitals, polyclinics, medical centers, mobile health services, etc.).
- Delivery of health services according to the life course (care packages) with high quality, that is, effective, safe, patient-centered, and timely.
- Coordination of local health service networks for routine and emergency preparedness. Coordination also takes place with other sectors (e.g., social services) and partners (e.g., community and international cooperation organizations).

The main challenge in measuring the performance of a health system in terms of quality and, in general, of the other dimensions, lies in the complexity of the task and the lack of consensus on the indicators to be used to make comparisons between countries. For example, the OECD uses as a measure of quality indicators of the supply of basic services (childhood vaccination programs, in-hospital mortality due to acute myocardial infarction and stroke, cancer survival and avoidable hospital admissions). Table 4.7 presents representative indicators for some LAC countries. Thus, slightly more than half of the LAC countries achieved the minimum immunization levels recommended by WHO to prevent the spread of diphtheria, tetanus and pertussis (DTP) (90%) and almost one third achieved the target set for measles (95%) in 2018. For the remaining indicators, related to in-hospital mortality for cardiovascular reasons, cancer survival, and preventable admissions, underreporting prevails in many countries. In the cases that are reported, in general the indicators show a lower performance than in OECD countries, with specific exceptions.

The other approach to measuring quality is based on user perception (Donabedian, 2001). Different surveys conducted in the region show that the existing systems for measuring quality of care are poorly developed and, therefore, the information available for decision-making is very precarious. However, with the information available, it can be argued that most health systems in LAC have a low performance in the provision of quality services and that, among the main reasons why sick people avoid or postpone the use of services are the cost of care, organizational problems (communication, inability to obtain an appointment or for follow-up), which have an impact on the low quality and availability, or the perception that the problem is not solved (Alvarez et al., 2020).

A unique case is Peru, where the National Household Survey reveals that long waiting times, the perception of poor effectiveness of first level services, and mistreatment—problems that have increased steadily in the last ten years—have become the main barrier to access to health services, above the cost of these services (Rojas Bolivar, 2016).

During the pandemic, this situation worsened even more. In order to minimize the effects of COVID-19, most of the sector's efforts (infrastructure, human resources, medical supplies, etc.) were devoted to the treatment of patients affected by COVID-19 and the early detection of cases. A collateral impact of these decisions fell on traditional patients, who were treated under very restrictive conditions or even suffered the postponement or interruption of their treatment (Barriga et al., 2021; Gómez Rincón, 2021; Union for International Cancer Control, 2020; Vela-Ruiz et al., 2020). Although there are not yet studies that have measured all dimensions of this impact, during the critical period of the pandemic, waiting times for elective surgeries were prolonged; difficulties in receiving emergency treatment also increased, the quality of cancer care deteriorated, and surgeries for cardiovascular disease declined (Iacobucci, 2021). This impact is no less significant for mental health and services for neurological conditions and substance abuse treatment, which were already in deficit before the pandemic. Well-established or steadily improving services, such as reproductive health, were also affected. According to PAHO, pregnancy and newborn care "has been interrupted in almost half of the countries of the Americas" (PAHO, 2021a). In the strictest stage of confinement, from March to August 2020, prenatal checkups were reduced by 40% in the region (PAHO, 2020b).

Table 4.7
Quality of care indicators
Source: Authors based on OECD and World Bank (2020).

Country	Childhood Vaccination		Cancer survival			In-hospital mortality due to:			Avoidable hospital admissions				
	Vaccination coverage DTP3	Vaccination coverage MCV1	Breast cancer	Cervical cancer	Colon cancer	Myocardial infarction	Hemorrhagic stroke	Ischemic Stroke	Asthma	COPD (Chronic Obstructive Pulmonary Disease)	Chronic heart failure (CHF)	Hypertension	Diabetes
	% of the population aged 1 year (2018)		Five-year survival rate (2010-2014)			In-hospital case mortality rates within 30 days of admission per 100 patients over 45 years of age (2017)			Standardized rates for patients over 15 years of age per 100,000 population (2017)				
LAC	90	90	78	60	52	10.6	11.7	22.2	18.4	99.3	100.3	38.8	122.5
OECD	95	95	84	66	62	6.9	7.7	24.0	41.9	183.3	233.0	84.3	128.9
Argentina	86	94	84	53	54	-	-	-	-	-	-	-	-
Bolivia	83	89	-	-	-	-	-	-	-	-	-	-	-
Brazil	83	84	75	60	48	13.3	16.8	27.7	22.8	85.2	116.7	48.1	91.8
Chile	95	93	76	57	44	8.2	8.3	21.3	18.5	79.6	96.4	17.5	118.7
Colombia	92	93	72	49	35	5.6	-	-	12.1	119.6	60.5	-	62.1
Costa Rica	94	94	87	78	60	0.3*	2.7*	1.6*	26.7	98.8	38.8	26	131.9
Cuba	99	99	75	73	64	-	-	-	-	-	-	-	-
Dominican Rep.	94	95	-	-	-	-	-	-	-	-	-	-	-
Ecuador	85	83	76	52	48	-	-	-	-	-	-	-	-
El Salvador	81	81	-	-	-	-	-	-	-	-	-	-	-
Guatemala	86	87	-	-	-	-	-	-	-	-	-	-	-
Guyana	95	98	-	-	-	-	-	-	-	-	-	-	-
Haiti	64	69	-	-	-	-	-	-	-	-	-	-	-
Honduras	90	89	-	-	-	-	-	-	-	-	-	-	-
Jamaica	97	89	-	-	-	-	-	-	-	-	-	-	-
Mexico	88	97	-	-	-	27.5	19.2*	29.9	7.6	76.9	57.0	75.3	248.5
Nicaragua	98	99	-	-	-	-	-	-	-	-	-	-	-
Panama	88	98	-	-	-	-	-	-	-	-	-	-	-
Paraguay	88	93	-	-	-	-	-	-	-	-	-	-	-
Perú	84	85	82	57	59	-	-	-	-	-	-	-	-
T. and Tobago	99	90	-	-	-	-	-	-	-	-	-	-	-
Uruguay	91	97	-	57	54	8.8	11.4	30.5	22.9	135.9	182.3	27.0	82.2
Venezuela	60	74	-	-	-	-	-	-	-	-	-	-	-

Note: Figures for LAC and OECD correspond to the average of available country data. CVA: stroke; DTP3: diphtheria, pertussis, and tetanus vaccine; COPD: chronic obstructive pulmonary disease; AMI: acute myocardial infarction; CHF: chronic heart failure; MCV1: first dose of measles vaccine. * indicates that the data are from 2015.

Cost and affordability

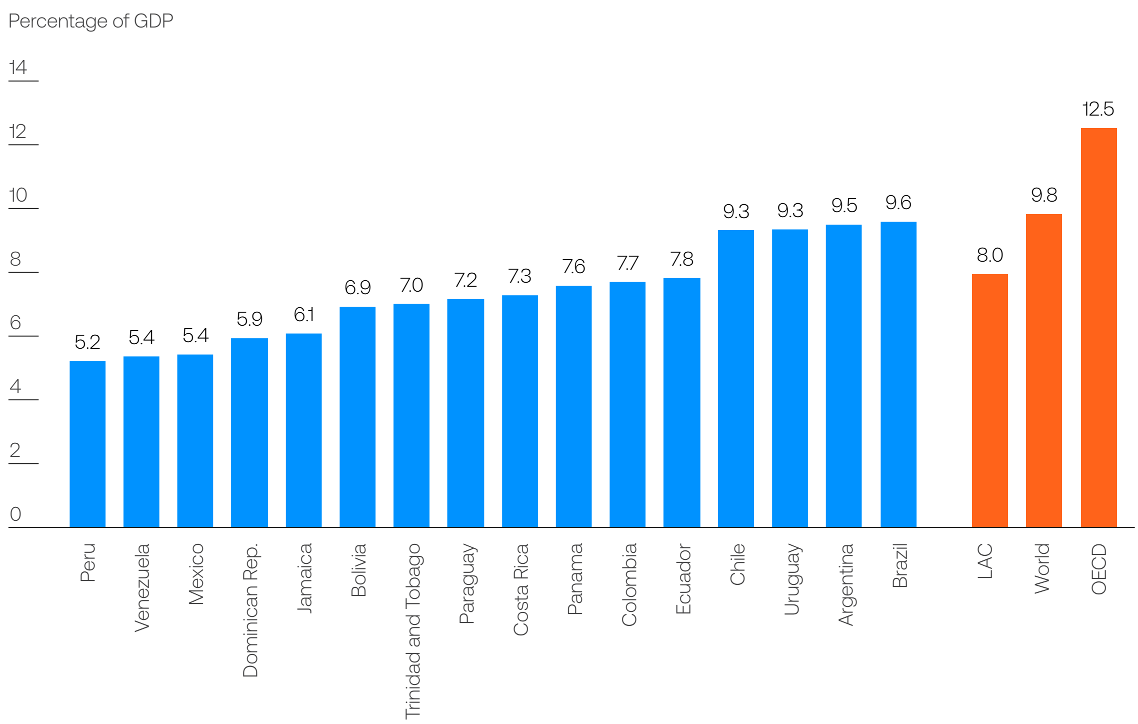
The dimension of the cost of health service provision can be approximated through total expenditure, which measures the final consumption of health goods and services, including health infrastructure, medicines and human resources (OECD, 2021c). This indicator is presented in aggregate form (total expenditure) or disaggregated by type of financing (public, private, out-of-pocket). In fact, the associated affordability dimension can be approximated by private health spending and, in particular, by out-of-pocket spending.

Total health spending (public and private) in the region as a percentage of GDP increased during the 21st century, from 6.4% in 2000 to 8% in 2019. This level is still below the 12.5% of OECD member countries or the world average of 9.8% (Alvarez et al., 2020). As can be seen in Garph 4.8, Brazil is the country with the highest total expenditure and Peru the lowest.

Public spending on health is allocated to investments, such as hospital construction, acquisition of medical equipment, salaries of health personnel, provision of medicines, and public health activities. A detailed analysis of the expenditure allocated for each of these elements that make up health action is more complex due to the absence of comparable sources (Podestá, 2020).

A significant percentage of this health expenditure is made by the public sector. According to WHO (2010), public spending as a percentage of GDP should exceed 6%. However, before the pandemic, the region spent an average of 4%, well below this threshold and a little more than half of what the public sector spends on average in OECD countries (7.7%). The only country above the WHO target was Uruguay, with 6.2% (see Graph 4.2).

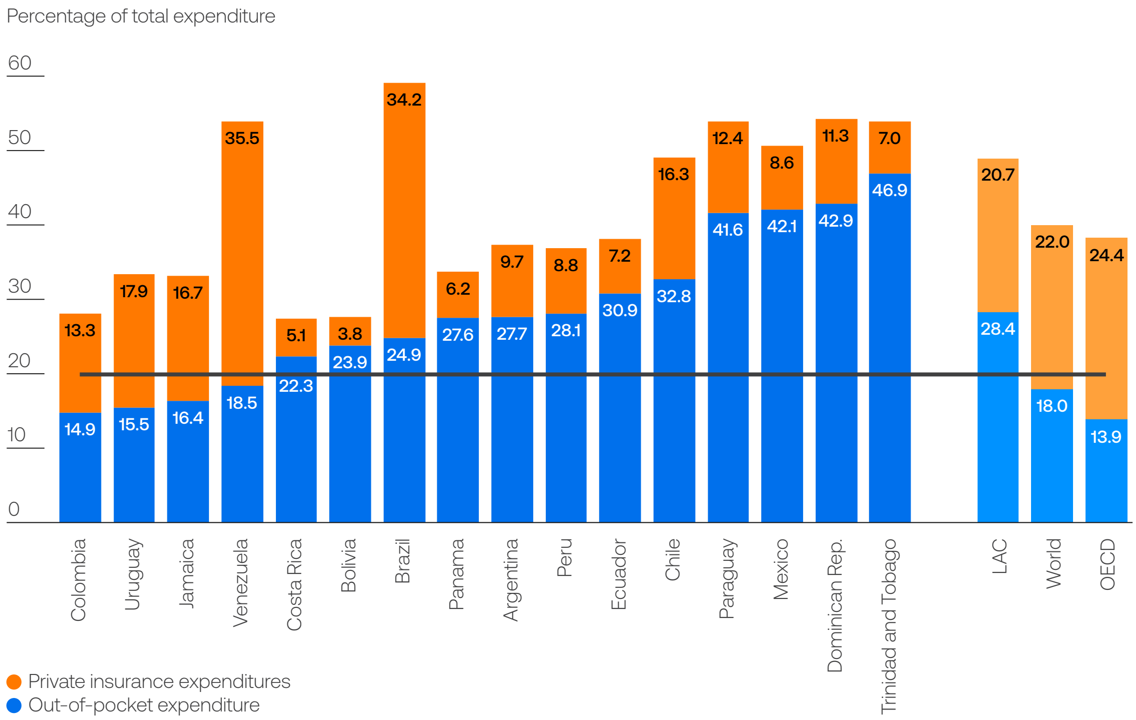
Graph 4.8
Total public and private health spending as a percentage of GDP in 2019
Source: Authors based on data from World Bank (n.d.a).



The complement to total health spending comes from contributions to the private system (private health insurance) and out-of-pocket spending. The latter allows to approximate what are the economic barriers faced by the population for the utilization of services (Fajardo-Dolci et al., 2015). Out-of-pocket spending on health is the direct financial contribution that people must make when using the health system, because, for example, services are not covered, they do not have insurance or they are attended privately (Montañez, 2018). Therefore, it is a key indicator of financial protection and relevant to evaluate access to health and the overall performance that the health system has.

Thus, the measure of the percentage of total health expenditure that comes from private spending makes it possible to analyze the affordability of the health system. The higher a country's out-of-pocket spending as a percentage of total health expenditure, the less access there will be to healthcare and vice versa, affecting the affordability of the system. The WHO recommends that out-of-pocket spending should not exceed 20% of total health spending. According to 2019 data, only Colombia, Jamaica, Uruguay and Venezuela had an out-of-pocket expenditure below 20%, while the rest of the countries analyzed exceeded the recommended limit (Graph 4.9). In fact, the private contribution (incorporating health insurance payments) represented 49% of total spending for the region's average (28% out-of-pocket spending and 21% private insurance spending). These figures are above the world average (18% and 22%, respectively) and the OECD values (13.9% and 24.4%, respectively). Undoubtedly, this high private spending hinders the affordability of the system, reflecting in health surveys that one of the main reasons why sick people avoid or postpone the use of services is the cost of care.

Graph 4.9
Private spending as a percentage of total health spending in 2019
Source: Authors based on data from World Bank (n.d.a).



Sanitation infrastructure to face climate change

The WHO special report for COP 26 concludes that "climate change is the greatest health threat facing humanity" (WHO, 2021h). Countries with deficient sanitation infrastructure will be the least capable of preparing and responding to the effects of climate change without help (WHO, 2021a). This especially includes countries that have not updated their building standards that take into account changing climatic conditions (IPCC, 2022a). Climate change will increase the demand for health services, including public health programs, disease prevention and control activities, health professionals and personnel, infrastructure, and health supplies (Field et al., 2014).

Despite these warnings about health risks, currently only half of the 95 countries surveyed by the WHO (2021e) have conducted climate change and health vulnerability and adaptation assessments. Of these, 58% have developed some type of adaptive response in this area (updating or incorporating plans and programs or allocating health resources oriented toward climate change). In LAC, only seven of 26 countries surveyed conducted assessments (of which five have already initiated some type of programmatic response or resource allocation), while another five countries are in the process of developing them.

Meanwhile, a compilation by the World Meteorological Organization (WMO) for the UN states that COVID-19 infections and heat waves, uncontrolled fires, and poor air quality combine to threaten global health. The report notes that this puts vulnerable populations at greater risk and that post-COVID-19 efforts should be aligned with national climate change strategies (WMO/UN, 2021). In this regard, a recent IPCC report (2022a) notes that increasing the climate resilience of health services protects and promotes human health and wellbeing. The report highlights that adaptation strategies in the sector should especially include early warning systems in the case of heat waves and water- and food-borne diseases; improvements in access to safe drinking water, reducing the exposure of health sector infrastructure to extreme events; surveillance and early warning systems and the development of vaccines in the case of vector-borne diseases; and improvements in access to mental health care and monitoring of socio-physical impacts in the case of mental health risks linked to climate change. Overall, the report recommends an integrated adaptation approach across different levels of government and sectors.

At the end of COP 26, a group of 50 countries committed themselves to two initiatives (WHO, 2021d):[66]

- Develop climate-resilient health systems. To this end, they propose conducting climate change and health vulnerability and adaptation (V&A) assessments; formulate a National Health Adaptation Plan (NHAP), informed by the V&A assessments, that is part of the National Adaptation Plan (NAP) to be published by a deadline; and using the V&A assessments and NHAP to facilitate access to climate change financing for health.

- Develop sustainable low-carbon health systems. To achieve this, set a target date for achieving net-zero emissions health systems (ideally by 2050); provide a baseline assessment of greenhouse gas emissions from the health system (including supply chains); and formulate an action plan or roadmap for developing a sustainable low-carbon health system that also considers human exposure to air pollution and the role that the health sector can play in reducing such exposure through its activities and actions.

66 This list included Argentina, Chile, Colombia, the Dominican Republic, Jamaica, Panama, Peru, and Peru.

Lessons learned: The beginnings of a resilient health system

The COVID-19 pandemic has exposed the level of preparedness of health systems in the region to face these kinds of disruptive events, which put it in a situation of extreme stress. This experience has made clear some changes that the sector must implement in order to be able to face other situations that also demand a rapid and effective response from the system.

It is possible to highlight lessons learned by the sector during the pandemic, among which the following stand out:

- On the governance side, institutional weaknesses in policy implementation were evident even in the measures taken in response to COVID-19. Response plans were not entirely effective and their objectives were not met, compounded by highly fragmented health systems in many LAC countries. However, governments demonstrated their capacity for rapid adaptation, establishing measures to control the spread of the virus, redirecting and expanding the necessary resources and deploying vaccination campaigns with varying success, though further improvements are still required. Strengthening governments' capacities to plan and develop legal, financial, and organizational tools that enhance response efficacy and timeliness is essential. Supranational coordination could have facilitated some of these strengthening efforts.

- Insufficient financing of the healthcare sector was another constraint. When the pandemic hit, LAC countries were already dealing with chronic underfunding and deficient public financing. This meant that countries had to inject resources or prioritize budget allocations, displacing public spending. New resources came from debt or contingency funds. It is important to review the financial sustainability and adaptation of the healthcare sector in the face of extreme disruptive events.

- Regarding the specific management of pandemics and public health surveillance, countries formulated or updated their standards and procedures for COVID-19 surveillance, extending its scope from healthcare facilities to commercial centers and other places. However, they faced challenges in coordinating, interoperating, and ensuring the quality of data from their information sources.

- The pandemic exposed existing deficits in the healthcare sector, exacerbating pre-existing gaps. Governments redirected public resources to address the deficiencies of healthcare services, increasing their capacity to care for COVID-19 patients, which affected people's access to care for conditions or illnesses not related to this disease.

- The weak resolutive capacity of first level of care resulted in attention and resource bias toward the biggest cities where hospitals with greater capacity are located. Key capabilities to consider in the first level of care are (i) diagnostic ability—including rapid methods or transferring samples to a support laboratory—and imaging equipment; (ii) emergency ventilatory support capacity (including the provision of medical oxygen); (iii) a capacity to refer patients to a network of specialized services; and (iv) internet connectivity for remote services, especially for patients who require traditional care.

- A critical factor in pandemic response was the healthcare workforce. Countries implemented various mechanisms to address system deficits in quantity and distribution. However, these measures faced their own limitations in terms of the total availability of qualified resources specialized in critical care management, the vulnerability of a significant proportion of staff due to age and comorbidities, as well as the pandemic's impact on the lives of healthcare professionals.

Countries with inadequate sanitation infrastructure will be less capable of preparing and responding to the effects of climate change without assistance.

- As for medical supplies, drugs, and vaccines, given the region's dependence on the trade of these elements and the lack of supranational mechanisms that would enable better negotiation conditions, countries procured them in an isolated manner from global market suppliers. An exceptional case was the COVAX mechanism, a tool created to supply vaccines through joint procurement mechanisms. However, COVAX quickly demonstrated its own limitations in supplying the required volumes within the expected timeframe. Countries with greater capacity and institutional development in the evaluation of health technologies and better regulatory structures to expedite the purchase of innovative products were able to access the vaccine more quickly than others. These countries have made more progress in establishing agreements for the medium term to have COVID-19 vaccine production plants in the region.

- Most countries have strengthened and expanded the health infrastructure network, but it is still insufficient for the population of their countries, beyond the actions taken in response to COVID-19. The increase in the number of ICU beds and critical equipment like mechanical ventilators was insufficient to meet the demand of the health emergency, even in countries that exceeded the standard required by the WHO before the pandemic.

Each of the lessons learned from the COVID-19 pandemic allows LAC's stakeholders to think about practical actions to increase the capacity of this sector to respond to events of this magnitude (whether epidemiological or extreme weather events), transforming the current health system into a resilient one. These practical actions will be explored in depth in chapter 5.

5

Infrastructure interventions for a better environment

Areas of intervention in economic infrastructure sectors

Every economic infrastructure sector, especially water and energy—which are the focus of this report—are facing multiple challenges stemming from countries' commitments to the SDGs, the CRCs, and resource conservation. These challenges are expected to affect everything from technical and operational dimensions (for example, changes in productive processes for the provision of services) to institutional and regulatory reforms in these industries.

First, this chapter will present the institutional context for the energy and water sectors. Second, it will highlight intervention opportunities that can help countries meet these challenges and comply with the Sustainable Development Goals. The final section of the chapter will delve into the challenges and opportunities in the health care sector.

The institutional context in the region

As varied and diverse as the institutional landscape in energy and water infrastructure sectors across Latin America and the Caribbean (LAC) is, a common thread running through many of these countries is the underdevelopment of these sectors, particularly in terms of institutional quality (Cont et al., 2021).

A strong presence and dependence on the public sector are also observed.

The energy sector

Energy transition trends focus on the electrical energy and natural gas subsectors. Therefore, this section will present a brief review of both institutional frameworks in LAC. The condition of the power sector can be summarized using the Power Sector Reform Index published by the World Bank (2017), which reflects four dimensions for reform: the establishment of an autonomous regulatory agency, vertical and horizontal sector unbundling, the introduction of competition into power generation, and private sector participation in the different segments of the chain. In Latin America and the Caribbean, especially in South American countries, the index is high compared to the rest of the world, above all after the reforms in the 1990s (Table 5.1).

Although institutional reform in the energy sector seems to be consolidated across the region, pioneering countries, such as Argentina, Brazil, Colombia, and Peru, showed a slight drop in the overall reform index from 2005 to 2015. These declining values are mostly associated with a more limited participation of the private sector (the sub-indices for regulation, vertical unbundling, and competition showing maximum values, as seen in the relevant columns in Table 5.1).[67] In other countries, for example Chile, the process is maturing.

Table 5.1
Power Sector Reform Index in 1995, 2005, and 2015
Source: Authors based on Rodríguez Pardina et al. (2022).

Country	Power Sector Reform Index			Index components in 2015			
	1995	2005	2015	Regulation	Vertical unbundling	Competition	Private sector participation
Argentina	99	99	96	25	25	25	21
Bolivia	2	10	34	0	0	25	9
Brazil	16	95	81	25	25	25	6
Chile	53	69	75	25	25	0	25
Colombia	80	82	77	25	12.5	25	14
Dominican Republic	17	96	82	25	25	25	7
Ecuador	16	79	77	25	25	25	2
Guatemala	17	98	92	25	25	25	17
Honduras	40	42	45	25	0	6.25	14
Mexico	31	40	53	25	0	25	3
Nicaragua	48	81	87	25	25	25	12
Peru	65	97	91	25	25	25	16
Venezuela	16	48	44	0	25	12,5	6
LAC	38	72	72	21	18	21	12
Rest of the world	6	31	38	16	7	9	6

Note: Bolivia established a regulatory system in the 1990s (sectoral regulatory agencies and a general regulatory agency), which is not reflected in its 1995 index. Chile has had a power generation competitive market since the mid-1980s, although data for 2015 reflect the absence of competition. Finally, Argentina's power generation market has been subject to different interventions since 2002.

67 It is important to highlight that it is complex to develop an index that reflects the multidimensional nature of the reform because changes need to be adapted to the characteristics of each country. This index includes the implicit assumption that a good system should be competitive and vertically unbundled, and include private sector participation and an autonomous regulatory agency. It does not consider, for example, the viability (or even efficiency) of competition or the desirability of vertical or horizontal unbundling for small systems. More detailed index information and observations can be found in Rodríguez Pardina et al. (2022).

Regarding natural gas, Argentina, Brazil, Colombia, Mexico, and Peru have the most developed markets in terms of final consumption. Other LAC countries—whether they are large producers (Bolivia and Venezuela) or importers (Chile, Uruguay, and some Caribbean countries)—lack a mature local market. In line with the dimensions identified for the power sector, Table 5.2 presents the regulatory status in these countries; vertical bundling of the sector; the existing exploration, production, or retailing competition; and the degree of private-sector participation. Overall, they have all unbundled the vertical components (production, transportation, distribution, and retailing), introduced competition where possible (production and retailing), and created an autonomous agency to regulate infrastructure segments.[68]

Table 5.2
Natural gas market structure
Source: Rodríguez Pardina et al. (2022).

Country	Regulation	Vertical unbundling	Competition	Private sector participation
Argentina	National Gas Regulatory Agency (*Ente Nacional Regulador del Gas*, ENARGAS)	Production, transportation, distribution, and retailing.	In the segments of production and retailing (unregulated customers). Regulated customers are served by distributors.	In all segments. YPF (state-owned company) leads production.
Brazil	National Oil Agency (*Agência Nacional do Petróleo, Gás Natural e Biocombustíveis*) for the production and transportation segments. State regulators for distribution.	Production, transportation, distribution, and retailing.	The new law on gas, enacted in 2020, promotes competition in production or exploration, and more participation in transportation.	Production: joint exploitation with Petrobras. Transportation: state-owned company Petrobras. Distribution: private sector participation (most are Petrobras distributors).
Colombia	Energy and Gas Regulatory Commission (*Comisión de Regulación de Energía y Gas*) to regulate the industry. Household Utilities Agency (*Superintendencia de Servicios Públicos Domiciliarios*) to audit performance.	Production, transportation, distribution, and retailing.	In the segments of production and retailing (unregulated customers). Regulated customers are served by distributors.	In all segments. There are 7 transportation companies and more than 40 distributors, mostly private sector businesses.
Mexico	Office of the Secretary of Energy (*Secretaría de Energía*): it defines the energy policy. National Hydrocarbon Commission (*Comisión Nacional de Hidrocarburos*): it regulates hydrocarbon exploration and extraction. Energy Regulatory Commission (*Comisión Reguladora de Energía*): it regulates storage, transportation, and distribution.	Production, transportation, distribution, and retailing.	Before the 2013 reform, state-owned Pemex monopolized production and exploration. The reform opened up the segment to private sector participation and competition.	Private sector participation in all segments. More than 35 businesses have been concessioned across the country, mostly including private sector participation. Private sector capital also participates in transportation, although Pemex has a significant share through Pemex Gas and Petroquímica Básica.
Peru	The Energy and Mining Investment Supervisory Agency (*Organismo Supervisor de la Inversión en Energía y Minería*) regulates natural gas transportation and distribution via gas pipes.	Production, transportation, distribution, and retailing.	Natural gas exploration, extraction, and processing are performed in a context of competition.	Private sector participation in all segments, including the Camisea oil field, transportation, and distribution.

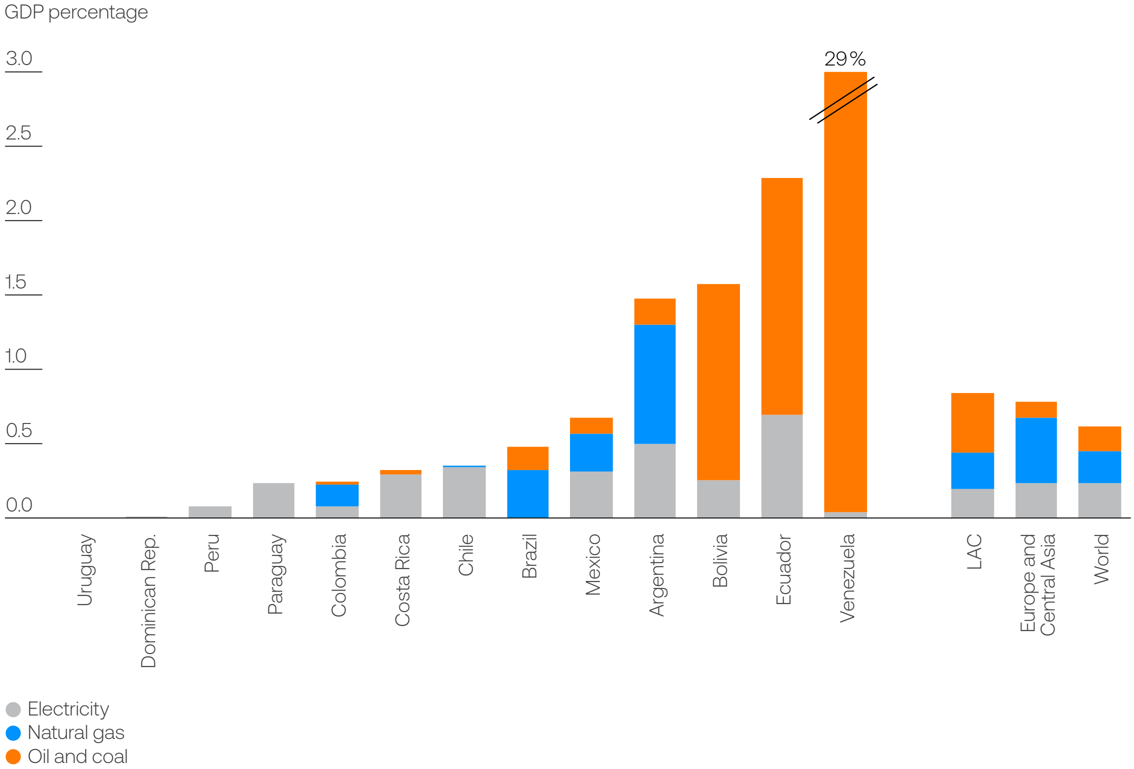
Tariff and subsidy policies are another significant institutional concern for the energy sector. In the context of energy transition, one of the main tariff-related challenges is associated to price

68 In some cases, such as Argentina, the regulatory agency has been subject to multiple intervention stages.

levels, accompanied by sectoral subsidy policies, since in many countries these do not cover the economic costs of providing the service. Efficient cost coverage is essential for the sector's economic and financial sustainability. Furthermore, it allows countries to identify rigidities that they may face when updating their energy policies. For example, the transition from oil derivatives to electricity can lead to conflict within a country if the consumption of the former is subsidized (in addition to other reasons described in Chapter 2). Subsidized electricity or natural gas services add another dimension because a subsidy implies consumption above the efficient level under current conditions, which may hinder demand-side policies favoring energy efficiency, for example.

The region has a long history of energy subsidies. According to the International Monetary Fund (IMF, 2021), the explicit subsidy by the state accounted for 0.84% of regional GDP in 2021 versus 0.62% of global GDP (see Graph 5.1). Oil derivatives and coal accounted for 48% (0.40% of GDP); natural gas, 29%; and electricity, the remaining 23%. The region exhibits significant disparity: at one extreme, one group has no or very limited subsidies (Peru and Uruguay), and at the other, subsidies can be equivalent to 1.5% and 2% of GDP (Argentina, Bolivia, and Ecuador). In fact, while Argentina provides large subsidies to electricity and natural gas, Bolivia and Ecuador heavily subsidize fuels.

Graph 5.1
Explicit energy subsidies in LAC countries by source as a percentage of GDP in 2021
Source: Authors based on IMF (2021).



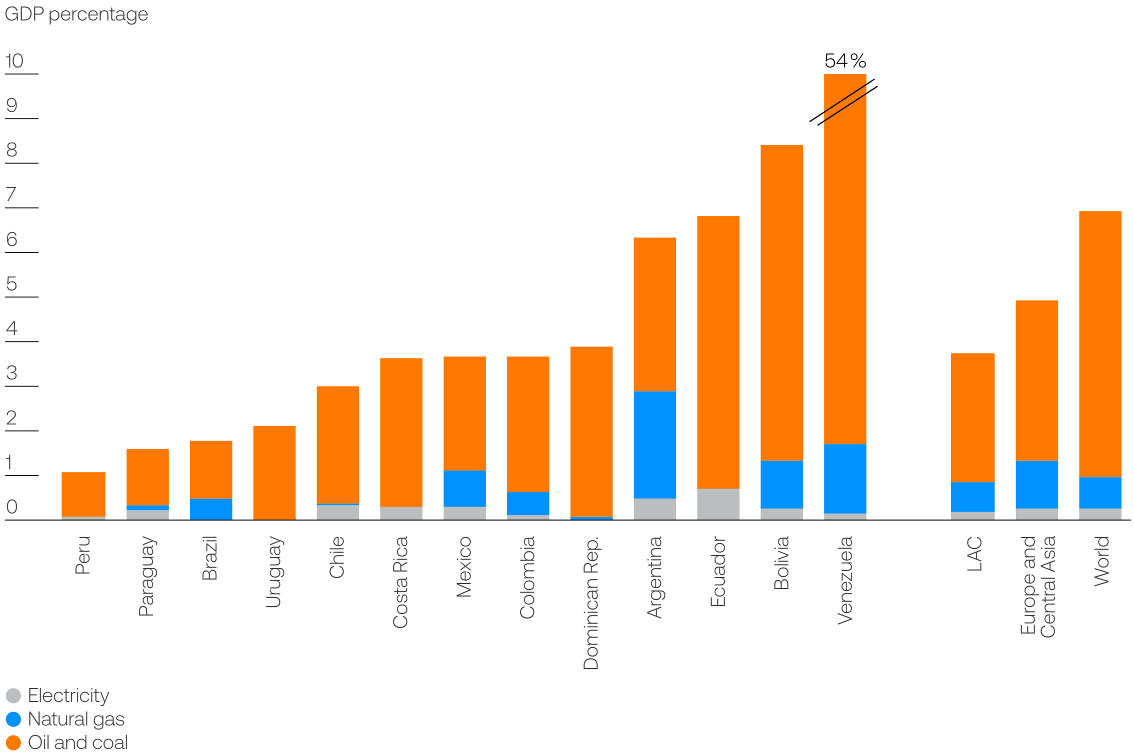
Note: Data are illustrative only; calculation differences between countries may exist.

Explicit subsidies are calculated as a difference between the price charged by suppliers and the price paid by end users on the demand side. However, the supply price does not necessarily include costs associated with externalities, particularly environmental ones (GHG emissions, local pollution, and congestion, among others). The IMF has also estimated external costs and total subsidies. These accounted for 3.7% of regional GDP in 2021 versus 6.9% of global GDP (Graph 5.2), reflecting the regional problem about the share of these sectors in the global emission of GHGs and other external effects. In general, LAC countries underestimate environmental costs.

These subsidies create inefficiencies in consumption, which translate into environmental damage caused by local air pollution. This, in turn, exacerbates congestion and other adverse secondary effects of the use of vehicles and increases atmospheric concentration of greenhouse gases. They can also generate incorrect incentives by discouraging investments in energy efficiency, renewable energies, and energy infrastructure. In the absence of cross-cutting mechanisms, these schemes impose burdens on the treasury, limiting resources for other purposes (e.g., for health care, education, and infrastructure), and requiring higher taxes or financing with public debt. Moreover, when these services are not locally sourced (e.g., fuel imports), a policy of heavy subsidies can impose conditions on the balance of payments. Furthermore, when these subsidies fail to reach low-income users, it adds to the inequality issues.

Regarding this last point, there is ample evidence that energy subsidies are inefficient in providing social protection. According to different sources, due to the lack of targeting in many subsidy systems, they can spend USD 10 to USD 12 for each USD 1 that reaches the low-income quintile (Robles et al., 2015; Feng et al., 2018).

Graph 5.2
Total energy subsidies in LAC countries by source as a percentage of GDP in 2021
Source: Authors based on IMF (2021).



Note: Data are illustrative only; calculation differences between countries may exist.

The tariff structure refers to the relative values charged to different tariff categories (users) and within each category (according to user consumption in the same category). Modernizing the energy sector requires designing and implementing an efficient tariff structure, where the adoption of schemes that promote efficient use of available resources is particularly important. Even more importantly, these schemes should foster medium and long-term investments. This is especially critical for the electricity sector, given the accelerated technological changes underway. From an economic perspective, the reduction in the cost of renewable sources makes low marginal cost electricity generation more frequent. Additionally, smart meters can record electricity consumption on an hourly basis. Finally, the introduction of prosumers imposes a restriction on the distribution component of the tariff. In a context of sustained increase in renewable energies, the implementation of increasing block tariffs (widely used in the region) becomes an obstacle to the progress and financial sustainability of the system. Users with higher consumption have more incentives to migrate to self-generation, which is more convenient from an individual perspective. This would result in a substantial loss of income for utility companies. Furthermore, a tariff based on fixed charges has negative distribution effects.

Electricity pricing for prosumers has evolved in the region under two modalities: net metering and net billing.[69] Net metering means that energy injected into the grid is valued the same as that consumed from the grid. In net billing, energy injected into the grid is sold to the utility at a set price (generally wholesale or "avoided-cost" price) and energy consumed from the grid is purchased at retail prices, in some cases including taxes (Dufo López and Bernal Agustín, 2015). In economic terms, net metering represents an allocative efficiency problem because the energy supply cost—generation, transmission, distribution, and retailing—is necessarily higher than the costs avoided by the company when receiving energy from a user under distributed generation, which includes the cost of generation and the impact on losses. This is to say that, under this rule, the user is given a credit that includes the cost of services that the user does not provide to the grid. This scenario is exacerbated when rates are mostly based on energy charges and when there is no time differentiation in tariffs. For large business and industrial users, in general, electricity rates include electric power charges, so allocative efficiency problems tend to be smaller. However, the costs of distributed generation—including in some cases not only intermittent renewables but also thermal cogeneration—are lower due to economies of scale. This can lead to the fact that even minor distortions in price signals can result in substantial inefficient investments in the system.

A net billing scheme, in turn, sends an efficient signal for resource allocation: the injected energy is valued at the avoided cost (including any impacts on losses), while consumed energy is valued at retail cost, which includes all production stages. A differentiation between energy and electric power charges also contributes to ensuring that a reduced load factor (of supply in the system) among users who installed distributed generation systems does not negatively affect the financial sustainability of the utility or the rest of the users.

Variants have been implemented across the region (see the review by Novaes Medjalani et al., 2019) according to the accumulation unit (money or energy), the period of accumulation, and the compensation upon period expiration (see Table 5.3). Four out of the 17 countries included in Table 5.3 use energy balances (net metering variants), while 11 use monetary balances (net billing variants). Brazil and Costa Rica use a combined method. In most cases (nine), balances are compensated when the period of accumulation expires, while in three cases balances are lost (Brazil, Chile, and the Dominican Republic).

69 Tariffs for grid operators to purchase electricity at premium prices (feed-in tariffs) and distributed generation without self-consumption arrangements (sell-all buy-all) are also possibilities to pay for distributed generation.

Infrastructure investments must consider organic growth, changes in demand and supply, and the need to increase system efficiency and resilience.

Table 5.3
Net billing mechanisms in LAC
Source: Novaes Mejdalani et al. (2019).

Country	Accumulation period		Accumulation Unit	After Expiration
	Number	Unit		
Uruguay	0	Month	kWh	Cashback
Dominican R.	1	Billing period	$	Write-off
Jamaica	1	Month	$	Cashback
The Bahamas	1	Billing Year	kWh	Cashback
Barbados	3	Month	$	Cashback
Argentina	6	Month	$	Cashback
Panama	12	Month	$	Cashback
Mexico	12	Month	$	Cashback
Costa Rica	12	Month	Combined	Cashback
Suriname	12	Month	kWh	Cashback
Nicaragua	12	Month	$	Cashback
Chile	12	Month	$	Write-off
Brazil	60	Month	Combined	Write-off
El Salvador	Undefined		$	
Guatemala	Undefined		kWh	
Honduras	Undefined		$	
Colombia	Undefined		$	

The water sector

In general, LAC's institutional framework in the water sector has evolved over time. Moreover, each country has different structures. These multiple institutional organizations include sectoral ministries or vice-ministries, basin or water authorities, and specific water and sanitation regulatory agencies. In some countries, these water authorities are autonomous. In others, they report to ministries, with the following hierarchy: 1) ministries and 2) water authorities and regulators. Some trends stand out regarding regional or municipal decentralization, and the institutional separation of sector functions: policy formulation and planning, creation of specific agencies for regulation and monitoring, and service operation (Lentini, 2015). Annex 4.1 presents a detailed description of state water agencies and the types of organizations existing in Latin America. Broadly speaking, the goal of these frameworks is to guarantee the human right to water, along with regulating and monitoring the authorization, management, preservation, conservation, and restoration of water resources.

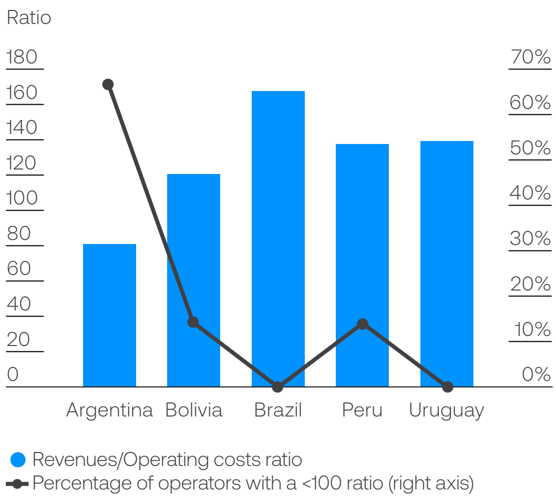
Regarding tariffs, Chapter 3 (Annex 3.1) presents detailed information on residential user expenditure and its representativeness with respect to average income. However, closing the coverage gaps, maintaining infrastructure in good condition, and ensuring service sustainability in the face of the challenges posed by climate change require mobilizing a high volume of resources. These will not necessarily come from tariffs. Nevertheless, the convenience of achieving at least sustainable tariffs in already developed systems can be proposed as a medium-term goal, i.e., tariffs that cover operational and maintenance costs. This could free up state funding going to subsidize users who already have the service and to finance new connections (Lentini and Ferro, 2014). In this regard, Graph 5.3 shows the condition of LAC operators reported by the *Asociación de Entes Reguladores de Agua Potable y Saneamiento de las Américas* (ADERASA) [Association of Drinking Water and Sanitation Regulatory Agencies of the Americas] for 2019. Except for Argentina, the operating situation is positive in the remaining countries. Individually, in two out of the seven operators in Bolivia, in seven out of 50 in Peru, and in two out of three in Argentina, revenues do not cover operating costs.

However, cost coverage conceals at least two problems. One is whether costs are efficient; for example, state-owned companies can be overstaffed or enforce more stringent internal controls compared to their private sector counterparts. The other is whether the excess billing relative to operating costs is sufficient to cover capital and sustainability costs.

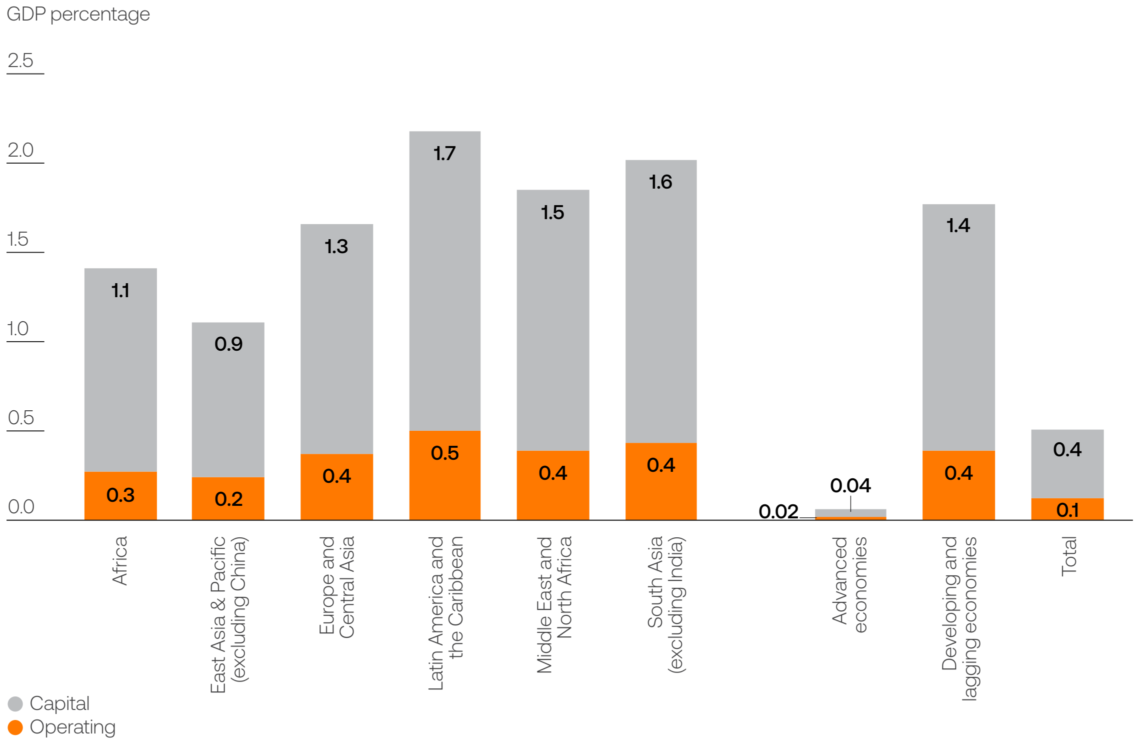
Another possibility is estimating the level of subsidies in the sector by comparing the operators' revenues with a benchmark technical cost (assuming a level of operation and investment efficiency, conditional to the size of operators, service coverage, and the levels of efficiency, among other factors). This approach was used by Andrés et al. (2020), who found that the cost of subsidies associated with the operations for the region is an estimated 0.46% to 0.56% of GDP, while for capital subsidies, this figure rises to 1.51% to 1.95% of GDP. The international comparison made by the authors reveals that LAC is the region with the highest sector subsidies, well above the world average.

In addition, water and sanitation subsidies also have targeting problems. In a complementary work, Abramovsky et al. (2020) conclude that the distributional incidence of these sectoral subsidies (studied in ten developing economies, including Jamaica, El Salvador, and Panama) is regressive and very favorable to the rich. They add that these subsidies, to a large extent, fail to achieve the goal of improving the accessibility and affordability of piped water among poor households.

Graph 5.3
Billing-cost ratio for selected operators in Latin America in 2019
Source: ADERASA (2021).



Graph 5.4
Operating and capital subsidies by regions in 2019
Source: Andrés et al (2020).



Note: Subsidies are not disaggregated by country.

Investments

Attaining the environmental objectives and facing the challenges that this poses will require infrastructure investments as a response to the sector's organic growth, the changes in the service supply and demand caused by environmental effects, efficiency improvements, and the sustainable use of resources, along with the need to develop resilient infrastructure and nature-based solutions.

Organic growth and changes in supply and demand

The projected economic growth of countries for the coming decades (approximately 2.5% per year at the regional level) indicates a rising trend in the demand for infrastructure services, such as water and energy (and also transportation and ICTs). At the same time, climate change and the increase in and greater variability of temperatures point to a likely acceleration in demand for these services in the future (for energy, in particular, at both temperature extremes). In order to respond to this anticipated higher demand, investments will be needed to expand systems.

A recent work by Yépez-García et al. (2019) estimates that electricity generation in LAC will range from 3,000 TWh to 3,500 TWh in 2040 (versus 1,639 TWh generated in 2020). It also anticipates that the region will need from 337 GW to 474 GW in capacity (vs. 457 GW in 2020). In addition, it will be necessary to replace obsolete infrastructure and expand transmission networks to meet higher demand. The investments included in the expansion plans developed by governments reach 202 GW of installed power (USD 269 billion) for the next two decades. Therefore, unplanned investments will be needed to add between 135 GW and 272 GW.

Similarly, changes are anticipated in the final consumption of energy patterns. Taking into account the goal of decarbonizing economies, migration from fossil fuel to electricity consumption is expected to occur in the transportation, household, and industry sectors, among others. Higher electricity demand will require enlarged generation and network capacities to achieve a more robust system that supports the growing demand. For example, replacing 30% of fuel consumption with electricity by 2030 will entail an incremental electricity consumption of 221 TWh, i.e. more than 30 times the current power consumption by the transportation sector, vs. 5.83 TWh in 2019 (see Chapter 2). Attaining the decarbonization goal requires meeting this increasing power demand by generating low-emission energy. Brichetti et al. (2021) estimated investment needs to meet the SDGs by 2030 and assumed that the electrification of public transportation would involve replacing 20% of the current bus fleet by 2030 plus required investments in charge stations and the reconfiguration of the electricity distribution network. These needs account for USD 11 billion in investments for the period 2019-2030 (0.016% of annual GDP).

On the supply side, as part of the energy transition, high GHG emission sources (mainly hydrocarbons and coal) must be replaced with low-emission energy sources, not just to generate electricity, but energy in general. In this framework, NCRE-based generation projects are particularly relevant. Renewable energy auctions have become very important in both developed and developing countries. According to IRENA (2017b), the potential of renewable energy auctions to achieve low prices has been a major motivation for their adoption. LAC has been no exception and several countries in the region have kicked-off renewable energy auction programs (Argentina, Brazil, Chile, Mexico, Peru, and Uruguay for the period 2010–2020).

In 2000, the penetration of NRCEs over the total energy supply exceeded 5% in only two LAC countries: Costa Rica and Paraguay. Two decades later, and to a large extent as a result of auction programs, renewable energies started to gain momentum in total energy generation. In Uruguay, nearly 42% of the energy supplied is renewable (except for hydroelectric and nuclear energy), while in Brazil, El Salvador, Honduras, and Nicaragua, renewable energy already exceeds 5%. For the next 30 years, these energy sources are expected to play a larger role in the energy matrix both worldwide and in LAC (see Graph 2.11).

Renewable energy auctions are an efficient mechanism for the decarbonization of the energy matrix. The main advantage of this market competition instrument is that it allows for competitive selection that guarantees more efficient prices and conditions. This has been the main motivation for its adoption in the region and the rest of the world. Auctions are effective and efficient for revealing prices under conditions of information asymmetry and can be adapted to different market designs. Long-term contracts reduce the risk for investors, providing income stability and leveraging capacity (financing secured by the project's cash flow). In particular, LAC countries have a large potential to develop renewable energy sources and, in some cases, they offer an attractive renewable energy market for investors and developers (Rodríguez Pardina et al., 2022). Given their characteristics, these are usually private-sector investments, which makes them especially important for countries with fiscal constraints. The region faces a sizeable challenge in terms of financing these investment projects. The private sector can be very helpful in this case, provided that it is offered the right incentives. According to the IEA (2021a), the private sector will need to carry out nearly 70% of clean energy investments, responding to market signals and policies set by governments.

A larger share of non-conventional renewable energy (NCRE) sources in generation capacity should be supported by planning in transmission and backup networks. There are two reasons for this: on the one hand, NCRE sources are often located far away from large consumption centers; on the other, given that several types of NCREs come from variable sources (wind, solar, tidal power, among others), their energy should be replaced with electricity generated somewhere else to offset deficits or export surpluses. Backup planning can extend beyond country borders to take advantage of the available infrastructure of international connections. For example, the best areas for photovoltaic generation in Chile are located in the north of the country, while hydroelectric dams, which can be used as if they were system batteries (without using water while solar and wind energy generation abounds), are located in the south. When there is no congestion, the transmission system can operate as an integrated NCRE system plus hydraulic dams, which reduces the impact of the variability of NCRE in the aggregate generation. In Argentina, the best sites to produce wind energy (some of the best in the world) are located in Patagonia and require transmission capacity to release their energy (Energypedia, 2011). In Brazil, 85% of the installed wind capacity is located in the Northeast region, because the winds in the area are strong and stable (Lucena and Lucena, 2019).

Decarbonizing the energy matrix can also be achieved by implementing new energy generation technologies (such as H_2) and others that complement GHG high-emission sources (such as CCUS). Both will require investments in infrastructure for energy production and use. In early 2021, according to a report released by the consulting firm McKinsey & Company (2021), the industry had announced more than 200 projects and investment plans, and over 30 countries had already published hydrogen roadmaps involving commitments for more than USD 70 billion in public funding regarding this innovation. In LAC, Chile was projecting investments of more than USD 7 billion in the coming years, within the framework of a project financed by the Bilateral Fund for Development in Transition in Chile (Electricidad, 2022). By the end of 2021, in Argentina, the Australian company Fortescue announced investment plans of more than USD 8 billion to produce green hydrogen (Guarino, 2021). In Brazil, initiatives have also been implemented to produce green hydrogen in Ceara and the north of Rio de Janeiro (Uchôa, 2021; Sánchez Molina, 2022). If these projects are executed, the Southern Cone will become a leader in generation from sustainable sources. It is worth highlighting that the regions of Rio Negro (in Argentina) and Atacama (in Chile) or Ceara (in Brazil) have a strong NCRE potential and hydrogen production can be a productive destination of surplus energy generation.

In recent years, progress has also been made in carbon capture, sequestration, and utilization (CCUS) activities. According to the IEA (2020b), CCUS projects represent around USD 27 billion—double 2017 investment levels. These projects—which include power generation and industries like cement and hydrogen—are expected to double the levels of CO_2 capture (IEA, 2020b).

It is worth noting that appropriate investment planning can help use energy interconnections to coordinate energy variability and partially replace investment demands.

The water sector, in turn, requires investments on the supply-side, which will be affected by the reduced availability of water as a consequence of climate change. This may involve a need for investments targeting the use of alternate water supply sources (for example, desalinization), using new water collection and processing technologies, and distribution networks.

In terms of water and sanitation, the main issue is basic access, mainly regarding rural areas and sanitation services. The issue is even more severe when considering the quality of water and sanitation (see estimates in the subsection below). Another recurrent problem in the region is the high level of unaccounted-for water. In addition, only 14% of the 1,549 listed utilities generate enough revenue to cover the total economic costs of service provision, while only 35% can cover at least the operation and maintenance costs of service provision (Andrés et al., 2020). To achieve universal access to water and sanitation services by 2030, annual investments of USD 12.5 billion are needed (García et al., 2021). However, as reported by INFRALATAM (2021) and the World Bank (n.d.c), investment in 2019 was USD 6.7 billion, highlighting the existing gap in basic access.

The investment gap in sustainable infrastructure

The traditional approach to infrastructure gaps has led to multiple estimates of infrastructure investment needs in LAC. To achieve universal access to basic services, maintain existing infrastructure, and reach a moderate annual GDP growth of 3% within ten years, investments equivalent to at least 3% of GDP are needed (Fay and Morrison, 2007). For LAC to reach values similar to those in developed countries (e.g., South Korea) in 20 years, investment needed rises between 4% and 6% of GDP. Globally, annual infrastructure investments of USD 3.4 to USD 3.7 trillion are needed to sustain projected growth in the coming decades, according to estimates in the documents by Dobbs et al. (2013) for the McKinsey Global Institute and by the Global Infrastructure Hub (GIH and Oxford Economics, 2017). In addition, the Global Infrastructure Hub claims that this is 19% higher than global investment trends in previous years, and 47% higher than levels recorded in the Americas (Cont et al., 2021).

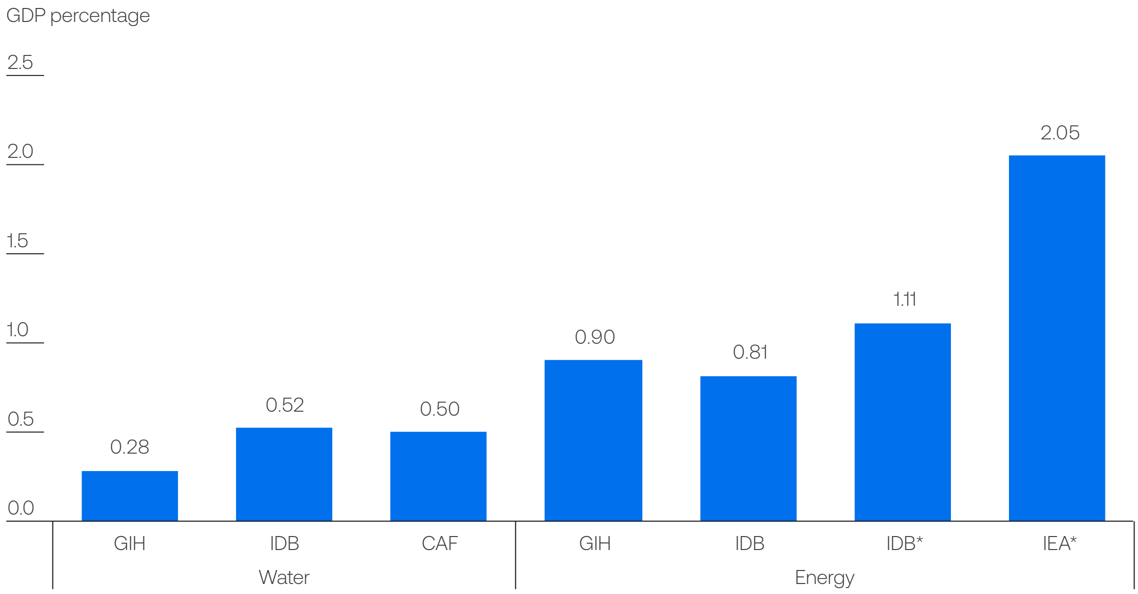
More recent estimates suggest that attaining universal access to basic services and complying with climate goals—i.e., increasing the use of renewable energies, adopting electrification, implementing Dutch flood protection standards, and expanding irrigation systems—would require annual investments in infrastructure amounting to 3.3% of GDP, supplemented by 1% of GDP for maintenance spending by 2030, in an intermediate spending-efficiency scenario (Rozenberg and Fay, 2019).

In the framework of the 2030 Agenda, the use of traditional infrastructure gap estimates to meet the SDGs has gained recognition as a valuable tool. In other words, these new measurements assess how much investment a certain country or region requires to meet these goals.

For the sectors prioritized in this report, Graph 5.5 summarizes findings from four different sources of estimates: CAF (Rojas, 2022), GIH and Oxford Economics (2017), IEA (2020a, Sustainable Development Scenario) and the IDB (Brichetti et al., 2021).

Graph 5.5
Investment needs to comply with the SDGs in LAC as a percentage of GDP

Source: Authors based on data from CAF (Rojas, 2022), GIH (GIH and Oxford Economics, 2017), IDB (Brichetti et al., 2021), and IEA (2020a).



Note: * Mexico is excluded.

Estimates were performed based on different time horizons (GIH, 2016-2040; IEA, 2019-2040; and the IDB, 2020-2030) and economic growth objectives (GIH: 1.7%; IDB: 2.4%; IEA: 1.9%, annually). They also have different objectives in their gap definitions. For example, GIH only takes into account the goals for universal access to electricity, water, and sanitation. According to CAF estimates of sector investment needs (Rojas, 2022; Lentini, 2022), historical investments in LAC should at least triple to achieve SDG-6 targets. The goals reviewed by Brichetti et al. (2021) are universal access to safely managed water and sanitation services, wastewater treatment (100% urban wastewater), and universal access to electricity (including investments in power generation plants and transmission lines). The IEA introduced the following SDGs in its analysis, using specific indicators: 7.1 (access to electricity and clean cooking practices), 7.2 (share of renewables), 7.3 (energy intensity), and 9.4 (CO_2 emissions).

On the basis of investments in the region for the period 2014-2019—reaching 0.6% of GDP in energy (0.5% of GDP if Mexico is excluded) and 0.2% of GDP in water[70]—these needs exceed recent water investments by 50% to 150%, and recent energy investments by 100% to 300% (in this case, comparing GIH and the IDB, excluding Mexico).

Efficiency and sustainable use of resources

Chapter 1 highlighted the importance of developing a clear agenda for the conservation and sustainable use of resources. Moreover, to mitigate climate change, energy efficiency (including efficiency in every sector that uses energy) is one of the environmental challenges (Challenge 2).

The limited amount of wastewater treated in LAC represents a problem for the water sector. New wastewater infrastructure investment needs in the region may exceed USD 16 billion during the next decade, roughly equivalent to 0.024% of the annual LAC's GDP (Brichetti et al, 2021). In addition to this centralized wastewater treatment modality, investments can target distributed or on-site wastewater treatment and reuse models, as indicated in Chapter 3. So far, these have been small-scale projects implemented by private sector stakeholders, such as building owners, with the support of local utilities. For example, in the United States, industrial companies decided to take control of their water management by investing in water recycling to face extreme drought and minimize exposure to water stress (Bonney Casey, 2018).

Regarding efficient water use, Chapter 3 described the regional issue of drinking water loss in domestic use and irrigation. Drinking water leaks during distribution normally occurs at pipe unions, elbows, and broken ducts and valves (Rodríguez et al., 2019). Inspection and maintenance of these parts of the distribution network can reduce water loss levels. In addition, new technologies can detect these leaks. For example, Rodríguez et al. (2019) proposed a prototype for a smart water system that can integrate different water flow measurement and detection sensors embedding an operating system showing sensor readings. These new technologies offer better accuracy, speed, and efficiency in detecting water leaks compared to older systems like iDroloc (which uses helium gas to detect leaks) or Hydrolux HL 50 (working with an ultrasonic sensor).

Other available technologies can improve irrigation efficiency. For example, progress achieved in hydroponics and modern closed or semi-closed greenhouse systems has reduced water needs. Therefore, investing in these technologies can help attain sustainable water use.

The energy sector also presents efficiency challenges, in two dimensions: energy efficiency (energy consumption given a level of activity), and system efficiency (energy needed for a level of consumption). In the first case, improvements can result from the use of more efficient household appliances, changes in lighting and light fittings, and investment in insulation and the operation of productive plants, among others. For example, Urteaga and Hallack (2021) point out that attaining the energy efficiency goals linked to the use of refrigerators (replacing them with more energy-efficient appliances) may require a total investment of around USD 7 billion—nearly 0.02% of the annual GDP of the main LAC countries, i.e., Argentina, Brazil, Chile, Colombia, and Mexico—assuming

70 Information developed by the authors based on data from Infralatam (2021) and the Private Participation Infrastructure Database (World Bank, n.d.c).

it is carried out within a ten-year period. In the second case, efficiency can improve if transformation processes are enhanced by investing in energy generation (e.g., improving combustion systems) or reducing non-technical electricity losses. These are mainly due to illegal electricity use; altered metering; unaccounted-for electricity; or administrative management, accounting, or customer management errors. Smart metering progress can help detect these losses (see Cont et al., 2021 for more information about the development of smart grids).

Resilient infrastructure

Infrastructure provides the basic services for people's wellbeing, improving the quality of life, and ensuring and boosting business productivity and competitiveness. Resilient infrastructure refers to assets that can withstand external shocks, especially those caused by natural hazards.

The UN and the Sendai Framework define resilience as:

> "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management." (UNDDR, n.d.).

Sustainable Development Goal 9 identifies the need to "build resilient infrastructure" to accommodate population growth, but also to face the physical hazards associated with extreme climate, natural disasters, and terrorism. This requires three complementary measures: reducing failure probabilities, minimizing consequences from failures (in terms of casualties, damage, and adverse social and economic consequences), and shortening time to "normal" system operation (Bruneau et al., 2003).

The above has different implications for each sector. For the water sector, Paltán et al. (2020) point out that, for example, if a reservoir faces drought, resilience means not just the time it takes to refill (which can result from rainfall or unexpected flow surges), but also the system flexibility to change its operation or adjust demand. If it faces an earthquake, resilience covers the time to repair the water supply failure, the capacity to interconnect the affected reservoir with others or to take water from alternate sources (water tankers), along with the communication to and preparedness of citizens to control demand and sustain adequate water supply.

Regarding the energy sector, extreme events (e.g., earthquakes, hurricanes, storms) can damage system networks, interrupting service for many users. In generation, hydrological changes can affect the capacity of hydropower production. In these cases, resilience also involves the time delay in restoring service or activating backup, and the system's flexibility to provide alternative supply solutions.

Hallegatte et al. (2019) note that improving the resilience of hazard-exposed assets alone would increase average annual investment needs for electricity by USD 20 billion (0.02% of global GDP) and slightly less than USD 5 billion for water (0.005% of global GDP). The authors also conclude that the benefit of investing in more resilient infrastructure in low and middle-income countries would be four times the cost.

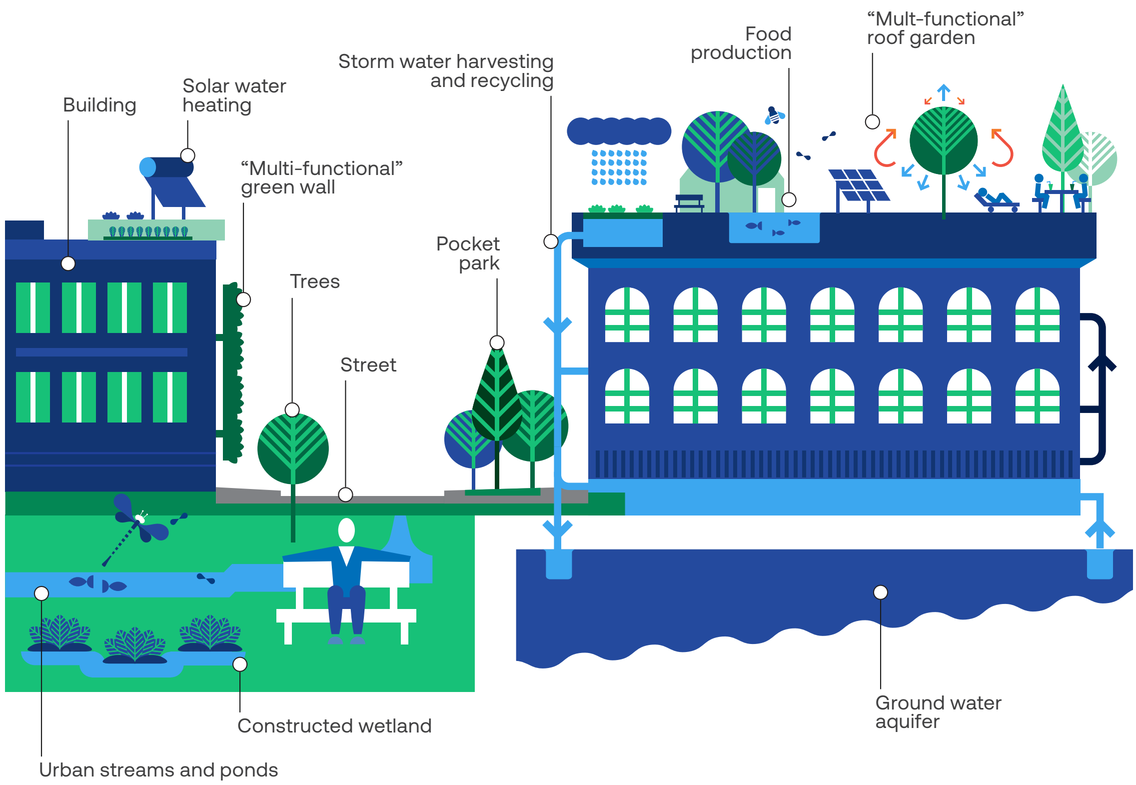
Different measures targeting key aspects to respond to extreme events can help improve sector infrastructure resilience; for example, investing in preventive measures, such as early warning systems that can anticipate the time and impact of extreme events based on risk mapping. Investments can also strengthen network systems that minimize event impacts on service supply. In the Miyamoto International paper (2021), engineering options are described to enhance infrastructure resilience based on a study of cases in Caribbean countries. Some of these measures for the water and sanitation sector are designing seismic-resistant structures, thicker tanks for water reservoirs, and keeping pipes filled with water to mitigate buoyancy effects. Energy sector examples include increasing the capacity of spillways in hydroelectric power plants to alleviate flood consequences and using vibration dampers in energy networks. Finally, investing in improved system flexibility can help control post-event impact damages, minimizing event effects and responsiveness. For example, in the energy sector, smart grids improve reliability, resilience, and responsiveness in case of a power system failure; in the water sector, the interconnection of reservoirs enables alternate water supply sources if one of the reservoirs fails.

Environmental challenges will lead to changes in infrastructure service costs, requiring a review of their regulations, structures, or tariff levels.

Nature-based solutions (NbS) and green and blue infrastructure

NbSs are inspired and supported by nature, and use or mimic natural processes. They cover green and blue infrastructure, which is understood as an interconnected network of natural and semi-natural areas that include water bodies and green and open spaces that provide multiple ecosystemic services. Among these, water storage for irrigation and industry use, flood control, water purification, and the preservation of wetlands for wildlife habitat are included (Ghofrani et al., 2017). The implementation of this type of infrastructure is particularly being considered for the design of urban zones because the blue-green infrastructure approach could be adapted to the foreseen climate change. There are also many benefits involved, such as climate change mitigation, and other ecological and social co-benefits. For example, the New York City Department of Environmental Protection published its Green Infrastructure Plan in 2010. The plan integrates nature-based solutions with the traditional "gray" approach for the management of urban runoff.

Figure 5.1
An urban example of green and blue infrastructure
Source: Image by Bozovic et al. (2017).



Ozment et al. (2021) identified 156 projects in LAC that utilize NbSs, that help restore and conserve ecosystems (forests, mangroves, floodplains, among others), create permeable pavements, and encourage sustainable farming. Most of these projects—which are located in Brazil, Colombia, Mexico, and Peru—aim to benefit primarily the water and sanitation sector.

According to the Unesco World Water Assessment Programme (WWAP, 2018), investments in these projects have been shown to generate interesting returns. However, despite a rapid increase in investments in NbS, evidence suggests that they continue to be less than 1% of the total investment in water management infrastructure, revealing an absolute predominance of grey infrastructure solutions. In addition, the report concludes that NbS generally involve redirecting and making more effective use of existing financing, not necessarily requiring additional financial resources.

A report presented by the United Nations Environment Programme (UNEP, 2021a) claims that, if the world is to meet its environmental targets (in the matter of climate change, biodiversity, and land degradation), investments in NbS ought to at least triple by 2030 and increase four-fold by 2050 in real terms. Based on the current value of these investments (USD 133 billion/year in 2020), this increase would be equivalent to an annual investment rate of USD 536 billion (nearly 0.6% of the world's GDP), distributed among forest-based solutions (USD 203 billion), silvopasture (USD 193 billion), and peatland (USD 7 billion) and mangrove (USD 500 million) restoration. The report estimates that annual investments in LAC are approximately USD 2 billion, with Latin America and the Caribbean being the region with the lowest level of investments in NbS (UNEP, 2021a).

Investment challenges

Given the multiple dimensions of the concept of sustainability in terms of development—economic, social, and environmental—, actions to tackle environmental challenges, including investments, should take into account potential trade-offs that may arise in economic and social dimensions. In this respect, there is concern that investment needs associated with climate change mitigation and adaptation may displace the investments required to expand services, especially those targeting low-income users. This would affect the universal access goal. Without clear incentives and regulatory monitoring, infrastructure companies may tend to invest in climate change adaptation assets to guarantee service for the rich to the detriment of service provision or expansion in poor areas. This effect would be even stronger if financial constraints exist, which is a characteristic of most developing countries.

In addition, the investments discussed in this section are for the long term; their implementation should assess any potential future scenarios that may affect the infrastructure's business cycle. An investing decision should be made many years ahead. In particular, these projects need to consider the possibility that assets that have not yet been developed are abandoned or cannot operate in the future, the so-called "assets to be stranded." For example, according to González-Mahecha et al. (2019), 456 planned fossil-based generators are reported, summing to 102 GW or 61% of current fossil-fueled capacity in the region (planned natural gas plants sum 87 GW). Building all planned power plants would raise emissions from 6.9 Gt of CO_2 to 13.6 Gt of CO_2, which would more than double the LAC average carbon budget consistent with the 2°C (6.2 Gt of CO_2) or 1.5°C (5.8 Gt of CO_2) scenarios. Along these lines, adding fossil fuel power plants may increase the risk of stranded assets in LAC.

Economic regulation

Based on the developments presented in Chapters 2 and 3, and in light of the institutional context, the following section reviews the challenges for sectoral and cross-cutting regulation. It identifies and analyzes five changes in the energy and water sectors that will lead to the compliance with environmental objectives, and their implications for the respective regulatory frameworks:

- Cost changes.
- Trends toward system decentralization (distributed systems).
- Development and inclusion of new technologies.
- Climate risks.
- Stranded assets.

Cost changes

Environmental issues and the solutions proposed to address them will bring about changes in the cost levels and composition in infrastructure sectors. These changes will make it necessary to modify service regimes, tariff levels or tariff structures.

In the energy sector, one of the first changes will be a decreased marginal cost of the power supply with the expected increase in the penetration of NCREs in coming years. The cost of generating NCREs, except for biomass, is nil, contrary to energy generation based on fossil fuels or hydroelectric dams (Fischer, 2020). The reduced cost of small-scale renewable energies increases the price elasticity of electricity demand on the system due to the lower cost of supply in isolated areas. This, in turn, restricts the possibility of cross-subsidies, if these are not prohibited by regulations, and fixed-cost recovery through variable energy charges. A new challenge lies ahead: how to pay for the cost of infrastructure, currently covered through fixed and variable rate components, in a cost structure that tends to be biased toward fixed costs. It is unclear whether volume-based tariffs, especially when including variable costs that increase per consumption interval, are viable instruments to reward distribution. However, a tariff scheme relying on uniform fixed charges could cause affordability problems. If it does, alternative schemes can be considered to pay for infrastructure. An example is a tariff menu with a low fixed charge, high variable charge option, only applicable to low-consumption users (Cont et al., 2021, propose this alternative).

Similarly, environmental changes can affect the cost of capital. The need for climate change adaptation and mitigation actions increases the capital intensity, which in turn raises the economic cost of providing services. For example, developing more resilient structures that can withstand extreme weather events can involve higher initial costs (Minoja et al., 2022). This effect is particularly pronounced in developing countries, where access to capital is limited and, therefore, the cost of capital is higher. On the other hand, energy transition requires creating institutional frameworks that establish clear market rules, enforce the rule of law, and encourage an efficient adoption of new energies. These changes provide an opportunity to foster competition among service providers and make the cost of capital more efficient. Whether the cost of capital will increase or decrease due to these conflicting effects is uncertain. Nevertheless, it is worth highlighting that any change in the cost of capital will have direct implications on sector tariffs.

Another factor that is expected to affect energy costs is improved energy efficiency (Challenge 2). For example, as discussed in Chapter 2, the region has high electricity transformation and distribution losses (accounting for 19% of the total). These losses are compensated by incurring additional energy generation costs. Identifying and controlling non-technical losses could reduce costs and associated tariffs. A mechanism to achieve this is identifying illegal electricity connections (a large component of distribution losses). One way to achieve this is to detect illegal electricity connections, which are a major component of distribution losses. However, this issue is expected to be more prevalent in low-income areas, leading to regressive distribution effects that could be addressed through targeted social tariffs (Cont et al., 2021).

The environmental situation calls for changes in the water sector due to factors like reduced availability of water resources in terms of quantity and quality, climate change, and the overexploitation and pollution of water sources. These changes will lead to an increase in the cost of service provision (water shortage, exploration of alternate sources, more expensive treatment processes). This cost increase will directly impact user spending or public resource allocation. However, the water sector can reduce existing inefficiencies in both consumption and productive activities (see “Sustainable use” in Chapter 3) to remove resource limitations and offset potential cost increases. Promoting a circular economy, particularly water reuse, can also reduce pressure on water resources. According to ADERASA (2021), only Colombia has a specific water and sanitation circular economy policy. Other countries, such as Ecuador, have general circular economy rules, while Argentina, Chile, and Peru have rules in place that encourage wastewater reuse.

On the other hand, a characteristic in multiple LAC countries is the fragmentation of water utilities. This is the result of decentralization, encouraged in the region. Under this approach, utilities’ scale is linked to a specific administrative unit, usually the municipality, leading to a large number of small companies scattered across the territory (Lentini and Ferro, 2014). This decentralized organization can cause economic and regulatory challenges, including externalities among operators, where untreated wastewater may be discharged downstream into water sources shared with other local governments.

In a highly fragmented sector, economies of scale are lost and the regulatory burden is bigger, while the opportunity to create cross-subsidy mechanisms is limited. Moreover, political rather than technical considerations may guide the management of the system, rural areas may face limited access to these services, and water catchment areas may not be adequately protected, among other factors (Jouravlev, 2003). Achieving economies of scale and scope can undoubtedly reduce the cost of service provision. Some LAC countries are already taking this approach. For example, in the past decade, Brazil has consolidated a community-based rural service management model, which involves the direct participation of the federal public water and sanitation utility, Agência Nacional de Águas e Saneamento Básico (ANA), local governments, rural communities, and multilateral investment agencies. In Peru, three projects have been identified with similar characteristics: La Huaca integral project, in Piura; the association of drinking water services Ingenio (*Asociación de Servicios de Agua Potable Ingenio*) project, in Ica; and the experience of the community association PESAR (*Proyecto Especial de Saneamiento Rural*), in Cajamarca. According to

Castillo (2016), these three partnership models based on economies of scale reduce operating, maintenance, and administrative project costs (see also estimates by Mercadier et al., 2016). However, centralized service supply can also have negative effects, such as decreasing system flexibility to respond to urban expansion, changes in the patterns of the natural supply of resources, and extreme events (Cavallo et al., 2020).

Regarding externalities, IWRM aims to address these issues through coordinated and shared basin management, setting boundaries based on ecosystems instead of administrative units. Achieving this goal may require the integration of small regional operators, which could mitigate economic and regulatory issues.

Trends toward distributed systems

In recent years, there has been a trend towards decentralization in the value chain of energy and water services.

In the electricity sector, decentralization is occurring at the end-user level through innovations in distributed generators and storage devices (Cont et al., 2021). Distributed generation has huge potential to contribute to energy transition goals like decarbonization. In 2021, the installed capacity of distributed generation in LAC reached nearly 1% of total capacity. First of all, efficient retail rate design rules should be considered to incentivize distributed generation among end users, who feel less encouraged to select this option when electricity supply from the grid is subsidized. Second, dual subsidy policies should be avoided to promote distributed generation projects in the context of aggregate subsidies. Third, cross-funding schemes should be revised (increasing-block tariffs). Retail rate design for distributed generation (such as the net metering and net billing variants), complementary to the system use rate, is often an alternative to foster the use of distributed systems and, at the same time, reduce grid funding problems (Satchwell et al., 2019; Darghouth et al., 2020).

In the water sector, distributed systems are physically linked to a central system by management but located in different geographical areas (Water Environment Federation, 2019). These small-scale facilities perform one or more supply chain activities, such as rainwater harvesting (catchment and provision), or local water reuse systems (pipes inside a building that divert used water for applications that do not require potable water), with centralized service management (Cavallo et al., 2020). These systems have multiple benefits, such as reaching remote areas at lower costs, saving energy as facilities are smaller, and increasing system resilience based on the use of alternate water sources and the replenishment of local aquifers (Water Environment Federation, 2019).

Although global development in this regard is still in its early stages, there are specific examples in LAC. For instance, in Brazil, the federal government implemented a program in 2003 called *Programa Nacional de Apoio à Captação de Água de Chuva e outras Tecnologias Sociais* to foster distributed rainwater harvesting for human consumption and food production in rural areas (Ministério da Cidadania, 2019). Under this program, the federal government funds the installation of water tankers with a capacity of up to 52,000 liters (around 13,700 gallons). In El Salvador, the use of similar distributed rainwater harvesting systems is a low-cost alternative to improve water access for off-grid households. However, their efficacy is limited during the dry season (Rovira et al., 2020). From a regulatory standpoint, the electricity sector should aim to create incentives for the development of distributed activities, ensure that these systems impact energy tariffs, and generate sector financing.

Development and inclusion of new technologies

Regulation cannot ignore the technological changes that are impacting infrastructure sector development. The transition toward compliance with environmental objectives will require monitoring and, in some cases, revising existing regulations to ensure that they facilitate competition and do not become barriers to new technologies or unduly protect more traditional methods of delivering services. For example, in the energy sector, hydrogen could become a major ally of matrix decarbonization. However, many countries have not adjusted their regulations to include it. Among the pioneers in the region, Costa Rica passed a bill (Dossier number 22,392) in April 2022 mainly to allow public utilities holding a current concession to commit their electrical energy production totally or partially to all stages of green hydrogen generation using the national electricity system's distribution or transmission networks. In Chile, the National Congress was discussing a Bill proposed by the Ministry of Energy and the Ministry of Finance for the use of green hydrogen combined with natural gas to drive green hydrogen demand (Ministerio de Energía and Ministerio de Hacienda, Chile, 2021). In 2021, Brazil was defining the technical parameters that would govern green hydrogen production (BN Americas, 2021).

Regulation should also establish clear rules that can create favorable environments for investments and private sector participation. For example, some countries do not allow private sector participation in the supply of drinking water and sanitation services (Bolivia and Ecuador), although they have signed agreements to implement public-private partnerships (Bonifaz, 2022). The involvement of the private sector in this industry can help develop and include new technologies that make it easier to tackle environmental challenges.

Climate risks

Climate change increases the likelihood of high-impact extreme weather events. This situation makes it much more difficult to ensure an efficient allocation of risks among the different stakeholders (companies, users, governments, and service providers). For optimal distribution, risks should be allocated to the party in the best position to manage them. In this regard, the International Finance Corporation (IFC, 2016) suggests that, if private players are only paid for the life of the contract and not for the life of the project, contractors do not have incentives to improve infrastructure resilience and reduce risks beyond the life of the contract due to the imposition of additional costs. Moreover, governments may require insurance to cover these risks. Therefore, innovative insurance products need to be developed. For example, in Uruguay, the state-owned hydropower utility company is insured against little rain. If precipitation falls below an agreed threshold, the company receives regular payments in line with the drought's duration and intensity. Therefore, the company avoids incurring high costs to purchase oil or gas as alternate energy sources during dry conditions.

Research conducted by the IDB has led to the development of a methodology to assess climate risks in new infrastructure projects (Barandiarán et al., 2019). In addition, this research originated the need to consider climate risks in infrastructure contracts, for example, for public-private partnerships (Frisari et al., 2020).

Climate-risk insurance can help the most vulnerable economies reduce uncertainty surrounding extreme climate events and encourage higher investments. However, a major barrier faced by these insurance markets is the lack of climate information, especially in developing countries, which hinders the definition of efficient risk premiums (Awojobi, 2018).

Another option for risk transfer mechanisms is the development of catastrophe or resilience bonds, which transfer the risk to the capital market (Hermann et al., 2016). Issuers of these bonds receive payment from bondholders if a catastrophe occurs; in exchange, investors receive interest payments (the bond coupon), reflecting the probability of loss of the invested capital. The main distinguishing feature between catastrophe bonds and resilience bonds is that the latter incentivize investments in risk reduction projects by offering lower coupon pricings reflecting the reduction in expected losses as a result of the implementation of resilience measures (Hermann et al., 2016). In 2014, the World Bank issued its first catastrophe bond to provide insurance to 16 Caribbean island countries (World Bank, 2015).

Stranded assets

Achieving the environmental objectives (including decarbonization) assumed by countries in the framework of international agreements may require a reevaluation of planned investments and an early retirement of certain assets before their expected end-of-life. This is mainly the case in power generation units and natural resource fields, such as oil, natural gas, and coal. Regarding investments made, the early retirement of assets has a substantial impact on service costs and necessitates planning compensation mechanisms. Employment related to these activities must also be factored in, and a complementary labor policy may be required to face the transition. In the region, many countries—Bolivia, Ecuador, Mexico, Trinidad and Tobago, and Venezuela—rely heavily on economic and tax revenues from hydrocarbons, which calls for a progressive and responsible transition.

Several options exist to mitigate the risks stemming from this transition. One such option is reducing the number of stranded assets. Some current initiatives are already underway to use existing fossil fuel infrastructure for renewable energies. For example, repurposing gas pipelines to transport green hydrogen. In the region, the Chilean Congress is discussing a Bill to authorize combining natural gas and hydrogen and transporting them through already existing gas pipelines.

In addition, as the transition to clean energy continues, authorities must implement monetary compensation mechanisms. For example, Germany plans to offer compensation payments through the federal budget to coal plant operators and their employees. Plans include payments of up to € 40 billion to be used for infrastructure improvements and new job creation (Hagen et al., 2019). However, any compensation mechanism implemented may make climate policies very expensive.

On the other hand, there is the risk that owners may overvalue their stranded assets. However, in the past, these types of disagreements were referred to international dispute resolution mechanisms. For example, compensation claims were filed in several European countries when coal-fired power generation plants were shut down due to the growing competitiveness of non-conventional energies (Verbeek, 2021). In the context of LAC, this issue requires special attention due to the precarious fiscal situation of some countries.

Public policies

Environmental challenges and the numerous measures aimed at achieving the proposed objectives can impact various dimensions of sustainability, without necessarily yielding favorable results in all cases. Solutions to environmental problems (like resilient infrastructure) may have negative economic and social impacts, such as higher costs for service provision, which can limit the payment capacity of certain user groups. Therefore, public policies should consider trade-offs, assess situations holistically, and take responsibility for balancing the different effects to maximize the present and future wellbeing of the population. An environmental institutional framework is crucial to achieving this balance, especially because it can play a key role in reconciling the three dimensions of sustainable development. Following this path requires empowering environmental management institutions. As a starting point, most LAC countries have already recognized the importance of environmental protection in their respective political constitutions or legal frameworks.

Moving forward, it is important to highlight situations where public policy plays a significant role in decision making, distinguishing between social, efficiency, and resilience policies.

Climate change increases the probability of experiencing more frequent and severe extreme events, making it challenging to efficiently allocate climate risks among different stakeholders.

Social policies (equity)

Climate change, among other environmental challenges, and the measures proposed to address it can have significant redistribution effects. For example, natural disasters and extreme events can have more devastating effects on low-income people because they generally live in more exposed and vulnerable zones, lose a larger fraction of their wealth, and have a lower ability to cope with and recover from these events (Hallegatte et al., 2020).

In addition, as discussed in the "Economic regulation" subsection, mitigation and adaptation policies, changes in resource availability, and higher demand for resources can affect the levels and structure of water and energy service provision costs. In many cases, this may increase costs or lead to tariff schemes with a larger component of fixed costs, negatively affecting service affordability.

In these cases, the design of social tariffs or well-targeted subsidies (in favor of the affected population) is especially important. However, existing subsidies, which are neither efficient nor targeted, interfere. Therefore, it should be reviewed whether more subsidies are required for these sectors (for environmental reasons) or whether restructuring is needed, despite the potential for social conflict. If more subsidies are necessary, it is also critical to assess fiscal revenue constraints in LAC countries, which worsened following the COVID-19 pandemic.

Similarly, some environmental policies can have progressive impacts on income distribution. For example, NCRE penetration and reduced costs of off-grid photovoltaic technologies guarantee power access in rural areas located far from distribution networks in a sustainable manner.

Box 5.1
A project on renewable energies in rural markets in Argentina (*Proyecto de Energías Renovables en Mercados Rurales*)

In Argentina, *Proyecto de Energías Renovables en Mercados Rurales* (PERMER), a project to provide access to energy from renewable sources to off-the-grid rural populations far from distribution networks, seeks to improve the quality of life of inhabitants. The project is undertaking multiple initiatives to benefit households, rural schools, agglomeration communities, and small productive entrepreneurial projects.

The program, which falls under the Secretariat of Energy, was established back in 1999 and has a nationwide reach. Funding for the project comes from the International Bank for Reconstruction and Development (IBRD) loan no. 8484, granted by the World Bank. The loan was split into two tranches: the first, from 1999 until 2015, and the second, in effect, of which USD 168 million has already been disbursed.

By 2021, the project had already invested USD 265 million and had over 600,000 beneficiaries, including them 2,700 schools, 66,500 households, 360 public establishments, 500 primary care centers, and nearly 50 protected areas (Mongelluzzo, 2021).

Policies to align incentives (efficiency and the environment)

The projects discussed in this report to facilitate addressing the challenges described in Chapter 1 have environmental benefits (positive externalities) that private actor may not weigh when assessing the advisability of making certain investments. Therefore, it is the State's role to align private incentives with environmental benefits in each country, along with the other social and economic effects.

Carbon pricing (in its multiple forms) is a typical way to internalize the social cost of GHG emissions in private decision-making processes. At present, carbon pricing systems cover about 23% of global emissions, according to the Carbon Pricing Dashboard published by the World Bank (n.d.b), and include all existing regulations at the national, regional, and subnational levels. This is to say that a large fraction of emissions remains unregulated.

Taxes are the most widely used instrument in the region, although some negotiable emission permit systems are being considered in Mexico and Chile. In Argentina, a carbon tax was enforced in 2018, applicable to CO_2 emissions from all sectors, at a 10% rate (close to USD 6/tCO_2, according to the World Bank, n.d.b) In Chile, the carbon tax was introduced in 2017 as part of a tax levied on compound emissions that pollute the air. It was enforced on CO_2 emissions, mainly in the energy sectors (all fossil fuels) and industry, at a rate of USD 5/tCO_2. In Colombia, a carbon tax on greenhouse gas emissions from all sectors was implemented in 2017. The carbon tax in Mexico, in turn, is included in the "special tax on production and services." It is not a tax on the total carbon content of fuels, but on the additional content of CO_2 emissions compared to natural gas. It covers all fossil fuels except for natural gas and applies to CO_2 emissions from the energy, industry, road transportation, aviation, maritime transportation, buildings, silviculture, waste, and agriculture sectors.

So far, countries have found it hard to set prices high enough to generate significant reductions in the use of fossil fuels: values do not exceed USD 10/tCO_2, compared to values estimated to achieve the Paris Agreement temperature targets of at least USD 40-80/tCO_2 by 2020 and USD 50-100/tCO_2 by 2030 (Carbon Pricing Leadership Coalition, 2017). In some countries, the enforcement of this type of measures has been held back because they are unpopular.

In light of this regional context, CAF (2022) has announced that it will support the creation of a carbon market in LAC, strengthening carbon markets in CAF's member countries and encouraging the competitiveness of carbon credit supply. The main goal of this project is to reduce GHG emissions by mobilizing new financial resources to address global warming and respond to international demand. The Latin American and Caribbean Initiative for Developing the Carbon Market will work on: i) institutional capacity-building, aligning interests and awareness of the situation; ii) knowledge generation; and iii) multisectoral dialogue to accelerate learning processes and reinforce capacities.

Carbon pricing can be a strong instrument to align private sector incentives with environmental goals tied to climate change. Regardless of this issue and until these measures can be implemented, there is room to design complementary instruments that foster energy transition (penetration of renewable energies, distributed generation, smart grids, reduced fossil fuel use, energy efficiency, and electrification of consumption), and the conservation of water resources (efficient water use, reduced pollution, and caring for water resources).

Although the cost of large-scale NCRSs has decreased, small-scale generation at competitive costs has not yet been developed. For these cases, incentives can be provided under energy pricing schemes and payments for the electricity injected into the grid (see the subsection "Economic regulation").

At the same time, energy subsidy policies discourage the replacement of fossil fuels and work against a carbon taxation framework, while fossil fuels are strategic resources for LAC countries. In principle, a change in existing subsidies could support the adoption of cleaner energies. However, implementing changes should be done with care, aligned with technological development, as they can impact the price of goods and services. Moreover, any changes should be accompanied by effective communication plans, transition measures, and compensation mechanisms for vulnerable groups.

National governments play a crucial role in the development of electromobility in LAC countries. In light of this, CAF published a roadmap (Ardanuy Ingeniería, 2019) that outlines important measures they can take: draft administrative and technical tender specifications, create a single fund to manage public revenue and subsidies, redefine fossil fuel subsidies (in line with single-fund creation), and enforce special taxes or exempt businesses from paying environmental taxes.

For the water sector, the main public policy instruments are: environmental taxes that incentivize best practices; regulations that enforce wastewater treatment and restrict or monitor water pollution; subsidies for the use of alternate water sources, such as sea water; regulations on water pricing to control consumer behavior; subsidies for water recycling; and regulations on acceptable limits of water withdrawal for use in different contexts (ESCAP, 2019).

In both sectors, pricing schemes to avoid overexploitation can support the efficient use of resources. In LAC countries, these sectors have subsidized service tariffs. Therefore, consumers do not perceive the real cost of service provision and, in many cases, consumption can exceed optimal levels for society.

Subsidizing technologies that improve sector efficiency is a potential measure to encourage the sustainable use of resources. For example, in Argentina, the City of Buenos Aires implemented a program in 2019 called *Pasate a LED* (Go LED) to incentivize people to exchange traditional bulbs for LED bulbs and reduce household consumption (Buenos Aires Ciudad, 2019). Another measure is the introduction of tax incentives for the construction of energy efficient buildings. For example, the US tax code grants USD 1,000 in tax credit for a manufactured home that is at least 30% more energy efficient than a standard home. In France, buildings that can demonstrate low energy consumption are exempt from property tax for up to five years (Buzaglo Dantas et al., 2015).

Resilience plan

Governments play a central role in the planning, organization, and implementation of resilience plans, particularly for infrastructure. Their responsibilities range from designing response strategies to managing vital information. Resilience objectives, standards, and regulations for infrastructure plans, aligned with other environmental plans, establish the framework, while financial incentives can complement this framework and ensure the provision of resilient services (Hallegatte et al., 2019). This field provides ample opportunities for action.

Improvement areas in the health care sector

The COVID-19 pandemic exposed the level of preparedness of the region's healthcare systems to face disruptive events that put them under extreme stress. This experience revealed a set of challenges that the sector must address to tackle other situations that also demand a rapid and effective response. Based on the lessons learned, Table 5.4 summarizes recommendations that, if implemented, could improve sector performance in the context of health care crises.

Table 5.4
Summary of challenges and recommendations for the health care sector
Source: Authors based on Chapter 4 in this document.

Challenge	Intervention
Chronic underfunding of health. Contingency funds or debt must be used to respond to emergencies.	Create an agile financing mechanism in LAC dedicated to responding to countries' needs in case of disruptive events.
Limited supranational cooperation to solve multiple current uncertainties, including scientific evidence, and strengthen cross-country interaction.	Strengthen a permanent regional mechanism that provides countries with training, expert support, and knowledge management to handle health care crises.
Development of future extreme scenarios to anticipate epidemiological and environmental risks, and the need for health care human resources, and medical infrastructure, equipment, and supplies.	Reinforce information systems, including epidemiological and environmental surveillance, and support applied research for scenario planning and evidence-based resource forecasting.
Reliance on international trade for health care technology and medical supplies.	Promote research and development, and establish coordinated negotiation mechanisms to respond to health care emergencies, in addition to logistics support instruments.
The rise of digital health care.	Strengthen the legislative framework, financing, infrastructure, and human capital training in health care and the digital transformation of the sector.
Insufficient infrastructure to meet demand peaks.	Reinforce primary care and design contingency plans for the temporary use of adapted hospital facilities.

The recommendations presented may be effective in the short term, but to achieve sustainable results, it will be necessary to address the structural problems of health systems, such as spending deficits and fragmentation. Although these problems are expressed heterogeneously in the countries of LAC, in general, it is about reviewing and reorienting the quality and coverage of insurance schemes. It also seeks to increase investment in the health sector, tend to reduce fragmentation, increase investment in strengthening primary care, achieve a more equitable distribution of services, improve quality, reduce the technological gap, and strengthen management (Guibovich, Zamora, and Castillo, 2022).

Chronic underfunding of health

A big challenge throughout the COVID-19 pandemic was the scarce funding available in this sector. Chronic lack of health funding and deficient public financing in LAC curtailed the sector's ability to respond to the crisis. Therefore, it is important to review, first, the funding required for financial sustainability and, second, the surpluses available for the management of extreme disruptive events.

Analyzing financial sustainability at a regional level is challenging due to the heterogeneity of financing profiles within and among countries, which is influenced by the fragmentation and segmentation of health systems. Nonetheless, reviewing this is essential because financing sources and the allocation of healthcare spending have an impact not only on the financial sustainability of health systems, but also on access to services and equity (Perea Flores, 2018).

To secure additional financing during the COVID-19 pandemic, many LAC countries improvised their search for funds, reallocating budget resources, using contingency funds, or taking on debt. This points to an opportunity to create regional agile financing mechanisms that can respond to countries' needs in the event of health emergencies. One example is a dedicated emergency fund for disruptive events.

In Mexico, the Wellbeing Health Care Fund (*Fondo de Salud para el Bienestar*) provided flexible and timely financial support during the pandemic. This fund for catastrophic spending was particularly helpful to buy personal protective equipment rapidly and in a centralized manner, replenish drug supplies and, in general, respond to the urgent need to keep hospitals running during the crisis (Institute for Global Health Sciences, 2021). The WHO (2021c) considers this element as one of the main surveillance and response indicators for assessing the required basic capacities to respond to public health emergencies.

Regardless of these financing needs, resource availability is a challenge for all economic sectors in LAC. Deficit fiscal systems make it difficult to use public funds to address situations of underfunding. Even more complex is that—given the current fiscal situation in LAC—countries lack the necessary margins of action to proactively address future contingencies.

Supranational cooperation and institutional strengthening

During the COVID-19 pandemic, one of the biggest challenges faced by LAC countries was the need to make decisions based on general considerations, without clear guidelines or well-supported evidence to manage the high levels of uncertainty. This highlights the need for supranational frameworks that strengthen regional information systems, including processes, instruments, technology, and human resource training. By establishing these systems, LAC countries could proactively monitor, analyze, alert, and respond promptly to health emergencies.

In addition, this framework would allow them to create a permanent regional mechanism, which could provide highly specialized, quick-response technical and, if necessary, logistical support for the adoption of best practices to create temporary emergency health infrastructure. A supranational training center for disease surveillance and control, health management, and research on health emergencies could also be considered to improve regional capacity.

In the European Union, the European Centre for Disease Prevention and Control (ECDC) was established in 2005 to strengthen Europe's defenses against infectious diseases. The ECDC analyzes and interprets data from EU countries on 52 communicable diseases and conditions (using the European Surveillance System); provides scientific advice to the EU governments and institutions; ensures early detection and analysis of emerging threats to the EU; coordinates the European Programme for Intervention Epidemiology Training and the European Programme for Public Health

Microbiology Training; helps EU governments prepare for outbreaks of disease, and organizes the European Scientific Conference on Applied Infectious Disease Epidemiology every year (European Union, 2005). In addition, the European Commission created the European Health Emergency Preparedness and Response Authority in September 2021 to prevent, detect, and rapidly respond to health emergencies. This authority will anticipate potential health crises through threat assessment, information exchange, research support, and a close dialogue with industry. In case a public health emergency at EU level is declared, it will promote financing and emergency measures, among others, under the steer of a high-level Health Crisis Board (European Commission, 2021b).

At the national level, failures in implementing plans to tackle the COVID-19 pandemic are an opportunity for governance improvements. These mainly include strengthening government capacities to plan and prepare a response to extraordinary events and develop a set of legal, financial, and organization tools to enhance response efficacy and timeliness. Finally, it is key that national institutions interact with supranational entities to gather relevant information, adopt action mechanisms, and develop anticipation and management systems to respond to disruptive events.

Anticipation of future extreme scenarios

The health system must be agile enough to respond to a new highly disruptive event of a similar magnitude. However, effective readiness calls for anticipating future scenarios and the most probable threats. In other words, sector infrastructure, human resources, technology, and other needs will be different depending on the characteristics of the future disruptive event. Therefore, anticipating future scenarios or events and the most likely needs can help improve preparedness efficiency.

For example, human resources were a critical factor during the pandemic. In particular, there was a dire need for health care professionals trained in providing medical assistance to mild or severe COVID-19 patients, lab diagnosing, and epidemiological surveillance and response. Training health care professionals takes many years. Therefore, if diseases or events that will demand a certain professional specialization are foreseen for the coming decades, measures can be adopted now to promote enrollment in relevant training courses. It is also important to anticipate the effects of pandemics on human health, such as the after-effects of post-COVID-19 on the respiratory and cardiovascular systems, and mental health, among others.

The above involves huge efforts to accurately monitor and assess the environmental factors that pose a risk for the emergence of pandemics. Health system capacity-building is also essential to adapt to environmental changes and reduce pandemic effects on human health, minimizing the vulnerability of populations (WHO, 2021h) and evaluating the effectiveness of interventions in the face of diverse climatic situations. Applied research and improved evidence-based decision-making processes are necessary developments to make sure that projections are as accurate as possible and response actions are consistent with the anticipated needs. Similarly, generating and gathering regional data will play a critical role in the projection of scenarios. This will be later discussed in more detail.

Reliance on international trade for health care technology and medical supplies

LAC relies on international trade for medical supplies, drugs, and vaccines. During the COVID-19 pandemic, this situation, along with the lack of supranational mechanisms to improve negotiation conditions, left countries without any other alternative than to source their supplies in isolation from suppliers on the global market.

Clearly, dependence on imported technology and medical supplies in a context of a global crisis can be a major constraint to the resilience of the health care system. This may be an opportunity for increasing investment in research and development, so that medical supply industries and laboratories can develop on some scale at the national and regional level. Establishing coordinated negotiation mechanisms with the main countries that produce these supplies in advance of health crises is another opportunity. To purchase COVID-19 vaccines through joint procurement mechanisms, COVAX was created. Beyond its limitations, LAC countries can take advantage of this tool to develop future joint negotiation approaches.

Solutions to environmental problems may have negative economic and social impacts, and public policy should balance these different effects.

The rise of digital health care: Data management and quality

A key element during the COVID-19 pandemic was the digitalization (or digital transformation) of the health care sector. This not only facilitated assisting and monitoring patients remotely, but also enabled data generation, collection, and analysis. However, LAC countries encountered barriers to mutual coordination, interoperability, and ensuring the quality of their data sources.

Data can play a critical role to anticipate and control diseases or catastrophes, and this is key to facing future disruptive events. Therefore, it is important to maintain and improve the digitalization mechanisms of health care processes to preserve data and information security, foster interoperability, and strengthen human resources training. Initiatives can be coordinated under a public surveillance framework defining standard regional indicators to monitor the number of cases according to diagnostic tests, along with the number of hospitalized patients and deaths. These numbers can then be contrasted with indicators of the supply of human resources, health infrastructure, equipment, inputs (including vaccines), and laboratory tests (Guibovich, Zamora, and Castillo, 2022).

For example, the European surveillance system, known by its acronym TESSy, provides EU countries with scientific evidence about infectious diseases. Its database integrates information from several surveillance networks that used to be independent. Therefore, TESSy is a unified data system (ECDC, 2011). More specifically, during the pandemic, ECOVIDNet, the European COVID-19 surveillance network, was created to provide decision-makers and public health experts with the information required to assess COVID-19 activity and take appropriate action (ECDC, 2022).

Flexible infrastructure to meet demand peaks

In the face of health crises, peaks in demand are difficult to meet, given a fixed health infrastructure supply. This is what happened during the COVID-19 pandemic, when, for example, a percentage of the affected population had difficulty accessing health services, hospitals, and the necessary equipment. In this context, governments in the region reallocated public resources to make up for health system shortfalls, increasing their capacity to care for COVID-19 patients (OECD, 2020).

Most LAC countries attempted to confront the crisis with improvised, short-term, palliative measures. For example, in Ecuador, ten field hospitals were set up in some of the most affected neighborhoods in Guayaquil. In Colombia and Peru, a strategy was implemented to expand high-complexity hospitals’ services to institutions such as hotels, closed health care facilities, and field hospitals.

Therefore, measures should be adopted to promote a flexible, agile, and responsive health infrastructure. Along these lines, contingency plans can help provide the health system with a temporary infrastructure network (e.g., field hospitals, infrastructure from other sectors), including the necessary human resources and complementary supplies, to respond to disruptive events causing excess demand.

Countries are conducting assessments to measure the health care sector's vulnerability and adaptive capacity to climate change. Gradually, they are updating or introducing plans and programs and reallocating resources to the sector to deal with climate change events. In this context, it is important that the lessons learned during the recent pandemic about surveillance, financing, infrastructure, coordination, scenario and resource planning, data management and quality, among others, are included in the public agenda so that the region and the world are better prepared to face any future epidemiological or climate events.

Annex 5.1
State agencies that participate in water services and types of organization in Latin America

Country	Water authority	Water and sanitation governing agency	Regulatory agency	Operator (predominant type of organization)	Does the country allow private participation?	Does the country have a national system for water resources?
Argentina	There are several provincial authorities of different rank*	Homeland, Public Works, and Housing Ministry (*Ministerio del Interior, Obras Públicas y Vivienda*)	There is not only one regulatory agency, but one per province**	Regional and municipal	Yes	No
Bolivia	Drinking Water and Basic Sanitation Social Control and Inspection Authority (*Autoridad de Fiscalización y Control Social de Agua Potable y Saneamiento Básico*)	Ministry of the Environment and Water (Vice-Ministry of Drinking Water and Basic Sanitation) (*Ministerio de Medio Ambiente y Agua [Viceministerio de Agua Potable y Saneamiento Básico]*)	Water and Basic Sanitation Social Control and Inspection Authority (*Autoridad de Fiscalización y Control Social de Agua y Saneamiento Básico* (AAPS))	Municipal	No	Yes
Brazil	National Water and Basic Sanitation Agency (*Agência Nacional de Águas e Saneamento Básico*)	Federative Republic of Brazil's Regional Development Ministry (*Ministério da Integração e do Desenvolvimento Regional)*	As in Argentina, there is not only one regulatory agency, but multiple***	Regional and municipal	Yes	Yes
Chile*****	General Water Authority (*Dirección General de Aguas*)	Ministry of Public Works (*Ministerio de Obras Públicas*)	Sanitary Services Regulatory Agency (*Superintendencia de Servicios Sanitarios*)	Regional	Yes	Yes
Colombia	National Water Council (*Consejo Nacional del Agua*)	Vice-Ministry of Water and Basic Sanitation (*Viceministerio de Agua y Saneamiento Básico*)	Drinking Water and Basic Sanitation Regulatory Commission (*Comisión de Regulación de Agua Potable y Saneamiento Básico*)	Municipal	Yes	-
Costa Rica	Water Authority (*Dirección de Agua*)	Ministry of the Environment and Energy (*Ministerio de Ambiente y Energía*)	Costa Rica's Public Utilities Regulatory Authority (*Autoridad Reguladora de los Servicios Públicos de Costa Rica*)	National and municipal	Yes	Yes
Dominican Republic	National Institute for Water Resources (*Instituto Nacional de Recursos Hidráulicos*)	Ministry of the Environment and Natural Resources (*Ministerio de Medio Ambiente y Recursos Naturales*)	National Drinking Water and Sewage Institute (*Instituto Nacional de Aguas Potables y Alcantarillados*)	Regional	Yes	Yes
Ecuador	Ministry of the Environment, Water, and Ecological Transition (*Ministerio del Ambiente, Agua y Transición Ecológica*)	Ministry of the Environment, Water, and Ecological Transition (*Ministerio del Ambiente, Agua y Transición Ecológica*)	Municipal Regulatory and Monitoring Agency (*Ente Municipal de Regulación y Control*, EMAPAG-EP): municipal and sectoral. Water Regulatory and Monitoring Agency (*Agencia de Regulación y Control del Agua*, ARCA): national and sectoral.	Municipal	No	Yes

Continued on next page

Country	Water authority	Water and sanitation governing agency	Regulatory agency	Operator (predominant type of organization)	Does the country allow private participation?	Does the country have a national system for water resources?
El Salvador	National Water Authority (*Autoridad Nacional del Agua*)	Ministery of the Environment and Natural Resources (*Ministerio de Medio Ambiente y Recursos Naturales*)	None	National and municipal	Yes	Yes
Guatemala	There is more than one water authority****	Vice-Ministry of Water (*Viceministerio del Agua*)	Municipal Development Councils (*Consejos Municipales de Desarrollo*, COMUDE)	Municipal	Yes	-
Honduras	Water Authority (*Autoridad del Agua*)	General Direction of Water Resources (*Dirección General de Recursos Hídricos*)	Drinking Water and Sanitation Regulatory Agency (*Ente Regulador de Servicios de Agua Potable y Saneamiento*)	National and municipal	Yes	Yes
Jamaica	Water Resources Authority (*Autoridad de Recursos Hídricos*)	Ministry of Land, Water, the Environment, and Climate Change (*Ministerio de Tierra, Agua, Medio Ambiente y Cambio Climático*)	Office of Utilities Regulation (*Oficina de Regulación de Servicios Públicos*)	National	Yes	-
Mexico	National Water Commission (*Comisión Nacional del Agua*, CONAGUA)	Office of the Secretary of the Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*)	None	Municipal	Yes	-
Nicaragua	National Water Authority (*Autoridad Nacional del Agua*)	National Council on Water Resources (*Consejo Nacional de Recursos Hídricos*)	Drinking Water and Sanitation Services Regulatory Agency (*Ente Regulador de Servicios de Agua Potable y Saneamiento*)	National and municipal	Yes	No
Panama	Panama's Water Resources Authority (*Autoridad de los Recursos Acuáticos de Panamá*)	Drinking Water and Sewage Subsector Authority (*Dirección del Subsector de Agua Potable y Alcantarillado Sanitario*)	National Public Utilities Authority (*Autoridad Nacional de los Servicios Públicos*)	National	Yes	-
Paraguay	Ministry of the Environment and Sustainable Development (*Ministerio del Ambiente y Desarrollo Sostenible*)	Ministry of Public Works and Communications (*Ministerio de Obras Públicas y Comunicaciones*), Drinking Water and Sanitation Authority (*Dirección de Agua Potable y Saneamiento*)	Sanitation Services Regulatory Authority (*Ente Regulador de Servicios Sanitarios*)	National and municipal	Yes	Yes
Peru	National Water Authority (*Autoridad Nacional del Agua*)	Ministry of Housing, Constructoin, and Sanitation (*Ministerio de Vivienda, Construcción y Saneamiento*)	National Sanitation Services Agency (*Superintendencia Nacional de Servicios de Saneamiento*)	Municipal	Yes	Yes
Uruguay	National Water Authority (*Dirección Nacional del Agua*)	Ministry of the Environment (*Ministerio de Ambiente*)	Energy and Water Services Regulatory Unit (*Unidad Reguladora de Servicios de Energía y Agua*)	National	Yes	-

Note: * For more information, please visit: https://www.oecd-ilibrary.org/docserver/bc9ccbf6-en.pdf?expires=1684760272&id=id&accname=ocid49029512&checksum=245ECC10890E6E5E09BAF438FD99DA6A; ** For more information, please visit: https://aferas.org.ar/entes-miembros/; *** For more information, please visit: https://abar.org.br/agencias-associadas-a-abar/; **** For more information, please visit: https://funcagua.org.gt/wp-content/uploads/2020/04/2018.-Institucionalidad-del-agua-en-America-Latina-UCA.pdf; ***** According to Bloomberg News (Thomson, 2021), the Chilean government sent a Bill to congress that will transform the Public Works Ministry as the Public Works and Water Resources Ministry, an entity that will oversee and coordinate the 43 water management institutions in Chile.

Source: Lentini (2015) and Bonifaz (2022)

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