ROADMAP FOR THE ENERGY TRANSITION TO 2050 IN LATIN AMERICA AND THE CARIBBEAN

South-South Collaborative
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TRANSFORMA

This technical document presents an approach to a roadmap for the energy transition for Latin America and the Caribbean. Document based on the most recent report of the IEA “Net Zero by 2050: A Roadmap for the Global Energy Sector”.

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Executive summary

The energy sector contributes to three-quarters of global greenhouse gas (GHG) emissions. Therefore, reducing the sector's emissions to net-zero by 2050 is consistent with efforts to limit average long-term global temperature increases to 1.5˚C. This requires nothing less than a complete transformation of how we produce, transport, and consume energy (IEA, 2021).

Additionally, the growing political consensus around reaching net zero emissions by 2050 is grounds for considerable optimism about the progress that the global community can achieve, but the necessary changes are yet to be explored. There must also be recognition that every country has comparative advantages, which bring with them challenges and obstacles that will need to be addressed throughout the process of planning the energy transition towards net zero.

This document establishes the starting point for an energy transition roadmap in Latin America and the Caribbean that is aligned with the Paris Agreement and the latest reports from the IEA (IEA) and the Intergovernmental Panel on Climate Change (IPCC), identifying the main challenges and opportunities that the region presents to reach the path towards a net-zero emissions sector by 2050. The efforts that governments should continue to significantly strengthen their energy and climate policies are highlighted, since the commitments made to date are still below what this path requires.

Also, provides a general overview of the region, understanding that countries do not start in the same stage in terms of progress and capabilities. Consistent with the IEA report and the seven pillars proposed therein, this document assesses progress and gaps in energy efficiency, behavioural change, electrification, renewable energy, bioenergy, hydrogen, and carbon capture, usage, and storage, identifying the opportunities that exist for the region.

The report seeks to generate a state of the art of the energy transition in the region towards net-zero and aims to strengthen the knowledge of the interested actors to influence decisions at the domestic political level and regional direction, increasing the ambition that allows reaching global climate goals.

Reaching net-zero not only implies innumerable policy decisions but changes in behavior and private investment. To overcome the different barriers and gaps that the region presents in the energy transition towards net-zero, it is also necessary to guide and strengthen the capacities of civil society and the private sector, for which it is also expected that this document will open the discussions to work within the countries to draw clear and oriented routes under the pillars proposed by the IEA.

Introduction

The climate crisis affects the world unequally, with many developing countries bearing the brunt of the consequences. One of the sectors that has the most implications with this crisis is energy, where the burning of fossil fuels generates emissions of GHG, which have triggered global warming.

It is imperative to act, and to carry out an energy transition with clear goals. This document sets out the pillars for this transition in Latin America and the Caribbean to 2050 guided by the report published in May 2021 by the IEA (IEA): "Net-zero Report to 2050: a Roadmap for the global energy system", which represents the agency's first effort to model a comprehensive energy pathway to limit global warming to 1.5 degrees Celsius.

The IEA's scenario does not see investment in new fossil fuel supplies as necessary. At the same time, the AR6 report from the Intergovernmental Panel on Climate Change (IPCC) emphasizes the need for an accelerated energy transition, particularly in the phase-out of fossil fuels if the 1.5 degrees goal wants to be reached.

In this way, we are approaching a decisive moment to focus on international and regional efforts to confront the climate crisis, a great challenge of our time. The IEA report sets out a cost-effective and economically productive path to achieving the goal of net-zero emissions globally by 2050, resulting in a clean, dynamic, and resilient energy economy dominated by renewable energy such as solar and wind instead of fossil fuels.

The energy transition path is designed to maximize technical feasibility, profitability and social acceptance while ensuring continued economic growth and a secure energy supply. It shows what is needed across major sectors by various actors for the world to achieve net CO2 emissions related to energy and industrial processes by 2050.

It is important to recognize the momentum in which Latin America and the Caribbean has begun to transform its energy matrix, showing the region's capacity to adapt to economic, environmental, and social changes. Historically, Latin America and the Caribbean had the cleanest energy matrix on the planet, thanks to its extraordinary water resources (Ministry of Mines and Energy, 2021).

This document aims to establish the starting point for an energy transition roadmap in Latin America and the Caribbean that is aligned with the Paris Agreement and the latest IEA and IPCC reports. In this way, consistent with the IEA roadmap, the report is developed in accordance with the seven proposed decarbonization pillars:

① Energy Efficiency,
② Behavioural Change,
③ Electrification,
④ Renewable Energy,
⑤ Hydrogen,
⑥ Bioenergy,
⑦ Carbon Capture, Utilization and Storage (CCUS).

These pillars and associated goals will be explained throughout this document considering in each pillar, a regional assessment on goals, gaps, challenges, and opportunities. Additionally, the report is made up of the following chapters:

- General aspects of the region and the results of the assessment in terms of the decarbonization pillars proposed by the IEA report.
- Roadmap for the energy transition in Latin America and the Caribbean for the seven decarbonization pillars, with context, regional assessment and goals, gaps, and barriers to meet the goals, and recommendations and opportunities for the region.
- Adaptation to climate change analysis in the energy sector, providing a context of the vulnerability of the region and sector and the different tools and plans that have been developed and implemented.

Overview of Latin America and the Caribbean

3.1. General situation in the region

The Latin America and Caribbean region have significant advantages for the transition to more sustainable energy systems. Mainly, in terms of the quantity of natural resources to produce biomass and wind and solar power (IDB, 2021). It also has the foundation of a historically clean energy mix due to the importance of hydroelectric energy, which makes up over half of the energy supply.

Nearly 58% of the electricity generated in Latin America and the Caribbean comes from renewable sources. Of this percentage, 77% is produced by hydroelectric power stations, followed by wind and solar power (which together represent 13%), biomass (9%) and geothermal power (1%) (IDB, 2021).

During the process of developing the roadmap for energy transition in Latin America and the Caribbean, a general assessment was made of the strategies, plans, roadmaps, and official guidelines adopted by government entities. This was done with the aim of ascertaining the current situation in the region's countries, in addition to their medium- and long-term goals, and then present recommendations for decision-making and steps to be followed regarding energy transition.

The assessment took into account public information and the results of the information gathered through meetings and surveys with the civil society organizations (CSOs) mapped and contacted in the region (See Annex 1[1]). The information consulted comes from, but is not limited to (see Annex 2[2]):

- Long-term decarbonization strategies
- Roadmaps (hydrogen, energy transition, climate change)
- Climate change regulation

In Annex 3, a matrix in Excel compiles all the results of the information-gathering process for this assessment, indicating the documents viewed, the data extracted from the documents, and a summary of the quantitative and qualitative goals identified for the countries in the region.

Based on the information collected, seven of the region's 18 countries were identified as having long-term strategies: Chile, Colombia, Mexico, El Salvador, Panama, Costa Rica, and Guatemala. However, the assessment was primarily focused on seven of the most representative countries in terms of size, population, and relevance in matters related to climate change and energy transition in the region: Argentina, Brazil, Chile, Colombia, Costa Rica, Peru, and Mexico.

It is important to acknowledge that countries like Venezuela and Ecuador play a significant role in energy transition due to their status as fossil fuel producers. However, the information that exists at a public and private level is highly limited, and it was not possible to determine their energy transition plans or their position towards the process in the region.

At a regional level, a series of projections have been made, both for the electricity sector and for the energy sector in general. These projections give a trend scenario where, by 2050, the total energy supply structure shows a drop in the supply of crude oil and derivatives from 38% in 2019 to only 37%; natural gas falls from 29% to 28% and coal decreases from 6% to 3% (Latin American Energy Organization-OLADE, 2021).

OLADE (2021) considered the PRO-NET ZERO scenario in conjunction with other strategies to significantly reduce emissions, showing that by 2050 crude oil and derivatives will reach 22%, compared with 19% for natural gas and 1% for coal. The projections for the trend scenario show a rise in CO2 emissions, from 1,762 metric tonnes in 2019 to 2,764 in 2050. However, with the PRO-NET ZERO scenario a reduction to 1,523 metric tonnes of CO2 is achieved by 2050.

This vision of OLADE starts out from a series of assumptions regarding the adoption of policies for energy transition, which includes the recent agreement in the region, reached through RELAC, aiming for a minimum share of 70% for renewable energy in the region, not only in installed capacity but also in generation.

1 Annex 1 of this document contains the results of the meetings and surveys conducted with the CSOs.

2 Annex 2 of this document includes a summary of every document consulted for each of the countries.

The outlook for other components remains limited, with no genuine signs of agreement towards any goal. Furthermore, the region does not have defined plans or targets beyond 2030, meaning that longer-term modelling exercises contain an element of political uncertainty that should be considered. OLADE suggests that some of the milestones, set by the IEA to enable the global energy sector to contribute effectively to meeting the goals of the Net Zero 2050 scenario, would not be applicable at regional level because of its energy-related and socio-economic characteristics (OLADE, 2021).

While the progress made in reaching a regional target for the share of renewable energy must be acknowledged, said target continues to be short term, and at present there are no common targets for the remaining pillars set out by the IEA. The lack of clear targets therefore results in modelling exercises that do not allow for meaningful progress and can show signs of slowing down the energy transition by allowing the inertia around the use of fossil fuels to continue.

This situation demonstrates the clear need to reach agreements regarding energy policy at both national and regional levels, which poses challenges for the development of an energy policy that is much more aggressive towards neutrality. The energy transition is one of the most pressing tasks facing modern societies, and as such its successful completion is dependent on considering the conditions of energy poverty that can represent economic or socio-cultural barriers to technological change. Consequently, it is essential to ensure that the implementation of these changes does not deepen inequality or create new forms of it.

3.2. Holistic analysis of goals of the countries of the region

To start this work, a qualitative and quantitative analysis was carried out that made it possible to identify in general terms the projections of the region based on the information and goals of the countries regarding the decarbonization pillars. The methodology and extended information of the results is presented in the annex 4, showing that there is not enough information at the official and unofficial level (private, CSO, NGO).

The indicator called "Level of Information-LI" aggregates the largest countries in the region (Argentina, Brazil, Chile, Colombia, Costa Rica, Peru, and Mexico). A scale of 1 to 3 is established at the country level, as follows:

1. does not have any type of information, goal, strategy, plan, etc. associated with the pillar;
2. there are roadmap plans, or strategy/regulation regarding the pillars;
3. represents that the country has information about the pillar and is aligned with the milestones of the IEA report.

The aggregated information for the region of this indicator is found in table 1 (for details of the selected countries, see the annex 4.1.):

Given the results of this analysis, the behavioural change pillar has a high rating because the IEA report does not have a global goal associated with behavioural change and is a measure open to many initiatives, likewise, it has been evident that each of the countries has been making different efforts to encourage changes in behavior associated with energy.

On the other hand, the countries in the region have been making progress in terms of energy efficiency and renewable energy at a documentary and strategic level. However, not all of them have established goals associated with this issue, or are they aligned with the proposals of the report.

Regarding electrification, Latin America and the Caribbean as a region has been proposing strategies and plans to increase electricity within its energy matrixes, however, the level of information shows that there are no specific goals for the countries, but focused goals have been proposed in the residential and transport sector.

Finally, it is evident that for the pillars of hydrogen, bioenergy and CCUS, the information in the region is very limited and not all countries have set quantitative goals for these issues, however, there is great potential to explore in the region in this process of energy transition.

Table 1. ***Regional analysis of the indicator "Level of Information - LI" compared to the decarbonization pillars of the IEA report, qualitative and quantitative***

	Pillar 1 Energy Efficiency	Pillar 2 Behavioural Change	Pillar 3 Electrification	Pillar 4 Renewables	Pillar 5 Hydrogen	Pillar 6 Bioenergy	Pillar 7 CCUS
Qualitative	2.43	3.00	2.00	2.43	2.00	1.43	1.57
Quantitative	2.00	3.00	1.43	2.14	1.29	1.29	1.14

04

Roadmap for energy transition in Latin America and the Caribbean america

Achieving a rapid reduction in CO2 emissions over the next 30 years requires a wide range of policy and technological approaches that are in line with the recent Paris Agreement and the IEA's Net Zero by 2050 report.

A general outline of trends in the region is provided below, based on the information found for the priority countries, the specific targets in the IEA report, and the proposed roadmap for each of the pillars, as well as other general aspects of the region for each pillar.

4.1. Energy efficiency

4.1.1. Context

Energy efficiency (EE) minimizes growth in energy demand and seeks to achieve more benefits with fewer energy resources. This is vital to the transition, since without the effective implementation of measures related to energy efficiency, behavioural changes, and electrification, final energy consumption would be around 300 exajoules higher in 2050: almost 90% above the level set in the 2050 scenario (IEA, 2021). Similarly, efficiency improvements also help to reduce the vulnerability of companies and consumers to potential interruptions to the electricity supply (IEA, 2021).

4.1.2. Assessment and regional targets

The IEA report lays out key milestones for energy efficiency based on the indicator for energy intensity of the economy (the amount of energy used per unit of GDP - TES/GDP). This indicator is mainly used because, at an aggregate level, it is an indirect measurement of the energy required to satisfy the demand for services. It is also an indicator that is relatively easy to calculate and compare across countries (IEA, 2021a).

The target set in the report is an annual reduction in energy intensity of 4.2% by 2030, followed by an annual reduction of 2.7% from that year until 2050. The Latin America and Caribbean region include countries like Mexico, Brazil, and Chile, which boast successful implementation programs and have strengthened the institutional and regulatory frameworks that have helped to support their different energy efficiency measures; however, not all the region's countries are moving forward at the same pace (IDB; OLADE; ECLAC, 2017).

A successful energy efficiency program aims to achieve additional and sustainable energy savings, i.e., those savings obtained as the result of specific measures that would otherwise not have been generated, while showing tangible results such as lower energy consumption or the displacement of electricity generation, transmission, and distribution capacity (IDB, 2013).

Chile, Colombia, El Salvador, Panama, and Mexico have set targets for the year 2030 that focus on annual reductions in energy intensity. However, they are not aligned with the IEA report, which proposes making the greatest efforts during the 2020-2030 period.

Argentina has been establishing related targets over a prolonged period, with the main goal of building an energy system with the highest possible levels of efficiency in the generation, transportation, distribution, and consumption of energy. It has also defined targets related to the residential sector, and the basic needs for energy services of every household are covered efficiently and reliably (Government of Argentina, 2019).

Table 2. ***Total energy supply: Annual improvement in energy intensity (MJ per GDP unit in USD)***

Country	Baseline[3]	Year 2030	Year 2050
IEA Report	2020 - 2030: -4.2%	2030- 2050 -2.7%	
Argentina[4]	2014-2019: -1.80%	-	Between -1.3% and -1.67%
Chile[5]	-	-0.9%	-1.3%
Colombia[6]	2013-2018: -11.2%	-2.6%	-
Mexico[7]	2014-2019: -15.33%	-1.9%	-3.7%
El Salvador[8]		-2.18%	-1.09%
Panama[9]	2014-2019: -5.33%	-1.2%	-1.16%

Practically all the countries in the region have National Energy Efficiency Plans, which have been collected by OLADE (2021). These plans define timeframes, targets, and the institutions responsible for implementation, which are underpinned by the legislation of each country. Some countries have also conducted a series of complementary programs for the implementation of the plans.

Nevertheless, not all the countries have set targets associated with this issue; at this point, it is vital to understand that national energy efficiency targets in each country must be defined by whichever state entity has access to a comprehensive overview of both the country's energy sector and social and economic sector. This is because having an overview of the inter-sectoral relationships will make it possible to ensure that all the national policies contribute towards energy efficiency programs (IDB; OLADE, ECLAC, 2017).

The different advances have primarily cantered on the development of energy efficiency policies, in addition to progress made in strengthening the legal framework, the creation of specific units for the subject, and the integration of energy efficiency plans into the sector's general planning process. However, as regards energy statistics and the use of performance indicators, apart from the steps forward taken by some countries the progress made is still insufficient from a regional perspective (IDB; OLADE; ECLAC, 2017).

Therefore, the collection of data during the design, implementation, and evaluation phases must be recognized as an essential part of any energy efficiency program, given that said data will enable the creation of baselines and indicators that are needed to track progress, carry out monitoring, and evaluate the energy efficiency initiatives (IEA, 2015).

4.1.3. Gaps and barriers

The last 40 years have witnessed rapid growth in energy demands, and the electricity needs of Latin America and the Caribbean have increased steadily above the global average, according to statistics from the International Energy Agency.[10] Energy demands are also expected to continue to rise similarly over the next few decades, and as such energy efficiency will be particularly relevant to the region (IDB et al., 2019).

Between 2010 and 2017, energy intensity decreased at an average annual rate of 2.1% across the world. Even so, Latin America and the Caribbean was the region that recorded the lowest reduction of 0.9%, below the figure of 1.7% seen in the Sub-Saharan Africa region (IDB, 2021).

The above makes it possible to identify the potential that exists in Latin America and the Caribbean to improve energy efficiency. Economic growth has also been linked to energy consumption, and enhanced access to it has helped to improve the quality of life of many people in the region (IEA, 2015).

It is important to mention that the region has shown energy consumption levels below global averages, at least when looking at per capita electricity consumption. In fact, according to the IEA (2022), per capita electricity consumption in Central and South America in 2019 stood at 2.1 MWh/capi-

3 The baseline was obtained from the reports for each country by the Climate Transparency organization - https://www.climate-transparency.org/

4 Towards a shared vision of Argentinian Energy Transition by 2050 (Government of Argentina, 2019).

5 Chile Climate Strategy on Climate Change: Path to carbon neutrality and resilience by 2050 (Government of Chile, 2021).

6 Program for Rational and Efficient Energy Use (PROURE) (UPME, 2021).

7 Energy Efficiency Roadmap (Government of Mexico, 2017).

8 El Salvador Energy Policy 2020-2050 (National Energy Council, 2019).

9 Panama National Energy Plan 2015-2050 (National Secretariat of Energy, 2014).

10 International Energy Agency (IEA) energy statistics, 1971-2017.

ta, which is markedly less than North America (10.3 MWh/capita), Europe (5.5 MWh/capita), and even the global average (3.3 MWh/capita).

It is important to consider that low electricity consumption levels mean there is even less scope for reducing them further. It is possible that climate change will lead to temperature increases, and as an adaptive measure this could result in increased energy requirements for cooling using different technologies (Arias-Gaviria et al., 2021).

Energy efficiency is related to actions to mitigate climate change, due to its ability to generate savings in energy consumption. Furthermore, both for developed economies and—albeit with reduced importance—for emerging economies, energy efficiency has other additional motivating factors: it reduces dependency on fossil fuels and imports, enables scarce resources to be conserved, enhances the competitiveness of productive sectors, provides better allocation of resources for infrastructure, improves energy security and access, contributes to reducing greenhouse gas emissions, and makes it possible to access international financing and the need to respond to non-tariff barriers.

Due to its potential benefits, there is a clear justification for promoting the development of a country's energy efficiency. However, tapping into the existing potential in terms of energy efficiency requires the breaking down of various barriers—economic, regulatory, political, institutional, cultural, technological, financial, and data-based—which hinder the development of a market for energy efficiency goods and services. For Latin America and the Caribbean, there are some barriers that are common to all sectors, and which are impeding improvements in energy efficiency. Table 3 describes some of the barriers that have been identified.

It is important to consider the vital role performed by governments in overcoming these barriers and ensuring that a solid institutional framework exists for successfully accelerating the implementation of energy efficiency measures. The need to boost investment in energy efficiency must also be considered, ensuring that support mechanisms are available to facilitate investment in energy efficiency by the public and private sector (IEA, 2015).

The processes related to energy efficiency require regulatory and legislative changes aimed at lifting the barriers present in each market. Taking action to develop energy efficiency legislation that incorporates policy instruments intended to break down these barriers is an important step in turning energy efficiency into government policy,—without being subject to the vision or ideology of whichever government happens to be in power—that has the potential to create direct benefits for consumers, protect and allocate the resources available, and protect the environment.

The Latin America and the Caribbean region is highly unequal with regards to the progress made with a regulatory framework that is applicable to the promotion of energy efficiency. However, as shown in Figure 1, twelve countries in the region already have existing laws in place regarding energy efficiency or rational and efficient use of energy is noteworthy, and there are five other countries that have an energy efficiency bill under consideration.

Table 3. ***Regional and sectoral barriers to energy efficiency in Latin America and the Caribbean***

Regional and sectoral barriers
Costs associated with recent technologies and processes
Inefficient energy price subsidies
Limited local experience and capacity to identify and explore energy efficiency opportunities
A lack of permanent institutional capacity for decision-making
Limited planning and coordination between ministries
Differences in the quality and availability of data and information on the energy sector and energy efficiency
Insufficient incentives for energy companies to promote energy efficiency
Inadequate financing mechanisms or lack of access for energy efficiency

Source: (IEA, 2015)

Figure 1. ***Status of Energy Efficiency Laws in Latin America and the Caribbean***

Source: Energy Efficiency Laws in Latin America and the Caribbean. OLADE 2021

4.1.4. Opportunities and recommendations

Currently, there is a wide variety of public policy instruments whose adoption could improve energy efficiency in the residential and transport sectors. These instruments can be arranged into three main categories: informative (energy efficiency labels), economic (taxes and incentives), and regulatory (vehicle efficiency standards and import controls) (IDB et al., 2019).

Informative and regulatory instruments have high potential for implementation, as their adoption faces fewer political barriers. In Latin America, successful related examples can be found, such as the use of energy efficiency labelling in Chile, the energy efficiency and CO2 emissions legislation passed in Mexico, and the Inovar-Auto program in Brazil (IDB et al., 2019).

Vehicle energy efficiency labelling, for example, enables consumers to make more conscious and informed decisions regarding fuel use and CO2 emissions, driving changes in their consumption patterns. The aim of vehicle energy efficiency standards is for vehicles to consume less fuel for every mile travelled and, in turn, reduce greenhouse gas emissions (IDB et al., 2019).

Table 4 shows some regional programs related to energy efficiency, with specific examples adopted in the countries and a range of recommendations for each program type, which should be considered during the creation and/or updating stages.

Table 4. ***Regional programs for energy efficiency in Latin America and the Caribbean***

Program type	Examples in the region	Recommendations for the region
Labelling codes, standards, and programs [11]	• Procel program in Brazil • MIEM program in Uruguay • CONUEE (National Commission for the Efficient Use of Energy) in Mexico • Peru's Energy Efficiency Plan • Use of energy efficiency labelling in Chile	• It is necessary to consider the diverse range of climatic areas that require different standards for the development of appropriate energy efficiency codes in buildings. • Government support is key to the creation, adoption, and implementation of energy standards in construction and MEPS that will ensure that the country's buildings have a basic quality standard. • In the case of existing buildings, the recommendation is for a combination of policies that improve minimum standards and building efficiency through better renovation, operation, and maintenance practices. • A mix of policies that raise minimum standards and building efficiency during the design, construction, and operation phases is suggested for new buildings.
Education, training, and awareness-raising programs[12]	• National Energy Efficiency Award in Uruguay • "Siga la corriente" program in Chile • PNESER (National Program for Sustainable Electrification and Renewable Energy) in Nicaragua	• Consumers need to be helped through education and awareness-raising, to make informed decisions based on energy savings and quality of life instead of only considering the initial cost when buying or renting houses or offices. • Awareness-raising and education among various interested parties in the energy sector, as well as among end consumers, is considered the first step in rolling out improved practices across all the sectors.
Incentive/subsidy programs[13]	• Industrial motors and industrial/commercial/ residential lighting from FIDE/CFE/NAFIN in Mexico (IDB loan) • Inovar-Auto program in Brazil • Program for Rational and Efficient Energy Use (PROURE) in Colombia	• The implementation of efficiency standards or labelling must be accompanied by a financial instrument since these combinations allow the countries to obtain greater benefits.

Sources : (IDB et al., 2019); (IEA, 2015); (UPME, 2021)

As outlined in Table 4, there is a wide variety of programs associated with energy efficiency in the sectors, with a series of challenges, obstacles, and opportunities for improvement. Here, it will be important to consider the fact that institutional capacity and continuity and sectoral political decisions must become key elements for providing expectations of success in creating, developing, and implementing the energy efficiency programs (IDB; OLADE; ECLAC, 2017).

Furthermore, most of the countries in the region assign responsibility for energy efficiency to the ministry of the sector. In some countries, however, this responsibility is divided between several agencies, or the designated agency may even be independent from the relevant ministry. This can have an impact on the capabilities and reach of those agencies are able to attain, which in turn translate into the adoption and implementation level of the measures required for the development of energy efficiency in a country.

Nevertheless, something that bears mentioning is that several countries have an advisory committee, council, or commission with the duty of providing guidance about energy efficiency. This represents a huge opportunity to encourage the participation of the different sectors of society (industry, trade, academia, civil society) in such a way that they could analyse, give their opinion, and work on key aspects of the development of energy efficiency.

For the above reasons, the definition of roles and responsibilities for the design and implementation of energy efficiency actions is a core aspect that must be addressed within the framework of an energy efficiency law. Without institutions that take responsibility for executing and implementing what is laid down in the law, for responding to nationally set goals and targets, and for fostering and ensuring compliance with energy efficiency measures, efforts and actions on the subject are reduced to individual and reactive initiatives by certain actors and are not consolidated as part of public policy with a genuine chance of bringing about meaningful change.

11The main objective is to define and enforce mandatory efficiency levels in buildings and products, and/or provide consumers with information on products' energy footprint.

12 The main objective is to inform consumers and suppliers about energy efficiency and take measures based on said information.

13Provide end users with incentives for them to choose efficient technologies over other alternatives. Operates through donations instead of loans.

It is clearly essential to have a regulatory instrument that is specific to energy efficiency and facilitates the sustainability of the actions implemented, as it is to allow for the establishment of mechanisms to overcome the barriers that have hindered the development of energy efficiency in several of the countries that make up the Latin America and Caribbean region. In this way, it becomes vital to have instruments that consider at least the following:

Table 5. ***Recommended elements for regulatory energy efficiency instruments***

Recommended elements for regulatory energy efficiency instruments
Institutional governance arrangements
Medium- and long-term plans
Mechanisms for monitoring and evaluating the energy efficiency policy and/or plan
Mechanisms to promote technological and process transition
Sectoral policies
Certification and control mechanisms
Sanctions
Tax and/or tariff incentives
Implementation mechanisms and their operation
Encouraging cultural change

Finally, a highly significant opportunity for energy efficiency is to consider the fact that some actions result in co-benefits that facilitate implementation, thus enabling the processes of energy transition to be leveraged and accelerated. For example, when energy efficiency is achieved and energy costs are reduced at the same time; or, also, the many electrification activities in the transport sector, which lead to a reduction in not only greenhouse gas emissions but also in particulate matter.

4.2. Behavioural change

4.2.1. Context

The large-scale transformation of the energy sector requires voluntary participation from citizens as well as using nudges to encourage better use of resources.[14] People drives the demand for energy-related goods and services, and social norms and personal choices will play a critical role in steering the energy system onto a sustainable path (International Energy Agency, 2021). The end consumers of energy must have all the necessary tools to make decisions regarding opting for and demanding increasingly efficient technology and processes for energy consumption.

Behavioural changes refer to changes in ongoing or repeated behavior by consumers which impact energy service demand or the energy intensity of an energy-related activity (International Energy Agency, 2021). The IEA shows three main types of behavioural change, which, through a wide range of governmental interventions could trigger the following changes:

- Reduce excessive or wasteful use of energy. This includes reducing energy use in buildings and motorways, for example, adjustments to internal temperature, adopting energy-saving practices in homes, and limiting driving on motorways to 100 kilometres per hour.
- Change in mode of transport. his includes changing to cycling, walking, sharing rides, or taking buses for trips within cities, which would otherwise be made by car, as well as replacing regional air travel with high-speed trains in regions where this is possible.
- Gains in material efficiency. This includes a reduced demand for materials, higher recycling rates, and improved design and construction of buildings and vehicles.

4.2.2. Regional assessment and targets

The IEA report does not include a global objective associated with behavioural changes, mainly because it is open to many initiatives that countries can adopt. However, it does include milestones related to transport and residential industries. Similarly, targets associated with behavioural changes are not region-specific; however, each country makes progress in different areas to incentivize behavioural changes associated with energy. Some clear targets for the year 2050 which include citizen participation are shown in table 6.

Table 6. ***Targets associated with behavioural change in Latin America***

Country	Year 2050
Chile[15]	• 10% of bicycle participation in small and medium cities. • 100% of new residential projects incorporate the estimated distance of displacement to places of work as a relevant variable in their evaluation.
Colombia[16]	• Between 70% and 90% of homes report carrying out activities to achieve a more sustainable home. • Between 40% and 50% of the population in capital cities travel by inclusive and alternative modes of transport to get to their places of work or study.

14 Some examples of these nudges are Brandon et al., 2019; Ruokamo et al., 2022.

15 Roadmap 2050: Towards a sustainable and inclusive energy for Chile (Comité Consultivo de Energía 2050, 2015).

16 Colombia's long term climate strategy E2050 to comply with the Paris

Chile is one of the countries which actively seeks to establish an energy culture at all levels of society as part of their energy transition plans, with an active role in optimizing domestic consumption, establishing quantitative targets associated with changes in transport (Energy Advisory Committee, Chile 2050, 2015).

Colombia, on the other hand, seeks to inform and raise awareness regarding better practices in urban and rural households through education strategies to meet targets associated with more sustainable homes. Colombia also seeks to incentivize changes in transportation through promoting alternative sustainable mobility (public transport, bicycle, electric vehicles), ensuring the necessary infrastructure for citizens to adopt sustainable mobility (Government of Colombia, 2021).

Within the context of behavioural changes, it is important to recognize the Measures for the Promotion of Cultural Change (MPCC) promoted by the Latin American Energy Organization (OLADE), which focus on several components grouped into six mechanisms. These mechanisms are presented in Table 7.

Table 7. ***Measures for the Promotion of Cultural Change (MPCC)***

Acronym	Type of measure
MPCC1	Labelling
MPCC2	Training programs and workshops for public and private sectors
MPCC3	Promote dissemination and demonstration programs and campaigns
MPCC4	Social participation, consultations, and access to public information
MPCC5	Inclusion of energy efficiency in study programs
MPCC6	Prizes, distinctions, and/or recognitions regarding energy efficiency

Source: Energy Efficiency Laws in Latin America and the Caribbean. OLADE 2021

Some countries in Latin America and the Caribbean are already implementing these mechanisms. The following is a list of countries in the region that have made some type of progress or effort related to these mechanisms:

Table 8. ***Summary of measures used in the promotion of behavioural change in the region's countries***

Country	Measures for the Promotion of Cultural Change (MPCC)					
	MPCC1	MPCC2	MPCC3	MPCC4	MPCC5	MPCC6
Argentina	☑	☑	☑		☑	
Brazil	☑			☑		
Chile	☑	☑		☑		
Colombia	☑	☑	☑	☑		☑
Costa Rica	☑		☑	☑	☑	
Cuba					☑	
Ecuador	☑	☑			☑	
Guatemala	☑		☑	☑		☑
Mexico	☑	☑		☑	☑	☑
Nicaragua	☑		☑	☑	☑	☑
Panama	☑		☑	☑		☑
Peru	☑		☑		☑	☑
Dominican Republic	☑		☑	☑	☑	☑
Uruguay	☑	☑	☑		☑	☑
Venezuela			☑		☑	☑

Source: Energy Efficiency Laws in Latin America and the Caribbean. OLADE 2021

As previously mentioned, not all countries have targets associated with behavioural change. However, there are additional initiatives not shown above, such as in the case of Ecuador, which developed a white book on circular economy,[17] which includes topics related to responsible consumption of resources, including renewable energy, thus seeking to influence people's behaviour through regulation.

Within the framework of behavioural change initiatives, it is key to identify those initiatives implemented by non-governmental or private organizations, such as in the case of Colombia, where there are strategies such as the "Decarbonization Actions Catalogue,"[18] led by The Climate Group, which seeks to provide regions with an educational tool on actions that can be taken in order to reduce emissions in the energy and transport sectors so that the local governments adapt them to their own contexts (The Climate Group, 2021).

Agreement (Government of Colombia, 2021).

17 https://www.produccion.gob.ec/wp-content/uploads/2021/05/Libro-Blanco-final-web_mayo102021.pdf

18https://www.theclimategroup.org/sites/default/files/2021-12/CATA%CC%81LOGO_ACCIONES_GENERAL_1_DIGITAL.pdf

4.2.3. Challenges, opportunities, and recommendations

Regarding behavioural changes, many countries have established different incentives within the transport sector which contribute to changes in modes of transport, for example, incentives for carpooling, commercial discounts on technical-mechanical revision and on obligatory insurance, as well as the extension of measures that restrict mobility such as the "*pico y placa"* number plate restrictions and no car days (Colombian Ministry of Mines and Energy, 2021).

On the other hand, within the residential sector, many of the measures implemented are associated with improving energy efficiency as they have the potential to reduce emissions without incurring significant additional costs. In several of the region's countries, it has been observed that when there are variations in the price of electric energy, the residential sector shows less awareness in modifying their electric consumption than the industrial and commercial sector due to consumption subsidies. This situation could limit the effectiveness of price policies to reduce the energy demand in homes (EUROCLIMA, 2017).

For this reason, it is necessary to improve subsidy schemes, since there is room for significant improvements in most of the countries of the region, where it will be necessary for countries to disassociate themselves from merely political objectives and allow subsidy programs to be designed and administered based on technical grounds for such energy subsidies to work (IDB, 2020).

With regards to successful cases related to energy price policies, in 2001, when experiencing a drought, Brazil had a reduction in hydroelectric energy production and generated a price scheme to satisfy the electricity demand, where households that had exceeded a consumption target would pay an additional charge, while those households that had consumed below the allowed limit received a discount (EUROCLIMA, 2017).

The strategy resulted in the successful reduction of electricity demand despite being an emergency measure. The success of the measure was strongly linked to the educational and informative campaigns regarding the benefits of said reduction, thus achieving comprehensive understanding of average energy consumption and a clear system of economic incentives for citizens.

Similarly, in Colombia, emergency measures related to energy use have also been applied. A strategy called *"Apagar Paga"* ("Switching Off Pays") was developed where users received financial compensation for the electricity they did not use within the residential and industrial sector during an energy crisis in 2016, which managed to avoid rationing. These strategies are understood as "emergency measures," which very quick and effective results are shown. However, once the reduction of the energy supply is achieved, the restrictive measures are removed, returning to previous behaviour. In this regard, the educational component plays a key role in generating synergy with regulations and trying to sustain said policies over time to ensure the measures are maintained.

It is necessary that citizens have a comprehensive vision of the impact behavioural changes can have, thus educational and informative campaigns will result in a positive, fast, and sustained impact regarding actions taken by countries and their citizens within their political, legal, and economic context. Additionally, it has become evident that small "nudges" have helped to improve consumer behaviour in several ways.[19]

The combination of actions mentioned are crucial for informing, educating, and incentivizing consumers to adopt consumption patterns which favour energy efficiency, both during the acquisition of technologies and in the direct consumption of electricity or other energy in their daily lives.

Cultural changes in consumers can only be stimulated if there are conditions which enable them to understand the importance of energy efficiency, establish differences between technology options available on the market, adopt and correct consumption patterns, and discover the potential benefits of adopting this change.

Each country makes progress and implements different strategies. It is important to consider that the scope, scale, and speed of behavioural changes varies widely between countries, depending on several factors, including the ability of existing infrastructure to support such changes as well as differences in geography, climate, urbanization, social norms, and cultural values (International Energy Agency, 2021).

4.3. Electrification

4.3.1. Context

Electrification refers to the process of substituting technologies which use fossil fuels (coal, oil, and natural gas) with technologies which use electricity as its source of energy. Depending on the resources used to generate it, this process can potentially reduce CO_2 emissions in transport, residential, and industry sectors (RFF, 2021).

There is immense potential associated with electrification in transforming and contributing solutions for the energy

19 https://www.behavioraleconomics.com/using-multiple-social-nudges-to-reduce-peak-energy-demand/

transition to climate neutrality. It is important to consider that, although electrification simultaneously creates its own challenges, a high degree of electrification is technically possible, increasingly politically backed, and can be driven further by emerging innovations (Alto et al.,2021).

However, it is also important to consider that there are elements that are not possible to electrify based on the current technology, for example, certain industrial processes (Bellona, 2018). The transportation sector is perhaps the most difficult to electrify, where there are limits to its decarbonization under the current growth paradigm (de Blas et al., 2020). Despite these issues, the aim is for a total reduction of emissions through partial electrification (Bellona, 2018).

4.3.2. Regional assessment and targets

According to the IEA Net Zero by 2050 report, direct use of low-emission electricity instead of fossil fuels is one of the most significant driving forces of emissions reduction and represents about 20% of the total reduction aimed for by 2050. The target put forward in this report is of 49% of the end energy consumption.

In Latin America and the Caribbean, the final energy consumption is dominated by oil and derivatives, with a share of more than 50% in 2019 and a trend of increasing use of electricity, natural gas, and renewable sources, where electricity accounted for 18% (OLADE, 2020). Therefore, it is evident that a set of strategies will be necessary to increase this participation in the end energy consumption to reach the target set by the IEA.

Table 9. ***Targets associated with the inclusion of electricity in the total end consumption (%)***

Country	Year 2050
IEA Report	49%
Argentina[20]	Highest possible levels of electrification of consumption.
Chile[21]	• 60% of the private electric vehicle fleet by 2050. • 100% electric public transport by 2040. • 39% of residential heating is by electricity.
Colombia[22]	26%
Costa Rica[23]	50% of commercial, residential, and institutional buildings

In accordance with table 9, it is evidenced that the countries that have established targets associated with the electrification are focusing their efforts on the residential and transport sectors, such as the case of Costa Rica, which seeks to implement electrification and digitalization strategies across different sectors of the economy including scenarios and routes for flexible investment (Costa Rica Ministry of Environment and Energy, 2018). Colombia foresees that, under effective cost conditions, by the year 2050, electrification will rise from 18% to 26%, although the carbon neutrality trajectory shows that the participation of electric energy should be between 40% and 70% of the end uses (Government of Colombia, 2021).

In Latin America and the Caribbean, the demand in households has a key role in the configuration of added energy consumption, since the consumption of electricity and gas in homes has more than tripled since 1971 and has overtaken high energy consumption sectors such as transportation and industry (IDB, 2020).

Access to electricity satisfies various fundamental and basic needs through modern technologies and low emissions of contaminants inside the home. Among these are lighting, food preservation (such as the modern fridge), cooking food using electric heat production methods, air conditioning, connection of health equipment for electro-dependent individuals, among others.

The recent population censuses in the region's countries show an average service coverage higher than 90% of homes, according to the Economic Commission for Latin America and the Caribbean (ECLAC) database. Despite this, in certain countries—especially in rural settlements—this coverage declines to levels that justify the need to develop a public policy focused on reaching universal coverage. In figure 2, the proportion of homes without access to electricity in different countries of the region can be observed.

According to this data, there are challenges to be addressed, especially in countries such as Guatemala, El Salvador, Honduras, and Nicaragua, since ensuring access to electricity is still an urgent task that has yet to be achieved in the region, particularly in informal urban settlements and rural areas where the geographic conditions seem inaccessible. However, the possibilities of implementing a decentralized model based on renewable energy, according to the territorial conditions, is a favourable alternative for less populated areas that are difficult to access.

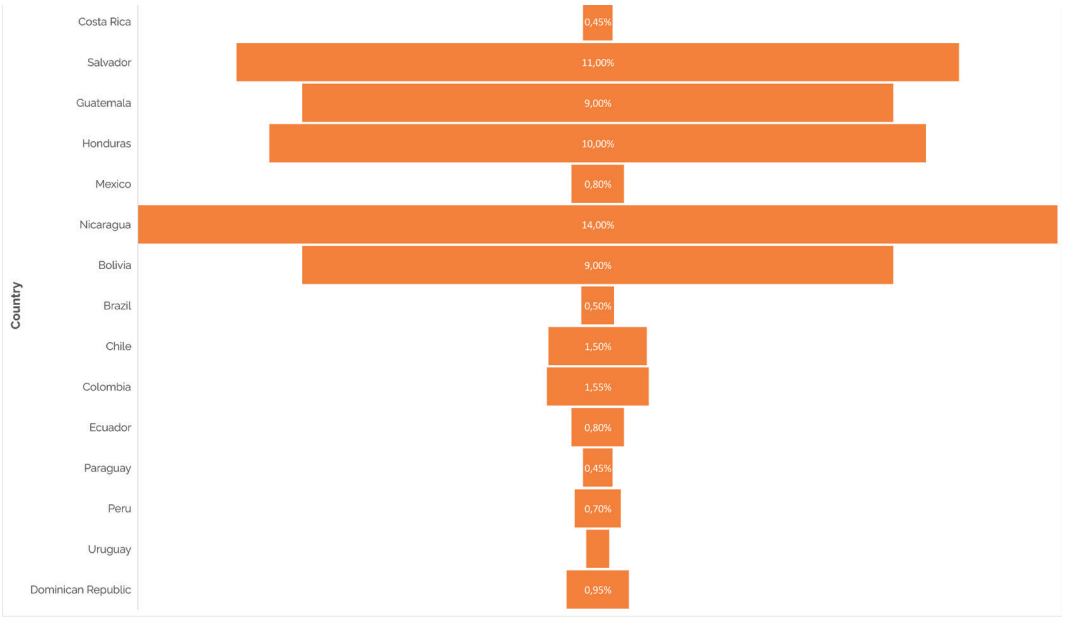
20 Towards a shared vision of Argentinian Energy Transition by 2050 (Government of Argentina, 2019).

21Chile Climate Strategy on Climate Change: Path to carbon neutrality and resilience by 2050 (Government of Chile, 2021).

22 Colombia's long term climate strategy E2050 to comply with the Paris Agreement (Government of Colombia, 2021)

23 National Decarbonization Plan (Government of Costa Rica, 2019)

Figure 2. ***Proportion and quantity of the population without access to electricity in their homes (%)***



Source: Development of energy poverty indicators in Latin America and the Caribbean. ECLAC (2021)

The lack of empirical measurements regarding access to electricity in the region was complemented with information provided by the World Bank to have an estimated and preliminary vision of concerning cases in the region. In the Caribbean, Haiti stands out from the general average, with lack of access to electricity reaching 55%, of which 97% live in rural settlements. To a lesser degree are Grenada and Guadalupe as the next countries with the least service coverage in homes, at 4.7% and 1.5% respectively.

4.3.3. Gaps and barriers

Latin America and the Caribbean have presented considerable progress in the struggle against poverty and the universalization of access to energy. However, it is estimated that at least a third of the region's rural population still lack access to electricity services. Consequently, increasing their access is, essentially, a rural issue (CAF, 2013).

In terms of equality in access to energy, significant barriers in energy prices as well as high efficiency technologies can be identified, also inequality in terms of energy consumption in homes. In a region that is distinguished by inequality, access to energy reflects the socio-economic conditions of the region's countries, which creates a worrying outlook for the prospects of a just energy transition.

In contrast, the complementarity of energy efficiency measures could be presented as a solution both to lessen the economic pressure on households and to reduce their consumption of fossil fuel-based energy. Although this objective is highly desirable, the high price of the most efficient appliances hinders autonomous technological change in households.

It is important to consider three economic factors which affect the satisfaction of household energy needs. Firstly, the excessive expenditure of energy services in relation to household income, mainly in low-income households, is likely to result in other relevant needs not being met, as well as excessive economic pressure. Secondly, considering the opposite scenario, energy underspending in low-income households probably reflects budgetary constraints and the need to satisfy other more urgent needs, leading to a lack of energy comfort. Finally, the excessive cost of efficient and safe technologies implies less capacity of low-income households to move towards high quality energy and technologies. Therefore, structuring clearly defined universal coverage support programs is part of this challenge.

Nevertheless, the above does not mean that problems do not also exist in urban areas. Many factors contribute to the generation of a gap in access to modern energy sources in equitable conditions, such as low income, lack of resources for building infrastructure, unavailability of appropriate technologies, weak legal and institutional frameworks, and even the absence of political will and commitment (CAF, 2013).

As a result of this, currently, the creation of energy policies by governments has prioritized the residential sector, mainly due to the issue of affordability (IDB, 2020). However, it is necessary to place greater relevance on issues associated

with access to quality energy services as a key element in the process of poverty reduction and improvement of environmental conditions for the most socially vulnerable groups (CAF, 2013).

In terms of energy quality, the results imply that the stability of electric supply in the region's countries is far from uniformly complying with international quality standards. In certain countries, this gap is related to the number of interruptions, while in others with fewer interruptions, the delay in restoring service is a concern.

Although the coverage of access to electricity in the region has reached positive figures, the quality of electric supply is concerting in certain countries due to their important level of interruptions as well as the average duration of each supply suspension. To improve the quality of this service, greater capacity in terms of response and adaptation of energy systems to surrounding threats is needed. A resilient and sustainable electricity supply is key for the region's human and economic development. The stability of this, commonly measured by the frequency and duration of interruptions, is a basic indicator to give an overall view of the quality of the electric system.

The SAIDI indicator (System Average Interruption Duration Index) takes account of the duration of electric interruptions experienced by clients, while the SAIFI indicator (System Average Interruption Frequency Index) indicates the average amount of electric interruptions per client. When both indicators are available, it is possible to calculate the CAIDI indicator (Customer Average Interruption Duration Index) which shows the average time taken in reinstating the electric service.

Using data from the World Bank's Doing Business Index for the main urban centres of the region, in the cases of Costa Rica, the Dominican Republic, Mexico, and St. Lucía, there is less than one interruption on average per year, which does not exceed 36 minutes in any of these countries. Chile and Peru are the fifth and sixth countries with the least power cuts, but the duration is higher than in the previously mentioned countries, varying between three and six and a half hours. In these two countries, although the interruptions are low compared to other countries in the region, the electricity system has not been able to resolve them quickly.

This situation is more extreme in Brazilian cities such as Rio de Janeiro and Sao Paulo, and countries such as Puerto Rico and Uruguay, where the average power cuts vary between 3.5 and 4.8 times a year and the duration is between 6.3 (Rio de Janeiro) and 14.4 hours (Puerto Rico), signifying a low response capacity regarding power supply incidences.

Table 10. ***SAIDI (hours of interruption), SAIFI (number of interruptions) and CAIDI (ratio between SAIDI and SAIFI) indicators for countries with the least power supply interruptions***

Country	SAIDI	SAIFI	CAIDI
Costa Rica	0.5	0.2	2.50
St. Lucía	0.2	0.3	0.67
Dominican Republic	0.6	0.3	2.00
Mexico	0.6	0.9	0.67
Chile	2.9	1.5	1.93
Peru	6.4	1.7	3.76

Source: Development of energy poverty indicators in Latin America and the Caribbean. ECLAC 2021

Seven of the region's countries exhibit an average higher than 10 power cuts per year. Among these countries, Guyana presents the most critical situation, with 106 cuts and a total of 113 hours on average in which its citizens cannot access electricity services. In the case of Nicaragua, there is also a high number of interruptions (45.7), as well as an average of 93.6 hours during which people are without electricity.

In the case of Jamaica, although the average is 10.7 power cuts per year, the system takes almost 2.5 hours to resolve them. The diversity of challenges for the quality of electric power is evident when comparing these three countries, given that, although Jamaica experiences a quarter of the interruptions experienced in Nicaragua and a tenth compared to Guyana, the average duration is 2.5 hours, while it is only two hours in the case of Nicaragua and one hour in Guyana.

Table 11. ***SAIDI (hours of interruption), SAIFI (number of interruptions), and CAIDI (ratio between SAIDI and SAIFI) indicators for countries with most power supply interruptions***

Country	SAIDI	SAIFI	CAIDI
Jamaica	27.1	10.7	2.53
Belize	14.2	13.8	1.03
Argentina	4.5	14.4	0.31
Paraguay	21.9	22.8	0.96
Honduras	32.5	23.4	1.39
Nicaragua	93.6	45.7	2.05
Guyana	113	106	1.07

Source: Development of energy poverty indicators in Latin America and the Caribbean. ECLAC 2021

Access to modern energy sources in the region has been dominated by different electricity and fuel subsidies. However, one of the main barriers has been the application of generic subsidies that do not have a specific orientation for the population, which has led to these subsidies also reaching consumers who should be excluded from the benefit, generating a decrease in the increase in coverage (CAF, 2013).

It is important to consider that subsidies are a necessary, viable, and convenient policy instrument to alleviate energy poverty. However, there is enormous potential for reorientation in the region which enables schemes with appropriate funding and transparent criteria which could be focused on target beneficiaries who should receive them (CAF, 2013).

As previously shown, almost 30% of rural areas in the region generally do not have electricity service and will not be benefited by the State subsidies. This generates an inequality gap which triggers environmental problems since, due to not having electricity, energy such as firewood is used for cooking and heating, which used inefficiently can result in health issues (CAF, 2013).

However, the region has experienced substantial growth in the use of natural gas as a fuel, mostly in the residential sector. But few countries in the region have analysed their reserves and future needs, as part of their compliance with climate and environmental agreements. For this reason, the region needs to limit its dependence on gas and restrict its use to those sectors that could go through a longer and more expensive transition, such as industry.

On this path to carbon neutrality, gas must play a part in a smooth transition from the current economic system to a low-emission model. However, investment in exploration, exploitation, infrastructure, and other areas of the gas sector, both regionally and worldwide, must not compromise the deployment of renewable energy and electrification strategies (UN, 2018).

Finally, in the electrification process, some barriers in the transport sector have become apparent. Despite the region showing considerable progress in private and public electric mobility, it should be noted that charging infrastructure remains one of the main obstacles to the rollout of electric transportation (MOVE, 2019).

4.3.4. Challenges, opportunities, and recommendations

In Latin America and the Caribbean, important steps forward have been taken regarding access to energy and electrification. However, in some cases the subsidy systems need to be reformed to specifically consider coverage, target populations, cost, equality, and efficiency. For this reform, access strategies and energy efficiency programs should be included and considered (CAF, 2013).

Additionally, urbanization trends in the region are expected to increase the demand for electricity, domestic gas (i.e., natural gas and LPG), and transport fuels. As such, it is necessary for the region to start thinking about integrated and long-term energy planning that includes all energy sub-sectors and prioritizes demand from all economic sectors (IDB, 2020).

Analysis of the SAIDI, SAIFI, and CAIDI indicators reveals two conclusions for the region. Firstly, the quality of the electricity supply and household access to high-quality energy services are negatively affected by the documented interruptions. In this respect, actions are needed to improve the resilience of the region's energy systems to overcome energy poverty conditions.

Secondly, the design of these improvement actions must be tailored geographically, as while the challenge for some countries lies more in the system's response capacity to resolve the interruption, for others it relates more to better adapting the energy system to an environment that is a constant threat to its infrastructure.

As part of the above, electrification in non-interconnected and remote areas must be considered, as these areas normally have important levels of poverty and government plans require private-sector involvement to achieve greater coverage. Given its status as one of the Sustainable Development Goals (SDG7), the target is to reach 100% of the population. Achieving this requires complementary business models that have been tested in other countries, such as the pay-as-you-go model, which allows a larger population to be covered with the participation of private capital (Montoya-Duque et al., 2022).

Finally, there is enormous potential for the development of renewable energy in the generation of electricity, with some countries managing to produce almost all their power using renewable sources. Nevertheless, one of the biggest consumers of energy across the region is the transport sector. Through the integration of renewable sources for electricity generation and the electrification of the transport sector, reliance on the importation of hydrocarbons would end, improving the countries' energy independence (MOVE, 2019).

4.4. Renewable Energy

4.4.1. Context

Renewable energy is a key part of reducing carbon emissions from electricity generation. In Latin America, hy-

droelectric energy occupies a significant proportion of the energy mix. The expectation is that the installation of wind and solar energy will help renewable energy gain a high share and take the place of thermal power stations around 2030, paving the way for low-carbon goals in the generation sector to be met by 2050.

Renewable energy also plays a key role in reducing the emissions of the transport, residential, and industrial sectors. For instance, renewable energy can produce electricity to charge electric vehicles in the transport sector, to heat water or residential spaces, or to generate thermal energy in industry (International Energy Agency, 2021).

Considering the above, the renewable energy pillar has two main targets to achieve carbon neutrality by 2050:

- Increasing the share of renewable energy in electricity generation.
- Increasing the share of renewable energy in final energy consumption.

4.4.2. Assessment and regional targets

The target in the IEA's report states that the share of renewable energy in electricity generation must stand at 61% by 2030 and 88% by 2050 (International Energy Agency, 2021). Renewable energy currently represents nearly 60% of the electricity generated in Latin America and the Caribbean, and the region has been working to increase this share, marked strongly by an energy system with historically low emissions from hydroelectricity.

The RELAC (Renewable Energy Latin America and Caribbean) initiative, made up of 13 countries—Colombia, Chile, Costa Rica, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, Paraguay, Peru, and the Dominican Republic—have the objective of promoting cooperation between the region's countries and managing to generate 70% of their electricity from renewable sources by 2030 (OLADE, 2021).

Latin American countries also have different targets in terms of the production of electricity based on renewable energy and, in turn, it is important to bear in mind that each country is starting out from a different renewable share of electricity generation. There must therefore be recognition of the efforts the countries have to make to reach to proposed targets. The share of renewable energy in the generation of electricity in 2020 can be found in Table 12, along with the targets found for 2030 and 2050 for some countries in the region.

Table 12. ***The share of renewable energy in electricity generation in 2020 and targets for 2030 and 2050***

Country	Year 2020[24]	Year 2030	Year 2050
IEA Report	29%	61%	88%
Argentina	26%		
Brazil	85%		
Chile[25]	47%	80%	100%
Colombia[26]	71%	~69% hydro + 8.6% NCRE 78%	
Costa Rica[27]	98%	100%	
Mexico[28]	20%	40% by 2033	50%
Peru	64%		

When the targets are reviewed in detail, several relevant conclusions can be made for each country. Brazil's aim is to increase installed wind capacity to 11.84% and reach a total share of 25% for wind and solar combined by 2024 (ONS, 2021), while Colombia hopes to produce 15% of its energy from non-conventional sources by 2029 (IRENA, 2019). The Dominican Republic has set a target of achieving a 15% renewable energy share by 2024 (OC, 2021), and El Salvador is aiming to use a variety of renewable sources, with 60MW to come from wind power, 290MW from solar, 80MW from geothermal, 137MW from small-scale hydropower, 45MW from biomass, and 35MW from biogas (IRENA, 2020). Other Central American countries have renewable energy targets that reach 64% by 2030 in Panama (EOR, 2018) and 80% by 2034 in Honduras. This shows the momentum in the region, taking advantage not only of natural resources but also the opportunities presented by the current situation resulting from the climate crisis.

Regarding renewable energy's share of total energy demand, the report sets targets of 12% by 2030 and 19% by 2050. Colombia is the only country in the region that has a target of between 8-15% by 2050 (Government of Colombia, 2021). Chile, in turn, has established targets of a 15% share by 2030, and 70% by 2050 for zero-emission fuels in non-electric end-use energy consumption (Government of Chile, 2021). In Costa Rica, more than 60% of end-use energy consumption comes from oil derivatives, and the country is aiming for the industrial sector to change their energy sources to break the link between growth in their activities and rises in their emissions by 2050 (Government of Costa

24 IEA Electricity generation by source, 2020.
25 Chile Climate Strategy on Climate Change, 2021.
26 PROURE, 2021.
27 Costa Rica National Decarbonization Plan, 2019.
28 Mexico's Climate Change Mid-Century Strategy, 2016.

Rica, 2019). Peru is talking about developing a diversified energy matrix, placing an emphasis on renewable energy and energy efficiency, without setting concrete targets (Government of Peru, 2010).

In addition, the following shares were recorded for renewable energy sources in 2019: 99.2% in Costa Rica, 69.8% in El Salvador, 61% in Belize, 58% in Guatemala, 55% in Honduras, 54.6% in Nicaragua, 53.1% in Panama, and finally 11.6% in the Dominican Republic.

Installed capacity in the sub-region stood at 23,452MW in 2019, a figure 5.9% higher than that of 2018. The Dominican Republic (21%) had the biggest power generating capacity in the sub-region in 2019, followed by Panama (17.6%), Guatemala (17.5%), Costa Rica (15.2%), Honduras (11.6%), El Salvador (9.6%), Nicaragua (6.8%), and Belize (0.7%).

It is estimated that Central American Integration System (SICA) member states will have 4,094MW of additional supply from new electricity generating plants for the 2020-2030 period. Of the total amount of additional energy, 56% corresponds to renewable energy, made up by hydroelectric (39%), wind (6%), solar (5%), geothermal (4%) and solar power (2%). The 44% figure for thermoelectric power is almost entirely accounted for by natural gas, and coal has been ruled out. This shows that, even against a backdrop of very favourable prices for natural gas, renewable energy are the most cost-effective option in Central America.

Furthermore, estimating the share of technologies in electricity generation by 2030 gives 82% for renewable energy (7% higher than in 2019) and 18% for thermoelectric energy. The share for each type of renewable energy is 54% for hydroelectric, 12% for biofuels (mainly agro-industrial biomass), 7% for geothermal, and 6% for wind. Natural gas, in turn, is entering the regional energy market (MER) via projects in Panama and El Salvador.

It is important to mention that El Salvador prohibited coal-based power generation several years ago. "The law preventing energy investments was passed on April 11, 2011, following its publication in the Official Gazette, and it 'prohibits the installation and operation of thermoelectric power plants that use mineral coal, liquid natural gas, or any derivatives of hydrocarbons or flammable material in the municipality of La Unión' and in the rest of the country."

It is important to consider the fact that not all the countries are able to give the green light to renewable energy sources such as hydroelectric power. In Panama, for example, water has strategic importance for both human consumption and the Panama Canal. The latter operates using this raw material, and its activities—which are the country's main source of revenue and economic development—could be jeopardized if water were unavailable or in short supply. Therefore, decisions regarding new hydraulic power stations—regardless of where they are in the country—are contingent on not having any impact on the natural production of water for the Panama Canal.

4.4.3. Gaps preventing fulfilment of the goal

Although investment in renewable energy has increased in recent years, particularly in countries like Brazil, Mexico, Chile, and Uruguay, regarding reaching the target set in the IEA's report a significant gap still exists between the markets that receive the most investment and the other countries in the region. A gap can also be found between the technologies. Despite investment in solar energy having risen over the last few years, investment in wind energy represented nearly two thirds of all investment in renewables (excluding hydroelectric power) between 2014 and 2016 (IRENA, 2016).

In terms of the use of renewable energy in end-use energy consumption, there is low penetration by technologies and infrastructure that enable the use of renewable energy in sectors such as buildings, transport, or industry. The electric vehicle market in Latin America, for example, is experiencing slow growth in comparison with other markets, and this reduces the possibility of generating electricity using renewable energy for the transport sector (IDB, 2020).

To reach the goals, it is therefore necessary to close gaps in the penetration of technologies that stimulate the use of renewable energy for end-use energy consumption across a variety of sectors. Securing adequate funding on favourable terms is required to successfully complete all these processes, which will allow the necessary investment to be made, above all using innovative financing mechanisms. It is important to underline the efforts being made by Latin American financial institutions in adopting sustainable financial practices.

A crucial element is that while the countries may have made accelerated progress towards various renewable energy targets, there has also been growth in the number of thermal generation sources in the region, like Mexico (SENER, 2021) and Brazil (MME, 2022), which have expanded steadily over the last decade. Furthermore, while the goal is energy transition, the process is complicated by the fact that there are still unexploited fossil fuel reserves.

4.4.4. Challenges, opportunities, and recommendations

One of the biggest challenges facing the region is the gradual phasing out of power generation from coal and other fossil fuels to allow for the introduction of renewables into the energy mix. In 2019 in Latin America, electricity generated from coal, oil, and natural gas represented 5%, 7%, and 19% of the energy matrix respectively, making a total

share of 31% for fossil fuel-based generation (International Energy Agency, 2021).[29]

However, there are some signs that the countries in the region are now acting to gradually phase out coal. As part of the ambitious pledges enshrined in the NDCs to reduce greenhouse gas emissions, work has been carried out on a substantial portfolio of renewable energy projects that could become a reality in the upcoming years. Efforts have also been made to bring the region's countries (Chile, Costa Rica, El Salvador, Mexico, Peru, and Uruguay) into the Powering Past Coal Alliance (PPCA), a coalition of governments, companies, and national and sub-national organizations that work to drive progress in the transition to clean energy (PPCA, 2022).

Furthermore, at the COP26 summit held in November 2021, Chile and Ecuador signed the Global Coal to Clean Power Transition Statement, through which the countries pledge to (UK COP26, 2021):

i) Rapidly expand the rollout of clean energy and energy efficiency measures in their economies, and assist other countries in doing the same;

ii) Rapidly scale up technologies and policies over this decade, to achieve a transition away from coal during the 2030s for major economies and during the 2040s worldwide;

iii) Stop issuing new permits for coal-based power generation projects, suspend the construction of new coal-based power generation projects, and end direct government support for coal-based generation projects; and

iv) Strengthen national and international efforts to secure financial, technical, and social support for the affected workers, sectors, and communities, to ensure a fair and inclusive transition.

In 2019, Chile also pledged to shut down all its coal power stations by 2040. Even so, in late 2021, the Chilean government announced that five of the twenty-eight existing plants had been closed by that point, and that they were working to shut down all the remaining plants by 2030 (Government of Chile, 2021). Countries such as Costa Rica and Uruguay, where renewable energy occupy around a 98% share of the energy matrix, have demonstrated that it is possible to move away from fossil fuel-based generation, provided that technical, economic, and social planning is conducted to enable a gradual transition.

Over half of the region's electricity is generated through hydraulic energy and a significant amount of solar energy resources. This situation provides an important opportunity due to the flexibility offered by hydraulic systems for the integration of renewable energy (Harby et al., 2019). As explained previously, Latin America has been increasing the share of its energy matrix represented by renewable energy, which brings demands for new storage requirements and flexibility at different timescales.

Finally, Latin America is on course to meet the targets proposed in the IEA's report for electricity generation from renewable energy, as the region's countries are working to increase installed capacity and generation from renewable energy, and the appetite for producing power using coal and other fossil fuel sources is waning. It is also necessary to consider other uses for renewable energy in the transport, industrial, and residential sectors to increase their share in end-use energy consumption, giving full consideration in planning to the need to ensure that the process takes place in an equitable way and that it allows the countries' energy and electricity needs to be met.

4.5. Hydrogen and hydrogen-based fuels

4.5.1. Context

The focus of using hydrogen is the transformation of fossil fuel-based energy to energy from low-carbon hydrogen, in such a way that existing transmission and distribution infrastructure can be used. This includes the use of hydrogen in industry, in refineries, and in power plants, and the mixing of hydrogen and natural gas for distribution to end users (International Energy Agency, 2021). The region boasts a portfolio of over 25 projects that even includes exportation projects. The hydrogen pillar has four main milestones:

- Increasing the share of low-carbon hydrogen
- Boosting total hydrogen production
- Expanding the use of hydrogen-based fuels
- Scaling up global hydrogen use to all sectors

Low-emission hydrogen can be produced via electrolysis, which uses electricity generated from renewable sources (green hydrogen), or by capturing and storing the carbon released in fossil fuel-based hydrogen production. Most of the low-emission hydrogen currently produced in the world is created by combining conventional production technology with carbon capture and storage. These systems manage to capture approximately 90% of the carbon generated, although this figure is still being verified at industrial level (IEA, 2021).

Hydrogen generation has the potential to play a key role in the energy transition, given that it would enable the large-scale integration of renewable energy (which in turn

29This data excludes Mexico and includes some Caribbean islands due to the regional distribution method used by the IEA.

would be the source for obtaining hydrogen), heighten the resilience of the system, and decarbonize the transport sector, and due to its uses in industrial energy and in powering and heating buildings.

The use of hydrogen as an energy source is in the initial stages, although it is promising. Several energy applications have been found, including fuel cells for commercial vehicles, buses, light, and heavy freight transport, forklifts, trains, trams, boat, drones, and aircraft. Hydrogen also has stationary applications for providing power and heating in airports, data centers, buildings, large stores, hospitals, and water treatment plants, for the storage of electrical energy, and as backup energy for small-scale stationary applications.

4.5.2. Regional assessment and targets

In terms of the production and total consumption of hydrogen-based fuels, the current IEA target is for 212Mt by 2030 and 528Mt by 2050 at a global level (IEA, 2021). In 2019, the total demand for hydrogen for industrial purposes stood at 4.1Mt in Latin America (close to 5% of global demand). In this way, the sector will serve as a basis for the large-scale production of hydrogen for domestic consumption and exportation. This is due to the expectation that, by 2030, hydrogen production in Latin America will exceed its projected demand of 6.8Mt per year, making the region one of the leading exporters of this energy source (IEA, 2021).

Table 13. ***Targets related to the hydrogen pillar for 2030 and 2050***

Total production of hydrogen-based fuels (Mt) Total consumption of hydrogen-based fuels (Mt)		
Country	Year 2030	Year 2050
IEA Report	212	528
Chile[30]	• Leading global exporter of green hydrogen and its derivatives: US $2.5bn per year • The greenest hydrogen in the world: <1.5 USD/kg • Leading global producer of green hydrogen from electrolysis 25GW	Reaching at least a 70% share for zero-emission fuels like green hydrogen.

Colombia[31]	• Install a minimum of 1GW of electrolysis capacity
	• Competitive green hydrogen, achieving costs of 1.7 USD/kg
	• Production of at least 50kT of blue hydrogen
	• Regarding demand:
	  • A fleet of at least 1500-2000 light vehicles and 1000-1500 heavy fuel cell vehicles for passenger and freight transport.
	  • A network of 50-100 hydrogen generating stations at a minimum
	  • 40% of the consumption of the industrial sector represented by low-emission hydrogen.
		Exportation to other regions and the activation of less technologically mature applications.

In the region, the use of hydrogen is primarily concentrated in seven countries: Argentina, Brazil, Chile, Colombia, Mexico, Trinidad and Tobago, and Venezuela (IEA 2021). However, only Chile and Colombia have set specific targets for this pillar, as shown in Table 13. In the region, there are another eight countries that are developing hydrogen strategies and roadmaps: Argentina, Bolivia, Brazil, Costa Rica, El Salvador, Panama, Paraguay, and Uruguay. There is also a portfolio of 25 low-carbon hydrogen projects at the development stage (IEA, 2021).

4.5.3. Gaps and Barriers

The production costs of low-emission hydrogen are the biggest barrier that must be overcome to enable its implementation and achieve regional targets. The cost of capital, investment in electrolysers, and other equipment, and the cost of energy and/or carbon capture and storage technology are factors that influence the costs involved in producing hydrogen.

The costs of using carbon capture technology must also consider the carbon price applied to uncaptured emissions, in such a way that the carbon price has a direct impact on captured and uncaptured production and storage where the carbon tax applies.

On the other hand, a lot of the technology for producing low-emission hydrogen is still in development. These technological gaps can be closed by means of research and the development of recent technologies, which could re-

30 (Government of Chile, 2020)

31 (Colombian Ministry of Mines and Energy, 2021)

sult in lower investment costs and stimulate the rollout of low-emission hydrogen production in the region (IEA, 2021).

4.5.4 Challenges, opportunities, and recommendations

In Latin America, hydrogen has the potential to drive the energy transition due to the fact it can replace fossil fuels in final energy uses that are incompatible with direct electrification, such as in heavy industry (e.g., steel or cement) and long-distance air and sea transport. It can also be used to complement other technologies and accelerate the decarbonization of some sectors, such as land transport (IEA, 2021).

Most of the countries in the region are already aware of this and are currently exploring the opportunities presented by hydrogen. The year 2020 saw the launch of H2LAC, a collaborative platform created by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the Euroclima+ program, ECLAC and the World Bank to boost the development of green hydrogen in the region and promote its production, use, and exportation. The platform features the participation of Argentina, Bolivia, Brazil, Colombia, Chile, Costa Rica, Ecuador, El Salvador, Mexico, Paraguay, Peru, the Dominican Republic, and Uruguay (H2LAC, 2021).

It is important to mention that the production of low-emission hydrogen could be beneficial to all the countries in the region, particularly in the decarbonization of the transport sector, although some countries could benefit more greatly than others. For example, Brazil and Mexico produce over 80% of the region's steel and could use hydrogen to reduce the emissions generated by the industry. It could also be used by other countries like Chile and Peru to replace diesel in the mining sector and bring down emissions. Countries with abundant and competitive renewable energy can take advantage of them to produce and export low-emission hydrogen (IEA, 2021).

Hydrogen offers an opportunity to export a product with low carbon emissions, to stimulate value chains and, in turn, to create employment and economic opportunities. Hydrogen could also improve the region's energy security and boost renewable energy for electricity generation (IEA, 2021).

The combination of conventional technologies and carbon capture, use, and storage (CCUS) techniques is the primary means of producing low-emission hydrogen at a global level and is likely to remain so in the short and medium term as its production costs are lower than those of other low carbon emission technologies. Depending on the process characteristics and the technologies used, it is estimated that over 90% of CO2 emissions associated with the production of hydrogen could be retained, although these capture rates are yet to be demonstrated on an industrial scale. The capacity to implement CCUS technologies greatly depends on the availability, aptitude and cost of transport infrastructure and CO2 storage.

Regarding the challenges, large scale and long-term implementation of hydrogen production, use, and exportation requires coordinated efforts on different fronts. For this, the commitment of all stakeholders such as governments, the industry, financial institutions, academia, and civil society is necessary (IEA, 2021). Furthermore, one of the greatest challenges to the production and use of low-emissions hydrogen is that many technologies are still in development. For this reason, decision-makers must design policies to support the research and development of these sustainable technologies, their infrastructure, arrival, and long-term permanence within the market (IEA, 2021).

Latin America must continue working to leverage low-emissions hydrogen potential; however, it is important to highlight that all countries present challenges and opportunities related to the demand and supply of hydrogen. Therefore, strategic planning plays a fundamental role in broadening the hydrogen panorama in the region.

The roadmaps which are being published determine the long-term vision and are the first step in moving towards the planned targets. Additionally, the region's countries must identify short term opportunities to speed up initial implementation, promote funding, and reduce the investment risk, encourage research and development, generate incentives for low-emissions hydrogen production, create market opportunities, and foster regional and international cooperation to put the region within the global hydrogen scene (IEA, 2021).

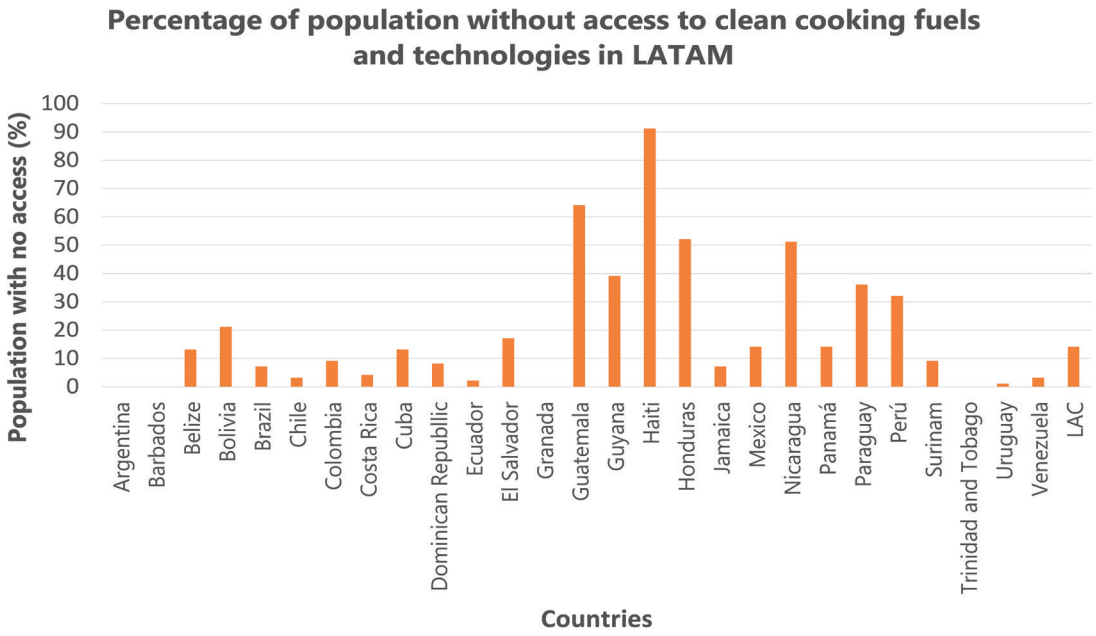
4.6. Bioenergy

4.6.1. Context

Biomass is organic material produced by agricultural, livestock, forestry, aquaculture, fishing, domestic, commercial, and industrial activities. Bioenergy are fuels obtained from biomass, they can be solid such as wood, agricultural materials such as waste and charcoal, liquids such as bioethanol, oils such as biodiesel, and gasses such as methane or hydrogen (Hernández, 2011).

Approximately 3 billion people currently use biomass such as wood or others for cooking or heating their homes (World Bank, 2018). Global primary demand for bioenergy was almost 65 EJ in 2020, of which around 90% was solid biomass. About 40% of the solid biomass was used in traditional cooking methods (IEA, 2021). In Latin America, specifically, the population without access to cooking fuels and technologies is shown in figure 3, in which several countries in a critical situation can be observed, where there are four countries over 50% and only four countries at 0%.

Figure 3. ***Percentage of population without access to clean cooking fuels and technologies in Latin America***



Source: OLADE-IDB, 2018

The current global use of bioenergy is less than 5% of the total energy needs. Therefore, the bioenergy pillar has two main targets:

- Broaden the proportion of sustainable biogenic fuels (biogas, liquid biofuels, and modern solid biomass extracted from sustainable sources) within the total energy use.
- Increase the global use of modern bioenergy to 100 EJ by 2050, covering almost 20% of all energy needs.

4.6.2. Regional assessment and targets

The IEA report establishes a target for a total global bioenergy supply of 72 EJ by 2030 and 102 EJ by 2050. This implies an annual increase of approximately 3% on average of the modern use of solid bioenergy until 2050. It is important to note that one advantage of bioenergy is that it can use existing infrastructure of certain fuels. For example, biogas can use natural gas pipelines and liquid biofuels can use existing oil distribution networks and can be used in vehicles with alterations (IEA, 2021), at the same time ensuring that these fuels are economically feasible for the Latin American context.

In Latin America, countries such as Brazil, Colombia, and Costa Rica are talking about expanding the use of biogenic fuels, however, only Colombia has a quantitative target (see table 14). Additionally, at the recent COP 26, twelve Latin American countries joined the Global Methane Pledge: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Panama, Peru, and Uruguay. The participants of this commitment agreed to take voluntary actions to reduce global methane emissions to at least 30% by 2030, in comparison with 2020 emissions (Global Methane Pledge, 2021).

In the Central American Integration System (SICA) countries, Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, and the Dominican Republic, the results obtained by different countries in relation to biofuels have not been favourable, the actual impact is less than 1%.

There are two key barriers for the development of these sources. The first is related to the incentives and protection of markets (the agriculture industry seeks a mechanism that secures them a floor price, independent from the international price of oil derivatives). The second barrier is related to the agricultural border, competition with lands dedicated to the production of basic food elements and food security. Experiences with new species (jatropha and castor oil plant, mainly) did not produce the expected results.

For this reason, in the future development of biofuels, one option is linked to the development of new varieties suitable for the conditions of the SICA countries, with the possibility of adaptation in rough terrain, and not competing with food production. The above must be evaluated within the context of sustainable development, considering the environmental services that biofuels can provide.

Table 14. ***Targets related to the bioenergy pillar by 2030 and 2050***

Total bioenergy supply (EJ)		
Country	**Year 2030**	**Year 2050**
IEA Report	**72**	**102**
Brazil[32]	• Different scenarios to expand bioenergy, one of the challenges is the diversification of biomass for biofuels and development of new biofuels. • Policies to promote the production and use of biofuels: National Program for the Production and Use of Biodiesel (PNPB), and the National Alcohol Program PROALCOOL) and RenovaBio.	
Colombia[33]	• National Circular Economy Strategy • Increase the use of residual biomass by 20%	
Costa Rica[34]	• Characterize the diverse types of industrial processes according to their energy requirements and promote the end of fossil fuel use through renewable electricity, bioenergy (generated by biomass or waste) and improvements in energy efficiency.	

Currently, in Latin American and Caribbean cities, more than 80% of people use gas as the main fuel for cooking. In rural areas, almost 50% use firewood as their main fuel (World Bank, 2020). Therefore, it is important to recognize that firewood and coal constitute a significant energy resource for the region, where countries have a high percentage of rural population whose principal source of domestic fuel supply comes from firewood in relatively high proportions, which is why the promotion of bioenergy in the region will be crucial.

4.6.3. Gaps and barriers

Currently in Latin America and the Caribbean, 56% of the population have access to modern energy services for cooking. However, 44% lack access to this technology, 15% have significant obstacles in accessing it, especially in rural areas, and 29% are in a transition process to improve their cooking technologies, mainly in the cities (World Bank, 2020).

It is key to consider that there are significant challenges related to the parallel use of fuels for cooking and stoves in a single household. Many households have modern fuels but continue to use firewood without making use of efficient cooking stoves due to socio-cultural customs and with the purpose of minimizing availability risks (World Bank, 2020).

Even though firewood is a solid biofuel, it has been used unsustainably. One of the main obstacles in the region with regards to technologically modernizing firewood or replacing solid fuels with clean fuels are access and price (Troncoso & Da Silva, 2017, 188-196), since the population with these needs are usually the poorest (World Bank, 2020).

Nevertheless, despite the benefits of firewood, certain countries in the region have opted to move away from this fuel, mainly due to risks associated with health, considering that smoke from firewood is damaging to health and the particulate matter from burning this solid fuel is associated with respiratory and heart diseases (EPA, Environmental Protection Agency of the United States, 2021).

The use of biomass with inefficient equipment and with insufficient extraction systems at home can generate negative impacts on people's health, this situation is of great concern in certain countries in Central America and the Caribbean, but also in southern territories such as Chile and Argentina where biofuels such as firewood, coal, and/or waste are used for cooking.

Contamination by particulate matter produces adverse effects in the population's health. In the residential case, this is generated using dirty fuels considered high in emissions, such as coal, biomass in general, manure, and/or kerosene. In certain cases, the low-income context makes it difficult to obtain cleaner and more efficient fuels increasing emissions and duration of exposure to pollutants.

It is estimated that 12.4% of the region's population is not using clean energy sources for these energy services (Carvajal et al., 2020). This number differs depending on the sub-region. For South America, an average per population of 6.8% is observed, 14.6% for North America represented by Mexico, 30.7% for the Caribbean, and the most concerning statistic being 40.4% of homes that use solid fuels in the case of Central America.

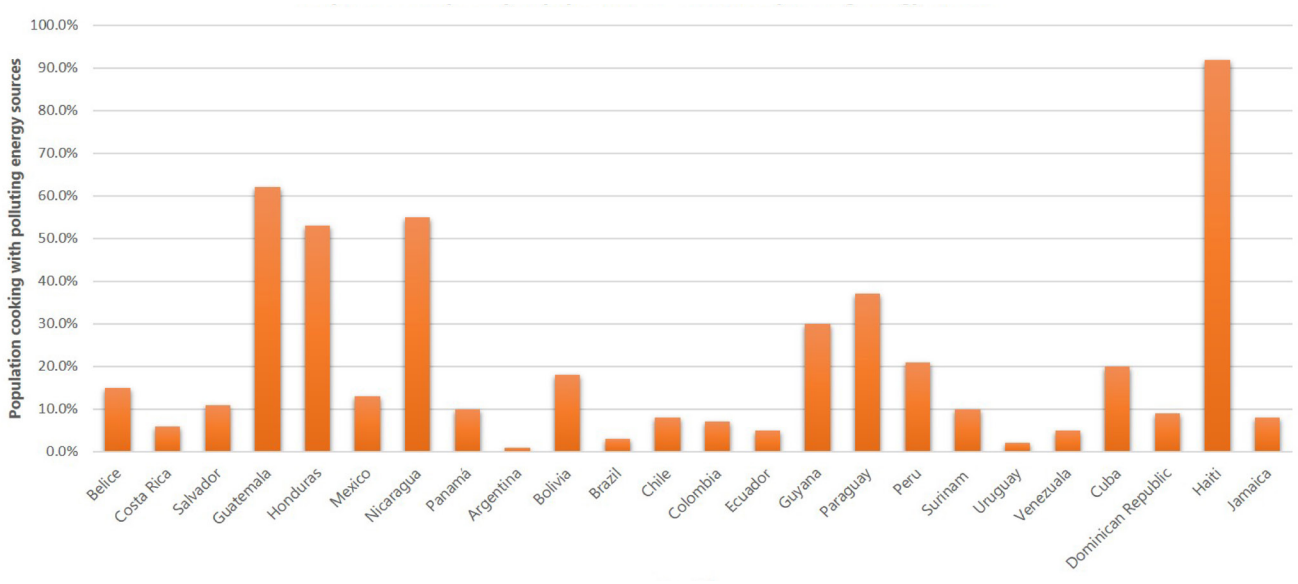
With regards to the Caribbean, a highly contrasting situation can be observed, since 50% of countries have less than 1% of homes not using clean energy. These countries are all territories with a dependant relationship with the United States, France, the Netherlands, and the United Kingdom, except for Trinidad and Tobago, the Bahamas, and Barbados, which are included in the 10 countries with the best Human Development Index (UNDP, 2019). In general, in the Caribbean, the average use of solid fuels is 8.3% (excluding Haiti). However, including Haiti, the average increases by almost 4 times due to the high rate of solid fuel use and other dirty energy sources that are used by 94% of this country's population.

32 National Emergency Plan 2050 / Ministry of Mining and Energy. Energy Research Company - Law Nº 13.576, December 26, 2017.

33National Circular Economy Strategy.

34 National Decarbonization Plan.

Figure 4. ***Proportion and quantity of population that cook with polluting energy sources***



Source: Development of energy poverty indicators in Latin America and the Caribbean. ECLAC 2021 and the Interamerican Development Bank (IDB) Database and the Economic Commission for Latin America and the Caribbean (ECLAC).

In the case of Central America, only Costa Rica maintains a value of less than 7% in terms of solid fuels use, while Honduras, Guatemala, and Nicaragua, with an average of 53% of the regional population, exceed 45% of households using polluting energy sources for cooking, being surpassed again by Haiti in this area.

A deeper understanding of the different forms of deprivation of energy services because of energy poverty in Latin America and the Caribbean must be obtained, integrating a specific vision of households and their territoriality. Placing the countries in a context of energy security allows for a better understanding of the context that conditions the possibilities of equitable access to quality energy services in the region's households, such as energy prices, local availability of biomass, climate conditions, connectivity, among others.

4.6.4. Challenges, opportunities, and recommendations

Latin America and the Caribbean have comparative advantages to promote bioenergy since they have availability of lands as well as the necessary climate conditions to produce energy. Therefore, there is also the potential of satisfying a significant part of the global demand for biofuels (ECLAC, 2007). However, a balance must be sought with regards to the climate objectives of the 2030 Agenda, since the development of bioenergy may generate competition in land use to produce biomass for food or bioenergy (ECLAC, 2019).

Given the productivity gaps with respect to the availability of land and water, as well as scientific and technological capacities, the region must be able to develop their bioenergy production plans whilst strengthening their contributions to regional and global food security (ECLAC, 2019).

Additionally, there is the opportunity to develop a legal framework for bioenergy since many of the region's countries have relevant public policies and institutions to develop the Bioeconomy,[35] in areas such as climate change, agriculture, bioenergy, and use of residual biomass. Therefore, the elaboration of strategies associated with bioenergy must be based on the identification and coordination of initiatives that already exist, together with the development of dialogue processes with the private sectors and other relevant stakeholders (ECLAC, 2019).

In the reactivation of initiatives for the promotion of biofuels in member states of the SICA, the social dimension of biofuels must be considered, considering creation of jobs and the impact on food security. For this reason, key elements for the commercial development of biofuels must be met; mandatory blending, production assurance, supply, pricing formulas, and payment guarantees. Mandatory blending is essential to produce compound fuels, the first step in establishing a biofuel market.

35 GBS 2018 Press Release: the bioeconomy can be defined from a global perspective, as "the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable economy."

Due to the size of the countries' markets and territories, coordination to implement a regional or sub-regional biofuel plan should be considered. In this case, the participation of institutions in charge of regulation and monitoring of hydrocarbon markets and the Committee of Hydrocarbon Directors of the SICA will be essential. In summary, studies need to be updated to determine the actual capacity of biofuel production, under scenarios and conditions that satisfy environmental and social restrictions and consider agro-industrial policies and food security. This will give an insight into possible blends and their limits (for example, between 5% and 7% biodiesel and 10% bioethanol). The next step would be establishing the basis for negotiations with agro-industrial sectors to secure biofuel production for blends and purchase based on clearly established pricing formulas with payment guarantees.

One of the main challenges associated with the current regional situation is the reduction of cooking emissions, where two key alternatives are recommended: (i) improve efficiency of firewood use; and (ii) promote a fuel change. However, due to the different barriers for fuel change, the most feasible solution is improving the efficiency of firewood consumption and promoting bioenergy in the region (World Bank, 2020)

In this regard, it is necessary for the region's countries to formally include the demand for modern energy for cooking in their national energy planning strategies, where different users and their needs are considered, as well as local markets and the energy potential of each country (World Bank, 2020).

On the other hand, because of the pandemic and volatility of fossil fuel prices, biofuels have gained recognition with the aim of contributing to the reduction of greenhouse gases in the transport sector. Studies related to biofuel use in aviation have been developed with the aim of discovering new raw materials, new conversion technologies, and the implementation of new supply chains (Wang et al., 2019, 1036-1050).

Liquid biofuels will play a significant role regarding the CORSIA aviation sector scheme[36] and is a great opportunity for Latin America due to the production capacity of certain countries such as Brazil. In 2019, biofuels in aviation had just begun a new stage of early commercialization, until then, the commercial production of biofuels in aviation had been achieved through hydro-processed esters and fatty acids.

According to the International Air Transport Association (IATA), by the year 2018, more than 150,000 commercial flights were made using biofuels (International Air Transport Association, 2008), where this biofuel came from renewable raw material and is considered a sustainable fuel source due to its potential to reduce emissions and improve energy security (Hileman and Stratton, 2014; IATA, 2013). It is estimated that CORSIA will mitigate around 2.5 billion tonnes of CO2 between 2021 and 2035, around 164 million tonnes annually (Aviation Benefits Beyond Borders, 2022).

4.7. Carbon capture, utilization, and storage - CCUS

4.7.1. Context

Carbon capture, utilization, and storage (CCUS) is the process of capturing carbon emissions generated by combustion, industrial processes, or directly from the atmosphere. The captured carbon emissions can be stored in underground geological formations, onshore or offshore, or used as an input or raw material in other processes (IEA, 2021).

CCUS could assist the transition towards carbon neutrality as, according to the IEA (2021) it can be used to:

- Tackle existing emissions;
- Tackle emissions of some of the most challenging sectors;
- Provide a cost-efficient way to increase hydrogen production with low emissions carbon;
- Enable the elimination of CO2 from the atmosphere through bioenergy with carbon capture and storage (BECCS) and the direct air carbon capture and storage (DACCS).

4.7.2. Regional assessment and targets

The IEA report sets out carbon capture targets of 1,670 Mt by 2030 and 7,600 Mt by 2050 globally. Currently, 40 Mt of carbon is captured per year globally (IEA, 2021). To comply with the target, 50% of carbon capture is planned to come from fossil fuel processes, 20% from industrial processes, and 40% from bioenergy and direct carbon capture.

In Latin America, Colombia is the only country with a target associated with this pillar. The Integral Plan for Climate Change Management of the Energy Mining Sector 2050 (PIGCC) established a greenhouse gases reduction of the energy mining sector of 11.9% through CCUS by 2050 in the fifth modelled scenario (Ministry of Mines and Energy, Colombia, 2021).

Similarly, there is a commercial carbon capture installation in Brazil where Petrobras has carbon separation and injection technology in eight floating production storage and offloading (FPSO) vessels located offshore in Cuenca de Santos. Carbon associated with natural gas is separated, compressed, and injected into wells to improve oil reco-

36 Carbon Offsetting and Reduction Scheme for International Aviation: The carbon offset and reduction plan for international aviation aims to reduce CO_2 emissions of international flights and curb the impact of aviation on climate change.

very. In 2020, this installation injected 7Mt of carbon and by June 2021, it reached 21.4 Mt of carbon accumulated injections since the beginning of the operation in 2011. The project expects to inject a total of 40 Mt of carbon by 2025, thus contributing to technological evolution and cost reduction and demonstrating CCUS technology security (Global CCS Institute, 2022).

4.7.3. Gaps and Barriers

The lack of information regarding carbon capture, usage and storage is one of the largest gaps, since this process is often confused with carbon capture in forests. This could be one of the reasons why there is only one country in the region which has concrete targets with respect to this pillar.

Furthermore, the costs of this technology per ton of carbon captured is the main entry barrier, as well as economic, political, and technical uncertainties which represent a gap which must be closed to achieve the deployment of this technology and meet capture targets. Likewise, many carbon capture and storage technologies are still being developed; Therefore, research and development can contribute to closing these technological gaps and barriers, reducing costs, and incentivizing the deployment of this technology in the region (IEA, 2021).

4.7.4. Challenges, opportunities, and recommendations

One of the biggest challenges for implementing carbon capture and storage is promoting technological innovation and development which reduces investment costs and guarantees efficiency of the systems. All the strategies laid out by the IPCC AR6 assumes a combination of different forms of carbon removal, both natural and through CCUS. The implementation of these removal systems requires the price of carbon applied to non-retained emissions to be considered, as mentioned in the gaps of low-emission hydrogen production from fossil sources with carbon capture.

Another challenge of carbon capture and storage is avoiding the potential for investments in these systems to result in reduction of investments in renewable energy. To avoid this, establishing targets of fossil fuel use of short to medium term transition is recommended. Therefore, it is important to highlight that research and development of CCUS technologies must go hand in hand with technological restructuring of all the sectors and energy transition to reduce carbon emissions.

The implementation of this technology brings the opportunity of capturing existing asset emissions, particularly in industries that are difficult to decarbonize. For example, the CCUS is the only scalable option to neutralize cement production emissions and remove carbon found in the atmosphere. This could be an attractive alternative for countries such as Brazil and Mexico, large producers of steel (IEA, 2021), or leading countries in cement production such as Brazil, Argentina, Colombia, and Peru (Perilli, 2021), which can be benefited by installing carbon capture technologies in existing plants. The remaining emissions can be managed through a well-structured market of robust carbon, like the European market (European Union Emissions Trading System - EU ETS), which enables the price of carbon to be fixed.

Similarly, it is important to consider that the development of CCUS for fossil fuels incentivizes the development of CCUS for other applications, general knowledge, and cost reduction benefits (IEA, 2021). For example, it can incentivize innovation in fossil fuel technologies reducing carbon emissions from this source.

Latin America must start to work on the implementation of CCUS technologies to meet carbon neutrality targets, especially in the already existing assets and in the most challenging sectors regarding decarbonization. Similarly, the region's countries must identify short- and medium-term opportunities to speed up the deployment of this technology in these sectors. However, the implementation of these technologies should not result in an increase in the use of fossil fuels particularly with the production of hydrogen. On the contrary, short- and medium-term targets are recommended for CCUS use in hydrogen production and the development of public policies which encourage research and development of CCUS technologies which maximize carbon capture at the industrial level.

In accordance with the above, a joint effort is needed between decision-makers, researchers and developers, academia, industry, and other sectors which can benefit from carbon capture technologies and generate market opportunities for the management of emissions that cannot be captured.

Climate change adaptation of the energy transition in Latin America and the Caribbean

5.1. Vulnerability of the energy sector in the region

According to the latest report of IPCC[37], the triggers of climatic impacts in the region are mainly related to variations in temperature, precipitation and wind, loss of glaciers and sea level rise. These would cause direct or indirect effects on the energy sector according to the conditions of the subregions of Latin America. One of the fundamental elements is uncertainty, where the impacts may be even greater than expected, where the precautionary principle must prevail.

Historically, the region has shown an increase in the average temperature and episodes of extreme heat (except for the southern subregion of South America), with forecasts of an increase in temperature and the number of days of extreme heat in Central and South America, and with more frequency. Similarly, there have been periods of cold and frost, which is expected to trend downward in the region (IPCC, 2021).

For precipitation variations, dissimilar impacts are expected according to the subregion. For example, the northwestern and southeastern subregions of South America will be affected by increases in average precipitation, while the southern Central America and northeastern subregions will be affected by decreased precipitation and with increased periods of drought. (IPCC, 2021).

Similarly, glacial volume loss and permafrost thaw are likely to continue in the Andes Mountains under all climate scenarios, leading to significant reductions in river flow and potential flooding from large glacial lake outbursts (IPCC, 2021).

Possible changes in precipitation have a direct impact on energy generation and supply. The energy supply would be affected by the increase in the frequency of extreme hydrometeorological events and the triggering of associated risks such as landslides, fires, floods, marine heat waves, coastal erosion, among others (IPCC, 2021).

Some effects that have been evidenced in the energy sector due to climatic impacts and necessary to consider for the development of new projects and the maintenance of existing infrastructure are (IPCC, 2021):

- Changes in wind density, which modify the wind energy endowment.
- Severe storms particularly threaten energy infrastructure, with peak wind speeds associated with downed trees and ruptured power transmission lines.
- Tropical cyclones and severe coastal storms can cause wind, water and coastal hazards causing damage to energy infrastructure, among others.
- High temperatures reduce the efficiency of power transmission lines.

On the other hand, the region has a relevant dependence on hydroelectric power in approximately 50% for the generation of its electricity, where the availability of water becomes an important vulnerability (IDB, 2014). Hydroelectric generation is affected by possible droughts in the region that can occur with greater recurrence in certain countries. The foregoing could threaten the stability of the energy supply in countries with a greater dependence on hydroelectricity such as Brazil, Colombia, Costa Rica, Ecuador, and Paraguay, impacting the ability to guarantee access to electricity to its inhabitants. (ECLAC, 2015 ; de Jong et al., 2018; de Queiroz et al., 2016, 2019; Hasan & Wyseure, 2018;

37 IPCC AR6

Macias & Andrade, 2014).

The case of Costa Rica is paradigmatic, as of the drought during the years 2017-2019 it had to import energy from the countries of the Central American region generated by fossil fuels. By 2019, it managed to increase its wind energy production, had to ration water from dams, and was forced to import electricity from Central America. Hydroelectricity has an impact on different climate change scenarios in the region, showing the need for complementarity with other generation technologies (Arango-Aramburo et al., 2019).

Regionally, the Interamerican Development Bank – IDB conducted a study in 2019 on the vulnerability to climate change of hydroelectric systems in the Andean countries. It was found that in several zones, the modeling shows an increase in the production of electricity in hydroelectric plants; however, the impacts of climate change are expected to be geographically differentiated. In addition, and as mentioned by the IPCC, there are regions where changes in precipitation are not expected, and there are others where the seasonality changes with differentiated trends for the dry and wet seasons.

Recent studies have documented that solar and wind energy transmission and productivity networks decrease their performance and efficiency in extreme heat conditions, which are expected to worsen in a context of climate change (Fant et al., 2016; van der Heijden, 2019; Viviescas et al.,2019; Zhang et al., 2019). The energy sector becomes much more vulnerable to the occurrence of hurricanes, as evidenced by the devastating Hurricane Maria in Puerto Rico, which left the state with electricity problems for 11 months.

In this transition process, the vulnerability of the energy sector to hydrometeorological events associated with climate change can be determined according to the impact as such on the energy system and its environment, which at the same time affects the quality, access and system redundancy and energy infrastructure.

In Latin America and the Caribbean, the vulnerabilities of the energy sector related to climate change have not yet been fully assessed, and the different advances in adaptation measures remain a challenge. Although, the issue of vulnerability to climate change and the need to adapt to its effects is receiving greater attention at the regional level and at some national levels; this attention must be translated into concrete actions in one of the most vulnerable economic sectors. For example, the region lacks in-depth assessments of the impacts of climate change on non-hydroelectric energy sources, vulnerability studies at the national level, and adaptation strategies (IDB, 2014).

5.2. Climate change adaptation in the energy sector

Adaptation is a key element in a vulnerable region to the impacts of climate change such as Latin America and the Caribbean. For this reason, the region has given great importance to adaptation to the climate crisis on the National Determined Contributions (NDC). Unfortunately, Brazil is the only country that does not mention adaptation in its updated NDC, despite mentioning it in the previous version (WWF, 2021)

In the region, various territorial, sectoral, or thematic areas are identified that are priorities in terms of adaptation to climate change. The countries that have included the energy sector adaptation are Bolivia, Costa Rica, Chile, Ecuador, Colombia, Costa Rica, Peru, Paraguay, Uruguay, El Salvador, Venezuela, and Mexico (European Comission, 2019)[38].

Some of these countries have developed their adaptation plans to climate change where they have different approaches and strategies. Table 15 presents a comparison of the components found in the latest plans for the energy sector.

The countries have been addressing different strategies to adapt to climate change in the energy sector and are supported by lines of action and measures. However, there are a series of common challenges as a region that must be managed as a priority, where the generation and exchange of knowledge will play a key role in the process.

Among the challenges that are evident in the plans are the following: information and dissemination of knowledge for planning, likewise, intersectoral coordination, public-private collaboration and local action were elements identified for the countries studied. One of the biggest challenges not only for the energy sector, but also for adaptation to climate change in general for the region, are the different financing alternatives and mechanisms, and the monitoring and evaluation components of adaptation progress.

To develop adaptation strategies, the region's energy sector will need to expand its knowledge of the vulnerability and potential impacts of climate change. Although there is evidence of possible adverse impacts of climate change, specific information is limited on the vulnerabilities of the energy sector, the magnitude of the risks related to climate change or the resilience capacity of the region. As mentioned before, the IDB recently studied the vulnerability to Climate Change for hydroelectric systems in the Andean countries, for which it is necessary to extend this knowledge to other energy generation systems dependent on climatic factors (IDB, 2019).

38 Additionally, the NDCs of the remaining countries were reviewed to identify the inclusion of the energy sector in the adaptation components https://www4.unfccc.int/sites/ndcstaging/Pages/LatestSubmissions.aspx

Table 15. ***Climate Change Adaptation Plans in LAC***

Component/ Country	Colombia[39]	Perú[40]	Chile[41]
Target	Incorporate climate risk management at the decision-making levels of the energy mining sector, to reduce the impacts generated by climate change and climate variability on the mining, hydrocarbon and electricity industries and thus protect their competitiveness	Promote actions and projects in alliance with the public and private sectors that increase the sustainability of electricity services in the face of the adverse effects of climate change	Promote the development of a resilient energy system, generating and strengthening the prevention and response capacity of the energy sector to the impacts of climate change
Strategic lines	1. Resilient infrastructure 2. Short- and long-term planning 3. Environment management 4. Information for adaptation	Not Applicable	1. An energy supply that is more resilient to climate change at different territorial scales 2. Towards energy transport better adapted to climate change and extreme weather events 3. An energy sector better prepared for increases in energy demand because of climate change 4. Institutional arrangements and intersectoral alliances in the energy sector that promote the adaptation of the sector to climate change 5. Technical capabilities at the forefront and dissemination of the Plan
Stakeholders	• Ministries of Environment and Energy • Companies in the energy mining sector • Energy planning units • Academy	• Ministry of Energy and Mines (includes organic and attached units) • Ministry of the Environment • Regional and local governments • Operations Committee of the National Interconnected System • National Environmental Certification Service for Sustainable Investments • Electric generation, transmission, and distribution companies	Not applicable
Actions/ measures	• Climate risk management in pipelines and transmission lines • Generate an early warning system for climate risks (short term) • Watershed conservation • Relationship strategy • Strengthening of climate events and threats information systems	• Increased water availability • Promotion of infrastructure development • Promotion of the implementation of protection infrastructure in the generation, transmission, and distribution of electricity • Efficient use of hydropower in hydroelectric plants • Implementation of a decision support service in hydrographic basins with hydro energy potential	• More geographically detailed analyzes of climate change impact projections • Implement capabilities in energy management for industry • Institutional coordination at the different territorial levels, to promote adaptation to climate change in the energy sector • Strengthen risk planning and management in the energy sector in the face of extreme events

Source: Adaptation Plans of the Energy Sector

39 Climate Change Management Plan for the Mining-Energy Sector - Ministry of Mines and Energy (2021)

40 Actions of the Ministry of Energy and Mines for adaptation and mitigation against climate change by 2030 - Peru (2019)

41 Climate Change Adaptation Plan in the Energy Sector Ministry of Energy (2018)

The nature of most renewables (intermittent weather-related) means that increasing their market share could lead to greater vulnerability of power systems. Therefore, if adaptation actions are to be designed and implemented to address such vulnerabilities, a greater understanding of the adaptation needs of the sector will be needed (IDB, 2014). Additionally, there may be events where climate change leads to reinforce the complementarity between resources, that is, the depletion of one resource may favor the availability of another.

The environmental conditions of thermal comfort are critical in most of the countries of the region during the hottest months of summer, a phenomenon that can be amplified if we consider the Urban Heat Islands in the large cities of Latin America and the Caribbean. This phenomenon can lead to a significant increase in the demand for cold, which has high energy demands. A public policy is required that anticipates these future conditions of lack of thermal comfort, to protect people's health and to reduce the energy demand of buildings.

Although Latin America is characterized by high temperature conditions, there are areas where low temperatures are a major problem for households, including southern Argentina and Chile, as well as Andean settlements throughout South America. In the case of cold places with biomass availability, the use of firewood for heating and cooking is a condition of energy poverty that has effects on people's health.

At the same time, energy efficiency is crucial to improve the capacity to respond to climate change thanks to the better use and lower demand for energy (Molyneaux et al., 2012). Therefore, the improvement of housing quality standards reduces the base energy demand and increases the thermal comfort conditions of homes. (Schueftan & González, 2015; Schueftan et al., 2016). Finally, it is important to consider that energy poverty can also generate a rebound effect of energy efficiency measures, reducing their effectiveness due to pre-existing conditions of lack of thermal comfort (Galvin & Sunikka-Blank, 2013, 2016; Teli et al., 2016), and therefore, it is a problem that requires particular care and attention during the transition process.

Finally, the universalization of modern energy services will constitute a fundamental milestone for the reduction of poverty. In the case of rural electrification, having lighting and other basic services will increase the resilience of populations. Similarly, by reducing the time spent collecting firewood, women and children will also reduce their vulnerability. Additionally, the use of renewable energy and the adoption of energy efficiency measures will help not only to reduce emissions, but also to improve productivity.

5.3. Monitoring and Evaluation of climate change adaptation in the energy sector

Due to LAC vulnerability to climate change, the energy sector is promoting the design and implementation of various plans and strategies for climate change adaptation that can minimize its impacts. However, it will be necessary for all these plans and measures to have a clear and up-to-date monitoring and evaluation system, which allows knowing the progress in adaptation (ECLAC, 2019).

Some experts suggest that the region should identify a common metric on how to measure progress or setbacks related to the reduction of climate vulnerability and progress in adaptation, to identify progress made in the region towards meeting the adaptation objectives of each of the NDCs (ECLAC, 2019).

Some of the countries mentioned before included in their energy climate change plans a chapter dedicated specially to monitoring and evaluation. Colombia for example, states that the monitoring of the Adaptation Plan will be carried out through the annual evaluation of each measure and its respective indicators, to identify possible difficulties and establish corrective measures. This monitoring, in addition, is expected to serve as the basis for the preparation of the Energy Policy Follow-up Report and for the preparation of the Annual Implementation Progress Report that must be submitted to the Ministry of the Environment.

Chile proposes to develop mechanisms that allow the evaluation of the adoption and implementation state of the emissions reduction and resilience actions proposed in its plan. The global evaluation and update of the Plan will be carried out every five years, in coherence with the National Energy Policy (PEN) and the National Plan for Adaptation to Climate Change (PNACC 2014), in a participatory process integrating all the relevant actors for the implementation of measures.

Central American countries' adaptation within the framework of SICA 2030, seeks an alignment between the regional goals with the NDCs. It also considers the vulnerability of the countries of the region (five of the SICA countries are listed among the 20 most vulnerable worldwide) and their need to integrate resilience and adaptation actions together with emission reduction measures.

Climate change adaptation in the energy sector, must consider evaluation systems as a fundamental pillar to promote learning on successes and failures, as well as continuous improvement (Mazzeo et al., 2019). Likewise, this may involve looking at the process in the implementation of adaptation-related investments, policies, plans and interventions, and/or impacts that these may have (adaptation results). (GIZ, 2017).

Conclusions

Latin America and the Caribbean has important comparative advantages for an energy transition towards more sustainable matrices, thanks to the large number of natural resources available to produce biomass, wind, and solar energy (IDB, 2021). Therefore, it will be necessary for the region to continue advancing in the ambitious plans for energy transition and reactivation of the economy, focusing its attention on large and timely measures that involve processes of innovation, decarbonization, and decentralization.

To overcome the different barriers and gaps that the region presents regarding the energy transition, it is necessary to guide society and strengthen its capacities, since they will become a fundamental edge having clarity of the energy use and consumption in each country. In addition, the key role that governments play in overcoming barriers and ensuring that there is a solid institutional framework in place to successfully accelerate the implementation of the proposed pillars and thus an energy transition, must be considered.

The Latin American region must move towards the decarbonization of the economy, without the need to give up economic growth. For this reason, it will be necessary to consider the Just Transition approach in all these aspects, integrating the different climate, social and economic agendas that aim at the sustainable development of the region.

In this way, it is expected that the region can harmonize the different energy, climate, and regulatory policies, likewise, that long-term energy planning includes all energy subsectors, prioritizes demand from all economic sectors, and additionally, consider the different users and needs, as well as the local markets and the energy potential of each country.

In recent decades, climate change has generated a major transformation of energy systems, consequently, at least three factors must be considered: reducing emissions of greenhouse gases and short-lived climate pollutants, maintain the resilience of energy infrastructure in extreme weather conditions and improve energy efficiency in energy production and use. To avoid increasing the conditions of vulnerability of LAC countries, this energy transition must consider the different gaps for equitable access to current and future energy, for which it is essential to overcome energy poverty. to achieve an effective energy transition.

It is worth recognizing that the IEA approaches identify that the world has a viable path to build a global energy sector with net-zero emissions in 2050, but it is narrow and requires an unprecedented transformation of how energy is produced, transported, and used.

The IEA roadmap shows the priority actions needed today to ensure that the opportunity for net-zero emissions by 2050 is not lost, however, as evidenced in this document, these milestones require a detailed analysis since that the Latin American and Caribbean region is not homogeneous, and needs to review the starting point of each of the countries with respect to the pillars and their goals, and the different efforts countries are making for a just and resilient energy transition.

The role of new technologies deserves continuous observation, such as large-scale electricity storage, the complementarity between renewable technologies, which allows taking advantage of periods with a wide range of different technologies. The role of green hydrogen in the region will be fundamental, not only for the transformation of the energy matrix away from fossil fuels, but also as a new export product for those countries that meet the necessary conditions for its low-cost production while conserving the quality standards and certifications of origin.

It is necessary to observe the progress of the capture and sequestration of carbon in the subsoil, as an alternative to using fossil fuels in those cases where the use of another technology is not possible. In the latter case, it is important to verify that the geological conditions allow safe storage in the reservoirs in the long term.

Under study are the carbon price mechanisms, which are currently being developed based on voluntary standards, national regulations, regional agreements, as well as international mechanisms such as Article 6 of the Paris Agreement, or the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) mechanism. These instruments always have the high challenge of verifying their effectiveness for the reduction of GHG in the different sectors in which they are applied. If any element of these mechanisms, such as the price signal, the independence of actors or the robustness of accounting, among others, has weaknesses, there is a great risk that the mechanism will lose its transparency or that, instead of generating actions

of effective mitigation, generate a dynamic carbon market, in which the end is the exchange and not effective climate action. It is necessary to demand transparent carbon price mechanisms that put downward pressure on the use of fossil fuels and constitute an effective tool for climate change mitigation and compliance with the NDCs.

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