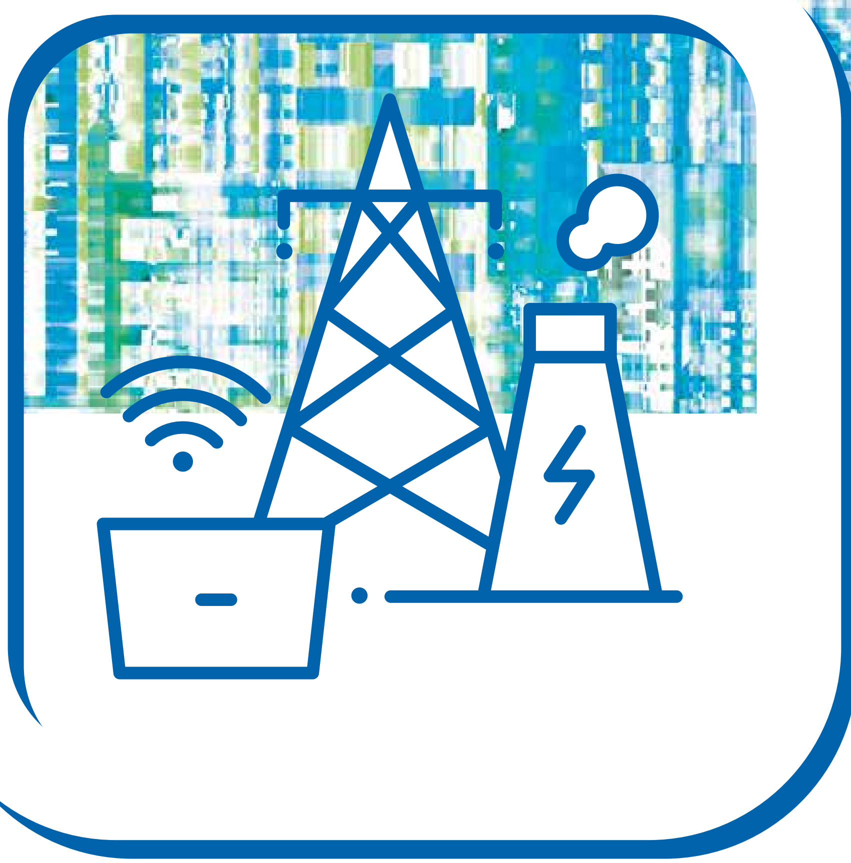
# Reducing emissions from the energy sector for a more resilient and low-carbon post-pandemic recovery in Latin America and the Caribbean

Carolina Grottera



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# Reducing emissions from the energy sector for a more resilient and low-carbon post-pandemic recovery in Latin America and the Caribbean

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This document was prepared by Carolina Grottera, with contributions from Tatiana Bruce da Silva, Lilia Caiado Couto and Eduarda Zoghbi, consultants in the Sustainable Development and Human Settlements Division of the Economic Commission for Latin America and the Caribbean (ECLAC), under the supervision of Camila Gramkow, Economic Affairs Officer of the ECLAC office in Brasilia, José Javier Gómez, Environmental Affairs Officer of the Sustainable Development and Human Settlements Division of ECLAC and Luiz Fernando Krieger Merico, Economic Affairs Officer of the same division, within the activities of the Development Account project "Coordination, Coherence and Effectiveness for Implementing the Environmental Dimension of the 2030 Agenda in Latin America and the Caribbean".



United Nations publication
LC/TS.2022/17
Distribution: L

Printed at United Nations, Santiago
S.21-00949

This publication should be cited as: C. Grottera, "Reducing emissions from the energy sector for a more resilient and low-carbon post-pandemic recovery in Latin America and the Caribbean", *Project Documents* (LC/TS.2022/17), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2022.

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# Introduction

The COVID-19 pandemic hit hard Latin American and Caribbean countries with an average interannual economic contraction of 7,7% of its Gross Domestic Product (GDP) in 2020 (ECLAC, 2021a). This drop in economic activity is the deepest economic drop in at least 120 years. The economic crisis has led to significant social impact. The unemployment rate reached 10,7% in 2020 (up by 2,6 percentage points) and a massive contingent of people left the labour market (ECLAC, 2021b). The prognostics for 2021 and the following years are harsh. The region is expected to recover the pre-pandemic levels of economic activity (GDP) only in 2024 (ECLAC, 2021a). An urgent response is needed, not only because of the recent (short-term) events associated with the pandemic, but also because there are deep structural (long-term) divides that ought to be addressed in order to help Latin American and Caribbean (LAC) economies to become more economically resilient and dynamic, socially inclusive and environmentally sustainable.

In this sense, the Economic Commission for Latin America and the Caribbean (ECLAC) has been developing an approach named "Big Push for Sustainability" to help the countries of the region to move towards development styles with economic, social and environmental sustainability. This approach, named the Big Push for Sustainability, is being developed at least since 2016 (ECLAC/FES, 2019), and has become even more relevant in face of the recent dramatic dimension of 2020 crisis in the region. More than ever, a transformative recovery with sustainability and equality is necessary. The urgent need to recover sanitary conditions, jobs and income, while reducing environmental pressures, however, introduces an unprecedented opportunity to build back better. There is a narrow window of opportunity to generate a Big Push for Sustainability, thereby producing a virtuous cycle of economic growth, generating decent jobs and income, while at the same time reducing inequalities and structural gaps.

Economic crises are not new. However, the way countries respond and seek to build back from their effects is an ever-evolving process. Economic response policies put in place in response to the previous global crisis, the Great Recession of 2008-2009, failed to put the world on a track to address the climate crisis then. Although green stimulus has been used for the first time ever as a tool to explicitly boost economic recovery based on pushing for low-carbon technologies, practices and sectors, overall, countries worldwide could not put the world on a low-carbon development path. Nevertheless, there was an important learning process and paradigm shift whereby protecting the environment became a driver (instead of a barrier) to economic recovery, growth and development (Gramkow, 2019). In addition, the previous decade has been of unprecedented progress for non-conventional renewable energy sources.

Kuzemko and others (2020) point a few reasons why one might expect greater efforts towards a sustainable energy transition at the present time. First, they highlight the more positive economic performances of renewables compared to fossil fuels during the pandemic. Second, behavioural changes and public attention towards fossil fuel demand, air quality, and support for climate change mitigation may also lead to structural changes. Finally, they advocate that new global accords now exist, such as the Paris Agreement and the UN's 2030 Agenda and its associated SDGs. These mechanisms provide quantifiable targets and direction for politicians and policymakers. They also can serve as powerful tools for civil society and interest groups to hold them to account.

In this study, the synergies and linkages between post-COVID 19 crisis recovery approaches and the energy transition in Latin America and the Caribbean (LAC) are explored. The study aims to identify recovery strategies for key sectors and technologies based on changes in policies, institutions, regulations and investments in such a way that it leads to more sustainable ways to produce and consume energy and the decarbonization of the economy. This includes prioritising greater generation of electricity from renewable sources, sustainable management of fossil fuels and biofuels; and greater energy complementarity (ECLAC/CGEE, 2020a).

This report is structured as follows. In addition to this Introduction, in Chapter I, an overview of energy systems in LAC is provided. Chapter II contrasts current policies scenarios with NDC-compliance scenarios in Latin American and Caribbean countries with a focus on energy. Chapter III reviews the social and economic impacts of major renewable energy deployment, which represent multiple opportunities for the region. Chapter IV discusses ways to improve the regulatory environment and public policy framework to foster non-conventional renewable energy in LAC. Chapter V focuses on harnessing the economic recovery while accelerating the energy transition in Latin America and the Caribbean. Concluding remarks close the document.

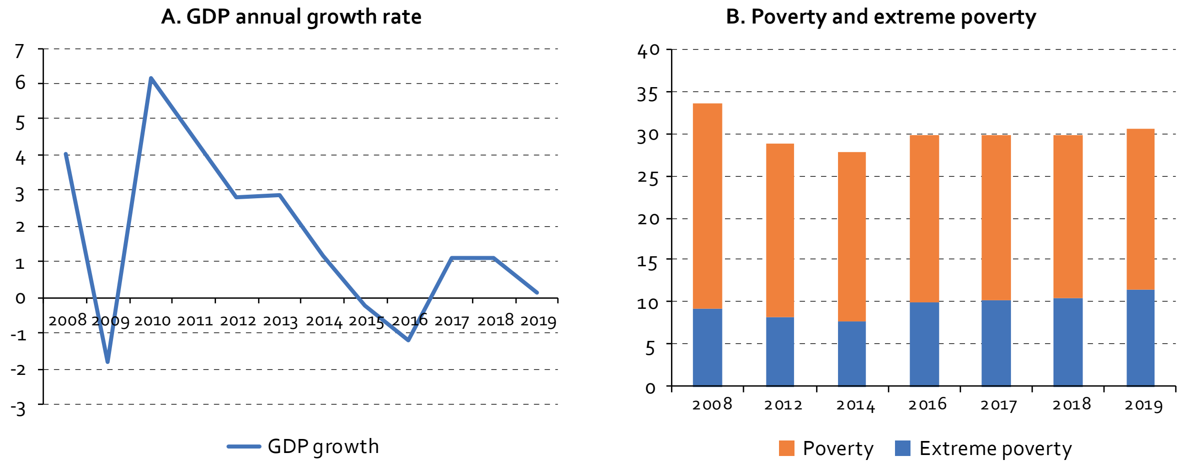
# I. Overview of energy systems in Latin America and the Caribbean

The Latin America and Caribbean region is composed by diverse countries in terms of geographical size, economic profile, demographics, type of development and resource endowment. In spite of their heterogeneity, they face similar challenges, common throughout the developing world, such as alleviating poverty, providing essential services, improving per capita income levels, and increasing productivity levels, among others.

The COVID-19 pandemic exacerbated development divides by constraining economic activities to essential services, which led to the most challenging economic recession ever experienced in at least a century and the loss of millions of jobs. Many Latin American countries were striving to cope with low economic growth (approximately 0,3% yearly growth on average between 2014 and 2019 according to ECLAC, 2020a), social deterioration (whereby extreme poverty and poverty reached 11% and 30,2%, respectively, of the region's population (see Figure 1);) and fiscal constraints hit the region even before the pandemic. For 2020, a drop in the GDP growth rate of 7,7% was expected, accompanied by an increase in the unemployment rate, which reached 10,7%, and a considerable worsening of inequality and poverty rates (preliminary estimates by ECLAC, 2020a).

Short-term policies aiming to mitigate social and productive costs of the pandemic have been intensified, requiring greater fiscal and monetary impulses. In this context, the responses in many countries have been constrained by the availability and possibilities of access to financing, within the context of fiscal and external restrictions. However, to move towards a transformative recovery with equality and sustainability that can support the construction of a welfare state and the strengthening of the productive sector, it will be necessary to maintain expansive fiscal and monetary policies (ECLAC, 2020b).

**Figure 1**
**GDP growth rate and share of population living under poverty and extreme poverty, 2008-2019**
*(Percentages)*




Source: Prepared by the author based on CEPALSTAT (2021).
Observations: For GDP, data covers all Latin American and Caribbean countries. For poverty and extreme poverty rates, data is only available for Latin American countries, for selected years.

Despite the tragic consequences of the pandemic, Latin American and Caribbean countries now face a unique opportunity to reshape their economies in such a way that development objectives are at the core of their recovery strategies. Namely, the Sustainable Development Goals (SDGs; UN, 2015) and the Nationally Intended Contributions (NDCs; UNFCCC, 2015) offer the main guidelines that allow to achieve a transformative recovery with equality and sustainability. More specifically, this means there is an opportunity to produce a virtuous cycle of economic growth, generating decent jobs and income, while at the same time reducing inequalities and structural gaps. In addition, such guidelines ensure a sustainable path to economic recovery, as preconized by the Paris Agreement, which aims at limiting global temperature increase at well below 2oC above pre-industrial levels, ideally at 1,5oC.

## A. A region endowed with abundant energy resources

The Latin American and Caribbean (LAC) region is endowed with substantial energy resources, both renewable and non-renewable. Yet, these are very unevenly distributed among countries. Resource endowment, geopolitical factors and past choices on energy deployment are elements that outline such diverse energy production and use profiles throughout the region. Even though electrification rates reach close to 95%-97% of the population (IRENA, 2016b; World Bank, 2017), lack of access to electricity is still affects between 14 to 18 million people (World Bank, 2017; Messina and Contreras Lisperguer, 2019), while 84 million people still rely on traditional biomass such as fuelwood (World Bank, 2017).

Latin America presents the cleanest energy matrix in the world due to the relatively high share of hydropower,[1] biofuels (mostly in Brazil, the largest country in LAC) and, to a lower degree, the recent substitution of oil by natural gas. The use of coal, which is the most carbon-intensive fossil fuel, is relatively less prominent compared to other regions of the developing world. The expansion of hydropower has been slowly decreasing in the past decades. Despite a substantial untapped hydropower potential, the remaining possibilities are frequently situated in regions that are socially and culturally sensitive, such as the Amazonian region (La Rovere and others, 2018).

[1] The region includes many of the countries in the world that have the highest share of hydropower in electricity supply: Uruguay, Colombia, Costa Rica, Ecuador, Brazil, Peru, Panama, and Paraguay.

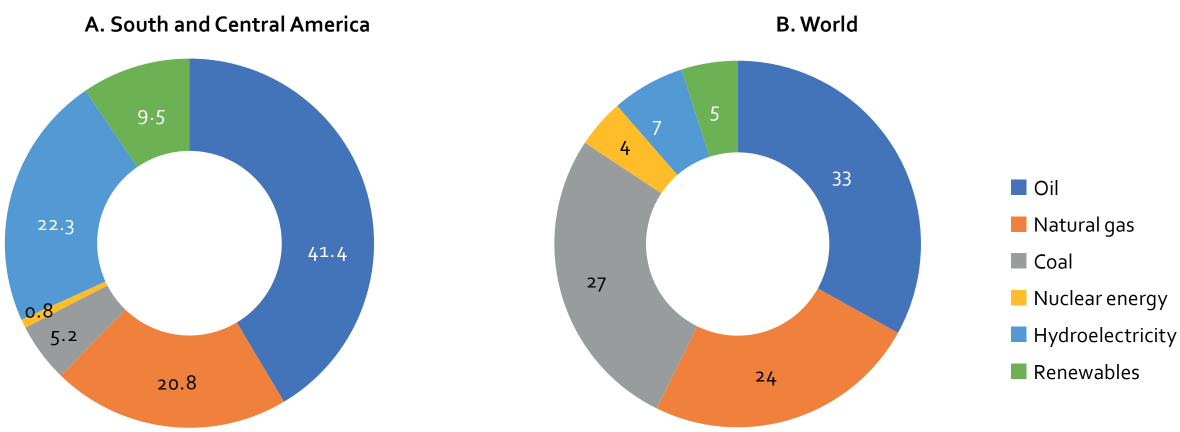
Moreover, they involve high capital requirements and are distant from consuming centres, which creates constraints on transmission and distribution. Growing popular resistance to large hydropower projects, barriers to obtaining environmental licenses, in addition to changing hydrological patterns (e.g. El Niño), have undermined further hydropower development. There is also growing uncertainty about the vulnerability of hydrological systems to climate change. Changes in precipitation, potentially combined with extreme weather events and erosion may alter river runoff and, consequently, hydropower output, hindering its future viability (IRENA, 2016b; OLADE, 2017; World Bank, 2017; IDB, 2020).

Despite remarkable hydropower and biofuel deployment, LAC still relies largely on fossil fuels. Even with large untapped proven oil and gas reserves, the region imports 43% of its gas and 35% of its oil (World Bank, 2017). Some Caribbean countries import most of their petroleum products (diesel and heavy fuel oil) used for electricity generation and transportation, which makes them vulnerable to international price fluctuations and supply disruptions (González, 2020).

Non-conventional renewable energies (NCRE, which include biomass, solar, wind, geothermal and biogas) accounted for 5% of total primary energy consumption in Latin America and the Caribbean in 2018, which is higher than the world average of 4% (ECLAC, 2020b). While some LAC countries have taken the lead on non-conventional renewable energy deployment, such as Brazil, Uruguay, Chile and Costa Rica, others only are starting to pursue such technologies. Existing hydropower reservoirs can be used to manage the short-term variability of these intermittent energy sources.

Regional electrical integration allows exploring the complementarity across NCRE in different locations in LAC, also helping mitigate variability and improving energy security in countries at lower system costs than developing renewable resources in isolation. The geographical and temporal complementarity of renewable resources is an important alternative to mitigate both daily and seasonal variability in electricity generation. This aspect constitutes a great opportunity for the integration of electricity markets with important economic, environmental and energy security benefits for the countries (Paredes, 2017).

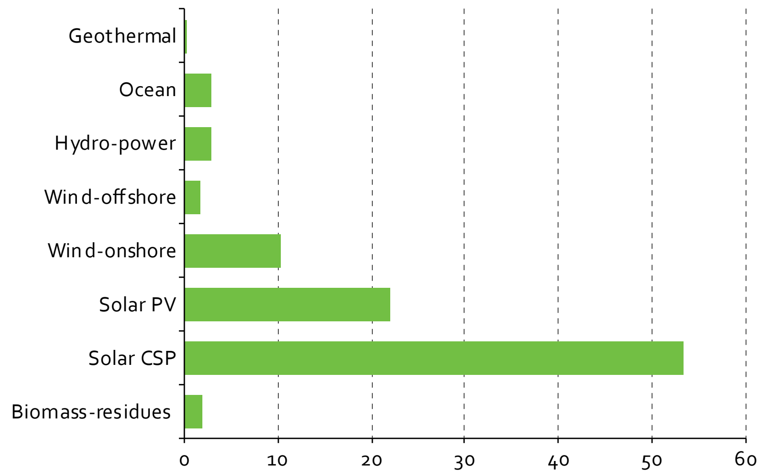
**Figure 2**
**Share of primary energy by source in South and Central America and world average, 2019**
*(Percentages)*




Source: Prepared by the author based on BP Statistical Review (2020).

Figure 3 depicts the estimated potential of the main renewable energy sources in Latin America. An assessment by Vergara and others (2015) calculates that the region could produce over 93 PWh of electricity from solar, wind, marine, geothermal and biomass energy combined, which is well above the foreseeable regional demand in the next century. Paredes (2017) also preconizes that LAC`s solar and wind potential is more than enough to address its actual and forecasted electricity needs.

**Figure 3**
**Estimated renewables resource endowment in Latin America**
*(Petawatt-hour/year)*




Source: Prepared by the author based on Krewitt and others (2009) In World Bank (2017).

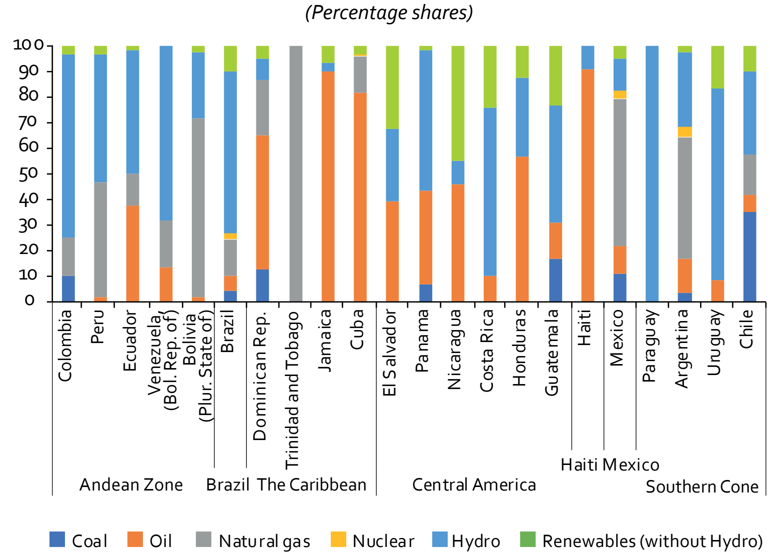
Note: Solar PV –photovoltaic; Solar CSP –Concentrated Solar Power.

Note: This assessment by Krewitt and others (2009) compared different scenario exercises to estimate the technical potential of renewable energy up to 2050. According to the authors, the potential solar resource was based on the following assumptions: space availability considering 269 million hectares for Mexico and Central America and 1.761 for South America; average land-use factor of 0.6; average solar irradiation of 152,4 to 175,9 W/m2; 25% conversion of efficiency, and a performance factor of 90%.

## B. The evolution of renewable technologies in Latin America

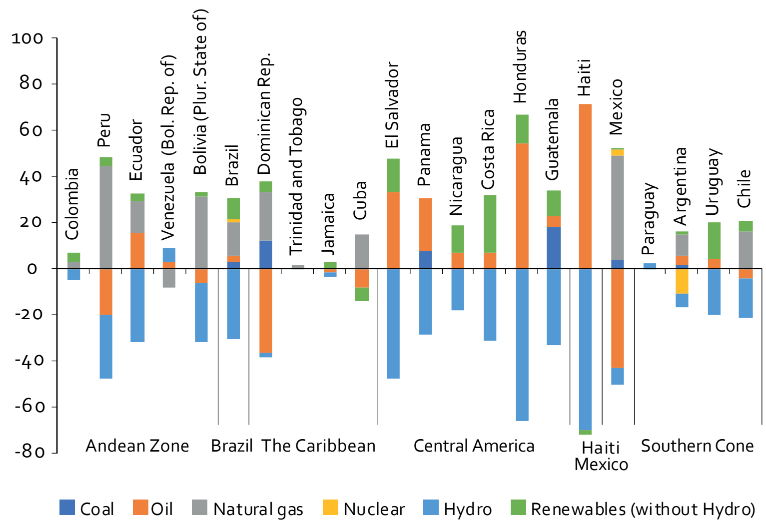
According to OLADE (2018), between 2007 and 2017, the installed capacity of its 27 member countries` power matrix increased by 50%. In 2007, 95,7% of the total installed capacity corresponded to hydroelectric and thermoelectric energy, while in 2017, that figure was reduced to 86,9%. Approximately 11,7% was made up of solar, wind, geothermal and renewable thermal energy. Figures 4 and 5 depict, respectively, the composition of LAC countries' electric generation profile in 2016 and how sources varied according between 1990 and 2014.

**Figure 4**
**Electricity output by country by source, 2016**
*(Percentage shares)*




Source: Prepared by the author based on World Bank (2017).

**Figure 5**
**Change in fuel source for generation by country, 1990 and 2014**
*(Percentages)*




Source: Prepared by the author based on World Bank (2017).

The uptake of renewable energy sources was made possible by the rapid decrease in energy technology costs. These are increasingly competitive with fossil fuels and, in LAC, among the lowest for some technologies worldwide. Hydropower is one of the most cost-efficient technologies in the region. However, the majority of countries have already exploited the most economically viable locations; hence there is less scope for cost reductions. Hydropower costs have been stable in LAC during the last decades.

The weighted average capacity factor (the energy produced from continuous operation at full rate)[2] for onshore wind in LAC is among the highest in the wind industry worldwide (approximately 42% in 2014, according to IRENA, 2016b). The levelised cost of electricity (LCOE)[3] for onshore wind has decreased by around 20% since 2010, and can currently compete with traditional sources such as hydropower and thermopower plants. Since 2012, the LCOE for solar PV has also decreased substantially, by 50%. The estimated weighted average Latin America LCOE for solar PV of US$ 110 per MWh in 2014, was the lowest globally.

The main causes of cost reductions are sector maturity, supported by the availability of local supply chains and labour, resource quality and reduced financing costs. However, significant discrepancies can still be found across LAC countries due to competing technologies prices, energy subsidies, differences in enabling policies and investment conditions (IRENA, 2016b).

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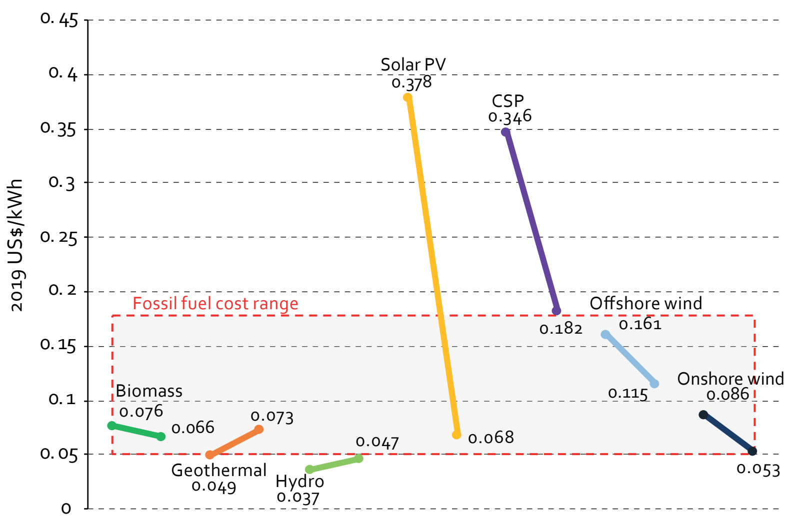
2 For renewable intermittent sources, the capacity factor is largely dependent on exogenous aspects, such as wind regime and solar radiation.

3 The LCOE is "the price of electricity required for a project where revenues would equal costs, including making a return on the capital invested equal to the discount rate" (IRENA, 2019d). It is the main tool for comparing the plant-level unit costs of different technologies over their operating lifetimes (IEA and NEA, 2020).

**Figure 6**
**Global weighted average levelized cost of electricity from utility-scale renewable power generation technologies in 2010 and 2019**
*(2019 US dollars/kWh)*




Source: Adapted by the author based on IRENA (2020 d and e).
Note: The lines connect the global weighted-average costs for each technology between 2010 (left) and 2019 (right). The single red rectangle represents the fossil fuel-fired power generation cost range.

## C. What role is there for renewable electricity in a low-carbon economy in Latin America?

Latin American and Caribbean countries have set out their climate mitigation and adaptation goals through their Nationally Determined Contributions (NDCs), in which the priority sectors and requirements for external support are established. According to Samaniego and others (2019), the energy sector is the most relevant in the case of mitigation, while the water sector is the most important area for adaptation actions. In the Latin American and Caribbean Technology Needs Assessments (TNA; CTCN, 2020),[4] 88% of countries prioritized energy as a mitigation sector, 53% transport and 24% agriculture. In the energy sector, governments are predominantly prioritizing technologies for energy-efficient buildings and lighting systems, bioenergy and solar energy.

The transformation in the energy system is not limited to shifting from fossil to carbon-free sources, but also adapting to the constraints and challenges imposed by emerging ways of producing and consuming energy. In this context, storage options such as reversible hydroelectric plants, water reservoirs and batteries become strategic (Dutra and Vasconcelos, 2020). Exploring the complementarity between intermittent renewable sources, including through the interconnection with other regions and markets should also be considered in forming the energy mix (Paredes, 2017).

Originally structured around a vertically integrated chain - with transmission and distribution linking centralized generation to the final consumer, electrical systems are now witnessing a proliferation

[4] According to CTCN (2020), "The Technology Needs Assessment (TNA) process identifies a country's development priorities. These are derived from ongoing policies, programmes and projects, long-term vision documents as well as strategies for climate change mitigation and adaptation already in place. These development priorities are used along with climate mitigation and adaptation criteria for identifying highest priority (sub) sectors, and for prioritising technologies for mitigation and adaptation within these (sub) sectors. Since 2001, more than 80 developing countries have conducted TNAs to address climate change. More recently, many countries have identified climate technology needs in their nationally determined contributions (NDCs)."

of distributed energy resources, defined as resources installed near or in the consumption centres themselves. Digitalization is an indispensable feature to integrate distributed energy resources to the main grid. It allows instant communication between devices, agents and applications, leveraging gains from decentralization.

The scalability and modular nature of these technologies, including through micro-decentralized networks, has the potential to democratize access to electricity (Dutra and Vasconcelos, 2020). For instance, PV systems are one of the most cost-competitive electrification option for small, isolated communities in the Amazon region (IRENA, 2016b). Digitalization, decentralization and universalization of access are the main drivers of the decarbonization of economies, with incentives to electrify other uses, as discussed in the next section.

### 1. Electrification of end-uses

An underlying premise of the energy transition is the shift from fossil fuel to renewable electricity consumption. The possibilities of electrification are spread across various sectors. In the residential sector, direct fossil-fuel consumption takes place mostly in heating and cooking, both of which can be electrified. For buildings, heat pumps are nearly 90% more efficient than gas boilers (ETC, 2020), while electric cooktops and ovens can replace liquefied petroleum gas for cooking.

In the industrial sector, decarbonization of industrial heat with electrification depends on the temperature level. Applications that require low and medium temperature heat can be electrified with heat pumps, solar or geothermal energy, such as the food and beverage sector (IEA, 2018a). For high-temperature heat industrial processes, such as some chemicals and in the manufacturing of steel, however, electrification is not suitable, and decarbonization can be achieved by other means, including hydrogen and synthetic fuels produced with renewable electricity.

In the transportation sector,[5] electric vehicles can decarbonize passenger's (automobiles and buses) and commercial vehicles.[6] Electric vehicles' costs have fallen by 87% in the past years (BNEF, 2019), and cost parity with internal combustion engine (ICE) vehicles is likely to be reached by the end of the 2020s – an inflection point for electric vehicles to start replacing conventional cars (BNEF, 2020). Besides, electric vehicles' maintenance costs are 28% lower than ICE vehicles' (Delucchi and Lipman, 2001) and, since they do not emit exhaust gases, their adoption contributes to improving air quality with direct benefits on public health. When combined with efforts to improve public transportation in urban areas, benefits slipovers to increased economic productivity, reduced inequality, better safety, among others (Borba, 2020).

Nonetheless, decarbonization through the electrification of end-uses in LAC is not a widespread policy. Current costs of such applications are substantial, and their implementation often requires further infrastructure investments. For the majority of countries, most decarbonization efforts focus on increasing renewables share in power generation – the "low-hanging fruit" of the energy transition, but whose development can build a foundation to decarbonize other end-uses in the future.

### 2. The role of hydrogen

Hydrogen is already largely deployed in specific industries nowadays. However, according to IRENA (2020b), 96% of all hydrogen is produced from fossil fuels, consisting either of grey hydrogen or blue

[5] Fossil-fuel use is predominant nowadays, accounting for 99.8% of final energy consumption for transportation in LAC (sieLAC-OLADE, 2018b).

[6] Electrification of long-haul trucks is more complicated because of battery weight and energy density. In order to have enough energy density to be used in road freight transportation, batteries would be too heavy for trucks to transport in addition to cargo weight. Green hydrogen and fuel cell vehicles, synthetic fuels (produced by synthetizing $CO_2$ and green hydrogen), and biofuels, however, are options to decarbonize road freight. In aviation and shipping, biofuels and synthetic fuels also are possible decarbonization options (IRENA, 2020c). See section I.C.2 for more details.

hydrogen, combined with Carbon Capture and Storage (CCS).[7] Only a small fraction is produced from renewable power through electrolysis, known as green hydrogen.

In the power sector, applications of green hydrogen can create a promising virtuous cycle for renewables-based electricity grids, as it can increase system flexibility, acting as a buffer to non-dispatchable renewable generation. It also can provide a seasonal balancing of renewable generation, since it can be stored in salt caverns and other underground reservoirs (IRENA, 2020b). In Latin America, this option ought to be contrasted with more readily available and less costly options presented by hydropower reservoirs as a regional storage facility and their potential to complement intermittent sources of energy such as wind and solar.

Ultimately, renewables will be key to produce the green hydrogen needed in the so-called 'hard-to decarbonize sectors`. There are several applications to reduce emissions in chemicals, refining, and iron and steel using green hydrogen to replace fossil fuel-based feedstocks and to provide high-temperature heat in industry. In the transportation sector, it can be used heavy freight transport (fuel cell electric vehicles), as well as to produce synthetic fuels for shipping or aviation.

Moreover, there are many opportunities to reuse the existing wide gas infrastructure in some Latin American countries, especially in South America. The transport of hydrogen in existing and refurbished gas pipelines offers a strategy that simultaneously avoids the lock-in of carbon intensity infrastructure and stranding those assets at the same time it accelerates the deployment of renewable energy (IRENA, 2020b).[8]

Costs of producing green hydrogen is falling steadily, both due to the lower cost of electrolysers and cheaper renewable energy needed. IRENA (2020b) estimates that green hydrogen will be competitive with blue hydrogen in the near future, especially in locations with rich renewable energy resources, offering interesting opportunities to some LAC countries.

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7 According to the IPCC's definition: "A process in which a relatively pure stream of carbon dioxide ($CO_2$) from industrial and energy-related sources is separated (captured), conditioned, compressed and transported to a storage location for long-term isolation from the atmosphere. Sometimes referred to as Carbon capture and storage" (IPCC, 2018).

8 According to IRENA (2020), upgrading of pipelines is required when concentrations of hydrogen exceed around 20% of the transported gas.

# II. Contrasting current policies scenarios with NDC-compliance scenarios in Latin American and Caribbean countries with a focus on energy

In this section, the current and planned energy investments in Latin America and the Caribbean (LAC) until 2030 are analysed. Energy planning for this period has been closely influenced by the Paris Agreement. In this landmark document, countries have agreed to limit global temperature increase until the end of the century to well below 2 degrees Celsius above pre-industrial levels, while pursuing efforts to limit it even further, to 1,5 degrees Celsius (UNFCCC, 2015). For such, the emission of greenhouse gases (GHG) that cause global warming ough to be contained through mitigation actions in several sectors, including energy. As of today, all LAC countries have joined the Paris Agreement and submitted their NDCs (WRI, 2019).

Although the NDCs are an important effort, they are not sufficient to attain the Paris Agreement targets (UNEP, 2020). Nevertheless, implementation of the commitments established in the NDCs is an opportunity for LAC countries to accelerate the deployment of renewable energy in the coming decades. In fact, for most countries in the region, the NDCs were drafted in close synergy with the power sector's energy expansion plans (IDB, 2019b).

An analysis conducted by OLADE (2018) estimates the investment needed to implement current energy plans and NDC targets in the power sector. Table 1 shows this information. An analysis from the IFC for LAC also estimates renewable energy investment potential to implement the commitments from NDCs: US$ 232 billion by 2030 for Argentina, Brazil, Colombia, and Mexico, and US$ 200 billion for all the other countries in the region (IFC, 2016). This analysis excludes investments in traditional large hydropower plants.

It should be noted, however, that the scenarios listed in Table 1 still contain investments in fossil fuel power plants. In fact, OLADE estimates that, by 2030, in both the current policies and NDC scenarios, fossil fuels will account for 32% and 28% of installed capacity in LAC, respectively. For the overall energy sector, new investment in fossil fuel technology is also expected, and capacity share for this type of fuel by the end of the period reaches 74% and 65% in the current policies and NDC scenarios, respectively.

**Table 1**
**Total investment cost in electricity generation for the 2015-2030 period**
*(Millions of dollars at 2015 prices)*

| Country | Current policies scenario[a] | "Adjusted" NDC scenario[b] |
|---|---|---|
| Brazil | 156.590 | 259.740 |
| Mexico | 122.252 | 135.212 |
| Central America[§] | 24.479 | 32.852 |
| Andean Subregion[§§] | 117.574 | 151.232 |
| Southern Cone[±] | 114.045 | 121.235 |
| The Caribbean[±±] | 24.971 | 28.661 |
| Latin America and the Caribbean | 559.811 | 782.932 |

Source: Prepared by the author based on OLADE (2018).
[a] Covers announced energy expansion plans. "It is assumed that the commitments made under the Paris Agreement were taken into account (if not entirely at least partially) in the drafting of said plans" (OLADE, 2018, p. 32).
[b] Scenario in which the NDC's economy-wide emission reduction goals were proportionally assigned to the energy and electricity sectors, thus representing a "more ambitious" version announced NDCs for these sectors in some countries. § Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama; §§ Bolivia, Colombia, Ecuador, Peru and Venezuela; ± Argentina, Chile, Paraguay and Uruguay; and ±± Barbados, Cuba, Grenada, Guyana, Haiti, Jamaica, Dominican Republic, Suriname and Trinidad and Tobago.

This fossil fuel infrastructure in LAC could potentially become stranded assets[9]. Mercure and others (2018) predict that stranded fossil fuel assets could amount to losses of up to US$ 4 trillion worldwide until 2050. González-Mahecha and others (2019) estimate that between 10% and 16% of existing fossil-fuelled power plants in the region would need to be stranded . Moreover, if the power plants that are planned for the region are effectively built, the need for stranding assets to meet average carbon budgets from IPCC would range between 52% and 55%. According to the authors, "*Building all planned power plants in LAC would add as much emissions as what all existing plants would emit over 28 years.*" The power sector in LAC currently emits 357 MtCO2 per year. If all planned fossil-fuelled power plants are built, they would commit 6,7 GtCO2 –the equivalent to 46 years of emissions.

Stranded assets not only represent an eventual misapplication of resources but also impose an opportunity cost on renewable investment and intensifies carbon lock-in, which, in turn, contribute to foster further market and policy failures that hinder the development of zero- carbon technologies (for more details, see Unruh, 2000). That is, instead of funding renewable energy projects that are necessary to mitigate climate change, scarce public and private funds are directed towards fossil fuel investment that will become economically obsolete in a few decades.

## A. Impacts of "Big Push for Sustainability" policies under different international scenarios amid the COVID-19 crisis

An analysis conducted by ECLAC (2020b) simulates four scenarios for Latin America and the Caribbean using the E3ME model, the same applied in the IRENA's Global Renewables Outlook assessment. The first scenario is a business-as-usual (BAU) scenario (without COVID), assuming that countries continue to follow a fossil-fuel-intensive development style and do not introduce any further mitigation policies in addition to the ones that are already in place. This scenario is based on the Current Policies Scenario presented in the *World Energy Outlook 2018* published by IEA (2018b). The second scenario (COVID scenario) is constructed by adding exogenous shocks (adverse consumption and investment shocks) to the baseline, representing the impacts of the COVID-19 pandemic.

9 Stranded assets are those that are retired before reaching the end of their useful life because their operation becomes uneconomical. In a context related to climate change, stranded assets are also those whose operation emits greenhouse gases that hinder the attainment of the Paris Agreement global warming targets.

The third scenario (Unconditional Big Push scenario) simulates a recovery from the adverse effects of the COVID-driven crisis that is brought about by policies designed to generate a big push for sustainability and fulfilling the commitments assumed under Nationally Determined Contributions (NDCs) by LAC countries. In this unconditional scenario, only the countries of LAC introduce a recovery package based on policies intended to drive a big push for sustainability.

Finally, in the fourth scenario (Conditional Big Push scenario), the rest of the world also complies with their NDCs commitments and there is support for climate change mitigation in developing economies. LAC countries introduce an expanded recovery package based on policies of the Unconditional Big Push scenario complemented by mitigation measures in the form of reforestation initiatives made possible by financial and technological resources provided by the rest of the world.

In all scenarios (including BAU and COVID), there is and expansion in the trade deficit, which is a reflection of pre-COVID structural stress points in the balance of payments of LAC countries. However, this deficit narrows under the big push scenarios and narrows even further if a global environmental agreement is in place. The smaller increase in the deficit reflects a reduced reliance on fossil fuel imports (fuel imports fall by 28% under the unconditional big push scenario and by 29% under the conditional scenario) and the greater competitiveness of the region's exports.

Big push policies lead to a significant decrease in carbon dioxide (CO2) emissions. Policies and regulations designed to boost the use of electric and hybrid vehicles and raise the biofuel blend requirement contribute to lower emissions from land transport (46,7% in the unconditional big push scenario and 48,1% in the conditional big push scenario by 2030). The expansion of electric vehicles pushes demand for electricity by 12,8% and 12,7% in the unconditional and conditional scenarios, but with minor reflections in power sector's emissions (no more than a 6% increase). This is a result of investment non-conventional renewable sources, which, as of 2030, would be 68,6% and 64,8% higher than the 2019 levels in the two scenarios.

The results from this exercise show that big push policies lead to improvements in a number of different macroeconomic variables. The only exception would be income distribution, which increases by 3,5% in the absence of an international environmental agreement. When there is international cooperation, inequality declines by 0,4%. This result may be explained by the following factors: smaller increases in electricity rates under the conditional scenario thanks to investment in renewable energy in the rest of the world, and lower prices for firewood, coal and other solid fuels as a result of investment in reforestation. These two categories of goods account for a larger share of the consumption basket for lower income households than they do for wealthier ones.

## B. Meeting growing energy demand with clean and sustainable electricity

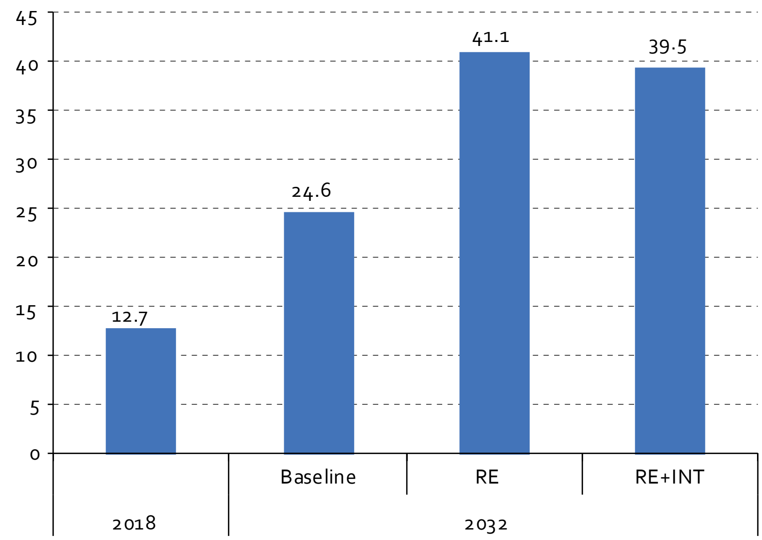
This joint initiative between the ECLAC, the Latin American Energy Organization (OLADE), the International Renewable Energy Agency (IRENA) and the Inter-American Development Bank (IDB) explores different scenarios for renewable energy expansion and grid integration in LAC (see ECLAC, 2020b Chapter 4).

The baseline scenario is comprised from the long-term expansion plans of the region's countries from OLADE (2018), updated to 2017, described in Section II. The second scenario (RE) incorporates a higher proportion of renewable energy (80%, including large-scale hydropower) but keeps the same interconnections as in the baseline scenario. The third scenario (RE+INT) considers a high share of renewables and expanded interconnections.

In the baseline scenario, the regional average of renewable participation reaches 24.6%. Central America contributes expressively to this, with a 50.2% penetration of non-hydro renewable energy in the electricity generation mix by 2032. However, Mexico only attains a 12.5% level mainly due to the low price of shale gas imported from the United States, while in South America the share of non-hydro renewables is over 20% (Figure 7).

In the RE and RE+INT scenarios, NCRE account for nearly 40% of the energy mix in 2032, with a fairly different situation in Mexico (approximately 57% of renewables). In these scenarios, Brazil is below the regional average (30% penetration of renewables in the RE scenario owing to increased use of natural gas and the reforms anticipated in the NG sector).

**Figure 7**
**Level of penetration of renewable sources (excluding large hydropower) in the power matrix between 2018 and 2032**
*(Percentage shares)*




Source: Prepared by the author based on ECLAC (2020b).
Note: Renewables comprise solar, geothermal, mini hydro, biomass and ocean.

The necessary investment in new electricity generating capacity between 2019 and 2032 in the baseline scenario is US$ 852 billion, a figure that falls to US$ 817 billion and US$ 811 billion in the RE and RE+INT scenarios, respectively. In the RE+INT, optimized grid utilization (countries can access the generating surpluses of their partners, instead of building new power plants) contributes to further reducing the total associated costs, annual investments of approximately 1% of the region's GDP from 2019 to 2032. In addition to a less carbon-intensive energy system, investing in a sustainable electricity infrastructure to promote regional interconnection would allow the creation of approximately 7 million new skilled and unskilled jobs in the region by 2030.[10]

The study highlights the importance of promoting and harnessing complementarity initiatives in the regional electricity network, as well as the necessary flexibility to replace synchronous hydrothermal generating with intermittent renewable sources.

## C. The positive impacts of a green recovery on growth and welfare are clear

This section seeks to review the existing literature assessing the nexus between accelerating the shift from fossil fuels to non-conventional renewable energy and its associated social and economic effects. The most relevant recent exercises providing results and insight for Latin America and the Caribbean at the regional level are reviewed.

[10] Considering construction, installation, operation and maintenance for solar, wind and biomass technologies (ECLAC, 2020b).

These studies differ in a variety of aspects, namely the selected methodology (e.g., computable general equilibrium models, macro-econometric models, sectoral models covering energy demand and supply specifically), the underlying premises (e.g., demographic and economic growth, technology costs and learning curves) and regional scope (e.g., whether LAC is a region within a global assessment or a region-specific exercise). Also, some studies are more conservative, while others, such as IRENA (2020a), consider bold and ambitious trends in the energy sectors, like maximum electrification and the use of green hydrogen to decarbonize "hard-to-electrify" sectors. The studies by the World Bank (2017) and ECLAC and others (2020b) present a narrower, regional scope and focus on the benefits of increased renewable energy deployment combined with regional integration. The IRENA study and the country-case study for Brazil (WRI, 2020) go beyond the socio-economic assessment and explore other aspects of welfare related to the energy transition (e.g., health, air pollution, other development benefits). Finally, some of them have been updated following the COVID pandemic and its anticipated effects on mid-to-long term on economic projections, energy prices and overall trends in the energy sector.

While differing in a variety of aspects, these studies also present many common points. In general, the pillars of the energy transition are characterized by increased electrification of end-uses combined with higher renewable energy use and power system flexibility, decentralization and storage management to address intermittence. As mentioned, green hydrogen is often considered a key technology to decarbonize hard-to electrify sectors, even though its role in scenarios up to 2030 is limited.

Another central message derived from the assessed studies is that the energy transition is likely to lead to a net job creation. Renewable technologies are more labour-intensive than fossil fuel-based and nuclear technologies, therefore, at least in the energy sector, one can expect positive gains in job creation in more ambitious scenarios. This nexus will be explored in depth in the next section.

Complementarily to job creation, positive impacts are usually estimated for other economic indicators, such as the GDP and trade balance, revealing that raising ambition on climate action and the shift from carbon-intensive to low-carbon technologies in the energy sector is intrinsically linked to a post-COVID green recovery.

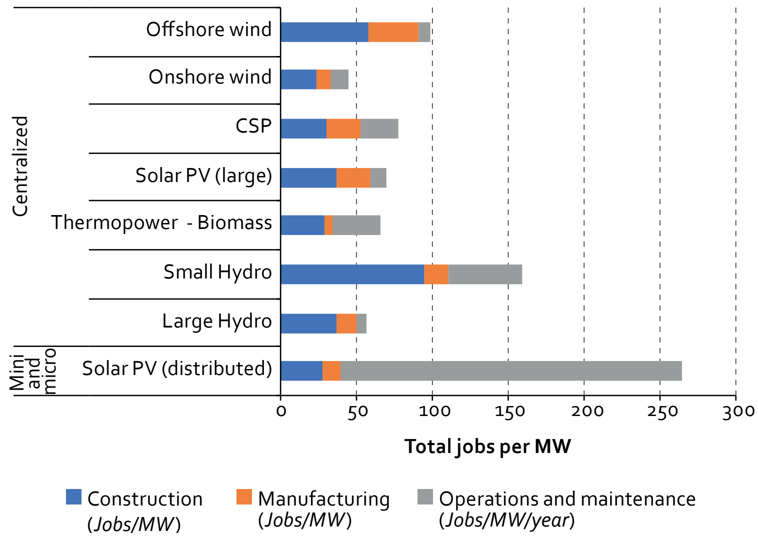
# III. The social and economic impacts of major renewable energy deployment: multiple opportunities in LAC

## A. Renewable energy socioeconomic co-benefits of a post-COVID-19 green economic response in Latin America

Promoting sustainable investments as a response to the economic crisis deepened by the COVID-19 pandemic would allow LAC countries to seize job and income creation opportunities laid by alternative renewable energy sources (Allan and others, 2020; Hepburn and others, 2020; IEA, 2020e). Although the alternative renewables share of total electricity generation remains relatively small, the diffusion trajectory for solar PV and wind power has already proven to be following an exponential curve globally (Grubb, Drummond and Hughes, 2020), as a result of steep cost reductions (Saget, Vogt-Schilb and Luu, 2020). Such technologies are more labour intensive on average than fossil-fuelled power generation, and the referred investment is projected to create new positions at the same pace (Gioutsos and Ochs, 2017; Fragkos and Paroussos, 2018; IRENA, 2019b; Saget, Vogt-Schilb and Luu, 2020). The region is home to more than 1.7 million jobs in the renewable energy sector (direct and indirect jobs). Solar, wind and geothermal together accounted for 175.000 jobs in 2015.

Figure 8 presents the employment factor for renewable energy sources. For comparison purposes, coal and natural gas-fired plants do not create more than seven positions per MW of installed capacity, considering construction, manufacturing, operation and fuel supply (ILO, 2013; Greenpeace, 2016). In as much as renewable energy projects require larger upfront investment compared to fossil fuel technologies (Saget, Vogt-Schilb and Luu, 2020), they prove to be more suitable for an economic crisis response through stimulus. The current section will explore job creation as an effect of alternative renewable energy investment in Latin America, highlighting socioeconomic development opportunities, including throughout the value chain.

**Figure 8**
**Average job creation per MW of installed capacity for selected renewable energy technologies[a]**




Source: Prepared by the author based on ECLAC/CGEE (2020b), IRENA (2019b), IEA (2017), Greenpeace (2016), EPE (2018) and Sooriyaarachchi and others (2015).

[a] Due to the lack of a comprehensive source of estimate covering all renewable energy technologies, the estimates are based on miscellaneous references. EPE (2018) provides employment factors for Brazil for selected technologies; Greenpeace (2016) provides world average employment factors and applies a regional adjustment factor for Brazil for selected technologies; the estimates found in Sooriyaarachchi and others (2015), IEA (2017b) and IRENA (2019b) cover the world average and/or miscellaneous (non-LAC) countries. Sooriyaarachchi and others (2015) point out that the employment factors used in different studies can vary drastically based on the country/region of study, project size and the decomposition of value chain. Figure 8 presents conservative estimates for employment creation. Other sources are Simas and Pacca (2014) for wind, Milani and others (2020) for CSP and Cameron and Van Der Zwaan (2015) for wind, CSP and solar PV.

## 1. Socioeconomic impacts of the energy transition

Socioeconomic impacts of the energy transition occur as a by-product of investment in new infrastructure. The so-called economic multiplier effect means the extent to which increased investment propels economic activity increasing GDP more, or less, than investment itself. In the post-pandemic context, in which stimulus packages through discretionary fiscal policy are being adopted by numerous countries, it is even more relevant to compare the multiplier effect associated with green and brown profiles of economic response, their underlying infrastructure and their subsequent technological lock-in. Renewable energy sources notedly tend to require higher upfront investment than fossil-fuelled thermal power plants, subsequently offset by lower O&M costs, leading to decreased lifetime overall costs (ECLAC/CGEE, 2020b). The deployment of renewables will therefore reveal to mean a higher increased capital investment with potentially more production and jobs along their supply chain (Saget, Vogt-Schilb and Luu, 2020) than an economic recovery reliant on traditional energy technologies investment.

Positive impacts relate to jobs, income and GDP created by increased economic activity as a consequence of investment. Negative impacts relate to socioeconomic losses (GDP, jobs etc.) in polluting sectors, such as coal mines and thermal plants that would have a relatively less relevant role in low-carbon or zero-carbon world. Gross impacts, in this context, are the direct, indirect and induced effects created by the chosen set of technologies for infrastructure expansion, whereas the net impacts also consider the net gains and losses, which can be analysed by building and simulating hypothetical scenarios in which such effects can be captured and quantified.

Direct economic impacts refer to positions created on-site, in this case within the power plant facility and income created by remuneration of its production factors (e.g., wages and rent for land). Indirect jobs, income and output effects occur throughout its value chain. This means, for example, jobs created in industrial sectors providing machine and equipment to power plants, base industry providing raw materials both to such transformation manufacturing and the construction site, and services provided. Induced impacts occur as direct and indirect income is spent, creating additional demand for goods and services across the economy (Milani and others, 2020). The value chain of renewable energy technologies in Latin America, where indirect effects occur, will be explored in section III.B.

### 2. The net socioeconomic impacts of energy transition scenarios

To determine the technological profile of new energy infrastructure investment in post-COVID-19 recovery packages, Latin American countries can draw on available evidence of socioeconomic impacts for alternative energy system scenarios. Various investment opportunities noticeably yield different levels of GDP, income and employment creation. Since many LAC countries are currently net importer of fossil fuels (Kuzemko and others, 2020), the energy transition is also an opportunity to improve the trade balance, helping to alleviate external constraints. Thus, scenarios which provide the most positive impacts can indicate the investments to be prioritized in order to maximize socioeconomic response.

Scenarios developed by IRENA (2019a, 2020e) show net employment and GDP benefits of the energy transition over the reference case, with relevant co-benefits observed for Latin America. When compared to a current policy scenario, IRENA (2020e) concludes that the transition to renewable energy would yield, in 2030, 5,9 million jobs in Latin America, with around 1 million net jobs created. Welfare, in turn, would be 3% higher in 2030 in the energy transition scenario than in the current policy scenario in Brazil, Mexico and the rest of Latin America (IRENA, 2016a). Positive effects on GDP and welfare would peak in 2030, as a consequence of increased investment, which will particularly benefit the rest of Latin America among world regions (IRENA, 2020d).

Notably, Saget and others (2020) analyse the net impacts of decarbonization in Latin America and conclude that, by 2030, positive net job impacts would be achieved through creating low and medium-skilled jobs. High-skilled jobs would have a neutral impact, with job gains in renewable sectors equal to job losses and therefore a net impact equal to zero. In contrast, medium skilled labour would have around a 13 million positions gain, against less than 5 million job loss in 2030, resulting in a nearly 8 million net positive impact. Also, around 6 million low-skilled labour positions would be created, against 2 million positions lost, meaning a 4 million job gain in 2030 (Saget, Vogt-Schilb and Luu, 2020).

Besides, Saget and others (2020) concluded that in a decarbonization scenario, fossil-fuelled electricity generation in LAC would lose 60,000 jobs, while renewable energy would create 100,000 additional jobs in 2030, resulting in a 40,000 net job creation. Looking ahead to the 2050 horizon, IRENA (2018) estimates that an economic stimulus resulting in a share of 65% of renewables in total global energy consumption in 2050 could increase global GDP in US$ 52 trillion between 2018 and 2050. The highest welfare improvements are estimated to take place in Mexico, followed closely by Brazil. Most relevantly, Latin America is among the regions with a positive GDP variation in the IRENA 2050 energy transition scenario, with a variation of over 1.5% in Mexico's GDP, over 1% in Brazil, and nearly 2% in the rest of Latin America. IRENA (2020a) also found positive global net per capita GDP gains in a scenario which is compatible with the Paris Agreement goal to maintain warming "well-below 20C" in comparison with the current policies planned by governments. The result for Latin America would be a US$ 235 per capita increase per year.

Globally, renewable energy jobs would overcompensate the loss in fossil fuel jobs from the reference scenario to the energy transition scenario (IRENA, 2018). The energy transition scenario would yield almost 5 million less jobs than the reference scenario, but REN, in contrast, would yield 11.1 million more positions. In 2050, the energy transition scenario results in 7.4 million less fossil fuel jobs than the reference scenario, whilst REN creates almost 14 million more jobs.

In 2050, Latin America would yield a positive net impact of over 3 million jobs when compared to the reference scenario (IRENA, 2020e). Renewable energy, energy efficiency, power grids and energy flexibility under the energy transition, with renewables accounting for 85% of total energy jobs, according to the World Renewable Energy outlook (IRENA, 2018). Also relevant to notice is that according to IRENA (2020e), Latin America and the Caribbean as the region presents the highest employment intensity of transition-related investments: 30 positions created per US$ invested, almost double the world average.

### (a) Solar

Solar electricity generation can be either PV or CSP, each of which has its own particular socioeconomic co-benefit creation capacity. Solar PV has the advantage of potentially being distributed, with effect over energy access, promoting dynamization of the local economy, boosting micro entrepreneurship and creating construction and installation jobs. Industrial development regarding PV supply chain is more challenging in LAC, since PV cells manufacturing plants have a high upfront investment, require a very large-scale demand to be financially attractive and therefore competition with imported products, particularly from China, tends to undermine investment (SEBRAE, 2017b). Markedly, in Chile, national suppliers for solar PV account for solely 17% of goods and services demanded by projects (Saget, Vogt-Schilb and Luu, 2020).

One should notice, though, that in the case of Brazil, PV modules are assembled and inverters and system balance equipment are produced nationally. Hence, local content can meet a relevant share of projects' demand (SEBRAE, 2017b). Although to date specific PV multipliers have not been calculated for LAC countries, globally, PV is the NCRE technology with the highest employment multipliers for manufacturing (18.8 jobs/MW) and installation (11.2 Jobs/MW) (Cameron and Van Der Zwaan, 2015).

CSP plants, in contrast, are normally large utilities which demand high added-value goods, creating opportunities for regional industrial development (Milani and others, 2020). They also have the advantage of providing firm energy through heat storage and hybridisation with other fuels, particularly biomass (Soria and others, 2015), as opposed to the intermittent profile of solar PV. CSP plants demand iron and steel manufactured goods for the solar field, mirrors for solar collectors, chemical fluids for both the Heat Transfer Fluid (HTF) and the Thermal Energy Storage (TES), as well as power machinery for its thermal electricity generation.

Milani and others (2020) assessed industrial capabilities for the CSP value chain in Brazil and concluded that the existing national industrial sectors have enough idle capacity to produce such components. CSP supply components have a high associated added value. Most of them are complex transformation manufacturing goods from industrial segments such as steel, glass, electronics and machine and equipment. The authors estimated jobs, income and output creation, indicating that during the construction phase, between 48 and 57 jobs could be created per MW installed along the CSP supply chain, depending on how much industrial development took place to supply local content. In the operation phase, 1.64 jobs would be created per MW installed, of which 0.72/MW would be in industrial and service sectors supplying to CSP plants, and 0.21/MW would be created through induced effects.

### (b) Wind

Wind power is the fastest growing renewable energy technology in the world and in LAC (IRENA, 2020a). Its supply chain refers mostly to the production of the aerogenerators for which, subcomponents comprise towers, made of concrete or steel, blades, made of glass and carbon fibers, plastic and other chemicals, motors and electronics (SEBRAE, 2017a).

While the largest wind-farm component manufacturer in the world is the Chinese producer Goldwind, European and American manufacturers such Vestas (second largest), GE and Siemens hold relevant market shares and have installed industrial facilities in countries with growing wind installed capacity such as Brazil (SEBRAE, 2017a; Gramkow, 2020). This causes a notedly positive regional impact of wind power capacity expansion. Component manufacturing industrial facilities not only create jobs themselves, but also demand materials and other subcomponents which will be supplied by local industry, creating numerous indirect jobs.

According to Simas and Pacca (2014), in Brazil, each MW of onshore wind installed capacity creates 14.11 positions, for concrete towers, and 13.53 jobs for steel tower, probably reflecting a lower labour productivity of the concrete sector when compared to steel. Each of the manufactured subcomponents create between 1.19 and 2.74 jobs per MW installed. Site contruction yields 7.32 jobs/MW for steel tower, and 7.82 jobs/MW for concrete tower (Simas and Pacca, 2014).

#### (c) Biomass

Solid biomass for cogeneration and thermal electricity generation is widely used in LAC. This source accounted for over 5% of total electricity generation in Chile and 9% in Brazil in 2019 (IEA, 2020a). IRENA (2020e) estimated that in 2050, under the Energy Transformation scenario, biomass sector jobs would account for a share as high as 60% of total REN jobs in the region. An important advantage of solid biomass electricity is that its plant components are mostly the same as traditional thermoelectric utilities' (ABDI, 2012). Therefore, countries where components such as boilers, steam turbines and motors are already produced nationally can provide a high local content for biomass plants, yielding larger socioeconomic co-benefits along plants' supply chain. In the case of Brazil, the widespread use of sugar cane bagasse cogeneration has led to the development of a national component industry which currently provides 100% of biomass-fired thermal plants' content (Soria and others, 2015).

Mexico and Brazil are the LAC country cases where renewables' supply chains are most considerably developed, according to the existing literature.

## B. Just transition, regional opportunities and gender issues

While renewable energy is more labour intensive and promotes larger upfront stimulus than fossil-fuelled technologies, a just transition ough to account for jobs lost in such industries and provide alternatives for workers. In LAC, Solano-Rodrigues and others (2019) estimated that 1.50C target-consistent pathways would strand between 50% and 70% of oil reserves by 2035, reducing fiscal receipts by up to US$6 trillion and therefore risking jobs (Solano-Rodrigues and others, 2019; Saget, Vogt-Schilb and Luu, 2020).

Phasing-out coal power plants is crucial for attaining long-term climate targets but can negatively impact entire communities that are economically reliant on coal mining and coal-fired power-plants in Chile, for example (Saget, Vogt-Schilb and Luu, 2020). Vogt-Schilb and Feng (2019) estimated that Chile's plan to phase-down coal use for electricity generation would suppress between 400 and 4,000 jobs by 2030. However, renewable electricity installed to replace coal plants would create 2,000 to 8,000 net jobs in the same case. The complexity of the challenge resides in the fact that such jobs will most probably be located in different areas and will not replace jobs lost in the same communities. Clearly, solar and wind largest resource potentials are not necessarily concentrated in the same areas as coal mines and thermal plants. Besides, in general, coal-related jobs yield higher income than renewable energy jobs and are associated with a different set of skills (Saget, Vogt-Schilb and Luu, 2020). Thus, large electricity generation companies could provide training to avoid redundancies, allowing their workers to adapt to alternative technologies.

Noticeably, regions with arid and semiarid climates present higher solar irradiation, which increases their potential for solar energy generation, at the same time as they undergo low water availability and agricultural potential and are more vulnerable to climate change impacts (Magrin and others, 2014). In such cases, renewable energy investment poses an even greater opportunity for socioeconomic co-benefit creation (Gazzo and others, 2011; Milani and others, 2020).

In this sense, cooperatives are seen as a solution for social organisation seeking to maximise solar and other distributed generation socioeconomic effects. Renewable energy cooperatives can act in installing and maintaining solar systems, as well as helping local micro entrepreneurs to access clean and affordable energy, promoting local development and potentially creating jobs. An example of this are solar PV cooperatives in Argentina (Saget, Vogt-Schilb and Luu, 2020).

Distributed wind and solar PV generation are key to promote the universalization of electricity access in isolated and least developed areas, helping to tackle energy poverty, enhancing living conditions and labour productivity. This also has a positive impact on empowering local micro-entrepreneurs (Saget, Vogt-Schilb and Luu, 2020). Several countries in LAC have implemented programmes to promote clean energy access in isolated, underserved areas. For example, the National Photovoltaic Household

Electrification Program in Peru, the National Program for Sustainable Electrification and Renewable Energy in Nicaragua, the Hinterland Renewable Energy project in Guyana, the Isolated Communities Electrification project in Mexico (Saget, Vogt-Schilb and Luu, 2020) and the Light for All programme in Brazil.

Alternative renewable energy also has the potential to transform the power sector into a more gender-balanced activity worldwide. IRENA (2019b) estimated that women represent 32% of the renewable energy workforce, while merely 22% of the oil and gas industry workforce is female. Boosting micro, small, and medium-sized enterprises (MSMEs) with clean, affordable energy access is another suitable means of increasing female employment. According to ILO (2017), 35% of small enterprises full-time positions in LAC are filled by women, while in medium enterprises they are 30% and in large enterprises they are solely 26%. Arguably, MSMEs are twice as likely to have women as their top managers as large companies in LAC (ILO, 2017).

# IV. Improving the regulatory environment and public policy framework to foster non-conventional renewable energy in Latin America and the Caribbean

## A. Adapting regulation and governance to a changing energy system

The way electricity is produced, transmitted and consumed is rapidly changing thanks to two driving forces: the transformation of consumer behaviour made possible by digitalization, and the transformation of electricity generation through decentralization. They are combined with other trends in the energy sector, namely the need to overcome variability constraints with cost-effective solutions such as storage technologies, demand response mechanisms, and investments in the interconnection of transmission networks (IDB, 2020).

Digitalization is enabled by innovations in information and communication technologies (ICT) that allow demand responses to change in electricity prices and other market conditions. The decentralization of electricity production results from rapidly decreasing costs of small-scale power generation, namely solar photovoltaic and batteries for energy storage.

The possibility of generating power from non-conventional renewables at a very small scale and storing it in batteries, coupled with improved possibilities to manage own usage profile is turning consumers from passive to fully responsive “prosumers”, that is, actors that both consume and produce electricity.

A more dynamic and competitive industry is emerging, and regulators need to prepare institutions and frameworks for a rapid transformation. The challenges ahead range from redesigning network services, tariffs that ensure cost recovery and affordability under new circumstances, the integration of other services such as electric mobility and promoting access to finance and risk mitigation (ECLAC, 2020b).

This section provides an overview of the current policies and regulatory frameworks in LAC countries designed to foster the energy transition. It also identifies the main limitations and discusses the necessary improvements in such frameworks to adapt markets to the trends described above, with a special focus on NCRE and electric vehicles.

## B. Policy and regulation landscape for non-conventional renewables in Latin America and the Caribbean

Renewable energy laws and policies provide a tangible framework and enabling conditions for the development of renewable energy. They can be of different natures, ranging from regulatory policies, fiscal or financial incentives and programmes or related to technical aspects (e.g., systems operation and technological development). They can also be integrated into other major development policies, such as housing and rural development.

According to a survey conducted by (IRENA, 2016b), as of 2015, there were at least 120 public institutions working on aspects such as renewable energy policy, regulation, research, innovation, finance, procurement, investment promotion, co-operation, among others. These institutions were designated to act in aspects as diverse as: policymaking and implementation; sectoral regulation; planning, advisory and co-ordination; education and training; research and development; energy access; development of technical norms and standards; setting of tariffs, taxes and subsidies; finance; project development; system operators and public energy companies (electricity and oil).

The tables below provide an overview of different renewable energy targets and policies in Latin American and Caribbean countries. We highlight that some of the initiatives mapped may be under development or implemented at the subnational level. For more details, the original sources can be consulted: REN21 (2020) and (IRENA, 2016b). Complementarily, a comprehensive overview of energy policies for Mexico and Brazil can be found in the OECD's "Tracking Clean Energy Progress" platform (IEA, 2020e).

The vast majority of LAC countries have incorporated NCRE in their regulatory framework by establishing renewable energy targets. Many of them explicitly included these in their NDCs. Tendering seems to be the preferred modality for capacity expansion, as opposed to feed-in-tariffs which were largely applied in the past decades but have been replaced by more dynamic schemes. Regarding economic incentives, most countries implemented fiscal rebates to the renewable energy supply chain products and services. However, a carbon tax is still very incipient in the region, with very few countries actively charging emissions. Virtually every country in LAC has at least one mechanism to finance renewable energy (e.g., funds, special credit lines, etc.). Technical aspects such as grid access (e.g., priority dispatch) or the incorporation of renewable energy into policies of different nature (e.g., social housing) have received lesser attention compared to regulatory and economic tools in the policy mix. The majority of these renewable energy laws are not associated with a binding obligation or any specific enforcement mechanisms. According to (IRENA, 2016b), Chile is the only country in Latin America to have established its target as binding by law, with clear penalties for non-compliance and a monitoring and enforcing mechanism through its Law no. 20698 (2013). Therefore, non-conventional renewable energy laws and targets are usually fairly contingent on political momentum and governmental priorities.

**Table 2**
**Renewable energy targets and policies in Latin American and Caribbean countries as of years 2015[a] and 2019[b], regulatory policies**

| | Regulatory Policies | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Renewable energy targets ♦ | Renewable energy in INDC or NDC ♦ | Feed-in tariff/ premium payment ♦ | Electric utility quota obligation or RPS ♦ | Net metering or billing ♦ | Biofuel blend, renewable transport obligation or mandate ♦ | Renewable heat obligation or mandate, heat FiT, fossil fuel ban for heating ♦ | Tradable REC ♦ | Tendering ♦ |
| **High income** | | | | | | | | | |
| Argentina | P | • | • | • | • | • | | | • |
| Antigua and Barbuda | P | • | | | | | | | |
| Bahamas | P | • | | | | | | | |
| Barbados | P | • | | | • | | | | |
| Chile | E , P | • | • | • | • | | | • | • |
| Panama | E | • | • | | • | • | | | • |
| Trinidad and Tobago | P | • | | | | | | | |
| Uruguay | HC | • | | | • | • | • | | • |
| **Upper-middle income** | | | | | | | | | |
| Belize | P | • | | | | | | | • |
| Brazil | E , P | • | | | • | | | | • |
| Colombia | E , P | | | | | | | | • |
| Costa Rica | P | • | • | | • | | | | • |
| Cuba | P | • | | | | | | | |
| Dominican Republic | E , P | | Removed | | • | | | | • |
| Ecuador | | • | • | | | | | | |
| Granada | E , P | • | | | • | | | | |
| Guatemala | E , P | • | | | • | | | | • |
| Guyana | E , P | • | | | | | | | |
| Jamaica | E , P | • | | | • | | | | • |
| Mexico | E , P , HC | | | | • | | | | • |
| Paraguay | P | • | | | | | | | |
| Peru | E , P | • | • | • | • | | | | • |
| Saint Lucia | E , P | • | | | • | | | | |
| Saint Vincent and the Grenadines | P | • | | | • | | | | |
| Suriname | | • | | | • | | | | • |
| Venezuela (Bolivarian Republic of) | P | x | | | | | | | |
| **Lower-middle income** | | | | | | | | | |
| Bolivia (Plurinational State of) | P | • | • | • | • | | | | • |
| El Salvador | | • | | | | | | | • |
| Honduras | E , P | • | • | | • | | | | • |
| Nicaragua | P | • | • | | | | | | |
| **Lower-income** | | | | | | | | | |
| Haiti | E , P | • | | | | | | | |

Source: Prepared by the author based on REN21 (2020) and (IRENA, 2016b).
Note: E - Energy (final or primary); P – Power; HC - Heating or cooling; T – Transport.
[a] ■ From IRENA (2016b), as of 2015. Assessed for the following countries: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, Venezuela.
[b] ♦ From REN21 (2020), as of 2019. Assessed for all countries listed in the table.

**Table 3**
**Renewable energy targets and policies in Latin America and Caribbean countries as of years 2015[a] and 2019[b], fiscal incentives and financing mechanisms**

| | Fiscal Incentives | | | | Finance | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Reductions in sales, energy, $CO_2$, VAT or other taxes ♦ | Investment or production tax credits ♦ | Energy production payment ♦ | Carbon tax ■ | Public investment, loans, grants, capital subsidies or rebates ♦ | Currency Hedging ■ | Dedicated Fund ■ | Eligible Fund ■ | Guarantees ■ | Pre-investment Support ■ | Direct Funding ■ |
| **High income** | | | | | | | | | | | |
| Argentina | • | • | • | | • | • | • | | | • | • |
| Antigua and Barbuda | | | | | | | | | | | |
| Bahamas | | | | | | | | | | | |
| Barbados | • | | | | • | | | | | | |
| Chile | • | • | | • | • | | • | | | • | • |
| Panama | • | • | • | | | • | | | • | | • |
| Trinidad and Tobago | • | • | • | | | | | | | | |
| Uruguay | • | | | | • | • | | • | | | • |
| **Upper-middle income** | | | | | | | | | | | |
| Belize | | | | | | | | | | | |
| Brazil | • | • | | | • | | • | • | | • | • |
| Colombia | • | • | | | • | | • | • | | | |
| Costa Rica | • | | | | | | | | • | • | |
| Cuba | | | | | | | | | | | |
| Dominican Republic | • | • | | | • | | | | | | |
| Ecuador | • | | | | • | • | | • | | • | • |
| Granada | • | | | | | | | | | | |
| Guatemala | • | • | | | | • | | • | • | | |
| Guyana | • | | | | | | | • | | | • |
| Jamaica | • | • | | | | | | | | | |
| Mexico | • | • | | • | • | | • | • | | • | • |
| Paraguay | • | | | | | • | • | | | | |
| Peru | • | | | | • | • | | • | | | • |
| Saint Lucia | • | | | | | | | | | | |
| Saint Vincent and the Grenadines | | | | | | | | | | | |
| Suriname | | | | | | | | | | | |
| Venezuela (Bolivarian Republic of) | | | | | | | | | | • | • |
| **Lower-middle income** | | | | | | | | | | | |
| Bolivia (Plurinational State of) | • | • | • | | • | | | | | • | |
| El Salvador | • | • | • | | • | • | • | • | • | • | |
| Honduras | • | • | | | | • | • | | • | • | |
| Nicaragua | • | • | | | • | • | • | | • | • | • |
| **Lower-income** | | | | | | | | | | | |
| Haiti | | | | | • | | | | | | |

Source: Prepared by the author based on REN21 (2020) and IRENA (2016b).
[a] ■ From IRENA (2016b), as of 2015. Assessed for the following countries: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, Venezuela.
[b] ♦ From REN21 (2020), as of 2019. Assessed for all countries listed in the table.

**Table 4**
**Renewable energy targets and policies in Latin America and Caribbean countries as of years 2015[a] and 2019[b], grid access and other policies**

| | Grid Access | | | | Others | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Transmission Discount / Exemption ■ | Priority / Dedicated Transmission ■ | Preferential Dispatch ■ | Other Grid Benefits ■ | Renewable Energy in Social Housing ■ | Renewable Energy in Rural Access Programmes ■ | Renewable Energy Cookstove Programme ■ | Local Content Requirements ■ | Special Environmental Regulations ■ | Social Requirements ■ |
| **High income** | | | | | | | | | | |
| Argentina | | | | | | • | | | | |
| Antigua and Barbuda | | | | | | | | | | |
| The Bahamas | | | | | | | | | | |
| Barbados | | | | | | | | | | |
| Chile | • | | | • | | | | | | |
| Panama | • | | | | | • | | • | | |
| Trinidad and Tobago | | | | | | | | | | |
| Uruguay | • | | • | • | • | | | • | • | |
| **Upper-middle income** | | | | | | | | | | |
| Belize | | | | | | • | • | | | • |
| Brazil | • | | | | • | • | | • | • | |
| Colombia | | | | • | | • | | | • | • |
| Costa Rica | | | | | | • | | | | |
| Cuba | | | | | | | | | | |
| Dominican Republic | | | | | | | | | | |
| Ecuador | | | • | • | | • | | • | | • |
| Granada | | | | | | | | | | |
| Guatemala | • | | | | | • | • | | | |
| Guyana | | | | | | • | • | | | |
| Jamaica | | | | | | | | | | |
| Mexico | • | • | | • | • | • | | | | • |
| Paraguay | | | | • | | • | | | | |
| Peru | | • | • | • | • | • | | | | |
| Saint Lucia | | | | | | | | | | |
| Saint Vincent and the Grenadines | | | | | | | | | | |
| Suriname | | | | | | • | | | | |
| Venezuela (Bolivarian Republic of) | | | | | • | • | | | | |
| **Lower-middle income** | | | | | | | | | | |
| Bolivia (Plurinational State of) | | | | | | • | | | | |
| El Salvador | | | • | • | | • | | | • | • |
| Honduras | • | • | | • | | | | • | | |
| Nicaragua | | | • | • | | • | • | | • | |
| **Lower-income** | | | | | | | | | | |
| Haiti | | | | | | | | | | |

Source: Prepared by the author based on REN21 (2020) and IRENA (2016b).
[a] ■ From IRENA (2016b), as of 2015. Assessed for the following countries: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, Venezuela.
[b] ♦ From REN21 (2020), as of 2019. Assessed for all countries listed in the table.

## C. Addressing the shortcomings in regulatory frameworks to the penetration of non-conventional renewable energy in Latin America and the Caribbean

IRENA (2016b) identified barriers to renewable energy investment of three different natures: macroeconomic factors, structure and organisation of the energy sector and the high cost of capital. These are discussed in further detail next, especially the aspects related to market design and regulation.

### 1. Macroeconomic factors

Some Latin American countries have persistently high inflation rates, which affect the operational and debt costs of renewable energy projects, especially if contracts are inflation-indexed. Inflation can also entail changes in monetary policy, with consequences to interest rates and debt costs.

Economic growth has also proven volatile. This contributes to increased uncertainty regarding future energy demand levels and the flow of projects necessary to meet them. The weak fiscal position of some countries hinders renewable energy investment as it increases the uncertainty associated with governmental funding capacities. The lack of fiscal austerity usually entails higher country risk premiums, increasing the costs of capital for renewable energy investors.

Volatile currency exchange rates also undermine investors` interest in renewable energy, especially foreign investors`. There is an increased risk of a mismatch when tariff remuneration (e.g., from power purchase agreements) and costs (debt costs, imported components, etc.) are denominated in different currencies. Contracting locally denominated debt contributes to mitigating currency exchange risks, as well as other mechanisms such as currency hedging.

### 2. Structure and organisation of the energy sector and its markets

#### (a) Pricing and market barriers

Prices are the ultimate mechanism through which policymakers can induce the behaviour of different agents interacting in energy markets. A policy mix that is successful on fostering NCRE is one able to send the correct price signals. Yet, a series of distortions in energy markets in LAC are still present. According to a report developed by IRENA (2016a), if environmental and social costs of non-renewable energy production were internalised, renewable sources would prove significantly more competitive, with the costs of doubling the share of renewable energy in the global mix by 2030 being negative.

According to the ECLAC (2020b), the push for renewable sources ough to be accompanied by measures to gradually eliminate fossil fuels from the supply mix (see the box below for an overview of global fossil fuels subsidies) . In this sense, they propose two lines of action:

(i) Gradually incorporate the real social costs into the economic costs of production so that subsidies for fossil fuels can be phased out. This, in turn, would allow a higher price on carbon emissions, acting as a stimulus for investment in renewables. They highlight the importance of social and public transport policies to minimize undesirable distributional impacts.

(ii) Prepare markets to absorb the closure of coal-fired plants. For this, countries ough to proceed with legislative reforms to provide the basis for an emissions trading regime, with emission rights decreasing as coal-fired power plants are withdrawn from the network.

#### (b) Improving the design of electricity auctions: lessons learned from two decades of tenders in Latin America

Along the past decades, as the cost of renewables decreased, support mechanisms moved from direct governmental incentives such as feed-in tariffs towards more dynamic and competitive tools. Long-term power purchase agreements (PPA) granted through auctions procedures have been the preferred option in Latin America and the Caribbean (Lopez Soto and others, 2019; IDB, 2020). Auctions are a cost-effective tool for policymakers because they can ensure the targeted amount of energy at low transaction costs. They also serve as a powerful price-discovery mechanism in the context of plummeting prices for renewable technologies (IRENA, 2016b). Besides, they offer flexibility for the auctioneer to combine design elements to meet deployment and development objectives in a given jurisdiction and ensure greater certainty regarding prices and quantities, since these are determined before the construction of new projects begins (IRENA, 2019c).

Most countries in the region have a combination of different types of auctions (IRENA, 2016b; Lucas and Gómez, 2017; IDB, 2019a). At least ten countries have implemented renewable energy-specific auctions: Argentina, Belize, Brazil, Costa Rica, El Salvador, Guatemala, Mexico, Panama, Peru and Uruguay (Gramkow, Simões and Kreimerman, 2019; IDB, 2019a). Innovative tenders with the potential to foster NCRE include auctioning public land in locations with high potential for solar and wind deployment or specific time blocks, which favour PV projects to win daytime slots against conventional sources, for example (IRENA, 2016b). While outlining the tender design, regulators need to balance the ability to assure the promotion of renewables and tariff competitiveness.

In terms of contractual arrangements, auctions systems usually include pooling mechanisms to collect revenues to remunerate generators. The distribution companies act jointly as the off-takers, resulting in the spreading of payment obligations and mitigated counterparty default risks. This type of arrangement can be found in auction design in Brazil and Panama, for example, and act as a de-risking mechanism for renewable energy projects (IRENA, 2016b).

In addition, auction-derived contracts are often tailored to the particular requirements of variable renewable generators, in order to reduce their exposure to production risks (when delivered energy does not match contractual obligations). For example, in Uruguay, generators can secure 20-year contracts with the state-owned utility National Administration of Power Plants and Electrical Transmissions,[11] which guarantees tariff remuneration and allows the recovery of investments (IRENA, 2016b).

However, such conditions do not apply for contracts negotiated in deregulated environments, usually bilateral agreements between power generators and large, energy-intensive industries. These deregulated consumers often prioritize technologies that fully ensure that the production profile matches their energy demand, that is, with lower variability. Besides, they are often not willing to enter such long-term contracts to avoid locking-in energy prices for a long period (IRENA, 2016b). The expansion of freely-negotiated energy contracts can, therefore, act as an obstacle to new investment in non-conventional renewable energy. Incentive and de-risking mechanisms to mainstream renewable energy deployment for deregulated consumers will be needed as electricity markets in Latin America become increasingly deregulated.

The expansion of transmission infrastructure necessary to integrate new power plants requires sizeable investments and careful planning. Mastropietro and others (2015) point out that the construction of renewable energy facilities is often shorter than that of transmission grids. Bayer and others (2018) show that, in Brazil, a very small share of awarded capacity in auction rounds reach commercial operation within the set-out deadline and that the most severe delays were caused by issues related to the expansion to the transmission grid. Other South American countries in which transmission recently constrained the integration of renewables to the grid include Uruguay, Guatemala and Panama (IRENA, 2016b; Bayer and others, 2018).

Mastropietro and others (2015) provide three general recommendations for efficient transmission grid expansion: (i) widespread application of competitive auctions for the selection of project developers and the determination of remuneration; (ii) the implementation of the "beneficiary-pays" principle, implying that transmission charges also be paid by generators (and they should not be uniform for all

[11] Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE).

the plants since it depends on the network node, this being essential to efficient generation siting); (iii) ex-ante establishment of transmission charges, allowing generation investors to calculate their bid knowing in advance the transmission tariff they will be charged.

#### (c) Closing the gap between optimal and current net-metering policies

In spite of fairly low levels of grid-connected small-scale self-generation, net metering or net billing[12] policies currently exist in 18 countries (see Table 2), including Brazil, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Panama and Uruguay. Declining costs, namely of rooftop solar panels, are expected to foster rapid deployment in jurisdictions with such policies, especially if combined with high electricity retail prices.

A major barrier to distributed electricity and net-metering systems is the opposition of incumbent utilities related to transmission and distribution. They usually raise issues related to rate design, cross-subsidies, income effects, reserve capacity and cost recovery (IRENA, 2016b). Indeed, most prosumers will opt to stay connected to the main grid as a means to cover peak demand, a market for excess power production, and a back-up supply – at least until the cost and performance of battery storage reach satisfactory levels. Prosumers provide benefits to the grid, such as by allowing deferral of upgrades, relieving network congestion and providing other ancillary services. However, the pricing structure of net-metering ough to ensure that users contribute to the fixed cost of the grid from which they benefit.

Moving from retail prices (for monetary compensation) or a proportion of 1 to 1 (for energetic compensation) reduces the financial disbursement of utilities but creates fewer incentives for prosumers. Exemptions related to the network use, system losses and charges may be gradually removed until the distributed energy reaches a significant level of traded energy within a given distributor`s jurisdiction. Most GD advocators that such mechanisms should not be triggered at levels lower than 5%-15% of traded energy (ABSOLAR, 2020).

Other barriers identified to GD penetration are the technical specifications needed to receive the authorization to sell energy directly to the grid (e.g., to ensure that the system is stable, the meter is reliable, and the installation follows technical standards). The fact that net-metering policies are adopted at the household level prevents users from seeking economies of scale or pooling upfront costs. Aggregated users may benefit from sharing operational costs among users or competing in the wholesale market with higher flexibility than individually (Mejdalani and others, 2018).

#### (d) Cost-reflective tariffs

Currently, the preferred price structure of choice for electricity remuneration is an energy charge — that is, the electricity bill depends mostly on the quantity of electricity demanded. Tariffs in a few countries such as Chile, Uruguay, Argentina, Bolivia and Mexico also include a share that is non-dependent on consumption (IDB, 2020). However, the emergence of prosumers and off-grid connections poses a threat to the current network design. The financial stability of energy distributors faces a fair degree of uncertainty resulting from such new services, leading to the need of reshaping the sector in order to ensure sustainability, efficiency, and equity.

Electricity tariffs, as currently designed, create two major distortions that are inconsistent with emerging technologies. First, for every extra unit of electricity demanded, consumers face a price that does not reflect the incremental cost of production - that is, the marginal cost of producing that extra unit, as part of it is associated to fixed costs. This disincentives electricity consumption, hindering the transition to electrification of some end-uses, for example, electric vehicles. Second, consumers are then over-incentivized to produce their own electricity by becoming prosumers even if it is inefficient system-wide. As the number of prosumers increases, charges directed to finance grid expansion and maintenance depress, deteriorating the grid funding capacity (Pardina and Schiro, 2018).

[12] A net-metering policy is described as permit given to utility-connected consumers to offset their consumption by inputting self-generated electricity surplus into the network and generating credits that can be used afterwards (Darghouth, Barbose e Wiser, 2011). These credits can be in the form of energy (net-metering) or monetary (net-billing). The term "net metering" is often used to refer to both schemes.

An even more perverse effect concerns the distributional effect of such transition. The consumers with higher demand are those who face the stronger incentive to become a prosumer, not to mention that they are those who can afford the upfront costs of solar systems (Meeus, Govaerts and Schittekatte, 2020). However, under the traditional scheme, they are the ones who usually pay cross-subsidies for low-income households through higher tariffs. Such cross-subsidies are largely applied throughout Latin America and the Caribbean (e.g., urban vs. rural, industrial vs. residential, high- vs. low-income areas) (Foster and Rana, 2019).

It is clear that the prevailing pricing structure is not consistent with the increased participation of intermittent sources and decentralization of production. According to the IDB (2020), the uncompromising principle for future tariffs is to be cost-reflective. This implies having consumers pay for the marginal cost of supplying electricity, with a smaller share of the tariff structure dependent on actual energy demand. The remaining costs would be covered either by a fixed charge or a capacity charge. Eventual cross-subsidies (social tariffs) would come in the form of a reduction on the fixed element of the tariff. An important feature of cost-reflective tariffs is the differentiation by time and location. Locational price signals and dynamic prices (e.g., hourly pricing schemes) are key to guarantee that final tariffs pass on at least part of the hourly wholesale price variation to consumers.[13]

### (e) Electric vehicle charging infrastructure

Electric vehicles (EVs) growth in the past ten years has been significant. The world EV fleet has grown from 17 thousand units in 2010 to 7,2 million in 2019 (IEA, 2020b). Such development has been fostered by a need to decarbonize transportation, which, in practical terms, translates into a series of incentives to reduce EVs' acquisition costs (purchase subsidies, exemption/reduction of registration fees), improve user experience (access to restricted traffic areas such as bus lanes and congestion zones, parking and toll charges exemption) and promote the deployment of charging infrastructure. Other regulatory measures, such as zero-emission vehicle (ZEV)[14] mandates and $CO_2$ emissions regulation, have also contributed to greater EV uptake. In the coming years, such incentives and regulatory measures, along with bans on internal combustion engine (ICE) vehicles, are expected to foster EV growth even further. Currently, EVs represent less than 1% of all cars in circulation worldwide and, for decarbonization of transportation to happen, this number ough to increase substantially.

In this sense, charging infrastructure deployment is an underlying condition for EV uptake. By the end of 2019, there were 7,3 million EV chargers installed around the world, of which 6,5 million were private light-duty vehicle (LDV) chargers – located at the drivers' residence and that require from 6 to 12 hours to charge the EV battery fully (IEA, 2020b). While most electric vehicles are charged at the driver's residence or workplace, available public chargers are the utmost condition for EV uptake because they reduce range anxiety and are the only option for residences without a dedicated place to charge (i.e., a garage) in demographically dense locations.

Regarding electric buses, there were 513 thousand units worldwide in 2019, mostly located in China (98%) (IEA, 2020b). There were nearly 450 electric buses in South America located in Argentina, Brazil, Chile, Colombia, and Ecuador. Santiago de Chile is home to the region's largest fleet (almost 400 as of 2019), leased from energy company Enel X for a ten–year period.

Investment in electric buses also brings about opportunities for the automotive industry in the region, which in LAC concentrates in Argentina, Brazil, and Mexico. Besides, Argentina, Bolivia and Chile are home to the world's largest lithium reserves, while Chile and Peru also have large reserves of copper — both materials are important for the manufacture of EVs (ECLAC, 2020b).

[13] The main options are time of use pricing, real time pricing, variable peak pricing and critical peak pricing (IDB, 2020).

[14] Zero-emission vehicles (ZEV) are those that do not emit exhaust gases from the onboard source of power (no tailpipe emissions) such as bicycles and battery electric vehicles (BEV). Electric Vehicles (EVs) refer more broadly to BEVs, plug-in hybrids vehicles (PHEV) e and hybrid electric vehicles (HEV).

Demand for buses in LAC is strong: 80% of the population in the region lives in urban areas (ECLAC, 2020b), and 68% of total travel is met by public transportation (Estupiñan and others, 2018; Yañez-Pagans and others, 2018) apud (ECLAC, 2020b). The rate of motorization in LAC is not high compared with developed countries (approximately 200 vehicles per 1.000 inhabitants). Still, it has been growing rapidly in the past years, leading to congestion and other mobility and environmental issues in urban spaces (ECLAC, 2020b). Further development of sustainable public transportation has the potential to ameliorate these issues. Although many electric buses in the region are imported, some manufacturers are already producing vehicles or their components in LAC countries such as Argentina, Brazil, Bolivia, and Mexico. Chile and Mexico have also been working on the conversion of conventional diesel to electric buses (ECLAC, 2020b).

Compared with conventional buses, electric buses also have a lower total cost of ownership (TCO). TCO considers not only the vehicle's acquisition cost, but also distance travelled per year, vehicle lifespan and the costs of maintenance and fuel or energy (ECLAC, 2020b). In a case study for Mexico City, fast-charge electric buses with a ten-year lifespan cost 20% less than diesel buses with Euro V technology[15] (World Bank, 2019) apud (ECLAC, 2020b). A similar result was found for Santiago (ECLAC, 2020b). This way, transitioning to clean mobility has both cost and environmental advantages.

Greater adoption of EVs will cause increased electricity demand that ough to be well managed to guarantee grid stability. In order to induce EV owners to charge outside peak hours (smart charging), dynamic pricing schemes with cheaper tariffs for off-peak electricity demand are a possibility. Its drawbacks are the need for smart metering infrastructure and a reliance on consumer response to price signals. Both shortcomings can be alleviated through an aggregator, a company that bundles the supply of flexible charging capacity. Because these companies ough to guarantee that charging from their customers will not be a threat to the grid, they have an incentive to adequately manage charging demand so that it does not rely on individual behaviour. Moreover, smart metering may not be necessary if other technologies are used, such as software applications that remotely control charging systems.

Besides smart charging, electric vehicles can also become a distributed energy resource (DER) by participating in the demand-side response. EVs' batteries can provide ultra and very short-term flexibility in ancillary services or balance supply and demand in longer-term periods (for instance, EV can be used as battery storage when variable renewable energy is not available). EV owners, however, ough to be adequately compensated for battery decay when providing these services. Table 25 lists the regulatory and market requirements that can contribute to better EV-grid integration.

Greater EV uptake will also impact transportation tax revenues. Governments usually collect transportation taxes from fuel use, vehicle use (registration and/or annual circulation taxes), and road use (e.g., highway tolls, congestion charges). In many countries, EVs are totally or partially exempt from road and vehicle use charges. Therefore, a good practice would be to phase-out such incentives when EVs reach cost parity with conventional vehicles – which will probably occur in the 2020 decade in more mature markets (Europe and China) (BNEF, 2020a).

Fuel use taxes are also relevant for the implementation of carbon taxes. The more EVs are adopted, however, the lower the revenues collected from fuel taxation. A good solution would be to gradually substitute fuel taxes with distance-based charges levied on the distance driven per vehicle, such as tolls. Compared to fuel taxes, they better recover transportation infrastructure costs and internalize air pollution costs because of their location-specific nature. Moreover, they can help counteract the effects of shared mobility services, which potentially increase kilometres driven per vehicle. On the other hand, distance-based charges are not easy to implement in urban environments, but technological progress is expected to reduce such implementation costs. According to the IEA (2019), an approach that "gradually increases taxes on carbon-intensive fuels, combined with the use of distance-based charges to recover infrastructure costs and to reflect the costs of pollution and congestion, can support the long-term transition to zero-emissions mobility while maintaining revenue from transport taxes" (IEA, 2019, p. 195).

[15] Euro V technology refers to engines that ought to comply with certain emission standards stipulated by the European Union: CO2eq – 1000 g/km; NOx – 3,51 g/km; PM10 – 0,10 g/km (CIVITAS, 2013).

**Table 5**
**Grid integration of EVs and regulatory and market requirements**

| EV grid integration levels | Description | Regulatory and market requirements |
|---|---|---|
| Grid-compliant charging | Phase where EVs are connected to the grid for their charging needs, but smart charging is not yet applied. | EVs comply with the local requirements and regulations. The charging power is below the thresholds prescribed by grid operators. |
| Level 1:<br>Controlled charging | The charging power and timing of charging can be shifted remotely by the distribution system operator, charging point operator, EV user, EV or home energy management system. | Dynamic electricity pricing levels are needed to incentivize charging behaviour. |
| Level 2:<br>Aggregated controlled charging | A charging profile is negotiated based on various drivers (monetary drivers or grid constraints), and responses are controlled and bundled by aggregators without direct individual user interaction. | Aggregators need to be authorized as market players. The wholesale, balancing and capacity markets (where applicable) need to be open to incentivize aggregated demand-side resources. |
| Level 3:<br>Bi-directional charging | EVs can also feed electricity back to the grid and home. This allows for the use of EVs as a distributed electricity storage mechanism and enhances the attractiveness for EVs as a frequency response measure. | Pricing of flexibility services needs to exceed the increased cost for the EV owner of bi-directional charging. Bi-directional charging requirements may be included in the standardization of charging stations and EVs. |
| Level 4:<br>Aggregated bi-directional charging | The enhanced flexibility capacities of EVs are managed by aggregators to be able to compete in the flexibility market with larger capacities. | Aggregators need to be allowed as a market player, benefits from bi-directional flexibility should be rewarded through electricity market dynamics. |

Source: Prepared by the author based on IEA (2019).

Fuel use taxes are also relevant for the implementation of carbon taxes. The more EVs are adopted, however, the lower the revenues collected from fuel taxation. A good solution would be to gradually substitute fuel taxes with distance-based charges levied on the distance driven per vehicle, such as tolls. Compared to fuel taxes, they better recover transportation infrastructure costs and internalize air pollution costs because of their location-specific nature. Moreover, they can help counteract the effects of shared mobility services, which potentially increase kilometres driven per vehicle. On the other hand, distance-based charges are not easy to implement in urban environments, but technological progress is expected to reduce such implementation costs. According to the IEA (2019), an approach that "gradually increases taxes on carbon-intensive fuels, combined with the use of distance-based charges to recover infrastructure costs and to reflect the costs of pollution and congestion, can support the long-term transition to zero-emissions mobility while maintaining revenue from transport taxes" (IEA, 2019, p. 195).

In sum, decarbonization of transportation will accelerate electric vehicle uptake in the next decades. Some countries in LAC are already establishing targets for this transition to happen. Currently, EVs' upfront costs are still higher than conventional vehicles (although maintenance costs are lower), but cost parity is expected to be achieved in a few years. Meanwhile, LAC governments can start planning for new transport tax systems, expand public charging infrastructure, and study solutions to promote EV smart charging.

## 3. Access to finance

Barriers to renewable energy finance include the high cost of capital and shortage of financing, reflecting both low diversification of capital sources and limited knowledge of the renewable energy sector. Adequate financing instruments to promote renewable energy projects ough to consider their relatively high upfront capital requirements, long amortisation periods and risk profiles. Tools for unlocking renewable energy investments include enabling policies, capital structures, financial risk mitigation instruments and structured finance mechanisms (IRENA, 2016c).

While the share of public finance on renewable energy is currently limited to 15% globally (IRENA, 2016b), private capital participation tends to concentrate on the most mature markets and the most sizeable economies of the region, which offer higher liquidity and enhanced opportunities for investors to trade assets rapidly without losing value. This is also valid for currency hedging mechanisms, which are available to the larger currencies (e.g., Brazilian real and Mexican peso), but in practice, are costly for currencies traded less frequently (IRENA, 2016b).

Public financial institutions such as the Brazilian BNDES and Mexican NAFIN are the main providers of capital for renewable energy in Latin America, able to leverage private capital. These institutions offer financial instruments that mitigate risks and reduce the risk premiums required by private players (IRENA, 2016b). Nonetheless, according to a survey conducted by IRENA (2016c), they have dedicated only nearly 4% of their total infrastructure risk mitigation issuance to renewable energy.

Small and medium-sized projects (as of most wind and solar plants) are especially susceptible to the limitations discussed above. Their scale often limits access to the most common instruments from development banks. The diversification of financing sources is, therefore, much needed, as well as alternatives such as the bundling of small and medium-scale projects for financing and risk-mitigation purposes (IRENA, 2016b).

## D. In search of the right policy mix

Countries in Latin America and the Caribbean have so far chosen different policy mixes to foster the energy transition within their territories. While there is no-size-fits-all and each nation will have to choose which policies and regulations are consistent their development strategy, one can still identify a common ground through which they navigate. This section sought to identify future trends in energy markets and the behaviour of energy suppliers and consumers. Regulators and policymakers will need to undertake major efforts to adapt their strategies to changes derived from increased electrification of energy services, higher variability of power generation, decentralization and digitalization, among others.

LAC countries undergo a series of structural macroeconomic constraints, such as low competitiveness, unpredictability and fiscal restrictions. While the solution to these barriers is beyond the scope of this report, it is clear that improving the macroeconomic environment is a necessary condition to speed up NCRE deployment. The COVID-induced crisis pushed energy prices to historically low levels, offering a unique opportunity to remove subsidies to fossil fuels and correcting the much-needed price signal in energy markets. This could also open up fiscal space to direct investment in green infrastructure, including of course, renewable energy.

Energy tariffs ough to be adapted to the higher variability of NCRE, as well as to decentralization. The rapid uptake of digital services may act as an ally in the sense that it allows promptly managing both energy supply and demand. This is also valid for the EV charging infrastructure, which is likely to push electricity demand, and will require that the right price signal be sent to users. Finally, net-metering policies in their current state often lead to adverse effects, causing distributional distortions. They are also inconsistent with the current remuneration design of electricity distributors. The decentralization of electricity supply and demand therefore requires a series of adjustments in tariff and tax design.

# V. Harnessing the economic recovery while accelerating the energy transition in Latin America and the Caribbean

The central challenges of economic policy in the post-pandemic are the construction of welfare states, the strengthening of productive development and the implementation of policies to promote environmental sustainability. In this sense, austerity policies are not the adequate response to address the fiscal and monetary challenges faced. Expansionary fiscal and monetary policies are needed (ECLAC, 2020c).

Indeed, Latin America and the Caribbean have witnessed unprecedented government financial policies in response to COVID-19. During the first months of the pandemic, governments have rightly put people's needs first by focusing on measures such as securing employment and income (e.g., cash transfers to workers and households, furloughs, etc.) and supplying liquidity to businesses across economies (Vivid Economics, 2020).

As the world overcomes the pandemic, spending can hopefully shift from the rescue typology to recovery measures (see Hepburn and others (2020) for such a distinction). This is arguably a historic opportunity to drive sustainable energy transitions and setting the global economy on a pathway towards net-zero emissions while delivering positive societal outcomes such as jobs, green growth and equity (Hepburn and others, 2020; IRENA, 2020e; Kuzemko and others, 2020; OECD, 2020; Vivid Economics, 2020). Considering that we are only one or two cycles of investment away from 2050, this is a timely and decisive issue regarding the window of opportunity to meet NDC goals in the medium-term and mid-century goals recently announced by several countries under the scope of the UNFCCC.

## A. A roadmap for addressing the climate and post COVID-19 economic crises

According to the Energy Policy Tracker (2020), since the beginning of the COVID-19 pandemic in early 2020, governments in selected countries in Latin America have committed at least US$ 9.34 billion to supporting the energy sector through new or amended policies. As of November 2020, such monetary, fiscal and other policies included:

- At least US$ 4.32 billion for unconditional fossil fuels through 33 policies (7 quantified and 26 unquantified)[16]
- Some public money committed for conditional fossil fuels (3 policies with the value of public money unquantified)[17]
- At least US$ 1.68 billion for unconditional clean energy through 17 policies (10 quantified and 7 unquantified)[18]
- At least US$ 19.27 million for conditional clean energy through 1 policy (1 quantified)[19]
- At least US$ 3.32 billion for other energy through 17 policies (8 quantified and 9 unquantified)[20]

Recovery packages will seek to stabilise expectations, restore confidence and channel surplus desired saving into productive investment (Hepburn and others, 2020). In this sense, it is often advocated that green stimulus policies have advantages over traditional fiscal stimulus (Hepburn and others, 2020; Kuzemko and others, 2020). Renewables generate more jobs in the short-term during the construction phase (when jobs are scarce in the middle of a recession), boosting the economy through its high multiplier. In the long run, they conveniently require less labour for operation and maintenance, freeing up labour as the economy returns to capacity. Green construction projects (e.g., retrofits and clean energy infrastructure) are usually less susceptible to offshoring to imports, therefore delivering high job and income multipliers (Hepburn and others, 2020).

Table 6 lists a series of interventions that governments in LAC can implement to develop the green economy through sizeable global stimulus packages. Governments can act as direct green energy investors by, for instance, purchasing zero-carbon goods or installing renewable energy technologies in governments buildings. They can also enact economic incentives to reduce renewable energy technologies' costs in face of incumbents' costs.

When providing financial support for companies affected by the crisis, governments may establish emission performance standards to be met to receive support. Greater private sector finance will also be key. De-risking mechanisms and green bonds can be instrumental to leverage the private funds that supports sustainable infrastructure investments.[21]

A consequence of the COVID-19 crisis was the fall in fossil fuel demand and prices, so policy makers can use this opportunity to cautiously remove fossil fuel subsidies. This would free up scarce publics,which could be applied to complement stimulus funding and train the unemployed workforce in green energy jobs.

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[16] Policies are classified as "fossil unconditional" if they support production and consumption of fossil fuels (oil, gas, coal, "grey" hydrogen or fossil fuel-based electricity) without any climate targets or additional pollution reduction requirements.

[17] Policies are classified as "fossil conditional" if they support production or consumption of fossil fuels (oil, gas, coal, "blue" hydrogen or fossil fuel-based electricity) with climate targets or additional pollution reduction requirements. The conditionality includes climate and pollution reduction targets as well as support to measures reducing environmental damage through carbon capture, utilization and storage (CCUS), end-of-the-pipe solutions such as reduction of methane leakages, extractive sites clean-up and other measures.

[18] Policies are classified as "clean unconditional" if they support production or consumption of energy that is both low-carbon and has negligible impacts on the environment if implemented with appropriate safeguards. These policies support energy efficiency and renewable energy coming from naturally replenished resources such as sunlight, wind, small hydropower, rain, tides, and geothermal heat. "Green" hydrogen, active transport (cycling, walking) are also included.

[19] Policies are classified as "clean conditional" ("potentially clean") if they are stated to support the transition away from fossil fuels, but unspecific about the implementation of appropriate environmental safeguards. Examples include: large-hydropower; rail public transport and electric vehicles (electric cars, bicycles, scooters, boats etc) using multiple energy types; smart grids and technologies to better integrate renewables; hydrogen in the case of mixed, but predominantly clean sources; and biofuels, biomass and biogas with a proven minimum negative impact on the environment (e.g. advanced biofuels). According to the Energy Policy Tracker (2020), this specification is important because, without appropriate environmental safeguards, such policies can still have significant impacts. For instance, if powered with coal- or gas-based electricity, EVs can have a significant impact on the environment. Large hydropower has a negligible carbon footprint, but can damage ecosystems. And even "advanced" biofuels can have a significant water footprint.

[20] Policies outside of the two "fossil" and two "clean" buckets, or in both of them, fall in this category. These policies support nuclear energy (including uranium mining), "first generation" biofuels, biomass and biogas (with proven negative impact on the environment), incineration, hydrogen of unspecified origin, and multiple energy types, e.g. intertwined fossil fuels and clean energy (a sizeable group, since many policies benefit both fossil and clean energy across the board).

[21] In Latin America and the Caribbean, green bonds reached roughly $14 billion in 2019 (Global Americans, 2020).

**Table 6**
**Green stimulus interventions available for policymakers**

| Type of intervention | Description | Examples |
|---|---|---|
| Support investments in clean physical infrastructure | Provide funding and direct investments in low-carbon technologies | - Renewable energy assets<br>- Storage (including hydrogen)<br>- Grid modernisation<br>- CCS |
| Green guidelines for government purchasing | Purchasing of low-carbon goods and services | - Purchasing electric vehicles (EVs) for public car fleets<br>- Low carbon government procurement guidelines |
| Economic incentives | Economic incentives that overcome disadvantages to incumbent technologies to accelerate the uptake of low-carbon technologies | - Tax credits for zero-carbon technologies (e.g., EVs, solar panels)<br>- Low-interest loans for retrofitting residential buildings<br>- Provide risk-mitigation instruments (e.g., guarantees) to mobilise private capital<br>- Implement carbon pricing to avoid distorted economic uptake as the pandemic recedes |
| Conditional sector support ("bailouts") | Financial support contingent upon implementing specific environmental improvements such as reduced carbon footprint, enhanced nature-related financial disclosures, and increased supply chain transparency | - Equity or government guarantees for automobile and/or aviation companies pending on emission performance standards implemented in predefined timeframe |
| Fiscal (reform) measures for additional revenue streams | Removal of existing fossil fuel subsidies or introduction of new taxes on fossil fuel use for generation of additional revenue streams | Profit from low oil and gas prices to phase-out fossil fuel subsidies or raise taxes |
| Low-carbon R&D | Accelerate R&D and roll-out of low-carbon technology pilot projects, linking to technologies considered for highest plausible ambition pathways | Funding for pilot projects in:<br>- heavy industry sector (e.g., hydrogen-based steelmaking, energy efficiency technologies in chemicals, cement, and steel)<br>- Transportation (electric vehicles, batteries, hydrogen vehicles, low-carbon fuel alternatives)<br>- Power sector (solar, wind, battery storage)<br>- CCS |
| Scale-up of skill development programs | Investment in education and training to address immediate unemployment from COVID-19 and structural shifts from decarbonisation | - Skill development and vocational training programs in the buildings sector to address need for specific skills for energy efficient retrofits |

Source: Prepared by the author based on Climate Action Tracker (2020b), Hepburn and others (2020), IRENA (2020e) and Vivid Economics (2020).

Table 7 breaks down the initiatives in Table 6 by energy sector. It also lists measures so that a lock-in fossil fuel investment and emissions is avoided. For instance, in energy and electricity supply, policymakers in LAC ough to avoid investments in "shovel-ready" fossil fuel projects. Governments ough to strongly avoid waiving environmental regulations or bailout fossil fuel companies. In land transport, policymakers ough to steer clear of loosening emission standards and providing financial support that is not tied to reduced emissions.

Such actions ough to also be avoided in the industry and buildings sectors. In aviation, it is not advisable to reduce carbon offset charges in tickets sold. In addition, international civil aviation was supposed to reduce emissions through the Carbon Offsetting and Reduction Mechanism for International Aviation (CORSIA) program based on emissions from year 2020. Given that aviation emissions in 2020 will be uncharacteristically low, it has been proposed to use 2019 as baseline year. As a result, ambition for emissions reduction in aviation will be lower than anticipated, but this moment should be used to increase ambition instead.

**Table 7**
**The Do's and Don'ts of the green economic recovery, green stimulus interventions and actions to avoid**

| | |
|---|---|
| **Energy and electricity supply** | DO'S<br>- Direct support for zero-emissions technologies and infrastructure<br>- Fiscal reform on fossil fuel subsidies<br>- Redesign the power market to provide stable long-term signals to renewable power generators while rewarding short-term flexibility<br>- Enhance cross-border electricity trading |
| | DON'TS<br>- Revive plans for 'shovel-ready' fossil fuel power plants<br>- Waive oil and gas industry environmental regulations<br>- Bailout fossil fuel companies without conditions for zero-emission transition |
| **Land-based transport and mobility** | DO'S<br>- Financial incentives for zero-emission vehicles<br>- Direct investments in low-carbon public transport<br>- Adopt ambitious targets and mandates in transport<br>- Promote behavioural changes and curtail non-essential travel.<br>- Adopt urban designs favourable for cyclists and pedestrians |
| | DON'TS<br>- Roll back emission standards for cars<br>- Support to automobile companies without conditions for zero-emissions transition |
| **Aviation** | DO'S<br>- Conditional sector support for aviation industry (e.g., bailout) and accelerated R&D efforts |
| | DON'TS<br>- Roll back regulations and taxes (e.g., ticket taxes)<br>- Recalibrate the Carbon Offsetting and Reduction Mechanism for International Aviation (CORSIA) baseline without substantially improving entire scheme |
| **Industry** | DO'S<br>- Support uptake of efficient appliances, lighting, and digital devices<br>- Low-carbon technology R&D and pilot projects (e.g., steel and cement) |
| | DON'TS<br>- Roll back climate measures and regulation (e.g., industry levy for supporting renewable energy)<br>- Support for industry without conditions for zero-emission transition |
| **Buildings** | DO'S<br>- Support for energy efficient retrofits of existing buildings<br>- Support for accelerated construction of low and zero-energy buildings |
| | DON'TS<br>- Stimulus programs for new buildings without energy efficiency criteria |

Source: Prepared by the author based on Climate Action Tracker (2020a) and IRENA (2020e).

In sum, policymakers in LAC ough to assure that stimulus funding provided to alleviate the COVID-19 crisis is attached to environmental and emission reduction targets. In addition, financial support that encompasses the roll back of current environmental protections ough to be avoided. Finally, the moment requires a scale up of ambition and green investment commitment, not the opposite.

## B. Policies for hydrogen development

Hydrogen is an energy carrier whose consumption does not emit greenhouse gases if produced from renewable electricity (green hydrogen). Therefore, green hydrogen is an option to decarbonize sectors where electrification may not be sufficient or suitable – such as in some industrial applications, heavy-duty transportation, and buildings heating (for more details, see section I.C.1).

Some LAC countries may profit enormously from hydrogen development to develop specific export markets, such as green steel, green chemistry (e.g., ammonia, methanol) and synthetic biofuels, all produced from green hydrogen. As seen in section I.C.2, green hydrogen production costs are expected to decrease in the coming years, contributing to accelerate its adoption. Enactment of national hydrogen strategies is an important initial step to stimulate its further development because clear established targets contribute to predictability for development.

In fact, many countries in LAC are currently preparing strategies or pilot projects to boost hydrogen development (IEA, 2020c). In Argentina, both renewables and natural gas[22] are being considered to produce hydrogen to be used in the transportation sector – in a pilot project, hydrogen will fuel public buses in Buenos Aires (CONICET, 2020; Ministerio de Ciencia Tecnología e Innovación - Argentina, 2020). Colombia is also developing a national hydrogen strategy that contemplates not only the production of green but also blue hydrogen[23] (Ministerio de Minas y Energía - Colombia, 2020).

The national hydrogen strategy in Paraguay aims to use the country's large hydro capacity and electricity surplus to produce green hydrogen (Viceministerio de Minas y Energía - Paraguay, 2020). In Uruguay, October 8 has been established as "Hydrogen Day" to increase awareness and promote the development of this energy carrier, planned for use in heavy transportation (ANCAP, 2019). Green hydrogen is also being pursued to decarbonize transportation in Costa Rica (IPHE, 2020). In Brazil, the forthcoming National Energy Plan 2050, which outlines planning objectives until mid-century (currently under public consultation), provides recommendations for regulatory design for hydrogen development, including considerations about blending hydrogen into natural gas networks (EPE, 2020).

Chile is the only country in LAC that has formally launched a national strategy for green hydrogen (as of December 2020). The country has renewable potential to increase current electricity generation capacity by 70 times. For instance, the Atacama Desert region has the most powerful solar radiation on the planet; and the onshore wind power capacity factor in the Patagonia region exceeds 60%, which is equivalent to offshore wind capacity factors in other countries (Ministerio de Energía - Gobierno de Chile, 2020b).

Chilean green hydrogen is expected to achieve the lowest levelized cost of production in the world by 2030 (Ministerio de Energía - Gobierno de Chile, 2020b), thus placing the country in an advantageous position in the international market. In addition to producing the cheapest hydrogen in the world, Chile plans to be among the top three exporters of green hydrogen by 2040, and to have 5 GW of electrolyser capacity under development by 2025.

Green hydrogen is a clean fuel that will contribute to decarbonization in LAC countries. It is not, however, the only option available at hand to decarbonize hard-to-abate sectors. Carbon Capture and Storage (CCS) is another technology that, like hydrogen, ough to reach significant cost reduction and scale gains in the coming years to be competitive. Biofuels, which are a mature technology in Brazil, are another option to replace fossil fuels in heavy transportation. Given the urgency to mitigate the impacts of climate change, all alternatives ough to be considered. Success will depend on local characteristics, such as resource availability, robust planning and clear commitments.

[22] Hydrogen produced with natural gas is called grey hydrogen.

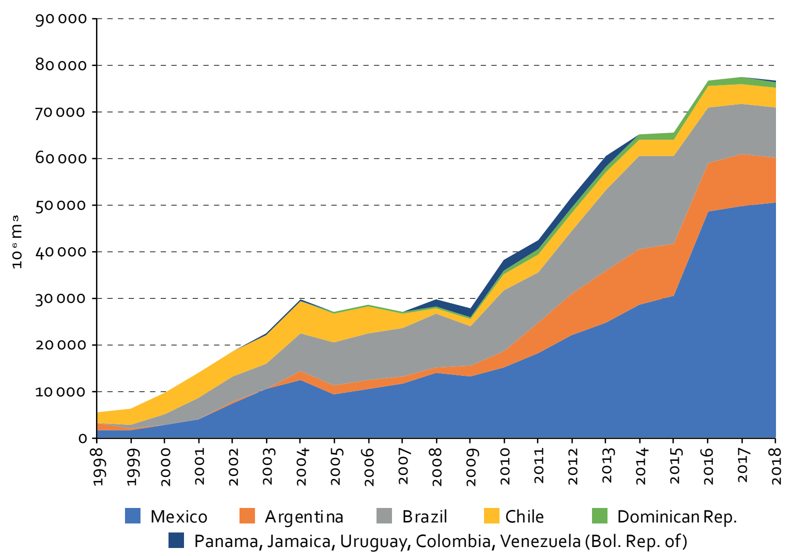
[23] Hydrogen produced with fossil fuels, but whose greenhouse gases emitted during production are captured and stored (CCS: carbon capture and storage).

### 1. Natural gas infrastructure in LAC: a future hydrogen foundation?

Natural gas is an important energy source in Latin America and the Caribbean. In 2018, Mexico, Venezuela, and Argentina were the region's largest producers, accounting for 18%, 16%, and 14% of natural gas extraction, respectively, followed by Trinidad & Tobago (11%), Brazil (10%), Colombia (7%), Bolivia (6%), Peru (6%), and other countries (1%).

As internal production is not sufficient to meet domestic demand in some countries, imports are needed. Figure displays the largest natural gas importers in LAC. As of 2018, the largest exporters in LAC were Bolivia (45%, by pipeline) and Trinidad & Tobago (53%, as liquified natural gas – LNG). Trinidad & Tobago exports LNG to the whole world (17 billion cubic meters in 2019), while Bolivia's main trade partners are Argentina and Brazil (4,9 and 6,4 billion cubic meters in 2019) (BP Statistical Review, 2020). Another important natural gas trade by pipeline takes place between the United States and Mexico, which imported 51 billion cubic meters from the former in 2019 (BP Statistical Review, 2020).

**Figure 9**
**Natural gas imports (LNG and pipeline) in selected Latin America and Caribbean countries between 1998 and 2018**
*($10^6$ $m^3$)*

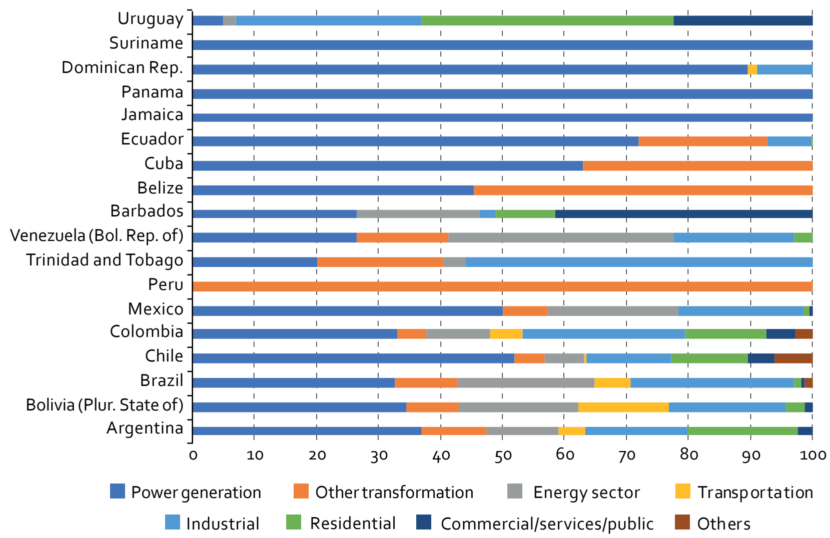



Source: Prepared by the author based on sieLAC-OLADE (2020).

Power generation plants, followed by the industrial sector, are the largest natural gas consumers in the region (Figure 10). In the industrial sector, natural gas is used to produce direct process heat, steam, and as feedstock (to produce methanol, ammonia, and hydrogen). In the iron and steel industry, natural gas is used not only as a source of heat, but also as a chemical reductor instead of coking coal (IEA, 2003). Natural gas consumption in the residential sector is relevant for heating in Argentina and Uruguay and, to a lesser extent, in Chile and Colombia.

Efforts to decarbonize LAC countries by reducing natural gas consumption could focus on power generation, industrial, and residential sectors. For power generation, greater uptake of unconventional renewable sources is a possibility. In industrial processes, natural gas can be replaced by green hydrogen as a reduction agent in iron and steel production. It can also be used to produce ammonia, which results from the combination of hydrogen and nitrogen, and methanol (IRENA, 2020c). For direct natural gas use in the industrial and residential sectors, hydrogen is an interesting option because it can repurpose natural gas infrastructure. In fact, IRENA (2020c) lists three options to decarbonize the natural gas grid:

**Figure 10**
**Natural gas consumption in selected LAC countries in 2018 by sectoral share**
*(Percentages)*




Source: Prepared by the author based on sieLAC-OLADE (2018).

(i) Replacing natural gas with biomethane or synthetic methane. Given the composition of either bio or synthetic methane and natural gas is nearly identical, the existing grid is already suitable to transport these alternative fuels. For this option to materialize, however, costs of green hydrogen production ough to decrease – IRENA reports that "synthetic methane costs are at least three times the price of natural gas for non-household consumers in Europe" (IRENA, 2020c);

(ii) Blending hydrogen into the natural gas grid and extract it downstream through different processes (pressure swing adsorption, membrane separation or electro-chemical separation (IRENA, 2020c)). According to current literature, it is possible to blend from 10% to 50% of hydrogen into existing gas grids without major issues or adjustments in transmission and distribution infrastructure, and in end-use appliances (Melaina, Antonia and Penev, 2013; Qadrdan and others, 2015; Penev and others, 2016; Maroufmashat and Fowler, 2017) apud (IRENA, 2020c);

(iii) Fully replacing natural gas with hydrogen. For such, the transmission grid needs to be retrofitted using hydrogen resistant material, such as plastic (polyethylene). The distribution grid also ough to be replaced by plastic pipes, and appliances that use natural gas need to be replaced or modified, as well as the metering infrastructure.

A sensible approach to replace natural gas with hydrogen would combine the options above. New grid infrastructure can be built with hydrogen-suitable specifications while the retrofitting of older natural gas infrastructure takes place. LAC countries already have more than 60 thousand kilometres of natural gas pipelines in place, which can be retrofitted at lower costs than building new hydrogen transmission and distribution infrastructure.

In sum, the existing natural gas infrastructure in LAC is an asset in the transition to the hydrogen economy. Moreover, similarly to natural gas, hydrogen can be stored seasonally. It can be produced with surplus renewable power. Worldwide, several initiatives are promoting the development and use of hydrogen (IRENA, 2020c). While LAC countries are currently developing roadmaps and strategies, this is the moment to ponder how to repurpose of existing natural gas infrastructure can contribute to the development of the hydrogen economy in the region.

# VI. Concluding remarks

The COVID emergency and the climate emergency undoubtedly share similarities. Both involve market failures, externalities, international cooperation, complex science base, political leadership and require immediate, collective action (Hepburn and others, 2020). As governments mobilise to address the former, their actions will determine whether they deepen or manage the latter. The present report gathered evidence showing that a recovery strategy for the LAC region that is thoroughly designed to include the energy transition can lead to better economic and social outcomes than stimulus policies focusing on the business-as-usual economy.

Chapter I provided an overview of the energy resources endowment and use in Latin American and Caribbean countries, as well as the recent evolution of non-conventional renewable energy in the region. Prospects for renewable energy for the coming decades were presented and discussed at the light of energy markets trends, such as the new uses, decentralization, digitalization, among others. This chapter discussed the role that NCRE can play for the much-needed decarbonization of the economy in the continent, for which electrification will be key. Given the existence of some "hard-to-electrify" sectors, the prospects for green hydrogen were also presented.

Chapter II analysed the energy expansion plans of LAC countries and their NDCs presented to the UNFCCC under the scope of the Paris Agreement, including the most recent updates from December 2020, and potential impacts of green recovery policies.

Chapter III focused on the social and economic effects of energy transition in LAC, with a focus on NCRE expansion. It analysed the potential job creation throughout the supply chains of different renewable technologies in LAC. NCRE offers higher multipliers for job and income creation than traditional fossil fuel-based technologies, including through indirect and induced effects. The evidence provided in this chapter showed the positive net job creation of the energy transition in the region. However, the transition is likely to create winners and losers, so that important aspects ought to be taken into account. These findings highlight the importance of considering locational impacts and the need to provide re-skilling for workers displaced from their jobs (e.g., coal mine workers and technicians from fossil-based plants). The chapter also underlined the synergies between renewable energy deployment and other development goals such as energy access and gender equality.

Chapter IV discussed ways to improve the regulatory environment and public policy framework to foster non-conventional renewable energy in LAC. It identified a series of aspects which will demand regulators and policymakers' attention, in light of increased electrification of energy services, higher variability of power generation due to the expansion of NCRE, decentralization and the emergence of "prosumers", digitalization, among others. In order to provide the right incentives and send the corrected market signals, policymakers ought to deal with removing existing subsidies to fossil fuels, undertake major reforms in electricity markets, namely regarding auctions, net-metering regulation, tariff structure and access to finance.

Finally, Chapter V assessed the stimulus policies current underway in selected LAC countries. The analysis showed that, within the energy sector, fossil fuels still account for a significant share of public resources directed to rescue initiatives in response to the COVID-crisis. As countries slightly shift from rescue to recovery policies, governments will need to prioritise sectors to which investment flows and stimulus will be directed. This decision is also strategic when it comes to private investment, given the public sector's ability to leverage private resources. Chapter V provided a brief series of guidelines to support governments in maximizing the benefits of their stimulus policies. Among the green stimulus options available for policymakers, the following are highlighted: (i) investments in clean physical infrastructure; (ii) green guidelines for government purchasing; (iii) economic incentives (e.g., tax exemptions); (iv) sector support conditional upon environmental improvements; (v) phase-out of fossil fuel subsidies; (vi) low-carbon R&D; and (vii) skill development programs.

In order to address the COVID-driven crisis, governments will need to undertake expansionary policies. There is a unique opportunity to accelerate the energy transition while fulfilling short-term objectives. Compared to fossil technologies, renewables require larger upfront costs and generate more jobs in the short-term during their construction phase, creating immediate jobs. In the medium-to-long terms, renewable plants present lower operational requirements and costs, and freeing up labour to other activities as the economy returns to its normal capacity.

The energy transition from fossil fuels to renewable energy will bring about several changes around the world that will impact not only energy supply and demand, but also the geopolitical stand among countries. For most of LAC, the energy transition is expected to be beneficial given the region's high renewable energy availability. For most states, investing in the low-carbon transition is a win–win strategy that both stimulates economic recovery and reduces the cost of future fossil-fuel imports (Kuzemko and others, 2020), improving trade balance and balance of payments outcomes (ECLAC, 2020b).

For countries that are home to large fossil fuel reserves, usually dependent on oil and gas exports, impacts may differ. Those countries ought to act in a timely manner to diversify their economies, otherwise they risk experiencing even greater losses as their resources become stranded assets (Overland and others, 2019). In fact, addressing the macroeconomic constraints to growth and efficiency and building domestic capabilities are crucial to prevent these issues from halting the transition towards renewable sources of energy, hence the importance of including industrial and technology policies in the recovery package for LAC (ECLAC, 2020b).

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Economic crises are not new, but the way countries respond to and seek to build back from their effects is an ever-evolving process. In the present context, the strategies adopted by Latin American and Caribbean countries to recover from the dramatic impacts of the coronavirus disease (COVID-19) pandemic are marked by an urgent need to also address the climate crisis. This publication examines the synergies and linkages between post-COVID-19 crisis recovery approaches stemming from a sustainable energy transition in Latin America and the Caribbean. The study aims to identify recovery strategies for key sectors and technologies based on policies, institutions, regulations and investments that can represent a big push for more sustainable ways to produce and consume energy and the decarbonization of the economy.

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LC/TS.2022/17