IDB WORKING PAPER SERIES Nº IDB-WP-01310

How Much Will It Cost to Achieve the Climate Goals in Latin America and the Caribbean?

Luis Miguel Galindo
Bridget Hoffman
Adrien Vogt-Schilb

Inter-American Development Bank
Climate Change and Sustainable Development Sector
and Office of Research and Chief Economist

March 2022

How Much Will It Cost to Achieve the Climate Goals in Latin America and the Caribbean?

Luis Miguel Galindo
Bridget Hoffman
Adrien Vogt-Schilb

March 2022

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Galindo Paliza, Luis Miguel.
How much will it cost to achieve the climate goals in Latin America and the Caribbean? / Luis Miguel Galindo Paliza, Bridget Hoffmann, Adrien Vogt-Schilb.
p. cm. — (IDB Working Paper Series; 1310)
Includes bibliographic references.
1. Climate change mitigation-Latin America-Costs. 2. Climate change mitigation-Caribbean Area-Costs. 3. Climatic changes-Government policy-Latin America. 4. Climatic changes-Government policy-Caribbean Area. 5. Environmental policy-Latin America. 6. Environmental policy-Caribbean Area. I. Hoffmann, Bridget. II. Vogt-Schilb, Adrien. III. Inter-American Development Bank. Climate Change Division. IV. Inter-American Development Bank. Department of Research and Chief Economist. V. Title. VI. Series.
IDB-WP-1310

http://www.iadb.org

Correspondence can be sent to gapaliza@unam.mx, bridgeth@iadb.org, or avogtschilb@iadb.org

How Much Will It Cost to Achieve the Climate Goals in Latin America and the Caribbean?

Luis Miguel Galindo, Bridget Hoffman, Adrien Vogt-Schilb

Abstract

Latin America and the Caribbean must respond to the challenge of climate change while making progress with other sustainable development goals. How much will it cost to meet climate change goals in this context? This work reviews the evidence on the costs of meeting the goals the goals of the Paris Agreement and the sources of finance available to do so in the region.

Its main thesis is that climate action does not consist solely or primarily of additional spending, but also requires a massive redirection of existing financial flows. The climate goals cannot be achieved without addressing other sustainable development goals intrinsically related to climate, such as those related to energy, transportation, water, agriculture, and ecosystem conservation, among others. Furthermore, climate action is closely linked to social spending since social conditions such as poverty, inequality, and lack of access to basic health services exacerbate vulnerability to climate change. Finally, the transition to a decarbonized and resilient economy must be fair. A so-called just transition means maximizing socioeconomic benefits, minimizing, or compensating transition costs, and involving all affected parties in decision-making processes. Consequently, climate action is also linked to competitiveness, education levels, labor markets, and social institutions.

We find that responding to the climate crisis requires annual spending on the provision of infrastructure services of between 2% to 8% of GDP and annual spending to address a variety of social challenges of between 5% and 11% of GDP. This will involve aligning in total from 7% to 19% of annual GDP, representing from US$470 billion to US$1,300 billion of infrastructure and social spending in 2030, with sustainable, resilient, and decarbonized development goals. The benefit of this redirection will be far greater than its costs because it will avoid the worst impacts of climate change and generate economic, social, fiscal, and environmental benefits.

Specific financing sources, such as green taxes and sustainable bonds, can finance part of the effort. However, to redirect public and private spending and foreign investment into solutions consistent with climate goals, governments will also need to reform policies and regulations in all sectors. Comprehensive climate strategies can help identify the necessary transformations to move toward a resilient, carbon-neutral economy in the region by 2050. Development banks can directly finance a small part of the necessary spending and support the design and implementation of reforms to redirect existing financial flows.

JEL codes: Q54, H51, H52, H53, H54, H55, H23
Keywords: climate change, costs, spending

Introduction

Latin America and the Caribbean must address the challenge of climate change while responding to the economic and social consequences of the COVID-19 pandemic and making progress with other sustainable development goals. How much will it cost to take on these challenges? This article reviews the existing literature to answer this question. The main finding is that meeting the climate change challenge requires structural transformations in various sectors such as infrastructure, health and social protection systems, and in financial institutions which reflect and enable a wide-ranging redirection, which goes beyond increasing financial flows in the region.

Climate change has significant effects on agricultural and industrial activities, labor productivity, infrastructure, population health, social conflicts, migration, forests and ecosystems, among others (Hallegatte et al, 2015). The impact of climate change will intensify and have increasingly important consequences throughout this century. The variation in average temperature is only part of climate change impacts, but each degree of temperature increase is associated with an estimated reduction of 1% to 4% of Gross Domestic Product (GDP) (Newell, et al., 2021, Acevedo, et al., 2018). Of the few studies of the total monetary costs of climate change, some suggest that inaction could have costs of up to 16% or more of global GDP or GDP of low-income countries or emerging economies with warmer climates (Acevedo, et al., 2018, Burke, et al., 2015).

Faced with costs of serious, though difficult to quantify, impacts, international leaders decided in the 2015 Paris Agreement to adapt to these impacts and contain climate change by limiting the rise in global temperature to between 1.5°C and 2°C, and as close to 1.5ºC as possible to avoid the worst impacts. Meeting these targets requires all countries to transition to a climate-resilient and decarbonized economy by 2050.

The climate plans that countries have presented in their Nationally Determined Contributions (NDCs), which contain country-specific mitigation and adaptation targets, typically for 2030, are still an inadequate basis for planning climate change spending. In general, NDCs are not aligned with resilience and deep decarbonization targets and lack a specific public policy strategy consistent with the proposed targets. To resolve this situation, countries can design climate strategies that start from long-term goals, and identify a roadmap for the investments, economic incentives and regulatory reforms needed across sectors to remove barriers and facilitate the building of a resilient and decarbonized economy by mid-century (IDB and DDPLAC, 2019, Cavallo et al, 2020). Several countries in the world—including Chile, Colombia, Costa Rica and Uruguay in the region—already have strategies to achieve resilient and net-zero emissions economies by 2050 (UNFCCC, 2021).

The region's greenhouse gas (GHG) emissions come largely (94%) from the supply of energy services (including transportation and housing) and food (WRI-CAIT, 2021). The use of fossil fuels for power generation and transportation accounts for almost half of total emissions and these are the two fastest-growing sources of emissions. In the agricultural sector, emissions come mainly from the use of artificial fertilizers and livestock digestion. In addition, agriculture, especially livestock, uses land that competes with forests and other high-carbon systems and is thus the main cause of deforestation, which produces more than one-fifth of the region's GHG emissions. Overall, GHG emissions in the region totaled 6.2 tCO_2e per capita in 2018, which is similar to the global average of 6.5 tCO_2e for the same year, and are increasing (WRI-CAIT, 2021).

A net zero emissions economy is technically possible. Each country will have to design its own path. In general, in the region, the main technical solutions include (IDB and DDPLAC, 2019; Bataille et al, 2020 IPCC, 2018):

- transition to carbon-free sources of electricity generation;
- use of electricity to displace fossil fuels in all sectors;
- electromobility and public and non-motorized transport to reduce use of private transport and fossil fuels;
- improved agricultural practices, including promotion of agroforestry practices, silvopasture systems, and reduced fertilizer use; and
- protection of high-carbon ecosystems, especially forests, and change of consumer diets to reduce pressure on deforestation.

Measures are also needed to reduce emissions from industrial processes and waste management (IDB and DDPLAC, 201). Infrastructure investment should also take advantage of nature-based solutions. For example, mangroves provide a buffer against the effects of rising sea levels or cyclones, and forests provide carbon storage and sequestration. Conversely, destruction of natural capital and ecosystem services has significant economic costs (Cavallo et al, 2020).

Decarbonization offers an economic opportunity equivalent to 1% of GDP for the region—thanks to financial savings in the energy system and transportation, improved health due to less air pollution, productivity improvements from reduced road congestion, and increased ecosystem services—and will create up to 15 million additional net jobs by 2030 (Saget et al, 2020; Vogt-Schilb, 2021). However, various regulatory, financial, social, and political challenges, among others, stand in the way of the transition to a resilient and decarbonized economy.

Climate action is not primarily about designing and implementing additional spending to respond to the challenges of climate change. It also requires a massive redirection of existing financial flows. All countries need to avoid investments that are not consistent with climate goals; for example, exploration and development of new fossil energy sources or building unprotected critical infrastructure in areas with climate risks. Simultaneously, countries need to ensure that financial flows lead to building a new resilient, net-zero emissions economy.

The cost of climate action cannot be considered independently of the cost of meeting other sustainable development goals for three reasons. First, the region needs to expand its provision of infrastructure services—for example, mobility, energy services and access to water and sanitation, and food production—and work to conserve its ecosystems and biodiversity (Cavallo et al 2020, Searchinger et al, 2019). These development goals are directly linked to achieving climate goals.

Moreover, Latin America and the Caribbean is the most unequal region in the world, suffering from high poverty rates, and gaps in access to health, education, or social protection. These gaps and inequality play a decisive role in countries' vulnerability to climate change impacts; consequently, achieving the goal of climate resilience also requires improving the region's social performance (Hallegate et al, 2015, 2017).

Finally, climate action has to be seen in the context of a just transition, that is, in a process that (Saget et al, 2020):

(1) maximizes the socioeconomic benefits of climate action. For example, ensuring that jobs created in the renewable energy industry enjoy decent working conditions and correspond to skills available in the country.
(2) limits or offsets transition costs. For example, by offering new jobs or financial compensation packages to employees of fossil-fuel power plants that close, or by adapting the timing of closure to coincide with employees' retirement.
(3) integrates the people and communities affected by the transition into decision-making processes. This includes, for example, unions and employees of affected industries, sectoral and subnational government agencies, young people, and indigenous communities.

In this respect, the cost of climate action partly overlaps with the cost of education and skills provision, labor protection, and introduction of participatory and inclusive democratic processes.

Building the infrastructure needed to provide basic services and meet climate goals requires annual investments of about 5% of GDP, with a range between 2% and 8% of GDP, until 2030, representing about US$280 billion in 2019 (Serebrisky et al., 2015; Rozenberg and Fay, 2019). In contrast, current annual investment in infrastructure is slightly less than 3% of GDP (about US$170 billion in 2019). Making this infrastructure resilient represents a modest additional cost of 3% to 10% of its cost (0.15% to 0.5% of GDP, or US$8 billion to US$28 billion in 2019). The benefits of resilience in terms of avoided costs of natural disasters and incentive to attract investments are four times higher than its cost (Delgado, et al., 2021). Decarbonization does not add a significant cost to infrastructure spending since, for example, renewable energy and electromobility are already competitive or cheaper than their fossil fuel-based counterparts during their life cycle (IEA, 2021).

The social investment required to build the resilience of the population and promote a just transition involves spending of between 5% and 11% of GDP (US$337 to US$741 billion in 2030). For example, offering a universal cash income to over-65s and under-18s would cost around 5% of GDP (Filgueira and Espíndola, 2015). Addressing the challenge of extreme poverty requires about 6% of GDP, while simultaneously addressing the challenge of extreme poverty, infant mortality and high school completion requires investments of about 11% of GDP by 2030.[1]

In total, the infrastructure and social spending needed to meet climate change goals in the region is between 7% and 19% of GDP by 2030 (US$470 billion to US$1,300 billion in 2030) depending on initial conditions and proposed economic and social targets.

To achieve these amounts, governments will need to ensure that public and private spending and investment, both domestic and international, are consistent with compliance with climate goals. To align public spending, it is essential to incorporate climate change goals, disaster risk reduction, and minimization of the transition risk associated with investment in stranded assets, as priorities in the plans of all relevant sectors, and in the processes of finance or planning ministries responsible for coordinating public spending (Delgado et al, 2021).

[1] Castellani, et al., (2019) estimate the spending needed to simultaneously respond to the challenge of infrastructure and extreme poverty at 10.6% of GDP, rising to 16% after incorporating the challenges of infant mortality and high school completion. We have subtracted 5% which corresponds to our estimate of necessary infrastructure spending to obtain the 6% and 11% in the text.

Green fiscal reforms and the elimination of fossil fuel subsidies could provide up to US$200 billion per year, or approximately 3.6% of GDP in 2019, to governments in the region to support the transition process (Delgado et al, 2021). Governments also need to prepare for the time when the global energy transition erodes the tax base of royalties and excise taxes on gasoline and diesel. This process will put billions in tax revenues at risk between now and 2035 (Solano-Rodriguez et al, 2019; Welsby et al, 2021). A long-term tax strategy will identify ways to replace these revenues.

To align private investment, governments can use regulations and economic incentives, including an appropriate environmental and financial fiscal policy. Instruments such as green bonds and sustainability-linked bonds can also support climate action financing and increase foreign financing (Delgado et al, 2021, Conde and Sanz, 2021).

Development banks can contribute to the necessary financing, although their current size is small compared to the needs. The World Bank, Inter-American Development Bank, and the Andean Development Corporation provide credits of between US$40 billion and US$45 billion (World Bank, 2019; IDB, 2019; CAF, 2019) per year in the region, which contrasts with requirements for building economic and social infrastructure which may amount to between US$340 billion and US$1,100 billion by 2030. Development banks can have a significant impact by providing technical and financial support for the design of climate and financial strategies and regulatory and institutional reform plans to help realign domestic and international flows, both public and private, with climate change and sustainability goals (Delgado et al, 2021; IDB and DDPLAC, 2019).

The rest of the paper is structured as follows. Section 1 highlights the urgency and magnitude of the climate change challenge. Section 2 compiles evidence on the costs of aligning infrastructure spending with climate goals. An appendix describes changes needed in specific sectors and includes a synthesis of the literature review on investment requirements. Section 3 reviews social lags and the spending required to ensure a just transition. Section 4 covers institutional and regulatory reforms needed to align public, private, and international spending with climate goals.

1. The urgency and magnitude of the challenge of climate change

Climate change is a barrier to development

Climate change has significant economic, social and environmental impacts with multiple consequences across all sectors. The negative effects of climate change have an impact on agricultural and industrial activities, on productive infrastructure, population health, labor productivity, poverty, inequality, migration, social conflicts, and biodiversity and ecosystems (IPCC, 2014; Hallegatte et al, 2015).

The impacts of climate change on production are substantial, although difficult to quantify. Recent studies indicate that temperatures above the historical norm affect economic output by 1% to 4% of GDP per degree Celsius of temperature, with more pronounced effects in warm countries and regions and in poor and developing countries (Acevedo et al., 2018; Kahn, et. al., 2019, Newell et al., 2021; Kalkuhl and Wenz, 2020).

However, these estimates do not reflect climate change's total cost and risks. Many climate change impacts are not directly associated with average annual temperature variations. For example, an average increase in global temperature may result in a much steeper increase in temperature at the regional or local level, leading to higher regional costs. Consideration must also be given to the effects of temperatures outside historical variations on economic activities, to tipping points and points of no return in the climate system, and to the presence of reinforcing effects that are cumulative over time. Moreover, the economic impacts of various manifestations of climate change, such as sea level rise or change in precipitation patterns, can cause damage that has not been monetarily valued, as is the case of forests and ecosystems or deterioration and disappearance of an ecosystem. This damage does not necessarily have a direct effect on the economy so it is not captured in these econometric estimates, but it can represent significant impacts in the future.

The total cost of climate change cannot be predicted with precision. However, there are some estimates of the total cost of climate change based on an aggregation of scientific studies and expert opinion which suggest the costs can be very high; for example, 16% of GDP at 3ºC or up to 99% at 12ºC for some regions or for the global economy (Howard and Sterner, 2017, Kahn et al., 2019, Acevedo, et al., 2018).

Some studies quantify the costs of specific climate change impacts. For example, projections for coastal flooding could generate estimated annual losses of approximately US$1 billion in the world's 136 largest coastal cities with sea level rise of 20 cm to 40 cm by 2050 (Hallegatte, 2013) and damage from natural disasters, including extreme weather events in Latin America and the Caribbean, is estimated at US$102.7 billion between 2010 and 2019 (Cavallo, et al., 2020, pp. 160).

Climate change also has social impacts that are not reflected in estimates of its macroeconomic cost. Poorer households and countries tend to be more exposed, more vulnerable and less able to cope with the consequences of climate change, such as natural disasters, water or mosquito-transmitted diseases, heat waves, and higher food prices (Hallegatte et al., 2018, 2019a). For example, heat waves will destroy the equivalent of 2.5 million jobs in the region in 2030, by reducing labor productivity (ILO, 2018). Informal sector workers, such as street vendors and farmers, will be the most affected. Climate change also increases inequality and poverty (Saget et al, 2020). For example, it is estimated that the impacts of climate change on natural disasters, health, and food prices will push between 30 million and 130 million people into extreme poverty globally by 2030, an effect of similar magnitude to the COVID-19 pandemic (Jafino et al., 2020).

Climate change can also impact migration. Falling agricultural yields and water availability and the presence of extreme weather events will have a negative effect on food security and intensify mass migration processes involving around 17 million people in the region, representing 2.6% of the population (Rigoud et al., 2018).

Finally, climate change will increase risks in the financial sector. For example, it will impact countries' credit ratings with a consequent rise in interest rates on sovereign debt (Klusak, et al., 2021).

Countries need to transition to climate-resilient and decarbonized economies by 2050

Climate change impacts will continue for decades irrespective of whether mitigation processes are implemented, in which case countries need to adapt and build resilience in all their productive systems, in their infrastructure, their social protection systems, the financial system, and to preserve their natural assets. The good news is that every dollar invested in making infrastructure more resilient represents four dollars in avoided impacts (Delgado, et al., 2021), which increase the resilience of the economy and improve social protection and health systems, as well as bringing development benefits far outweighing their costs (Hallegatte et al., 2018, 2019).

To contain the increase in global temperature to 1.5ºC, all countries in the world need to reduce their net greenhouse gas (GHG) emissions to near zero by around 2050 (Fay et al, 2015; IPCC, 2018). Achieving net-zero emissions, or decarbonizing the economy, means reducing carbon emissions produced by human activity and offsetting the remaining emissions, for example, by increasing areas of forest cover.

The region's greenhouse gas (GHG) emissions come largely (94%) from provision of energy services (including transport and housing) and food (WRI-CAIT, 2021). Use of fossil fuels for power generation and transportation accounts for almost half of total emissions (44%) in the form of carbon dioxide (CO_2) and covers the two fastest growing sources of emissions: private car transport and natural gas-based electricity generation. In the agricultural sector, emissions come mainly in the form of nitrous oxide (N_2O) from the use of artificial fertilizers, and as methane (CH_4) from livestock digestion. Moreover, agriculture and livestock use land that competes with forests and other high-carbon systems, and is thus the main cause of deforestation, which produces more than a fifth (21%) of GHG emissions in the region (see next paragraph). The rest of the emissions come from waste 6% and industrial processes 4% (WRI-CAIT, 2021).

In a world with finite arable land and growing demand for food over time, deforestation stems from the competition between land use to produce food, biofuels, and other inputs and its use to maintain and recover ecosystems and habitats for biodiversity and carbon sequestration (Searchinger et al., 2019, Svenson et al, 2021). In this context, agriculture is the main cause of deforestation in the world (Searchinger et al, 2019). In this sector, beef production occupies 80% of arable land directly in pasture or indirectly, for example, in soybean crops to feed cattle (ibid.). Latin America and the Caribbean is part of this dynamic, with the world's highest per capita beef consumption (Searchinger et al, 2019).[2] For the same reason, biofuel production from crops is generally not a solution for reducing greenhouse gas emissions considering its impact on land use competition (Searchinger et al, 2019).

Almost all countries in the region have either adhered to the goal of achieving carbon neutrality by 2050 or have declared that they are working toward this goal (Calero et al., 2020). Latin America and the Caribbean can achieve a net-zero emissions economy by 2050. To do so, five types of immediate actions are critical (Fay et al, 2015; IDB and DDPLAC, 2019; Bataille et al, 2020): (i) eliminate fossil fuel-based electricity generation, shifting to carbon-free sources, such as wind, solar, hydro, and geothermal energy; (ii) use electricity instead of fossil fuels in transportation, industry, cooking and heating; (iii) reduce the use of private transportation, increasing the use of public transport, walking, cycling, and teleworking; and (iv) improve agricultural practices, including promoting agroforestry practices, silvopasture systems, and reducing fertilizer use; and (v) halt and reverse the reduction of forest cover and deterioration of ecosystems. In this context, all infrastructure investment and planning must take sustainability objectives into account (Bhattacharya et al, 2019).

Far from being a sacrifice, these transformations can create 15 million net new jobs, and add 1% of economic growth in the region by 2030 (Saget et al, 2020; Cavallo and Powell 2021). IDB studies in Peru

---

[2] The region is an important food exporter. Saget et al (2020) estimate that 15% of GHG emissions from the food system in Latin America and the Caribbean relate to its exports to the rest of the world. In addition, 21% of land used for agriculture and livestock in the region and 19% of emissions from deforestation correspond to exports.

and Costa Rica show that reaching net-zero emissions has a net economic benefit of US$140 billion and US$41 billion respectively by 2050 (Quirós-Tortós et al., 2021, Groves et al., 2020). In Chile, a similar study finds a benefit of 5% of GDP in 2050 (Benavides et al, 2021).

In the land-use sector, adoption of sustainable practices and regenerative agriculture can lead to increased agricultural and livestock productivity, while increased carbon sequestration by forests generates more ecosystem services, such as the supply of non-timber forest products, benefits for water and soil, carbon storage and sequestration, and support for tourism and cultural heritage (Groves et al, 2020; Quiros-Tortos et al, 2021).

In the energy sector, the most important benefit is the low cost of renewable energy sources. In the transportation sector, the economic benefits derived from energy savings, fewer accidents, time saved thanks to reduced vehicle congestion, and a decrease in the negative health effects of air pollution can more than offset the initial costs of switching to electric vehicles and building infrastructure for net-zero-emission public transport. Energy savings in buildings, efficiency gains in industry, and the economic value of recycled materials and treated water also generate benefits (Groves et al, 2020; Quiros-Tortos et al, 2021).

Nationally Determined Contributions (NDCs) are insufficient and need to be reinforced

As part of the Paris Agreement, governments have designed various versions of plans to reduce emissions by 2030, known as Nationally Determined Contributions (NDCs). The first set of NDCs was not aligned with the 2050 decarbonization goals. For example, globally, NDCs, as they existed in 2018, allowed emissions of 52 to 58 GtCO2eq in 2030, instead of the 15 to 30 GtCO2eq needed to meet the 1.5°C target (UNEP, 2018). This was also the case in the region. For example, meeting these NDCs would not increase the percentage of carbon-free electricity sources, rather it would expand the role of natural gas. This is not consistent with the goals of the Paris Agreement and long-term decarbonization and creates a risk by allowing investment in technologies that could become stranded assets during the transition (Gonzalez-Mahecha, et al., 2019, Binsted, et al., 2019).

Likewise, the 2030 targets of the new NDCs are also not aligned with long-term decarbonization (UNEP, 2021). More than 120 parties to the Paris Agreement, including major emitters such as China, the United States, India, and the European Union, have updated their NDCs since the Agreement. Twelve countries in the region have followed suit. However, these have a very limited impact in 2030, reducing projected emissions by only 7.5% compared to previous NDCs, rather than the 30-55% needed to limit warming by 1.5°C -2°C (UNEP, 2021).

The long-term targets announced by countries, if all implemented, could limit the temperature rise to 1.9 °C (Meinshausen et al, 2022). Several countries announced long-term emission reduction targets, typically net zero emissions by 2050[3] in their NDCs or their long-term climate strategies (LTS). If these are implemented, temperature increase could be limited to below 2C. However, in most cases, there are no concrete strategies to implement the announced long-term goals—Costa Rica and Chile in the region are two notable exceptions (CAT, 2021).

Apart from implementing their NDCs as they exist, governments in the region must design and implement climate strategies that will lead to net-zero emissions and a climate-resilient economy by

[3] China's targets of 2060 and 2070, respectively, are important exceptions.

around 2050 (IDB and DDPLAC, 2019). These strategies have to be constructed with the involvement of all sectors of the economy and make the country's development goals consistent with climate goals. To be useful, they must identify the transformations needed in each sector over time, starting immediately, avoiding investments in sectors with high carbon content that involve emissions that are difficult to prevent in the future. This information is essential for updating NDCs and aligning them with long-term resilience and deep decarbonization goals. The long-term strategies are also useful for identifying regulatory, economic, fiscal, or social barriers to decarbonization, anticipating winners and losers, and designing public policy strategies to remove those barriers and ensure a just and inclusive transition (Government of Costa Rica, 2019; Saget et al., 2020, IDB and DDPLAC 2019).

2. Infrastructure to meet climate change goals

Climate targets increase the infrastructure investment gap in the region

Infrastructure investment in Latin America and the Caribbean is insufficient for delivering quality basic services to the population (Cavallo, et al., 2020). Infrastructure investment represented 2.8% of annual GDP on average between 2008 and 2018, approximately US$125 billion per year (Serebrisky, et al, 2020, pp. 40) of which 2.3% corresponds to public investment and 0.5% to private investment (Infralatam, 2021). This level is lower than in other regions of the world (Fay, et al., 2017).

This level of investment leads to deficits in access and quality of services, such as intermittent provision and power cuts, insufficient and low-quality water supply with significant losses, and lack of or poor-quality transport services relative to international averages (Cavallo, et al., 2020, Fay, et al., 2017, Serebrisky, et al., 2018).

The annual investment in infrastructure needed in Latin America and the Caribbean to meet the Sustainable Development Goals, including resilience and decarbonization goals, is around 5% of GDP representing approximately US$279 billion in 2019, with a probable range from 2% to 8% of GDP (Serebrisky and Suárez-Alemán, 2019; Rozenberg and Fay, 2019)[4]. This represented between US$111 billion and US$447 billion annually in 2019.[5] The ranges in estimating the required infrastructure investment are broad since there are several solutions that reach net-zero emissions. The estimates depend on growth and demographic trajectories, technologies, quality, inclusion of maintenance and operating costs, public policies, and incorporation of nature-based options (Rozenberg and Fay, 2019).

Infrastructure investment has to be aligned with climate goals

Incorporating the need for resilience in infrastructure construction has a modest additional cost of between 3% and 10% of the cost of infrastructure (between US$8 billion and US$28 billion in 2019) and can result in benefits 4 times greater than the costs (Cavallo, et. al., 2020).

[4] The following studies reach similar conclusions and estimation ranges: Perrotti and Sanchez, 2011, Kohil and Basil, 2010, Ruiz-Nuñez et. al., 2015, Fay and Yepes, 2003, Fay and Morrison, 2007, CAF, 2011, Serebrisky, 2014, Serebrisky et al., 2015, Serebrisky and Suárez-Alemán, 2019, Serebrisky, et al, 2018, Gaspar, et al., 2019, Schmidt-Traub, 2015, Fay et al., 2017. The study by Cavallo et al., (2020) estimates a range of infrastructure investment between 4% and 7% of GDP for Latin America and the Caribbean.
[5] Estimates use constant dollars at 2010 prices and a scenario with recovery of LAC GDP in 2021 and a 2% average annual growth rate between 2022 and 2030.

Meeting the decarbonization goal of the energy system has a zero, or negative, marginal cost, especially taking into account maintenance and operating costs and the continuous reduction in costs for renewable energy generation (Rozenberg and Fay, 2019). Renewable energy is already the cheapest in the world (IEA, 2021). In many markets, electric vehicles are already cheaper than diesel and gasoline vehicles over their lifetime, thanks to lower operating and maintenance costs and the falling costs of batteries (BNEF, 2018; IEA 2020).

In this context, the average infrastructure investment gap is around 2.2% of GDP (US$123 billion annually in 2019) and is concentrated in the energy and transportation sectors, and to a lesser extent in water and sanitation and telecommunications (Infralatam, 2021, Serebrisky et al., 2018). These sectors are critical for achieving a decarbonized and resilient economy.

Consequently, meeting climate goals requires redirecting the set of infrastructure investments, which take into account the decarbonization and resilience goals from the planning and design stages but does not necessarily require an additional investment. For example, reducing emissions is not about building a natural gas plant, and then spending more to add a filter, rather it requires planning from the outset that the new investment has to be in decarbonized sources, such as renewables. As another example, building a new road further from the coast to avoid flooding due to sea level rise can be much cheaper than building the same road in a flood zone, and then spending more to build protection. Therefore, climate strategies are important for anticipating long-term objectives in government planning and managing risks appropriately. The appendix includes examples of changes needed in each sector.

3. Social spending to ensure a just transition

The transition to net-zero emissions will create winners and losers, with possible negative social impacts if it is not carefully approached. Well-designed long-term climate strategies ensure a just transition. A just transition is defined with three components (Saget et al., 2020; EIB, 2021). First, maximize the economic and social benefits of the transition. Second, anticipate, minimize, and compensate for negative impacts through specific policies and complementary measures. Third, consider and include all climate policy stakeholders through consultation and communication campaigns before implementing the reforms.

Climate policies need to be accompanied by other policies that facilitate relocation and retraining of workers,[6] promote decent work in rural areas, offer new business models, and support displaced workers (Saget et al., 2020). During the transition to a net-zero emissions economy, 7.5 million jobs in the sectors of fossil-fuel electricity generation, fossil fuel extraction, and livestock-based food production could be destroyed in the region by 2030, as a result of controlling the expansion of the agricultural frontier (Saget et al., 2020). However, new employment opportunities will more than offset these losses by creating 22.5 million jobs in agriculture, plant-based food production, renewable energy, forest management, and construction and manufacturing (Saget et. al., 2020).

Supporting affected communities is also important for a just transition (Saget et. al., 2020). For example, closing coal-fired plants in Chile will destroy an estimated 4,000 jobs concentrated in 6 municipalities

[6] So that workers can contribute to a decarbonized economy, either with updated skills in their present sector of activity (e.g. for bus drivers learning to operate electric vehicles), or in another sector, if the sector has to downsize during the transition (e.g. if workers from coal power plants need to find a different job).

(Viteri, 2019). In the most affected communities, about 7% of the population works in a coal-fired power plant. Public investments, for example, that support education and job training or unemployment transfers, can help communities create new employment opportunities.

In this respect, social protection, and compensation strategies are essential for cushioning the social costs of decarbonization. For example, 30% of revenue associated with a carbon price in the region would in principle be sufficient to finance cash transfers to compensate poor and vulnerable households affected by its impact on food, transport, and electricity prices (Vogt-Schilb et. al., 2019).[7]

Moreover, social protection is an efficient measure for reducing the impact of natural disasters on households and in building resilience to climate change impacts (Solórzano and Cárdenes, 2019). For example, cash transfers can be used as an implicit insurance mechanism against the impact of natural disasters, particularly if governments are financially and institutionally ready to process payments quickly after natural disasters (Hallegatte et. al., 2019). The response of governments to the COVID-19 pandemic demonstrates the effectiveness of this approach (Lowe et al 2021).

More generally, poverty, inequality, and lack of access to health services are determinants of countries' vulnerability to climate change impacts (Hallegatte et al, 2015, 2016). For example, one impact of climate change impact to expand the geographical spread of mosquito-borne diseases (such as Zika, yellow fever, or dengue). Access to basic health services is critical for protecting the population against these impacts. Thus, a just transition to a resilient and decarbonized economy means moving ahead with the implementation of purely climate policies simultaneously with provision of quality services, elimination of poverty, improvement of health, and creation of quality jobs based on increased productivity and educational levels.

The required social spending in the region is between 5% and 11%. For example, Filgueira and Espíndola (2015) estimate that about 5.2% of GDP is required to set up a universal cash transfer system for the over-65s and households with children under age 18. This cost can be lowered to 2.8% of GDP if a single benefit is delivered to each household under the poverty line. In their study, Castellani et al. (2019) estimate the spending needed in the region to close the infrastructure gap (see this section) and eliminate extreme poverty and find that spending of 10.6% of GDP would be needed by 2030 (approximately US$715 billion in 2030). Their estimate rises to 16% of GDP in 2030 (US$1,079 billion in 2030) if they also include the reduction of under-5 child mortality and secondary school completion. These estimates give an idea of the order of magnitude of spending required to ensure good performance in health, education, and poverty elimination, which are necessary for building the region's resilience to climate change impacts and facilitating a just transition.

4. Green finance, fiscal policy, and regulations

The financial flows in the region are currently insufficient for meeting the climate goals. Public and private financial flows need to be increased and redirected in a way that is consistent with a resilient, net-zero emissions economy.

---

[7] The study assumes linear impacts of the carbon tax on prices – so the 30% figure is valid for any amount of carbon tax.

Greening public spending

To ensure that public investment is consistent with climate goals, some regulatory and institutional reforms are needed (Delgado et. al., 2021). Governments can develop long-term multisectoral climate strategies aimed at achieving carbon neutrality and climate resilience by 2050, align all sectoral strategies and planning with the climate strategy, and incorporate decarbonization and resilience criteria into public investment and budget systems. Such measures favor greater economic efficiency, reduce the risk of investing in stranded assets, and send a market signal to the private sector about the importance of climate goals.

Managing the impact of natural disasters is an essential part of an adaptation policy (OECD, 2021c; Hallegatte et al, 2017). From the 1970s to the 2010s these events tripled in frequency and their costs for the region rose from US$7.40 billion to US$103 billion (Cavallo, et al., 2020). The average annual frequency per country in the region has risen by more than 50% in recent decades from 0.20 between 1980 and 2000, to 0.30 between 2001 and 2019 (Delgado, et al., 2021). Natural disasters cause damage to infrastructure, such as water and sanitation, roads and bridges, increase school dropout rates, disrupt economic circuits and affect public finances. The occurrence of an extreme weather event is associated with an increase in the fiscal deficit of 0.8-1.1% of GDP. This suggests an annual fiscal impact of extreme weather events in Latin America and the Caribbean from 2001 to 2019 of between 0.2% and 0.3% of GDP (Delgado, et al., 2021).

Efficient risk management requires an integrated approach, including, among others, risk identification, improved building codes, better territorial and watershed planning, analysis of budgetary impact of risk, and financial preparedness, including use of insurance and reinsurance financial instruments (Delgado, et al., 2021; OECD, 2021c). The Index of Governance and Public Policy in Disaster Risk Management (iGOPP), developed by the IDB, provides a quantitative estimate of government preparedness for natural disaster risk along different dimensions. It is estimated that a 1% increase in iGOPP leads to an average 3% reduction in fatalities and up to 6% reduction in economic losses from disasters (Delgado, et al., 2021). The development of a risk management system will reduce the impacts of natural disasters on public finances and contribute to forming a capital market consistent with the Paris Agreements on Climate Change.

Greening fiscal policy

Governments also need to align their tax strategies with climate goals (Delgado, et al., 2021; Cárdenas et al, 2021).

Dependence on fiscal resources derived from hydrocarbon production is a medium-term risk. Between 2013 and 2018, fossil fuel sales accounted for more than 5% of public revenues in Bolivia, Trinidad and Tobago, Ecuador, and Mexico (OECD, 2021a). However, as the global energy transition progresses, demand for the region's oil will decline and revenues will fall. It is estimated that in scenarios that meet the Paris agreement targets, regional oil production will fall 60% by 2035 compared to pre-COVID-19 levels, and about US$3 trillion in tax revenue will be lost in the region (Solano-Rodriguez et al., 2019). Similarly, the role that natural gas plays in the region's economy will be progressively reduced, leaving half the reserves untapped and reducing associated tax revenues by up to 80% (Welsby et al, 2021).

Consequently, hydrocarbon producers must identify the fiscal risks associated with the energy transition and develop a strategy to reduce and manage them (Delgado et. al, 2021). This means reducing or canceling investments that increase reliance on fossil fuels, such as natural gas power plants, and substituting revenues from fossil fuel taxes (e.g., Huxman et al., 2019, 2020).

In other countries, such as Uruguay and Costa Rica, gasoline and diesel excise taxes constitute a significant part of their tax base, 6% and 11% of their resources, respectively (DGI, 2020, MHDA, 2020). Examples of solutions include new or reformed taxes on electricity, vehicle ownership, value added or eliminating some tax exemptions (IEA, 2019; Rodríguez-Zúñiga, 2021).

At the same time, fossil fuel consumption subsidies persist and are counterproductive to a decarbonization process. These subsidies represented US$44 billion in 2017, about 1% of GDP in the average country in the region (Coady et al., 2019, Delgado et al., 2021). Most of these subsidies relate to petroleum-derived fuels. These energy subsidies provide perverse incentives, are costly for public finances, and are highly inefficient and economically ineffective. For example, it costs on average US$12 to transfer $1 to poor households in the region using energy subsidies, but only US$2 to achieve the same result using cash transfers (Feng et. al., 2018). However, reforming subsidies is difficult since reforms can affect poor households and be politically difficult. To facilitate reforms, governments can redirect part of spending on subsidies into social programs (e.g., Fent et al., 2018; Schaffitzel et al., 2019), and, more generally, design compensation policies in a public consultation process with the affected groups (Rentschlet and Bazilian, 2017).

The use of environmental taxes in the region is incipient. Environmental tax revenues in the region represented about 1.2% of GDP in 2019, below the OECD average (OECD, 2021a). For example, carbon pricing is currently applied only in Argentina, Chile, Colombia and Mexico in a range below US$6ton/$CO_2$ (WB, 2021). This provides an incentive of only US$0.01 per liter of gasoline (negligible compared to daily oil price variations), and generated tax revenue of less than 0.1% of GDP in these countries in 2020. This contrasts with international recommendations to apply carbon prices of around $40 and $80 per ton of CO_2 by 2030, or even higher prices to facilitate meeting the Paris Agreement targets (Stiglitz et al, 2017, Stern and Stiglitz, 2021).

Green tax reforms could help provide funds to cover part of the spending needed to achieve climate targets and generate the price signals and economic incentives that contribute to the process of decarbonizing the economy, provided they take into account and offset negative impacts on vulnerable households and businesses (Delgado et al, 2021). By adding savings associated with the elimination of energy subsidies, the revenue associated with a carbon tax (of $40/t$CO_2$), and the revenue associated with other green taxes—such as taxes to internalize the cost of air pollution and vehicle congestion—the region could raise US$224 billion per year (Coady et al. 2019). Thirty percent of these revenues would in principle be sufficient to finance transfers to compensate poor and vulnerable households for their impact on food, transport, and electricity prices (Vogt-Schilb et. al., 2019). These compensation processes are critical to a just transition.

Greening private spending and foreign investment

Redirecting private investment toward climate solutions is also essential. To back deployment of solar and wind power generation, for example, auctions have been very successful. Regulatory reforms are also necessary, for example, related to the use of existing power plants, net metering, or connections to high-voltage power lines. To support electric mobility, effective options include tax schemes that incentivize the purchase of electric vehicles or reforms in bidding processes for bus services (Beltrán et al, 2021). Updating agricultural and livestock practices can be supported by agricultural training services and subsidy reforms. Finally, the use of forests and other ecosystems for carbon sequestration can be supported by payments for environmental services. These regulatory reforms are essential in all sectors to attract private spending and investment. Private investment is also dependent on pricing reforms and structuring subsidies and economic penalties in a way that is consistent with decarbonization.

Achieving climate goals also requires changes in the purpose and dynamics of foreign direct investment (FDI). FDI accounted for 3.2% (US$179 billion) of regional GDP in 2019 (ECLAC, 2020b, pp. 11) but it is not yet fully aligned with climate goals. On the one hand, FDI is contributing to building a low-carbon economy; for example, between 2015 and 2019, 15.5% of FDI was concentrated in renewable energies reaching US$21 billion in 2019. The main countries that made FDI announcements directed to renewable energies were Brazil, Chile, Mexico and Colombia (ECLAC, 2020b, pp. 40). On the other hand, investments in carbon-intensive activities persist. FDI in oil- and coal-derived products represented 38.212 billion dollars of foreign investment in Brazil and Mexico in 2019 (countries that concentrated 92% of the weight of this sector between 2010 and 2019 (ECLAC, 2020b, pp. 33, 34 and 35).

To transform this dynamic and structure of private investment and FDI in the region, it is essential to implement a strategy of regulations and economic incentives, including an appropriate environmental tax and financing policy that discourages investment in activities with high carbon content and promotes new investment with important value chains in the region (Delgado et al, 2021).

Debt is the region's main channel for financing investment (Cavallo et al., 2020). Green bond markets can contribute to financing climate action. For example, global sustainable investment markets were valued at around US$31 billion in 2018 (Delgado, et. al., 2021, pp. 100). Redirection of pension funds, which in the region manage approximately US$3 trillion (Cavallo, et al., 2020), can also contribute. To tap these funds, governments need to develop clear climate spending targets and set up portfolios of sustainable and economically viable investment projects to ensure that flows of resources from green bonds and sustainability-linked bonds are targeted at climate action (Delgado, et al., 2021, Conde and Sanz, 2021).

Increase international green finance and make use of technical cooperation

Current international financing is insufficient to close climate spending gaps and implement the necessary structural transformations in the region's economies.

Financing from multilateral development banks in Latin America and the Caribbean totaled US$40 to US$45 billion annually in 2019. This includes, for example, US$14 billion of annual financing from the World Bank Group (World Bank, 2019), US$16 billion from the Inter-American Development Bank group (IDB, 2019) and US$13 billion from the Andean Development Corporation (CAF, 2019) in 2019.

In the case of the IDB and WB, about 30% of this financing is associated with climate change (IDB, 2020; WB, 2021). In total, international climate finance for Latin America and the Caribbean reached an estimated $35 billion annually on average in 2019 and 2020 (IPC, 2021). These bilateral or multilateral funds were also instrumental in channeling more resources into various projects; for example, for every US$1 of IDB financing, additional resources of US$2.6 were mobilized (Viguri, et al., 2020).

The OECD estimates that climate finance from developed countries to those in the region totaled US$12.4 billion in 2019 (OECD, 2021b). OECD estimates of the amounts lent by multilateral banks are weighted by the donor countries' share in its capital, making it possible to estimate the flows that contribute to meeting developed countries' pledge of $100 billion per year to fight climate change in developing countries. In contrast, the CPI estimates all international finance, even if it is a "south-south" flow.

Conclusion

Addressing climate change requires long-term planning that goes beyond the commitments set out in the current Nationally Determined Contributions. To meet the goals of the Paris Agreement, the countries of the world collectively will need to transition to a resilient, decarbonized economy in the first half of the 21st century. Fortunately, achieving these goals is not technologically or financially insurmountable since it does not require substantially more expenditure. Moreover, the transition will generate economic benefits that are higher than its costs.

Consequently, one challenge is to redirect a large portion of existing financial flows so that they align with the sustainable development goals, including the goals of just transition to a net-zero emissions and resilient economy. We estimate that the total amount of annual infrastructure and social capital spending required in Latin America and the Caribbean by 2030 will be US$472 billion to US$1,281 billion (5% to 19% of GDP). With such an investment, the region would be able to take on the challenges of climate change and set out on the path to sustainable and inclusive growth.

This is a complex and unprecedented task for which the region's governments will need to leverage international cooperation to pilot new technological solutions and finance and coordinate public policies. Development banks can play an important role. The most obvious steps are to ensure that their own financing is aligned with climate goals and to encourage knowledge creation and sharing. But the most transformative step could prove to be leveraging finance by helping governments design and implement comprehensive climate strategies and by supporting the regulatory and institutional reforms needed to ensure that domestic and foreign public and private finance are all aligned with climate goals.

Acknowledgments

This work was funded by the IDB institutional priorities program (BK-C1044). The authors are grateful for comments and feedback from an anonymous reviewer, and from Mariana Alfonso, Raul Delgado, Maricarmen Esquivel, Jaime Fernandez-Baca, Amy Lewis, Hilen Meirovich, Omar Samayoa, Gloria Visconti, and Graham Watkins. English translation by Gabriel Dobson, proofreading by Alejandra Goytia.

Appendix. Examples of necessary climate actions, by sector

This appendix highlights some of the most important transformations to a resilient, net-zero emissions economy, with associated costs where data could be found.

Electricity

Significant progress has been made in coverage and expansion of the electricity grid in the region; however, gaps persist in coverage (mainly in rural areas) and in quality of service reflected in intermittency and power cuts. For example, one indicator of the quality of infrastructure services in the region is situated between 3 and 4 on a scale of 1 (low) to 7 (high) (Serebrisky, et al., 2020).

Nearly half the region's electricity generation comes from hydroelectric power plants and non-conventional renewable energies are growing. Of total electricity produced, 58% is from renewable sources: 45% hydropower, 6% wind, 5% biomass, 1% solar and 1% geothermal (Yépez et. al, 2021). Total renewable energy generation capacity nearly doubled in Central America and increased by 50% in South America between 2010 and 2019 (IRENA, 2020).

However, investments in electricity infrastructure related to use of fossil fuels, particularly natural gas and liquefied petroleum gas, persist (Gonzalez-Mahecha et al., 2019). For example, an inertial scenario suggests that natural gas would still have a 23% share of electricity supply in 2040 (Yépez-García, et al., 2019 and Yépez-García, et al., 2018). These investments are not consistent with the Paris goals and have a high risk of becoming stranded assets during the energy transition (González-Mahecha et al., 2019, Binsted et al., 2020). This investment in high-carbon assets should be redirected to decarbonized sources, and governments should plan for the progressive closure of coal, diesel, and natural gas plants and for the potential technical, economic, and social impacts (Saget et al 2020; Delgado et al, 2021).

To meet the Paris Agreement targets, electricity must be almost completely carbon-free by 2050 (Audoly et al., 2018), which can be achieved by increasing solar, hydro and geothermal generation capacity. This will require taking up the challenge of electricity supply variability by developing flexible and sustainable electricity based on new technologies, such as energy storage systems and digitization, which lead to a decentralized supply (IEA, 2020, Serebrisky, et al., 2020). The good news is that the cost of electricity generation with renewables is already generally lower than the cost of carbon-intensive generation and will become much cheaper in the future (IEA, 2021).

In addition, the electricity generation and distribution system must be made resilient to climate change impacts, which include more frequent natural disasters, changes in precipitation and temperature, and sea level rise (IEA, 2021).

Consequently, electricity use will need to become universal throughout the economy (in transport, buildings, and industry) to reach net-zero emissions, which will require additional investment in electricity generation (IEA, 2021).

A decarbonized electricity generation and distribution system that is resilient to climate change impacts is essential for meeting Sustainable Development Goal 7.1 "ensure access to affordable, reliable, sustainable and modern energy for all," given that renewable energy is the most affordable in the world, and reliability depends on resilience to climate change impacts. Investing in renewable energy and electrification of energy uses achieves Sustainable Development Goal 7.2 "increase substantially the share of renewable energy in the global energy mix by 2030."

In the region, the investment needed to make a decarbonized, resilient, and inclusive electricity sector is estimated at between 0.90% and 3% of GDP (between US$503 billion and US$167 billion in 2019) (Rozenberg and Fay, 2019).

Transportation

Building a sustainable transportation system for people and goods is fundamental for moving to a low-carbon economy, particularly given the high proportion and high dynamics of emissions from this sector. Construction of modern, efficient, and affordable transport has positive effects on labor productivity.

Demand for transport is growing rapidly mainly in urban centers and for movement of goods. Motorization rates in the region increased from 127 to 201 vehicles per thousand inhabitants between 2005 and 2015 and will continue to grow – as a reference the motorization rate in the United States and Canada is 805 per capita (Serebrisky and Suárez-Alemán, 2019, Cavallo, et. al., 2020). In particular, the demand for private transportation in urban areas is increasing. This reflects the migration of low- and middle-income groups from public to private transport due to obsolete, low quality, and unsafe public transport that does not meet the needs of the newly emerging middle classes in the region (Cavallo, et al., 2020).

Private transport creates significant negative externalities, such as congestion and road accidents, local air pollution and greenhouse gas emissions (Coady et al., 2019, Calatayud, 2021). Therefore, responding to the transportation challenge requires decoupling demand for private transport and transport in general from the evolution of gross domestic product. This, in turn, requires development of modern, efficient, and inclusive public transport; infrastructure that facilitates walking and cycling; and urban planning focused on access to centers of employment, commerce, social services and entertainment rather than mobility (OECD, 2021d).

There has been significant recent investment in Bus Rapid Transit Systems (BRT), even so they are still insufficient for providing an adequate, efficient, and quality service in response to rapidly increasing demand. For example, Cavallo, et al., (2020) find that Latin America and the Caribbean has 1,900 km of BRT in 55 cities in 10 countries;[8] however, the time spent on public transport is longer and the distance traveled shorter than in advanced economies. Therefore, there is an urgent need to invest in modern, efficient, and low-carbon public transport infrastructure consistent with mitigation targets.

Structural transformations in transportation for a deep decarbonization process will be particularly important in the coming decades. Achieving net zero emissions requires reducing the share of fossil fuels in total demand from about 90% to less than 75% in 2030 and to 10% in 2050, which means electric cars will have to account for 60% of new sales in 2030 and electric truck sales for 50% in 2035 (IEA, 2021, pp. 20, pp. 70, pp. 89). This should lead to CO_2 emissions reductions in the transport sector of 95% by 2050 (IEA, 2021, pp. 133, IPCC, 2018, pp. 142).

In the region, the required transport infrastructure represents between 0.53% and 3.3% of GDP (around US$29 billion to US$184 billion in 2019), including notably maintenance costs, which can reach up to half the investment (Rozenberg and Fay, 2019). The cost of infrastructure investment changes significantly depending on quality, type of mobility and maintenance costs (Cavallo et al., 2020).

Moreover, policies inconsistent with deep decarbonization goals persist in this sector. For example, countries in the region spend on average 1% of GDP on energy subsidies (Coady et al., 2019). Price reforms, designed to eliminate these subsidies and impose a range of taxes, need to be implemented to combat the negative impacts on households and businesses (Delgado et. al., 2021). These measures must contribute to resolving a complex political economy that stands in the way of implementing a deep decarbonization process. Regulations can also be a barrier to decarbonization. For example, public transport service bidding processes are often incompatible with the use of electric vehicles, and need to be updated accordingly (e.g., Ramirez Cartagena, 2020, World Bank 2020).

[8] Crote, Galarza and Navas (2020) estimate that in 2020 there were about 180 BRTs in the world.

Water and sanitation

Providing access to water and sanitation in adequate conditions and quality has positive effects on the population's health and is fundamental for meeting the SDGs and building resilience to climate change impacts (Hallegate et. al., 2015, 2017). The region is experiencing progress in development of water and sanitation infrastructure; however, gaps in coverage and quality persist, along with service interruptions (Fay et al., 2017). For example, it is estimated that more than 30% of the water distributed is lost in leaks, while treated water accounts for only 30% of the total (Fay, et. al., 2017, Cavallo, et. al, 2020.).

Likewise, water demand for agricultural activities represents about 67% of total water extraction in the region (FAO, 2013). This will increase in the coming years due to the growth of agricultural production and the use of irrigation as an adaptation mechanism to climate change (Seo and Mendelson 2007).

Investment needs in water and sanitation for Latin America and the Caribbean range between 0.32% and 0.65% of GDP, or about US$17 billion to US$36 billion in 2019 (Rozenberg and Fay, 2019). Serebrisky, et al. (2020) estimate that about US$33 billion will need to be invested to treat two-thirds of polluted water by 2030. Costs depend on coverage and quality targets and on maintenance and operating costs, representing between 54% and 58% of total costs (Cavallo, et. al., 2020, Rozemberg and Fay, 2019). In addition, between 0.12% and 0.20% of GDP–US$6 billion to US$11 billion–is required for irrigation (Rozenberg and Fay, 2019).

Water supply and quality are also associated with ecosystems. Forests and other ecosystems contribute to the water regulation cycle, and the process of extraction from surface sources and aquifers can have negative effects on ecosystems and therefore on their capacity to provide regulatory services to ecosystems with negative economic consequences (Cavallo, et al., 2020). These relationships indicate the importance of developing nature-based solutions that have positive economic, social, and environmental effects and are cost effective (Serebrisky et al., 2020).

Waste and circular economy

The economy in Latin America and the Caribbean has a low-level recycling capacity that has negative consequences on the creation of value added and generates negative externalities, such as water, soil and air pollution and contributes 6% of total greenhouse gas emissions in Latin America and the Caribbean.

Waste generation in Latin America and the Caribbean was approximately 541,000 tons/day and is projected to increase to 670,000 tons/day by 2050, while more than 35,000 tons/day are not collected (United Nations Environment Program, 2018). Currently, only 1% to 20% is recycled, while approximately 90% of municipal waste goes to landfills or is burned, about 15% of available food is lost or wasted, and 70% to 80% of wastewater is not treated (United Nations Environment Program, 2018). This contrasts with the high recycling rates of developed countries. For example, 70% of wastewater is treated in rich countries (United Nations Environment Program, 2018). The lack of recycling also results in losses of water, fertilizers, and land use.

Agricultural sector

Agricultural activities face the simultaneous challenge of providing affordable food and inputs for a growing economy and population, while at the same time limiting their land use, maintaining sustainable use of land and water resources, and reducing their greenhouse gas emissions (Searchinger, 2019). A global inertial scenario projects an increase of more than 50% in food demand by 2050, with a 68% increase in milk and meat consumption, which is particularly intensive in land use. At the same time the sector needs to cut greenhouse gas emissions, which currently represent around 25% of total global emissions (Searchinger, 2019).

Agricultural activities in Latin America and the Caribbean directly contribute 25% of total regional emissions and were associated with another 20% of emissions from land-use change in 2018 (Climate Watch, 2020). The evolution of these emissions depends on expansion of land use for agricultural activities, production of inputs, such as timber, and provision of bioenergy (Calvin, et al., 2015; Svensson et al, 2021).

Meeting the carbon neutrality target requires raising agricultural efficiency and productivity above their historical trend, controlling and making substantial changes to the existing demand structure, controlling and limiting land use for bioenergy generation which creates additional competition for finite land resources, eliminating losses in food production and consumption, implementing adaptation processes, combining the increase in agricultural yields with a virtuous relationship and preservation of the environment (forests, ecosystems and biodiversity), and eliminating use of fossil fuels in the agricultural sector (Calvin, et al.using, 2015; Searchinger, et al, 2019; Svensson et al, 2021).

The available mitigation scenarios show that reaching net-zero emissions requires the stabilization and possibly even shrinking of the agricultural frontier (IPCC, 2018, pp. 97). For example, the agricultural area decreases in 1.5ºC scenarios along with increased productivity, reduced food losses, and diets shifting toward foods that require less space per unit of product (IPCC, 2018, pp. 97, pp. 144, ILO and IDB, 2020, Searchinger, et al., 2019). Food losses of 24% of total consumption will have to be reduced. In particular, changes required in the sector include reduced losses in the final consumption chains, production using more efficient production practices, and increased recycling processes (Searchinger, et al., 2019).

Ecosystems and nature-based solutions

Latin America and the Caribbean have a great diversity of ecosystems that contribute—through their services of provisioning, regulation, and culture—to generating economic value and social wellbeing. For example, Hernández, et. al. (2020) estimate a total current value of ecosystem services in Latin America and the Caribbean of US$15.3 trillion which could increase by an additional 25% in the context of a green economy. There is also growing use of nature-based solutions to develop green infrastructure that has the dual effect of helping to preserve natural capital and generating economic value (Serebrisky, et al., 2020). For example, mangrove restoration in developed and developing countries has costs for each case of US$42,801 and US$1,413 per hectare respectively, and coral restoration of US$4,479,769 and US$48,308 per hectare respectively. Preservation of mangroves and coral reefs contributes to reducing the effects of extreme weather events and the impacts of flooding on infrastructure and productive activities and are therefore considered cost-effective measures (Cavallo, et. al., 2020).

Mining

Mining activities play a very important role in the economies of Latin America and the Caribbean. The region's mining exports accounted for 17% of total exports in 2017 and contribute to employment and tax revenues. In global terms, the region has 39% of lithium, 39% of copper, 18% of bauxite and aluminum and 32% of nickel reserves (Spano, et al., 2021).

However, mining has a high carbon footprint, particularly considering the value chains in which it participates. Mining generates about 4% of global greenhouse gas emissions directly and has high transportation costs and is involved in activities associated with high emissions such as cement and steel production (Spano, et al. 2020).

Achieving carbon neutrality by 2050 means that mining activities must meet traditional and increasing demand for various minerals used as inputs for clean energy and mobility technologies, at the same time as reducing their carbon footprint. For example, the World Bank estimates that meeting the demand for energy storage technologies in a 2°C scenario will require increasing global production of graphite, lithium and cobalt by more than 450% between 2018 and 2050 and reaching aluminum and copper production of 103 and 29 million tons by 2050 (Hund, et al., 2020).

To achieve this, mining will have to reduce its direct emissions and its carbon footprint. This requires structural transformations since, in moderate scenarios of technological improvements and CO_2 intensity reduction, substantial increases in emissions still occur (Spano, et al., 2020). Recycling processes are important but insufficient because of a lack of available material and appropriate technologies. For example, global recycling rates for aluminum and copper, known as end-of-life, are 42%-70% and 43%-53% respectively (Hund, et al., 2020).

Thus, to move ahead with deep decarbonization of mining activities requires reducing energy intensity, recycling close to 100% of products, regulating and imposing standards on waste generation and recycling, and looking for technological alternatives. These measures will contribute to making optimal use of localization of mineral extraction in Latin America and the Caribbean to build strong low-carbon value chains (Spano, et al., 2020).

Infrastructure investment requirements

Estimates of infrastructure investment requirements globally and in Latin America and the Caribbean

Authors	% of GDP	Annual amount
Global		
Rozenberg, *et al*., (2019)	Average value 4.5% of GDP Range: 2%-8.2%.	USD 1.5 trillion Range: USD 640 - $2.7.
OECD (2006)	3.5% del GDP.	USD 6.4 trillion. Scenarios with Millennium Development Goals.
OECD (2017)	5.3% del GDP.	USD 6.9 trillion. Scenarios con SDGs.
UNCTAD (2014)	N/A	Total investment required: USD 5 to 7 trillion. Scenarios with SDGs include mitigation and adaptation.
Woetzel, *et. al*., 2016	3.8% of GDP.	USD 3.3 trillion. The gap increases including SDGs.
McKinsey (2013)	4.1% of GDP.	USD 2650 trillion*
Ruiz-Nuñez and Wei (2015)	2.2% of GDP.	USD 836 billion*
Developing countries and/or low- and middle-income countries or emerging economies		
Gaspar *et. al*., (2019)	Emerging economies 4% of GDP (2.5% of global GDP)	USD 2.6 trillion.
UNCTAD (2014)	N/A	Investment in developing countries is USD 3.9 trillion Range USD 3.3 to 4.5 trillion.
Schmidt-Traub, Guido (2015)	4% of GDP	USD 1.4 trillion. Range: USD 1378 - 1459]
Bhattacharya, Romani, and Stern (2012)	6%-8% of GDP.	USD 1.8 to 2.3 trillion. Increases 10%-15% of total costs.
Latin America and the Caribbean		
Fay and Morrison (2007)	4%-6% of GDP.	Investment required to reach Korea's infrastructure level.
Fay and Morrison (2007)	3% and 7% of GDP.	Investment level required given expected growth plus costs of achieving universal coverage in water, sanitation and electricity.
Perroti and Sánchez (2011)	5.2% of GDP.	Reaching the level of Southeast Asia requires investment of 7.9% del GDP.
Kohli Basil (2011)	3.8%-4% of GDP.	
CAF (2011)	4%-6% of GDP.	USD 200,000 to 250,000 billion
Ruiz-Nuñez and Wei (2015)	6.1% of GDP.	1,104,537
Serebrisky and Suárez-Alemán (2020)	4%-7%	
Serebrisky (2014)	5% of GDP	USD 250,000 billion 2010.
Serebrisky, *et al*., (2015)	5% of GDP	

Authors	% of GDP	Annual amount
Fay and Morrison (2017)	3%-8% with most probable range 4%-5%	
Centennial Group (2010)	5%-6%	
Fay and Yepes (2003)	3.2%	
Castellani, et al., (2019)	Infrastructure and addressing extreme poverty 10.6% GDP in 2030. Infrastructure, extreme poverty, infant mortality and completion of secondary: 16% of GDP in 2030.	

Notes: Estimates of the magnitude of infrastructure investment are based on:

1. Estimate infrastructure needed for a level of economic growth associated with the evolution of GDP per capita.

2. Define a ratio of infrastructure capital stock to optimal or target GDP per capita to which the required infrastructure is adapted.

3. Engineering models that simulate expected demand for various public services such as electricity, transportation or water.

4. Estimate coverage levels (e.g., universal coverage) for the population of some services, such as residential water supply and sewerage or residential electricity or to build resilient infrastructure to meet climate change mitigation goals.

5. Estimate infrastructure requirements for a given level of GDP per capita and infrastructure requirements for providing, for example, universal residential water, sanitation and electricity services or resilient infrastructure to meet climate change mitigation targets.

Infrastructure investment requirements differ in definition of targets and specific trajectories selected including timing of the investment; quality of new infrastructure and technologies to be used; magnitude of spending on operation and maintenance of infrastructure; economic and demographic scenarios; economic, social, environmental, geographic and climate heterogeneity across countries and regions; use of nature-based solutions which is still difficult to value monetarily, and even the definition of infrastructure investment is different (Rozenberg, et al., (2019).

Source: Prepared by the authors based on a review of the literature. * Approximate values based on a review of the literature.

References

Acevedo, Sebastian, Mico Mrkaic, Natalija Novta, Evgenia Pugacheva y Petia Topalova (2018), The effects of weather shocks on economic Activity: What are the channels of impact?. IMF Working Paper WP/18/144.

Audoly, Richard, Adrien Vogt-Schilb, Céline Guivarch, and Alexander Pfeiffer (2018), Pathways toward Zero-Carbon Electricity Required for Climate Stabilization, Applied Energy, 225, 884-901. Septiembre 2018,

Auffhammer, Maximilian, (2018), Climate Adaptive Response Estimations: Short and long run impacts of climate change on residential electricity and natural gas consumption using big data, NBER, Working Paper 24397.

Atteridge, Aarón y Claudia Strambo (2021), Siete principios para una transición justa hacia una economía baja en carbono, Stockholm Environment Institute (SEI).

Banco Interamericano de Desarrollo (BID), y Descarbonización Profunda para América Latina y el Caribe (DDPLA); (Adrien Vogt-Schilb, Hervé Breton, Guy Edwards, Marcela Jaramillo y Amal-Lee Amin) (2019), Como llegar a Cero Emisiones netas: Lecciones de América Latina y el Caribe

Banco Interamericano de Desarrollo (BID), y Descarbonización Profunda para América Latina y el Caribe (DDPLA); (Adrien Vogt-Schilb, Hervé Breton, Guy Edwards, Marcela Jaramillo y Amal-Lee Amin) (2020), Como llegar a Cero Emisiones netas: Lecciones de América Latina y el Caribe

Banco Interamericano de Desarrollo (2019), '¿Cómo está América Latina en términos de saneamiento?'.

BID, 2019. Informe I, 2019

Banco Mundial (2020, junio 8), La COVID-19 (coronavirus) hunde a la economía mundial en la peor recesión desde la segunda guerra mundial, Washington, D.C: Comunicado de prensa junio 8, Banco Mundial.

Banco Mundial (BM) (2019) Informe Anual de Banco Mundial: Poner fin a la pobreza, invertir para generar oportunidades 2019.

Banco Mundial (BM) (2021), State and trends of carbon pricing 2021

Banco mundial 2021 COMUNICADO DE PRENSA N.º 2020/015 LAC

Bataille, Christopher, Henri Waisman, Yann Briand, Johannes Svensson, Adrien Vogt-Schilb, Marcela Jaramillo, Ricardo Delgado, et al. "Net-Zero Deep Decarbonization Pathways in Latin America: Challenges and Opportunities." Energy Strategy Reviews 30 (July 1, 2020): 100510.

Benavides, C., Cifuentes, L., Diaz, M., Gilabert, H., Gonzales, L., Gonzalez, D., Groves, D., Jaramillo, M., Marinkovic, C., Menares, L., Meza, F., Molina-Perez, E., Montedonico, M., Palma, R., Pica, A., Salas, C., Torres, R., Vicuña, S., Valdes, J.M., Vogt-Schilb, A., 2021. Opciones para lograr la carbono-neutralidad en Chile: una evaluación bajo incertidumbre. Inter-American Development Bank.

Beltrán Real, Ó.M., 2021. Lecciones aprendidas en la implementación de modelos de negocio para la masificación de buses eléctricos en Latinoamérica y el Caribe. BID

Bhattacharya Amar, Mattia Romani, y Nicolas Stern (2012) Infrastructure for development Meeting the challenge, policy paper, junio. Center for Climate Change Economics and Policy, Grantham Research Institute on Climate Change and the Environment, en colaboración con Intergovernmental Group of Twenty-Four on International Monetary Affairs and Development (G-24).

Bhattacharya Amar, Joshua P. Meltzer, Jeremy Oppenheim, Zia Qureshi, and Nicholas Stern (2016), Delivering on sustainable infrastructure for better development and better climate, Global economy and development at Brookings y Grantham Research Institute on Climate Change and the Environment. Obtenido de

Bhattacharya, A., Contreras Casado, C., Jeong, M., Amin, A.-L., Watkins, G., Silva, M., 2019. Attributes and Framework for Sustainable Infrastructure. Inter-American Development Bank.

BID, DDPLAC, 2019. Cómo llegar a cero emisiones netas: Lecciones de América Latina y el Caribe (Resumen Ejecutivo). Inter-American Development Bank.
BID (Banco Interamericano de Desarrollo) (2021), Informe de sostenibilidad del BID, 2020
Binsted Matthew, Gokul Iyer, James Edmonds, Adrien Vogt-Schilb, Ricardo Arguello, Angela Cadena, Ricardo Delgado, Felipe Feijoo, André F.P. Lucena, Haewon McJeon, Fernando Miralles-Wilhelm, Anjali Sharma (2019), Implicaciones del Acuerdo de París sobre activos abandonados en América Latina y el Caribe.
Black-Arbeláez, Thomas (2018), Análisis económico y ambiental de las Contribuciones Previstas Determinadas a nivel nacional presentadas en América latina y el caribe, CEPAL, Santiago de Chile.
Bloomberg (2018, 19 de junio). El crecimiento de las baterías permitirá que para 2050 el mundo obtenga la mitad de la electricidad de energía eólica y solar. Servicio Bloomberg Profesional
Burke, Marshall, Solomon M. Hsiang y Edward Miguel (2015), Global non-linear effect of temperature on economic production, Nature, 527 (7577), 235-239.
CAF (2011), IDeAL 2011. La infraestructura en el desarrollo integral de América Latina. Diagnóstico estratégico y propuestas para una agenda prioritaria. IDeAL, Caracas: CAF.
CAF (2019) Informe Anual de Corporación Andina de Fomento (CAF), 2019". Banco de Desarrollo de América Latina. Caracas: CAF.
Calatayud, Agustina, Santiago Sánchez González, Felipe Bedoya Maya, Francisco Giráldez y José María Márquez (2021), Congestión urbana en América Latina y el Caribe: características, costos y mitigación, Banco Interamericano de Desarrollo (BID).
Calero, Diego, Carolina Chambi, Ana María Majano, Diana Ubico, Pía Zevallos, (2020), Hacia un desarrollo resiliente y bajo en emisiones en Latinoamérica y el Caribe, Progreso en la implementación de las Contribuciones Nacionalmente Determinadas (NDC), Reporte LEDSenLAC, 2019, LEDSLAC, PNUD, BID, EUROCLIMA y Libélula.
Calvin, Katherine, V., Robert Beach, Angelo Gurgel, Maryse Labriet y Ana María Lobo Guerrero (2015), Agriculture, forestry and other land use emissions in Latina America, Energy Economics, vol. 56, mayo, pp. 615-624.
Carbon Brief. (2015). Analysis: Developing countries need $3.5 trillion* to implement climate pledges by 2030. Carbon Brief.
Cárdenas, Mauricio, Juan Pablo Bonilla, and Federico Brusa. Políticas Climáticas En América Latina y El Caribe: Casos Exitosos y Desafíos En La Lucha Contra El Cambio Climático. Edited by Rita Funaro. Inter-American Development Bank, 2021.
Castellani, Francesca, Marcelo Olarreaga, Ugo Panizza y Yue Zhou (2019), Investment Gaps in Latin America and the Caribbean, International Development Policy, *Ráterationalonale de politique de développement*.
Cavallo, Eduardo A., and Andrew Powell. "2021 Latin American and Caribbean Macroeconomic Report: Opportunities for Stronger and Sustainable Postpandemic Growth." Inter-American Development Bank, March 2021.
Cavallo, Eduardo A., Andrew Powell, and Tomás Serebrisky, eds. From Structures to Services: The Path to Better Infrastructure in Latin America and the Caribbean. Inter-American Development Bank, 2020.
Climate Policy Iniciative (CPI); (Barbara Buchner, Baysa Naran, Pedro Fernandes, Rajashree Padmanabhi, Paul Rosane, Matthew Solomon, Sean Stout, Costanza Strinati, Rowena Tolentino, Githungo Wakaba, Yaxin Zhu, Chavi Meattle, Sandra Guzmán, (2021). Global Landscape of Climate Finance. CPI Report.
Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute. Available at: https://www.climatewatchdata.org/ghg-emissions.
CAT. "Global Update: Climate Target Updates Slow as Science Demands Action." Climate Action Tracker, 2021.

Coady, David, Ian Parry, Nghia-Piotr Le, Baoping Shang, (2019), Global fossil fuel subsidies remain large: An update based on country-level estimates, Fiscal Affairs department, IMF Working Paper. Working Paper No. 19/89, IMF. ISBN/ISSN: 9781484393178/1018-5941

Comisión Económica para América Latina y el Caribe (CEPAL) ª2020a), Panorama Social 2020. Ed. CEPAL. ISBN: 9789211220681, 262 p. obtenido en

Comisión Económica para América Latina y el Caribe (CEPAL) (2020b), La Inversión Extranjera Directa en América Latina y el Caribe 2020. Comisión Económica para América Latina y el Caribe. CEPAL ISBN: 9789211220544,198 obtenido de

Conde, Bianca y Carole Sanz (2021), Sustainability-Linked Bonds Come With Great Perks for Businesses. IDB Invest

Crafts, Nicholas (2009). Transport Infrastructure Investment: Implications for growth and productivity. Oxford Review of Economic Policy, Volume 25, (3), 327–343.

Crotte Amado, Diana Galarza Molina y Cristian Navas, (2020, abril 23) La nueva tendencia en concesiones de BRT en América Latina. Moviliblog. BID.

Delgado, Raúl., Huáscar. Eguino y Aloisio. Lopes (ed) (2021), Política fiscal y cambio climático. Experiencias recientes de los ministerios de finanzas de América Latina y el Caribe, Banco Inter-Americano de Desarrollo (IDB).

Dell, Melissa., Benjamin F. Jones y Benjamin A. Olken (2012), Temperature Shocks and Economic Growth: Evidence form the last half century, American Economic Journal: macroeconomics, 4(3), 66-95.

Dell, Melissa., Benjamin F. Jones y Benjamin A. Olken (2014), What do we learn from the weather? The New Climate-Economy Literature, Journal of Economic literature, 52(3),–740 - 798.

Deschênes, Olivier y Michael Greenstone (2011), Climate change, mortality and adaptation: Evidence form annual fluctuations in weather in the U.S., American economic Journal: Applied economics, vol. 3(4), 152-185.

DGI 2021, Boletín estadístico año 2020, Dirección general impositiva de Uruguay

Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., Kerr, T., 2015. Decarbonizing Development: Three Steps to a Zero-Carbon Future. World Bank Publications, Washington DC, USA.

Fay, Marianne, Luis Alberto Andres, Charles Fox, Ulf Narloch, Stephane Straub, and Michael Slawson (2017), Rethinking Infrastructure in Latin America and the Caribbean: Spending Better to Achieve More. World Bank, Washington, DC.

Fay, Marianne, Mary Morrison. (2007), Infrastructure in Latin America and the Caribbean: Recent Developments and Key Challenges, Directions in Development, Infrastructure. Washington, DC: World Bank.

Fay, Marianne. y Yepes, Tito, (2003). Investing in Infrastructure: What is Needed from 2000 to 2010? Policy Research Working Paper; No. 3102. World Bank, Washington, DC.

Feng, Kuishuang, Klaus Hubacek, Yu Liu, Estefanía Marchán and Adrien Vogt-Schilb (2018), Managing the distributional effects of energy taxes and subsidy in Latin America and the Caribbean, Septiembre, pp. 424-436. IDB Working Paper Series 947

Filgueira, Fernando (2020), Estudio de costeo de intervenciones de cuidados en México, documento de trabajo, ONU Mujeres, México.

Filgueira, Fernando. y Ernesto Espíndola (2015), Hacia un Sistema de transferencias monetarias para la infancia y los adultos mayores. Una estimación de impactos y posibilidades fiscales en América Latina, Series de Políticas Sociales, Comisiones Económica para América Latina y el Caribe (CEPAL).

Gambhir, Ajay, Fergus Green y Peter J.G. Pearson (2018). Towards a Just and Equitable Low-Carbon Energy Transition. 26. Imperial College of London, London.

Gaspar, Vitor, David Amaglobeli, Mercedes Garcia-Escribano; Delphine Prady; Mauricio Soto (2019) Fiscal Policy and Development: Human, Social, and Physical Investment for the SDGs. 45 p. IMF Staff Discussion, ISBN/ISSN: 9781484388914/2221-030X

Global Commission on Adaptation (GCA), (2019), Adaptation: A global call for Leadership on climate resilience. Global Commission for Adaptation.

Gobierno de Costa Rica. Plan Nacional de Descarbonizacion 2018-2050, 2019.

González-Mahecha, Esperanza., Oskar. Lecuyer, Michelle. Hallack, Morgan. Bazilian y Adried Vogt-Schilb (2019), Committed Emissions and risk of stranded assets from existing and planned power plants in Latina America.

Grau, Javier, Horacio Terraza, Velosa Rodríguez, Diana Milena, Alfredo Rithm y Germán Stuizegger, (2015) Situación de gestión de residuos sólidos en América latina y el Caribe, Banco Inter-Americano de Desarrollo

Groves, David G., James Syme, Edmundo Molina-Perez, Carlos Calvo, Luis Víctor-Gallardo, Guido Godinez-Zamora, Jairo Quirós-Tortós, et al. *The Benefits and Costs Of Decarbonizing Costa Rica's Economy: Informing the Implementation of Costa Rica's National Decarbonization Plan under Uncertainty*. Inter-American Development Bank, 2020.

Hallegate, Stephane, Colin Green, Robert J. Nicholls and Jan Corfee-Morlot (2013), Future flood losses in major coastal cities, Nature Climate Change. 3(9), 802-806, DOI:10.1038/nclimate1979

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., Vogt-Schilb, A., 2015. Shock waves: managing the impacts of climate change on poverty. The World Bank.

Hallegatte, Stephane, Adrien Vogt-Schilb, Mook Bangalore, and Julie Rozenberg. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Washington, DC: World Bank, 2017. Hallegatte, Stephane, Jun Rentschler Julie Rozenberg,. (2019). Lifelines: Tomando acción hacia una infraestructura más resiliente. Sustainable Infrastructure. Washington, DC: World Bank.

Heckman, J., S. Moon, R. Pinto, P. Savelyer y A. Yaritz (2010), "The rate of return to the highscope Perry Preschool Program", Journal of Public economics, 94, (1-2) 114-128.

Heckman, James, Rodrigo Pinto y Peter A. Savelyev (2013), Understanding the mechanism through which an influential early childhood program boosted adult outcomes, American Economic Review, 103(6), 2052-2086.

Hernández-Blanco, Marcello, Robert Costanza, Sharolyn Anderson, Ida Kubiszewski, and Paul Sutton. "Future Scenarios for the Value of Ecosystem Services in Latin America and the Caribbean to 2050." Current Research in Environmental Sustainability 2 (December 2020): 100008.

High-Level Commission on Carbon Prices (Stiglitz, Joseph. E., Nicholas Stern, Maosheng Duan, Ottmar Edenhofer, Gaël Girau, Geoffrey Heal, Emilio Lèbre la Rovere, Adele Morris, Elisabeth Moyer, Mari Pangesta, Priyadarshi R. Shukla, Youba Sokona y Harald Winkler) (2017), Report of the High-Level Commission on Carbon Prices. Carbon Pricing Leadership Coalition (CPLC), Washington, DC: World Bank mayo 29, pp. 68.

Howard, Peter H. y Thomas Sterner (2017), Few and not so far between: A meta-analysis of climate damage estimates, Environmental Resource economics, 68, 197–225.

Hund, K., La Porta, D., Fabregas, T., Laing, T. y Drexhage, J. (2020), Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition, Banco Internacional de Reconstrucción y Fomento/Banco Mundial, Climate-Smart Mining Initiative, Washington, DC: World Bank Publications, p. 11,

Howard, Peter, y Thomas Sterner (2017), Few and not so far between: A meta-analysis of climate damage estimates. Environmental Resource Economics, 68(4), 1-29 DOI:10.1007/s10640-017-0166-z

Huang Kaixing, Hong Zhao, Jikun Huang, Jinxia Wang, Christopher Findlay (2020), The impact of climate change on the labor allocation: Empirical evidence from China, Journal of Environmental Economics and Management, 104, 102376.

Huxham, Matthew, Muhammed Anwar, and David Nelson. “Understanding the Impact of a Low Carbon Transition on South Africa.” Climate Policy Initiative (CPI)., 2019.

Huxham, Matthew, Muhammed Anwar, Eoin Strutt, and David Nelson. “Understanding the Impact of a Low Carbon Transition on Uganda’s Planned Oil Industry.” Climate Policy Initiative (CPI)., 2020.

IEA (2019). “Government Revenue from Taxation.” In Global EV Outlook 2019. International Energy Agency.

IEA (2020), Introduction to system integration of renewables, International Energy Agency, (IEA), Paris.

IEA (2020), Electric Vehicles, IEA, Paris

IEA (2021), Net Zero by 2050. A Road map for the Global Energy Sector, International Energy Agency (IEA). Obtenido de

Ilkkaracan, Ipek., Kijong. Kim and Tolga. Kaya (2015), The Impact of Public Investment in Social Care Services on Employment, Gender Equality and Poverty: The Turkish Case. Istanbul and New York: Istanbul Technical University Women’s Studies Center and the Levy Economics Institute at Bard College.

Infralatam (2021) “Datos de inversión pública en infraestructura económica en América Latina y el Caribe”. [dataset] descarga mayo (2021)

Intergovernmental Panel on Climate Change (IPCC) (2014), Climate change 2014: synthesis report. Contributions of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R. K. Pachauri y L. A. Meyers (eds.)]. IPCC, Ginebra, Suiza.

Intergovernmental Panel on Climate Change (IPCC), (2018) Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

International Labour Organization (ILO) (2018). World Employment and Social Outlook 2018: Greening with Jobs. Report. International Labour Organization, May 14, 2018

International Renewable Energy Agency (IRENA) (2019), Global Energy Transformation: A Roadmap to 2050 (2019 edition), International Renewable Energy Agency, Abu Dhabi, 2019

IRENA (2020), Renewable Capacity Statistics 2020, International Renewable Energy Agency, Abu Dhabi.

Jacobs, David, Natacha Marzolf, Juan Roberto, Wilson Rickerson, Hilary Flynn, Christina Beckerbirck, and Mauricio Solano-Peralta (2013) Analysis of Renewable Energy Incentives in the Latin America and Caribbean Region: The Feed-in Tariff Case. Energy Policy 60. Elsevier: 601–10. doi:10.1016/j.enpol.2012.09.024

Jafino, Bramka Arga, Brian Walsh, Julie Rozemberg and Sthephane Hallegate (2020), Revised Estimates of the impact of climate change on extreme poverty by 2030, Policy Research Working paper No. 9417, World Bank, Washington, D.C., World Bank.

Kahn Matthew E., Kamiar Mohaddes, Ryan N. C. Ng, M. Hashem Pesaran, Mehdi Raissi and Jui-Chung Yang (2019), Long term macroeconomic effects of climate change: A cross-country analysis, national Bureau of Economic Research (NBER), Working Paper 26167, Cambridge, Agosto.

Kalkuhl, Matthias. y Leonie Wenz (2020), The impact of climate conditions on economic production. Evidence from a global panel of regions, Journal of Environmental Economics and Management, 103:102360, 1-20.

Kamps, Christophe. (2006). New estimates of government net capital stocks for 22 OECD countries, 1960-2001. IMF Staff papers, 53, 120-50. ISBN 9781451848939/1018-5941

Klusak, Patrycja, Matthew Agarwala, Matt Burke, Moritz Kraemer y Kamiar Mohaddes (2“21) "Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthin”ss," Cambridge Working Papers in Economics 2127, Faculty of Economics, University of Cambridge.

Kohli, Harpaul Alberto, y Phillip Basil, (2011), Requirements for Infrastructure Investment in Latin America under Alternate Growth Scenarios: 2011–2040.” Global Journal of Emerging Market Economies 3 (1), 59–110.

Lowe, C., McCord, A., Beazley, R., 2021. National cash transfer responses to Covid-19.

McGlade, Christophe y Paul Ekins, (2015), The geographical distribution of fossil fuels unused when limiting global warming to 2oC, Nature, 517:18-90.

MDB (2019), Principles of Just Transition, publicado en UNSG Climate Action Summit, 22 septiembre 2019.

Meinshausen, Malte, Jared Lewis, Zebedee Nicholls, and Rebecca Burdon. “COP26 Briefing Paper: Updated Warming Projections for NDCs, Long-Term Targets and the Methane Pledge. Making Sense of 1.8°C, 1.9°C and 2.7°C.” Climate Resource, 2022.

Mendelsohn, Robert, Nordhaus, William D. y Daigee Shaw, (1994), Measuring the impact of global warming on agriculture, American Economic Review, 84, 753–771.

New Climate Economy (NCE) (2014) Better growth, better climate. The new climate economy report. The global Commission on the Economy and Climate. Washington, DC.

Newell, Richard, Brian Prest, Steven Sexton (2020), The GDP-Temperature Relationship: Implications for Climate Change Damages, Resources of the Future, Working Paper (18-17). Obtenido de

Newell, Richard.G., Brian C. Prest, Steven E. Sexton (2021), The GDP-temperature relationship: Implications for climate change damages, Journal of Environmental Economics and Management, 108,102445. ISSN 0095-0696

MHDA (2020). Marco fiscal presupuestario de mediano plazo 2020 -2025. Ministerio de Hacienda de Costa Rica

Nordhaus, William D. y Andrew. Moffat (2017), A survey of global impacts of climate change: replication survey methods and a statistical analysis, National Bureau of Economic Research working paper 23646. DOI 10.3386/w23646

Organización Latinoamericana de Energía (OLADE) (Castillo Tatiana, Fabio García, Luis Mosquera, Targelia Rivadeneira, Katherine Segura, Marco Yujato)(2019) Panorama Energético de América Latina y el Caribe 2019, OLADE, sieLAC. SBN 978-9978-70-134-8

Organización de las Naciones Unidas (ONU) Medio Ambiente (2018) Movilidad eléctrica: avances en américa latina y el caribe y oportunidades para la colaboración regional. Publicado por el Programa de las Naciones Unidas para el Medio Ambiente (ONU Medio Ambiente), noviembre 2018.

Organización de las Naciones Un–das - Mujeres / Comisión Económica para América Latina y el Caribe (ONU mujeres /CEPAL) (Filgueira, Fernando) (2020), Estudio de costee de intervenciones de cuidado en México. Fundamentación y estimación de costos y efectos en el producto, en el empleo y en los ingresos fiscales del sistema de cuidados infantiles. Documento de Trabajo, ONU-Mujeres, México.

OECD (2021a), Revenue Statistics in Latin America and the Caribbean 2021, OECD Publishing, Paris

OECD (2021b), Climate Finance Provided and Mobilised by Developed Countries: Aggregate trends updated with 2019 data, Climate Finance and the USD 100 Billion Goal, OECD Publishing, Paris,

OECD (2021c), *Managing Climate Risks, Facing up to Losses and Damages*

OECD (2021d). Transport Strategies for Net-Zero Systems by Design.

Organización para la Cooperación y el Desarrollo Económicos (OCDE) (2017), Investing in Climate, Investing in Growth, OECD Publishing, Paris, 2017.

Organización para la Cooperación y el Desarrollo Económicos (OCDE) (2006), Infrastructure to 2030: Telecom, Land transpáterwater and electricity, Paris, OCDE.

Parry, Ian W. H. y Small. Kenneth A. (2005), Does Britain or the United States have the right gasoline tax?, American. Economic. Review., 95(4), 1276-1289.

Pérez-Urdiales, María, Rigoberto Ariel Yépez-García, Mauricio Tiomno Tolmasquin, Claudio Alatorre, Alejandro Rasteletti, Marco Stampini y Michelle Hallack (2021) El papel de la transición energética en la recuperación sostenible en América Latina y el Caribe, División de Energía, Departamento de Infraestructura y Energía, Nota Técnica No. IDB-TN-02142.

Perrotti, Daniel E., y Ricardo J. Sánchez (2011) La brecha de infraestructura en América Latina y el Caribe. Santiago: Comisión Económica para América Latina y el Caribe, Serie Recursos naturales e infraestructura 153, División de Recursos Naturales e Infraestructura, Comisión Económica para América Latina y el Caribe (CEPAL). ,ISSN 1680 9017.

Pindyck, Robert S. (2017), The use and misuse of models of climate change policy, Review of Environmental Economics and Policy, 11(1), 100-114.

Pottier, Antonin, Mark Fleurbaey, Aurelie Mejean y Stéphane. Zuber (2021), Climate change and population: An assessment of mortality due to health impacts, Ecological Economics, 183.

Quirós-Tortós Jairo, Guido Godínez- Zamora, Daniel Gerardo De La Torre Ugarte, Carlos Heros, Juan Lazo Lazo, Elías Ruiz, Berioska Quispe, Daniella Diez Canseco, Freddy Garro, Jimena Mora, Lorenzo Eguren, Milagros Sandoval, Silke Campos, Micol Salmeri, Richard Baron, Jaime Fernandez-Baca, Ana Saori Iju Fukushima, Valentina Saavedra, Adrien Vogt-Schilb (2021), Costos y beneficios de la Carbono Neutralidad en Perú. Una evaluación robusta, Banco Inter-Americano de Desarrollo (BID). Monografía del BID ; 895.

Ramírez Cartagena, Francisco, Benoit Lefevre, Jaime Fernández-Baca, and Rafael Capristán. “Análisis y Diseño de Modelos de Negocio y Mecanismos de Financiación Para Buses Eléctricos En Lima, Perú.” Inter-American Development Bank, February 2020.

Rentschler, Jun, and Morgan Bazilian. “Policy Monitor—Principles for Designing Effective Fossil Fuel Subsidy Reforms.” Review of Environmental Economics and Policy 11, no. 1 (January 1, 2017): 138–55.

Reymond, A., Egler, H.-P., Masullo, D. y Pimentel, G. (2020), Financing sustainable infrastructure in Latin America and the Caribbean, Banco Interamericano de Desarrollo, marzo de 2020,

Rigaud, Kanta Kumari, Alex de Sherbinin, Bryan Jones, Jonas Bergmann, Viviane Clement, Kayly Ober, Jacob Schewe, Susana Adamo, Brent McCusker, Silke Heuser, Amelia Midgley, (2018) Groundswell: Preparing for Internal Climate Migration. World Bank, Washington, DC.

Rosenzweig Cynthia, Kenneth M. Strzepek, David C. Major, Ana Iglesias, David N. Yates, Alyssa McCluskey, Daniel Hillel (2004) Water resources for agriculture in a changing climate: International case studies. Global Environmental Change 14 (2004) 345–360

Rozenberg, Julie, Adrien Vogt-Schilb y Stephane Hallegatte (2017), Instrument Choice and Stranded Assets in the Transition to Clean Capital, Journal of Environmental Economics and Management, 100: 102183,

Rozenberg, Julie, y Marianne Fay (2019), Beyond the Gap: How countries can afford the infrastructure they need while protecting the planet. Sustainable Infrastructure series. Washington, DC. World Bank.

Ruiz-Nunez, Fernanda y Zichao Wei (2015), Infrastructure Investment Demands in Emerging Markets and Developing Economies, Policy Research Working Paper 7414. World Bank, Washington, D.C.

Saget, Catherine, Adrien Vogt-Schilb, and Trang Luu. Jobs in a Net-Zero Emissions Future in Latin America and the Caribbean. Inter-American Development Bank and Internacional Labour Organization, 2020.

Schaffitzel, Filip, Michael Jakob, Rafael Soria, Adrien Vogt-Schilb, and Hauke Ward. “Can Government Transfers Make Energy Subsidy Reform Socially Acceptable? A Case Study on Ecuador.” Energy Policy 137 (February 1, 2020): 111120.

Schlenker, Wolfram y Michael J. Roberts (2009), Non-linear temperature effects indicate severe damages to US crop yields under climate change, PNAS, 106 (37), 155594-98.

Schmidt-Traub, Guido (2015). “Investment Needs to Achieve the Sustainable Development Goals—Understanding the Billions and Trillions.” SDSN Working Paper Version 2. Disponible en línea:

Searchinger, Tim, Richard Waite, Craig Hanson, Janet Ranganathan, Patrice Dumas, and Emily Matthews. Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. Washington DC: World Resources Institute, 2019.

Seo, Niggol; Robert Mendelsohn, (2007). A Ricardian Analysis of the Impact of Climate Change on Latin American Farms. Policy Research Working Paper; No. 4163. World Bank, Washington, DC. © World Bank.

Serebrisky, Tomas, Ancor Suárez-Alemán, Cinthya Pastor, Andreas Wohlhueter, (2017) Aumentando la eficiencia en la provisión de infraestructura pública, Washington, D.C. Banco Inter-Americano de Desarrollo (IDB).

Serebrisky, Tomas, Ancor Suárez-Alemán, Diego Margot y Maria Cecilia Ramírez (2015), Financiamiento de la infraestructura en América Latina y el Caribe: como cuanto y con quién?, Banco Inter-Americano de Desarrollo (IDB).

Serebrisky, Tomas, Ancor. Suárez-Alemán, Cinthya Pastor y Andreas Wolhueter (2018), Lifting the veil on infrastructure investment data in Latin America and the Caribbean, Inter-American Development Bank (IDB) Technical paper IDb-TN-1366.

Serebrisky, Tomas, Juan Pablo Bricheti, Allen Blakman y Mauricio Mesquita-Moreira (2020), Infraestructura sostenible y digital para impulsar la recuperación económica post-covid de América Latina y el Caribe: Un camino hacia más empleo, integración y crecimiento, Banco Inter-Americano de Desarrollo (BID).

Serebrisky, Tomas. (2014), Sustainable Infrastructure for Competitiveness and Inclusive Growth. Banco Inter-Americano de Desarrollo (BID).

Serebrisky, Tomas. y Ancor Suárez-Alemán (2019), La provisión de servicios de infraestructura en América latina y el caribe. Puede la región hacer más y hacerlo mejor?. Un análisis de frontera de eficiencia de la infraestructura económica, Banco Inter-Americano de Desarrollo (BID).

Solano-Rodríguez, Baltazar, Steve Pye, Li Pei-Hao, Paul Ekins, Osmel Manzano, Adrien Vogt-Schilb (2019), Implications for climate change targets on oil production and fiscal revenues in Latina America and the Caribbean, Washington, D.C: Banco Inter-Americano de Desarrollo (IDB).

Solórzano, Ana e Iliana Cárdenas (2019), “Social protection and climate change: WFP Regional Bureau for Latin America and the Caribbean’s vision to advance climate change adaptation through social protection”. Programa Mundial de Alimentos en colaboración con Oxford Policy Management.

Spano, Christian, Paolo Natali, Charles Cannon, Suzanne Greene, Osvaldo Urzúa, Carlos G. Sucre y Adriana Unzueta (2021), Latin America and the Caribbean 2050: Becoming a global low-carbon metals and solution hub, technical note No. IDB-TN-02172.

Standard & Poor’s. 2015. Global Infrastructure Investment: Timing Is Everything (and Now Is the Time). Standar d & Poor’s Ratings Services, McGraw Hill Financial.

Stern, Nicholas y Joseph E. Stiglitz (2021), Getting the Social Cost of Carbon Right, The World Opinion Page, Project Syndicate. Project Syndicate, febrero 15, 2021. Obtenido de

Svensson, Johannes, Henri Waisman, Adrien Vogt-Schilb, Chris Bataille, Pierre-Marie Aubert, Marcela Jaramilo-Gil, Jam Angulo-Paniagua, et al. “A Low GHG Development Pathway Design Framework for Agriculture, Forestry and Land Use.” Energy Strategy Reviews 37 (September 1, 2021): 100683.

TCFD (2021), 2021 Status report, Task Force on Climate-related Financial Disclosures (TCDF).

Tong, Dan, Qiang Zhang, Yixuan Zheng, Ken Caldeira, Christine Shearer, Chaopeng Hong, Yue Qin, Steven J. Davis (2019), Committed Emissions from existing energy infrastructure Jeopardize 1.5oC climate target. Nature, Research Letter. 572, Agosto

UN Environment Program (UNEP) (2018) Emissions Gap Report 2018, Executive Summary, United Nations.

UN Environment Program (UNEP) (2021), Emissions Gap Report 2021, Executive Summary, United Nations.

United Nations Conference on Trade And Development (UNCTAD) (2014), World Investment Report 2014. Investing in the SDGs: An Action Plan, United Nations Conference on Trade and Development (UNCTAD). Obtenido de

UNFCCC, 2021. Communication of long-term strategies [WWW Document].

Vergara Walter, Ana R. Rios, Paul Trapido, Hector Malarín (2014) Agricultura y Clima Futuro en América Latina y el Caribe: Impactos Sistémicos y Posibles Respuestas. Banco Interamericano de Desarrollo.

Viguri, Sofía, Sandra López-Tovar, Mariel Juárez-Olvera y Gloria Viguri (2020), Analysis of the external climate finance access and implementation. A review of the GCF, GEF, CIF and PCPF projects and programs by the Inter-American Development Bank, Inter-American Development Bank.

Viteri, Andrade Alicia (2019), Impacto económico y laboral del retiro y/o reconversión de unidades a carbón en Chile, Inter-American Development Bank (IDB)

Vogt-Schilb, Adrien y Kuishuang Feng (2019), The labor impact of coal Phase down scenarios in Chile, Octubre, Inter-American Development Bank (IDB).

Vogt-Schilb, Adrien, Brian Walsh, Kuishuang Feng, Laura Di Capua, Yu Liu, Daniela Zuluaga Marcos Robles, Klaus Hubaceck (2019), Cash transfers for pro-poor carbon tax in Latin America and the Caribbean, IDB working Paper Series, 2019-IDB-WP-1046.

Vogt-Schilb, A., 2021. Stronger Sustainable Growth, in: Cavallo, Eduardo, Powell, A. (Eds.), Opportunities for Stronger and Sustainable Postpandemic Growth. Inter American Development Bank.

Weischer Lutz, Linde Warland, David Eckstein, Stephan Hoch, Axel Michaelowa, Michael Koehler y Stefan Wehner. (2016). Investing in Ambition: Analysis of the Financial Aspects in (Intended) Nationally Determined Contributions. Bonn: German Watch and Freiburg: Perspectives Climate Group.

Welsby, D., Solano, B., Pye, S., Vogt-Schilb, A., 2021. High and Dry: Stranded Natural Gas Reserves and Fiscal Revenues in Latin America and the Caribbean. Inter-American Development Bank.

World Bank (Margulis Sergio y Urvashi Narain) (2010). The Cost to Developing Countries of Adapting to Climate Change. New Methods and Estimates, Washington, DC, The World Bank Group.

World Bank. "Lessons from Chile's Experience with E-Mobility : The Integration of E-Buses in Santiago.," 2020.

WRI-CAIT, (2021) Base de datos [Database] http://cait.wri.org

Yépez-García, Ariel, Yi Ji, Michelle Hallak, David López-Soto (2018), The energy path of Latin America and the Caribbean, Inter-American Development Bank (IDB), .

Yepez-García, Ariel, Luis. Carvajal, Franco. Hallack, Michelle. Snyder, Virginia (2021). Cinco cosas que debes saber sobre el sector energía en América Latina y el Caribe. BID.

Yépez-García, Ariel, Antonio Katherine y David López (2019). Las plantas de combustible fósil continuarán funcionando por un tiempo, aunque deje de invertirse en ellas. BID.

Zhao, Xiaobing, Mason Gerenty, Nicolai V. Kuminoff (2018), Revisiting the Temperature-Economic Growth Relationship Using Global Subnational Data, Journal of Environmental Management, 223, 537-544. DOI: 10.1016/j.jenvman.2018.06.022