



Getting to Zero in Latin America:

Decarbonizing the Building Sector by 2050

Report prepared for the Inter-American
Development Bank

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I. Executive Summary

Looking forward, increased carbon emissions could result in severe and irreversible impacts on ecosystems and people. The Intergovernmental Panel on Climate Change (IPCC) has recently declared that limiting the average surface temperature below 1.5°C above pre-industrial levels is our best shot to avoid or mitigate these impacts (IPCC 2014). Achieving this temperature target by the end of the century requires that the world reaches net-zero carbon emissions by 2050 (WRI 2020b). However, achieving net-zero carbon emissions will require substantial shifts in the energy, infrastructure, and industrial sectors. For instance, the infrastructure system must undergo deep changes in urban planning and construction techniques, transportation systems, and buildings (IPCC 2018).

The decarbonization of the building sector is particularly important since the construction and use of buildings account for around 30 percent of total carbon emissions (Palme et al. 2013). Future population and economic growth are likely to result in additional floor space, which could further increase energy demand and associated carbon emissions. Rising incomes and living standards will also boost the demand for appliances and equipment. Thus, achieving net-zero carbon emissions in buildings will require a range of technical and technological shifts—from building design, efficiency, and electrification to low-carbon materials and construction—and sound public policies. In Latin America, the Inter-American Development Bank (IDB) plays a critical role in supporting countries' low-carbon development pathways. It is in a unique position to support and promote policies, technologies, and additional measures that aim to achieve net-zero carbon emissions within the building sector.

Carbon Emissions in Buildings

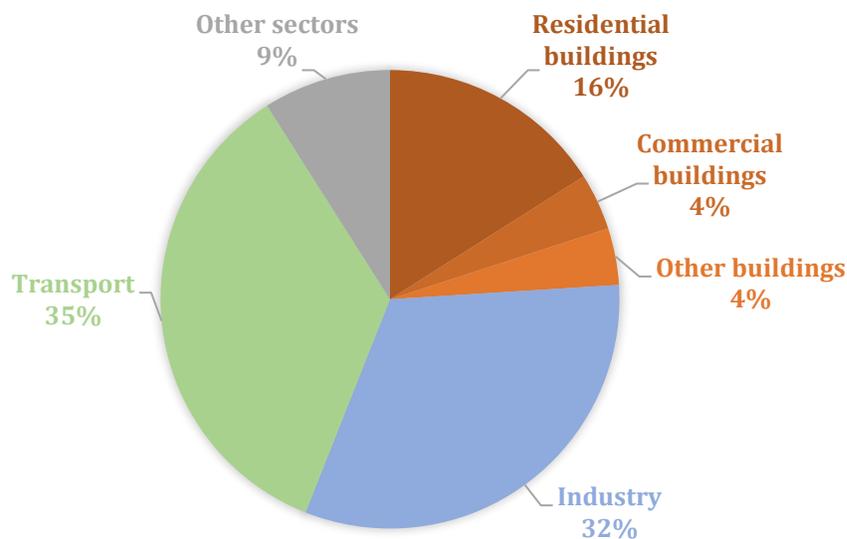
The entire lifecycle of a building encompasses both operational and embodied carbon. On one hand, operational carbon results from the energy needed to operate systems—such as lighting, heating, cooling, and ventilation—and appliances (Pacheco-Torgal et al. 2018). On the other hand, embodied carbon consists of all the emissions associated with the construction of buildings—including the extraction, manufacturing, transportation, installation, and disposal of materials (Cameron 2020).

Operational carbon from buildings accounts for 21 percent of total carbon emissions in Latin America (IEA 2019c). While operational carbon from fuel combustion—including coal, oil, natural gas, and biomass—accounts for 8 percent of total carbon emissions, carbon arising from electricity and heating accounts for 13 percent of total energy-related carbon emissions (see Figure 1).

Embodied carbon from buildings represents around 11 percent of total energy-related carbon emissions. However, embodied carbon is difficult to quantify and can vary significantly within and across geographic locations. In addition, the amount of embodied carbon in buildings depends on the origin, manufacture, durability, and recyclability of construction materials (GlobalABC 2020). Cement

and steel are two of the largest contributors to embodied carbon in buildings. While no regional figures are available for Latin America, the cement and steel industries contribute with around seven and nine percent of global carbon emissions, respectively. In cement production, clinker is the largest source of carbon emissions and accounts for as much as 80 percent of emissions during the entire lifecycle of concrete products (Becker-Birck et al. 2020). In conventional steel manufacturing, 43 percent of carbon emissions arise from the combustion of coking coal in blast furnace stoves and 30 percent from burning natural gas in miscellaneous processes (EPA 2012).

Figure 1. Share of carbon emissions by sector in Latin America, 2018



Source: adapted from [GlobalABC \(2020\)](#).

While it is possible to reduce some fraction of operational and embodied carbon in buildings through direct activities inside the building sector (such as the electrification of appliances, increased efficiency in systems, improved construction techniques, and the reuse/recycle of construction materials), a significant portion of emissions reductions—particularly for embodied carbon—are contingent on activities outside the building sector. Thus, increased efficiency in industrial processes (and the eventual electrification of the industry) will be needed to achieve net-zero emissions in buildings.

To attain both operational and embodied carbon reductions, effective policies and technologies must encompass the whole lifecycle of new and existing buildings—including the design, development, operation, maintenance, refurbishment, and decommissioning. Effective collaboration among several stakeholders will be critical at the regional, national, local, and project levels to align the building sector with the goals of the Paris Agreement.

Policies to Reduce Operational and Embodied Carbon in Buildings

Mandatory building energy codes are key policy instruments to reduce operational carbon because they specify the minimum energy requirements for buildings' components and performance. However, the uptake of mandatory energy codes in new and existing buildings is still low across the region (see Figure 2).

Figure 2. Building energy codes in Latin America, 2018



Source: [GlobalABC \(2020\)](#).

Besides incorporating passive design and energy efficiency measures, building codes should delineate requirements for on-site renewable energy systems and electrification. In addition, they should encourage the electrification of systems and appliances in buildings. All-electric appliances could be achieved through the implementation of “reach” codes (energy codes that reach or go beyond building standards) (Margolies 2020; DiChristopher 2020). Reducing embodied carbon requires that building codes incorporate minimum environmental standards for building materials (detailing performance requirements and promoting low-carbon products).

Building labels and certifications could complement building codes by assessing the performance of buildings on a scale from less efficient to more efficient. IFC's Excellence in Design for Greater Efficiencies (EDGE) is a certification system that identifies cost-effective approaches to reducing energy use in buildings and embodied energy in materials (EDGE 2021).

One other approach that can help achieve efficiency improvements is to measure the energy use of a building, benchmark it, and disclose such information (NASEM 2021). **Benchmarking and**

disclosure of energy performance in buildings should become mandatory in all Latin American countries to create a virtuous circle of improvement and demand for high-performing buildings (IMT 2021). Benchmarking and disclosure practices should also incorporate environmental impacts and materials to inform policymaking, enforce regulations, and drive reductions in embodied carbon.

Federal governments in Latin America should consider the implementation of an **emissions cap** for federally owned buildings. These buildings could accomplish emissions reductions through energy efficiency upgrades, electrification, and on-site renewable energy generation (NASEM 2021). Emissions caps in federal buildings could become models for states and municipalities to set standards for both public and private buildings. In addition, **energy audits** should be conducted on a regular basis—particularly in buildings with high energy demand (GlobalABC 2020).

Public and private entities can contribute to phase out inefficient systems and appliances through **green procurement**. Government agencies could incorporate green procurement policies as part of their operations at the national and local levels. To reduce embodied carbon, public procurement should incorporate requirements for minimum recycled content and reusability of materials. Since these policies could be harder to enforce in the private sector, governments should publicly encourage firms to adopt voluntary sustainability standards. Firms would have to perform well in all aspects of purchasing social responsibility (PSR) to keep their reputation intact (Appolloni et al. 2014).

Financial and non-financial incentives can encourage people to own and develop low-carbon buildings, purchase and manufacture efficient systems and appliances, and adopt sustainable materials in buildings. For instance, nudge policies are excellent non-financial incentives that encourage energy conservation. Some electric bills include information about the energy use of customers' neighbors, which creates social pressure and competition—thus encouraging consumers to reduce their energy consumption relative to their neighbors (Cleary and Palmer 2020). Financial incentives could drive new construction techniques that enable embodied carbon reductions (GlobalABC 2020). In particular, the use of low-carbon alternative materials—such as clinker substitutes for cement production or timber instead of steel—should be strongly incentivized.

Additional Strategies to Reduce Operational and Embodied Carbon in Buildings

Building passports could incentivize reductions in operational and embodied carbon by informing relevant stakeholders on relevant data at every stage of a building's lifecycle. A building passport is a document that includes useful information about the building—including materials, systems, energy use, renovations, and retrofits (GlobalABC 2020). However, the adoption of building passports has been minimal in Latin American countries. **Lifecycle assessments (LCAs)** are a powerful tool to estimate both operational and embodied carbon in buildings. These assessments quantify the materials used, energy flows, and environmental impacts over a building's lifecycle (Sharma et al. 2010). LCAs can be used to assess the environmental impacts of construction materials throughout the

whole lifecycle of buildings—from material extraction and manufacturing to decommissioning and disposal.

Strategies to Further Decarbonize Appliances and Systems

Across the region, many standard appliances—including refrigerators, washing machines, and air conditioners—have **mandatory energy performance standards (MEPS)**, endorsement labels, or rating systems in place (GlobalABC 2020). However, these standards should be expanded to all countries and revised regularly to ensure enhanced performance. **Product labels** also provide relevant information by specifying the performance, energy demand, carbon emissions, and cost of operation of an appliance during its entire lifecycle. Thus, they should become mandatory for all building appliances and systems.

Higher efficiency in household appliances is necessary to drive reductions in energy demand and associated emissions. Technologies such as air-source heat pumps, hybrid cooling, and efficient lighting have the potential of significantly contributing to emissions reductions. While increased efficiency is necessary over the medium-term, the electrification of all household and commercial appliances is crucial to achieving net-zero buildings by 2050. Governments in Latin America should aim to establish national **zero-emission appliance manufacturing standards** covering space heating and cooling, water heating, and cooking. Appliance electrification policies could mirror electric vehicle mandates, requiring appliance manufacturers to sell an increasing fraction of electric products while allowing emissions trading among them.

Strategies inside the Building Sector to Further Reduce Embodied Carbon in Buildings

Reducing embodied carbon in buildings requires a range of actions inside the building sector—such as lowering material demand and switching to low-carbon materials. An optimized design of buildings can significantly reduce material demand, thus driving reductions in embodied carbon.

Some **optimization strategies** include the use of precast concrete, 3-D printing, and building information modeling (BIM). Other efficiency strategies include reducing cement content in concrete and lowering the clinker-to-cement ratio.

Within the building sector, significant opportunities for reducing embodied carbon are possible through the reuse and recycling of construction materials. Buildings should be designed in the context of a **circular economy**. Developing guidelines for circular economy implementation and choosing circular economy indicators should be done in the early stages of a project and based on lifecycle assessments and material flow analyses (Stephan and Athanassiadis 2017). In addition, governments should develop local and national decarbonization strategies by setting targets for embodied carbon in building projects.

Strategies outside the Building Sector to Further Reduce Embodied Carbon in Buildings

Reducing embodied carbon in buildings also requires a range of actions outside the building sector—such as enhancing energy efficiency in manufacturing and opting out from carbon-intensive sources of energy (Energy Transitions Commission 2018a). **Material labeling** and **environmental product declarations (EPDs)** are useful strategies to reduce embodied carbon in buildings. While material labels provide useful information on embodied carbon across the whole lifecycle of materials, EPDs are independently verified and registered documents that communicate transparent information on the lifecycle environmental impact of materials (EDP 2021).

Increasing energy efficiency in the manufacturing processes of construction materials is a necessary first step to reduce embodied carbon. Thus, the **best available technologies (BATs)** should be developed and promoted in Latin American countries to maximize energy efficiency. Specific indicators to monitor energy use in production processes should be established, tracked, and compared against BATs. While energy efficiency measures may be adequate over the medium term, the **decarbonization of production processes** will be necessary over the long run. Tracking embodied carbon in construction materials could incentivize manufacturers to shift to cleaner energy mixes and even develop circular approaches—such as the use of biofuels—in production processes.

Conclusions

The decarbonization of the building sector is a crucial step towards achieving the tenets of the Paris Agreement. The IDB is uniquely suited to help Latin American countries develop and adopt a range of policies, technologies, and additional measures that reduce both operational and embodied carbon in buildings. However, effective collaboration among several stakeholders—including policymakers, urban planners, architects, construction companies, materials suppliers, utility companies, developers, and investors—will be critical at the regional, national, local, and project levels.

The IDB could promote and prioritize strategies with the potential to curb both operational and embodied carbon in buildings. At the national level, the adoption of mandatory building codes—that include operational energy requirements and embodied carbon specifications—will be particularly relevant to attain carbon-neutral buildings by 2050. At the project level, building passports and lifecycle assessments could incentivize reductions in both operational and embodied carbon by informing different stakeholders on relevant data at every stage of a building's lifecycle.

Strategies like appliance electrification, increased efficiency in systems, improved construction techniques, and the reuse and recycle of construction materials can achieve significant emissions reductions inside the building sector. However, actions outside the building sector are also crucial to aligning the building sector with the goals of the Paris Agreement. To this end, the IDB should promote efficiency and electrification strategies—as well as information benchmarking and disclosure—in energy-intensive industrial processes such as the cement and steel industries.

II. Background

The Challenge of Climate Change

Climate change is the most critical and complex environmental challenge facing the planet this century. Some of its effects are already happening: temperatures are rising, oceans are warming, ice sheets are shrinking, sea levels are increasing, and extreme events are becoming more frequent (NASA 2020). Scientific evidence suggests that it is extremely likely—greater than 95 percent probability—that human activity has been the major cause of global warming since the last century (IPCC 2013). While population and economic growth, energy consumption, and land-use changes are the main drivers behind increased anthropogenic carbon emissions, technology and climate policies are the chief tools for mitigation (IPCC 2014).

Looking forward, increased carbon emissions could result in severe and irreversible impacts on ecosystems and people. Scientists anticipate that heatwaves will be more frequent and last longer, extreme precipitation events will become more intense, oceans will further acidify, and sea levels will continue to rise (IPCC 2014, 10). The impacts of these climate-related events—such as food insecurity, disruption of economies, and forced migration—will disproportionately affect vulnerable and disadvantaged populations. The Intergovernmental Panel on Climate Change (IPCC) has recently declared that limiting the average surface temperature below 1.5°C above pre-industrial levels is our best shot to avoid or mitigate these impacts (IPCC 2014).

The Paris Agreement and Net-zero Emissions

The 2015 Paris Agreement is the culmination of more than 20 years of international climate diplomacy and negotiations—which started in 1992 at the Earth Summit in Rio de Janeiro. It is a legally binding international treaty that aims to limit global warming well below 2°C—aiming for 1.5°C—compared to pre-industrial levels (UNFCCC 2021b). To achieve this goal, the 197 signatory countries are required to communicate their Nationally Determined Contributions (NDCs) every five years. NDCs are national climate plans that outline climate actions, targets, policies, and measures that governments intend to implement in response to climate change (UNFCCC 2021a). In addition, the Paris Agreement exhorts countries to formulate and submit voluntary long-term low emissions development strategies (LT-LEDS). These strategies provide vision and direction for future development by placing NDCs into the context of countries' long-term planning and development priorities (UNFCCC 2021b).

The latest science from the Intergovernmental Panel on Climate Change (IPCC) suggests that to limit global warming to below 1.5°C during the 21st century, the world must reach net-zero carbon emissions by 2050 (WRI 2020b). "Net-zero" means bringing anthropogenic emissions—like those arising from burning fossil fuels and industrial processes—as close to zero as possible, and then balancing the remaining emissions with an equivalent amount of carbon removal techniques—such as afforestation and carbon capture technologies (Levin and Davis 2019). So far, nineteen countries and the European Union have adopted net-zero targets, and more than 100 are considering doing so (Levin

et al. 2020). To date, Bhutan is the only country in the world that has already achieved net-zero (and even net-negative) carbon emissions (WRI 2020a).

Achieving net-zero carbon emissions will require substantial shifts in the energy, infrastructure, and industrial sectors. For instance, the infrastructure system must undergo significant changes in urban planning and construction techniques, transportation systems, and buildings (IPCC 2018). The energy sector will require zero-emission technologies and best practices—including energy efficiency mechanisms. However, these system shifts may be hindered by economic, institutional, and socio-cultural barriers that depend on countries' capabilities, sector-specific circumstances, and the availability of financial resources (IPCC 2018).

The Role of Multilateral Development Banks

Development institutions play an important role in scaling up financial resources and shaping public policies that aim at low-carbon, climate-resilient development. Multilateral Development Banks (MDBs) are particularly relevant to the implementation of the sustainable development agenda. In 2019, MDBs committed more than USD 164 million in climate finance and climate co-finance (EBRD 2019). While climate finance refers to the banks' own resources, climate co-finance entails partnerships with external public and private parties. In addition, MDBs are pivotal in mobilizing other sources of capital, such as private equity. But the importance of MDBs goes beyond financial assistance. They generate the knowledge needed to advance development, facilitate dialogue with and among governments, and support countries to outline effective public policies. Therefore, the role of MDBs is critical to the attainment of carbon-neutral economies by 2050.

In alignment with the Paris Agreement, MDBs have committed to making their operations and financial flows consistent with low-carbon and climate-resilient development. In 2015, they agreed on a set of standardized definitions, guidelines, and activities aimed at supporting and financing climate change mitigation and adaptation strategies (EBRD 2019). In 2018, MDBs reinforced their commitment to combatting climate change by presenting a joint approach that aligns all their activities with the goals of the Paris Agreement. The approach rests on six building blocks (World Bank 2018):

Building Block 1 – Alignment with Mitigation Goals. Support operations that are consistent with country-specific low-emissions development pathways and aligned with the objectives of the Paris Agreement

Building Block 2 – Adaptation and Climate-resilient Operations. Fund projects that increase the ability of communities to adapt to the adverse impacts of climate change

Building Block 3 – Climate Finance. Scale-up climate finance to support low-emissions and climate-resilient development pathways and help countries achieve their Nationally Determined Contributions (NDCs)

Building Block 4 – Engagement and Policy Development. Support countries with long-term strategies for low-emissions and climate-resilient development while ensuring consistency with the Sustainable Development Goals (SDGs)

Building Block 5 – Reporting. Develop tools and methods for characterizing, monitoring, and reporting on activities aligned with the Paris Agreement

Building Block 6 – Alignment with Internal Activities. Ensure that internal operations—including facilities and internal policies—are aligned with the tenets of the Paris Agreement

Building block 4 is particularly essential to the attainment of the goals of the Paris Agreement. By offering policy support at the national and local levels, countries can outline effective long-term decarbonization strategies that enable significant shifts in key economic sectors. In addition, the continuous engagement of relevant stakeholders in policymaking can result in higher country ownership, which in turn increases climate action commitments and accountability. Although policy support and development are the pivotal elements of the MDBs' joint approach, it is also essential that MDBs support and encourage operations that incorporate mitigation and adaptation strategies. Thus, building blocks 1 and 2 are necessary complements for building block 4.

To implement building blocks 1 and 2, MDBs must overcome several complexities when assessing projects and operations. First, there is no “one-size-fits-all” approach when evaluating projects vis-à-vis consistency with low-carbon and resilient pathways. These characterizations must take into consideration country-specific contexts and capabilities. Second, most countries have not yet defined what constitutes a low-carbon and resilient pathway sector by sector. Moreover, countries' national strategies are not yet in line with emissions pathways leading to a 1.5°C scenario. While many countries have stated more ambitious targets in their 2020 NDCs, many others are still lagging. Finally, assessing the consistency of projects with low-carbon and resilient development pathways is more complex than just comparing a set of indicators against benchmarks. Assessments must consider the particular context of each country and analyze economy-wide effects that stretch beyond the direct impacts of carbon emissions (IDB 2020b). Although MDBs require country-specific analyses for the implementation of building blocks, these assessments must be complemented with sectoral guides that outline the overall challenges—and potential solutions—for the decarbonization of key economic sectors.

The Inter-American Development Bank

In Latin America, the Inter-American Development Bank (IDB) can play a critical role in supporting and strengthening countries' climate-resilient and low-carbon development pathways. In line with the Paris Agreement, the IDB is currently working with various Latin American countries on long-term decarbonization strategies. These strategies are crucial for countries to achieve net-zero emissions by

2050. In addition, they can help governments and other stakeholders to plan and deploy sustainable infrastructure and public policies in different economic sectors (Watkins 2020).

Besides leveraging funding, the IDB can play a significant role in designing long-term decarbonization strategies and national plans through policy design and effective stakeholder engagement (Watkins 2020). For instance, the IDB supported Costa Rica with the design of its National Decarbonization Plan (considered an international example) as it aims to become a net-zero economy by 2050 (IDB 2020a). Under the Plan, Costa Rica aims to increase by 10 percent the use of wood, bamboo, and other local materials in buildings. By 2030, the design and construction of all new buildings will incorporate low-emission and resilience systems and technologies under bioclimatic parameters. By 2050, half of all commercial, institutional, and residential buildings will operate under emission standards—including electrification and renewable energy for cooking and water heating systems (Government of Costa Rica 2019).

The decarbonization of the building sector is particularly important since the construction and use of buildings account for around 30 percent of total carbon emissions (Palme et al. 2013). Future population and economic growth are likely to result in additional floor space, which could further increase energy demand and associated carbon emissions. Rising incomes and living standards will also boost the demand for appliances and equipment. Thus, achieving net-zero carbon emissions in buildings will require a range of technical and technological shifts—from building design, efficiency, and electrification to low-carbon materials and construction—and sound public policies. In Latin America, the IDB is in a unique position to support and promote policies, technologies, and additional measures that aim to achieve carbon-neutral buildings by 2050.

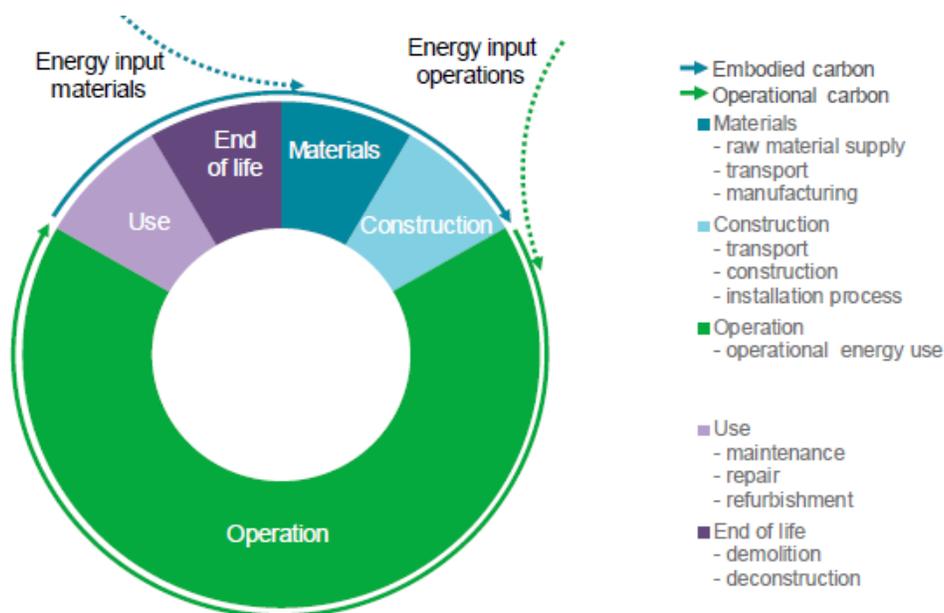
This report aims to inform the IDB (and other international financial institutions with operations in Latin America) on a range of strategies for the decarbonization of the building sector in Latin America. The rest of the report is structured as follows: section III gives an overview of the direct and indirect carbon emissions associated with buildings; section IV emphasizes the current trends, risks, and opportunities within the building sector; section V offers a range of action items—including technologies, policies, and project-level efforts—to reduce operational carbon emissions in buildings; section VI outlines a range of actions inside and outside the building sector to reduce embodied carbon in buildings; section VII concludes. The IDB could leverage this report to support countries to formulate national climate plans and deploy building-related projects consistent with the goals of the Paris Agreement.

III. Carbon Emissions from the Building Sector in Latin America

Distinct from their direct use of energy and associated carbon emissions, buildings drive additional indirect emissions from carbon-intensive activities from building materials and construction. As such, the entire lifecycle of a building encompasses both operational and embodied carbon (see Figure 1). Operational carbon results from the energy needed to operate systems—such as lighting, heating,

cooling, and ventilation—and appliances (Pacheco-Torgal et al. 2018). On the other hand, embodied carbon consists of all the emissions associated with the construction of buildings—including the extraction, manufacturing, transportation, installation, and disposal of materials (Cameron 2020). While operational carbon contributes with 72 percent of carbon emissions in buildings, embodied carbon accounts for 28 percent (WGBC 2021).

Figure 1. Carbon footprint over the whole lifecycle of buildings

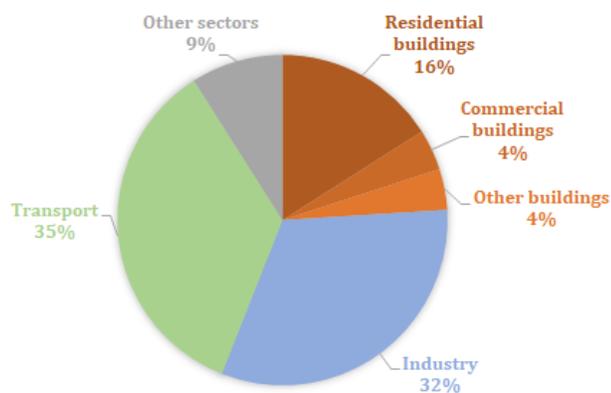


Source: [GlobalABC \(2020\)](#).

Operational Energy and Carbon

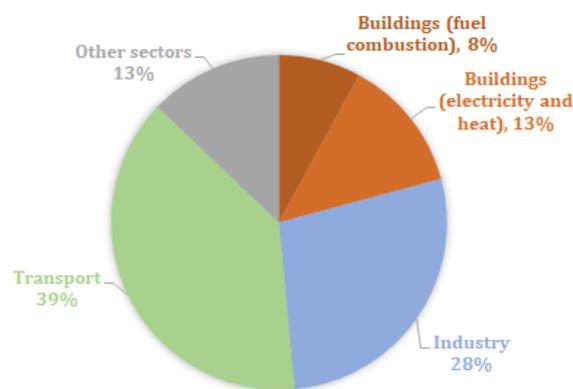
Operational energy in buildings accounts for 24 percent of total energy consumption and represents 21 percent of total carbon emissions in Latin America (IEA 2019c). As mentioned before, these figures exclude material manufacturing and construction. While commercial buildings account for 4 percent of final energy consumption, residential buildings account for 16 percent (see Figure 2). The main contributor to energy consumption in buildings, with 43 percent, is electricity usage—followed by wood, natural gas, and LPG (Balza, Espinasa, and Serebrisky 2016; IEA 2019b; SIELAC 2019). Carbon emissions from operational energy are divided into two categories: i) emissions arising from burning fuels such as coal, oil, natural gas, and biomass (which account for 8 percent of total carbon emissions), and ii) emissions from electricity and heating (which account for 13 percent of total emissions) (see Figure 3).

Figure 2. Share of final energy consumption by sector



Source: adapted from [GlobalABC \(2020\)](#).

Figure 3. Share of carbon emissions by sector



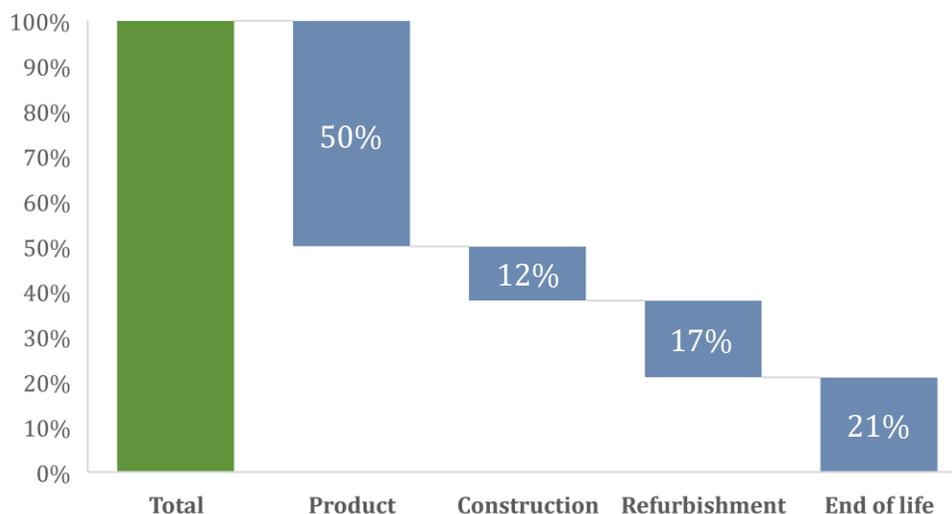
Source: adapted from [GlobalABC \(2020\)](#).

In Latin America, there is significant potential for reductions in operational energy (and thus operational carbon) within the building sector. In 2018, carbon emissions from operational energy in buildings totaled 240 megatons of carbon dioxide (MtCO₂). According to the International Energy Agency, improved efficiency in coal, natural gas, and oil consumption in buildings could deliver an estimated reduction of 28 MtCO₂ per year. The decarbonization of the grid and increased efficiency in building appliances could deliver additional reductions of 107 MtCO₂ per year (GlobalABC 2020).

Embodied Energy and Carbon

Globally, embodied carbon from buildings represents 11 percent of energy-related carbon emissions. However, embodied carbon is difficult to quantify and can vary significantly within and across geographic locations. In addition, the amount of embodied carbon in buildings depends on the origin, manufacture, durability, and recyclability of construction materials (GlobalABC 2020). A study conducted in the UK calculated the embodied carbon for a basic masonry dwelling unit with a design life of 50 years. Preliminary results showed that the product stage—which includes raw materials supply, transport, and manufacturing—accounted for 50 percent of embodied carbon (see Figure 4). While the construction process accounted for 12 percent of emissions, repair and refurbishment of building components accounted for 17 percent. The end-of-life stage (including demolition, transport, waste processing, and disposal) accounted for 21 percent of embodied carbon (Moncaster and Symons 2013). While no similar studies are available across Latin America, these results offer a stage-by-stage rough estimate of the embodied carbon in masonry buildings. In the Andean Region, masonry constitutes 55 percent of all residential dwellings (Yepes-Estrada et al. 2017).

Figure 4. Share of embodied carbon in a masonry dwelling unit by stage



Source: adapted from [Moncaster and Symons \(2013\)](#).

Cement and steel are two considerable contributors to embodied carbon in buildings. While no regional figures are available for Latin America, the cement industry contributes with 7 percent and the steel industry with 9 percent of global carbon emissions. Approximately half of these figures result from buildings and construction (WorldGBC 2019). In cement production, clinker is the largest source of carbon emissions. A recent study found that clinker production accounts for as much as 80 percent of emissions during the lifecycle of concrete products (Becker-Birck et al. 2020). In conventional steel manufacturing, 43 percent of carbon emissions arise from the combustion of coking coal in blast furnace stoves and 30 percent from burning natural gas in diverse processes (EPA 2012).

According to the International Energy Agency, direct carbon emissions from cement production increased 0.5 percent per year between 2014 and 2018. To achieve the goals of the Paris Agreement, a 0.8 percent decline in cement emissions is required each year to 2030 (IEA 2020a). On the other hand, the steel industry—which is the second-largest industrial energy consumer in the world—must reduce its energy intensity by 1 percent each year to 2030 (IEA 2020c).

External Considerations

It is possible to reduce some fraction of operational and embodied carbon in buildings through direct activities inside the building sector (such as the electrification of appliances, increased efficiency in systems, improved construction techniques, and the reuse/recycle of construction materials). However, a significant portion of emissions reductions—particularly for embodied carbon—are contingent on activities outside the building sector. For instance, the decarbonization of the energy sector will be paramount to achieving carbon-neutral buildings by 2050 (Climate Bonds Initiative

2017). While some countries like Brazil, Panama, Peru, and Uruguay have high shares of renewable generation, other countries like Argentina, Bolivia, Chile, Honduras, and Mexico are highly dependent on fossil fuels. In addition to utility-scale renewable projects, large-scale distributed renewable generation can lead to the decarbonization of the electricity sector (GlobalABC 2020). Increased efficiency and the use of renewable energies in industrial processes (such as cement and steel manufacture) will also be necessary to achieve net-zero emissions in buildings.

Siting is one other external consideration that affects carbon emissions in buildings. At the urban scale, the siting of buildings has both direct and indirect impacts on energy use. For instance, the physical characteristics of the built environment (such as shape, size, density, configuration, street network, and public spaces) are an important determinant of energy demand. (GlobalABC 2020). In addition, the siting of buildings can affect—to a lesser or greater extent—carbon emissions from the transport sector. As such, adequate urban planning is important to support the transition toward net-zero emissions by 2050.

IV. Trends, Risks, and Opportunities within the Building Sector

Demographic and Economic Trends

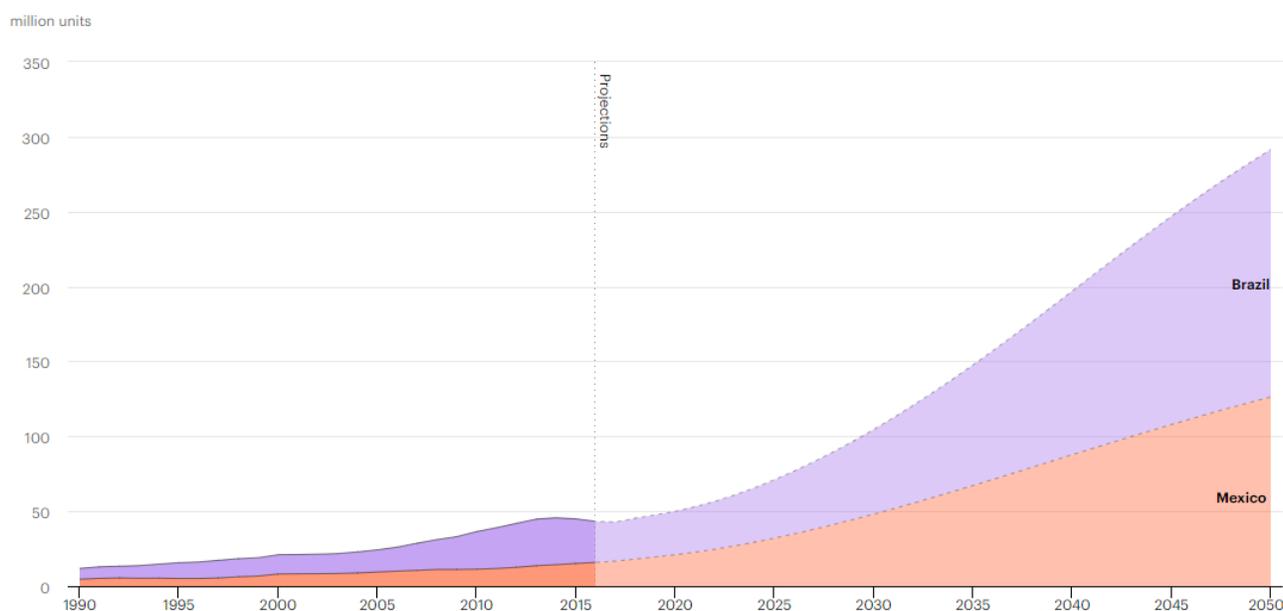
Economic expansion and population growth will result in additional demand for buildings in Latin America. The population has been growing at an average pace of 6 million people per year and is expected to reach its peak by mid-century (ECLAC 2019). Latin America is a highly urbanized region where 80 percent of its population lives in urban areas (UN DESA 2019). By 2050, an additional 150 million people are expected to live in urban areas (GlobalABC 2020). On the other hand, Latin America accounts for 6 percent of the gross world product (IMF 2019). Before Covid-19, the region had seen more than three decades of continuous economic growth (World Bank 2019). Although the impact of Covid-19 has resulted in the worst recession in a century (with an estimated economic contraction of 7.7 percent in 2020), Latin America's gross regional domestic product is expected to rebound in 2021 (Bárcena et al. 2020). Consequently, floor space is expected to increase by 65 percent by 2050, driven mainly by an additional 11 billion m² in residential buildings (IEA 2017). Mexico alone projects around 2.6 million new residential units between 2018 and 2025 (Mackres and Loutfi 2020).

The need for additional buildings will result in an increased demand for construction materials. In 2015, cement consumption in Latin America amounted to 188 million tons (Federación Interamericana del Cemento 2018). During the same year, steel consumption for the construction industry totaled 35 million tons (Asociación Latinoamericana del Acero 2019). Compared to 2015 figures, cement production is projected to rise by more than 60 percent and steel production by more than 45 percent by 2050 (Energy Transitions Commission 2018b; Fitch Ratings 2020).

Rising incomes and living standards will also boost the demand for appliances and equipment. For instance, the International Energy Agency estimates that the number of households owning an air conditioner will grow by a factor of more than six by 2050 in countries like Brazil and Mexico (see

Figure 5) (IEA 2019a). Since the effects of climate change entail hotter days and longer dry spells, the energy demand of household appliances could further increase. Thus, it is critical to ensure that additional appliances operate efficiently to limit the amount of carbon dioxide released into the atmosphere.

Figure 5. Historic and projected air conditioners in Mexico and Brazil, 1990 – 2050



Source: [IEA \(2019\)](#).

Climate Change Vulnerability in Latin America

Due to its socioeconomic conditions, demographic factors, and geographic location, Latin America is particularly vulnerable to the effects of climate change. Over 50 percent of people in Latin America live in countries with high or extreme climate vulnerability risks—being Small Island Development States the most likely to suffer the gravest effects of climate change (The Resource Foundation 2019). In addition, 30 percent of the population in Latin America lives in poverty, which renders them even more vulnerable to the risks of climate change (GlobalABC 2020). Due to the low adaptive capacity of socioeconomic systems in Latin America, the economic costs of climate change have been estimated between 1.5 and 5 percent of the region's GDP by 2050 (CEPAL 2015). These conditions underscore the importance of developing buildings and dwellings that are climate-resilient. In this sense, buildings must incorporate mitigation strategies that include adaptation measures such as nature-based solutions and passive design.

The Importance of Decarbonizing the Building Sector

The decarbonization of the building sector in Latin America is crucial to achieving the goals of the Paris Agreement since it accounts for 21 percent of all energy-related carbon emissions. Moreover, the building sector contributes with significant additional emissions that arise from the manufacture of

building materials—such as cement and steel—and construction processes. Yet, buildings in Latin America offer opportunities for significant reductions in carbon emissions, as well as for universal access to electricity and clean cooking technologies. According to the International Energy Agency, annual emissions from buildings in Latin America could be 51 percent lower than today (even after considering a 60 percent GDP growth and a 67 percent increase in floor area). These savings are equivalent to the emissions from over 30 coal-fired power plants (GlobalABC 2020).

To attain both operational and embodied carbon reductions, effective policies and technologies must encompass the whole lifecycle of new and existing buildings—including the design, development, operation, maintenance, refurbishment, and decommissioning. To align the building sector with the goals of the Paris Agreement, effective collaboration among several stakeholders—including policymakers, urban planners, architects, construction companies, materials suppliers, utility companies, developers, and investors—will be critical at the regional, national, local, and project levels.

V. Action Items to Reduce Operational Carbon in Buildings

The IDB and other international financial institutions can support countries to achieve net-zero buildings by 2050. To this end, both new and existing buildings must reduce their operational energy demand and associated emissions. Passive design strategies and software technologies could be leveraged to improve the performance of buildings. Additional measures like certifications and lifecycle assessments could bring the sector closer to net-zero by 2050. Ultimately, the IDB could support countries to enact policies at both the national and local levels to reduce operational carbon in buildings. This section outlines a range of technologies, policies, and other measures that the IDB (and other international financial institutions) could take to support countries to reduce operational carbon in buildings—thus contributing to their alignment with the goals of the Paris Agreement.

Technologies and Strategies to Reduce Operational Carbon in Buildings

Passive design consists of construction techniques that maximize environmental characteristics to create comfortable conditions inside buildings, thus reducing or eliminating the need for heating or cooling. Some passive design strategies are building orientation, shading, sealing and insulation, thermal mass, glazing, and skylights (McGee 2013). External shading and reflective surface finishes (e.g., painting roofs with light colors) are effective measures to block out solar radiation in new and existing buildings (GlobalABC 2020). Scientists have recently invented a white paint that reflects 98 percent of the sun's light and can cool surfaces by up to 4.5°C (World Economic Forum 2021). Some studies suggest that appropriate passive design strategies could achieve between 20 and 60 percent energy savings (Ochoa and Capeluto 2008; Liu et al. 2020). However, the correct selection of passive design strategies depends on the building type and climate conditions.

Widespread use of **design tools** could enable the adoption of efficient passive design strategies in buildings. Although simulation tools—such as thermal and daylight simulation—and building information modeling (BIM) can optimize passive design choices, their use across the region is minimal (GlobalABC 2020). Software tools constitute a more accessible approach to incorporating passive design strategies. For instance, ARUP’s Passive Design Assistant could be particularly helpful with passive thermal design, including factors such as insulation, thermal mass, ventilation, and solar gain (ARUP 2021). IFC’s free EDGE software calculates buildings’ energy savings and reductions in carbon footprint. It includes a dashboard that depicts the additional cost of building green and the estimated time it would take to offset such costs through operational savings (EDGE 2021).

Increased adoption of **energy management systems (EMS)** could help better manage energy demand and identify additional efficiency opportunities. EMS control and monitor energy-consuming devices (such as heating and cooling equipment, fans, pumps, and lighting), allowing building owners and managers to make more informed decisions regarding energy usage (US DOE 2021a; AIT 2021). The basis of an EMS could be a simple network of digital energy meters or a smart meter. EMS could also be linked to **digital sensors and control systems** to achieve even more efficient operations. Control systems can range from fully centralized systems to simpler systems like programmable thermostats. In recent years, control systems have started to incorporate machine learning to optimize building operations based on internal and external conditions (GlobalABC 2020). For this reason, smart controls are considered a great niche for energy savings across the region.

Building passports could incentivize reductions in operational carbon by informing relevant stakeholders on all building-related data at every stage of a building’s lifecycle. However, their adoption in Latin America has been limited. A building passport is a document that includes relevant information about the building, including systems, energy use, renovations, and retrofits (GlobalABC 2020). These documents can help financial institutions improve investment decisions and policymakers design better programs and policies (One Planet Network 2019).

Nature-based solutions are important strategies to reducing carbon emissions and increasing the adaptive capacity of buildings by harnessing natural capital (Cohen-Shacham et al. 2019). Moreover, they generate additional social and economic benefits (known as “co-benefits”) beyond the scope of climate change mitigation and adaptation. Green roofs and walls are nature-based solutions that reduce carbon emissions and improve air quality in buildings. Green roofs and walls are also effective in mitigating extreme heat effects because vegetation keeps the air cool through evapotranspiration (by releasing moisture into the atmosphere) (NYC DDC 2007).

Policies and Climate Instruments to Reduce Operational Carbon in Buildings

Energy codes and standards are key policy instruments to reduce energy consumption in buildings because they specify the minimum requirements for components and performance. To date, most countries lack codes for minimum energy performance in buildings (see Figure 7). Jamaica and French Guyana have mandatory building codes that apply to the entire sector and include minimum standards

for energy efficiency both in new and existing buildings. Argentina, Brazil, Chile, and Mexico have partial mandatory energy codes for some parts of the sector. The remaining countries have voluntary or no codes at all (GlobalABC 2019). International Financial Institutions can play a significant role in helping countries develop energy codes. For instance, the International Finance Corporation has supported green building codes at the national level in Costa Rica, Panama, and Peru. In Colombia, it has also worked on the development of building energy codes at the city level (World Bank 2016).

Building codes and standards should include bioclimatic and passive design principles to maximize energy efficiency (GlobalABC 2020). Bioclimatic design takes into account climate and environmental conditions—as well as architectural elements and techniques—to reduce the carbon footprint of buildings by minimizing dependence on mechanical systems (Croft 2019). Bioclimatic and passive design guidelines should be developed for specific building types (e.g., single-family, multi-family, commercial) and regions—taking special considerations when applied to existing buildings (GlobalABC 2020). According to the International Energy Agency, all countries must establish mandatory energy codes by 2030 to align with the Sustainable Development Scenario (IEA 2021).

Figure 7. Building energy codes in Latin America, 2018



Source: [GlobalABC \(2020\)](#).

Putting energy codes in place is necessary but not sufficient to achieve net-zero buildings by 2050. The compliance and enforcement of energy codes is a crucial—yet challenging—step that should be carried out at the local level. One additional challenge is the high rates of informal construction in the region, which account for up to 75 percent of new dwellings each year (World Bank 2017). Capacity building, construction guidelines, affordable materials and tools, and stakeholder engagement will be paramount to increasing code compliance within the informal sector. Monitoring frameworks, financial incentives, and passive strategies can also facilitate and enable compliance within the informal sector. Still, local experts believe that achieving total compliance will be challenging and estimate that only around 50 percent of new buildings will reach code compliance by 2050 (GlobalABC 2020).

Energy codes and standards for energy efficiency refurbishment are virtually unused in Latin America. Chile is the only country where the building code covers the retrofit of existing buildings (GlobalABC 2020). The refurbishment and retrofit of existing buildings often involve modifications that improve energy efficiency or decrease energy demand (US DOE 2021d). Therefore, existing buildings should be gradually refurbished to meet the performance standards of new buildings and increase their lifetime. The government of Mexico City recently launched the Efficient Buildings Challenge as part of the United Nations Sustainable Energy for All (SE4ALL) initiative. The program aims to promote energy efficiency measures in existing buildings—both public and private. The objective is to achieve 10 percent savings in energy consumption among participating buildings within one year (WRI Mexico 2021).

Besides incorporating passive design and energy efficiency measures, building codes should delineate requirements for on-site renewable energy systems and electrification. To date, few countries establish requirements for clean energy integration in building codes. Relevant stakeholders—from national authorities to builders—should participate in all stages of buildings to ensure the incorporation of appropriate technologies and applicable renewable energy requirements (GlobalABC 2020). In addition, they should encourage the electrification of systems and appliances in buildings. All-electric appliances could be achieved through the implementation of “reach” codes (energy codes that reach or go beyond building standards) (Margolies 2020; DiChristopher 2020).

Building labels and certifications can help assess buildings' performance on a scale of less to more efficient, thus enabling information sharing and increasing awareness for consumers and investors (GlobalABC 2020). Energy certifications are programs that evaluate the performance of a building and its energy systems. For instance, IFC's Excellence in Design for Greater Efficiencies (EDGE) is a certification system that identifies cost-effective approaches to reducing energy use (EDGE 2021). IFC's EDGE certification was designed exclusively for developing countries and is currently present in all Latin American countries (Dalaison, González-Mahecha, and Rocha 2020).

The LEED Certification is a green building rating system that provides a framework for highly efficient green buildings—including the construction, operations, and maintenance stages (USGBC 2021). The LEED Certification is applicable for all building types and all building phases. To date, there are more than 4,000 LEED-certified projects in Latin America—with Brazil and Mexico hosting the highest

number of projects (Stanley 2019, 2020). The American Society of Heating, Refrigerating, and Air-Conditioning Engineers has developed two labels for buildings. The “As Designed” label rates buildings' potential energy use under standard conditions, independent of occupancy and usage. The “In Operation” label rates buildings' actual measured energy use, which depends on occupancy and usage (Architect Magazine 2013).

Most Latin American countries have adopted energy performance certification programs in buildings; however, they remain mostly voluntary and only applicable to some projects (see Figure 8). As a result, only a few buildings receive labels or certifications. However, local public and private certification systems are becoming increasingly adopted. Excluding the residential sector, building labels and certifications should become mandatory for all public and private buildings (GlobalABC 2020).

Figure 8. Building energy certification programs in Latin America, 2018



Source: [GlobalABC \(2020\)](#).

While codes and certifications are essential policies for new and existing buildings, additional measures are needed to incentivize efficient operations. **Energy audits** can be powerful mechanisms to assess opportunities for energy savings. Therefore, they should be conducted regularly—particularly in buildings with high energy demand (GlobalABC 2020).

One other approach that can help achieve efficiency improvements is measuring the energy use of a building, benchmarking it, and disclosing the information to the building's owner, manager, or occupant (NASEM 2021). Since **benchmarking** consists of measuring and comparing energy use

across similar buildings, it allows building managers and owners to understand their building's energy performance and identify opportunities for energy savings. Therefore, benchmarking and the disclosure of energy performance in buildings should become mandatory in all Latin American countries to create a virtuous circle of improvement and demand for high-performing buildings (IMT 2021).

Federal governments in Latin America should consider implementing an **emissions cap for federally-owned buildings**—both new and existing. The US National Academies of Sciences, Engineering, and Medicine suggests that the cap could decline by three percent per year. In this sense, buildings could achieve emissions reductions through energy efficiency upgrades, electrification, and on-site renewable energy generation (NASEM 2021). Emissions caps in federally-owned buildings would serve as role models for states and municipalities to set standards for both public and private buildings.

Financial and non-financial incentives could encourage people to own and develop low-energy and low-carbon buildings. One of the most effective strategies to spur innovation and increase the uptake of green building technologies is rewarding developers and homeowners with the best-performing buildings (USGBC 2014). Financial incentives include tax credits, fee waivers, grants, and special loans (e.g., green mortgages). Similarly, non-financial incentives—such as expedited permitting and increased floor area allowances—are powerful tools to encourage the construction and retrofit of low-energy buildings (GlobalABC 2020). Other types of incentives—such as free planning, certification training, and technical assistance—can also encourage developers to build green (USGBC 2014).

Financial and non-financial incentives could also promote **on-site renewable generation** in buildings—an effective strategy to reduce carbon emissions. To date, only a few buildings in Latin America incorporate on-site renewable generation (GlobalABC 2020). Residential and commercial buildings may fully or partially meet their energy needs with on-site renewable heat and electricity generation systems. In addition to reducing carbon emissions, local generation of renewable heat and electricity offers co-benefits such as decreased indoor pollution, greater energy security, and better possibilities of energy governance at the community level. Widespread adoption of distributed energy generation could be encouraged through feasibility studies of on-site systems in new and existing buildings (GlobalABC 2020). Thus, non-financial incentives—such as expedited product approvals and permits—could create an enabling environment for on-site renewable energy technologies. Similarly, financial incentives could accelerate the deployment of such technologies by encouraging private investment.

To further enable wider adoption of on-site renewable energy systems, countries should outline **clear regulatory frameworks** for distributed renewable generation in buildings. Regulatory frameworks define operating rules, connection permits, the use of networks for distributed resources, goals, incentives, market conditions, prices for surpluses, and other factors that allow a simple adoption of on-site energy generation (GlobalABC 2020). In this sense, a clear, well-designed, updated, and consistent regulatory framework can enable widespread adoption of renewable energy generation systems.

Box 1. Best practices to reduce operational carbon in buildings

- Mexico implemented its “Energy Conservation Code for Buildings,” which outlines minimum energy efficiency requirements for new buildings, including air-conditioning and water heating systems, appliances, solar gains, and the building envelope. The Code was created at the federal level and its implementation is voluntary. However, if the Code is adopted at the local level, it becomes mandatory (GlobalABC 2020).
- In the US, the International Code Council outlines building energy codes every three years that are adopted by state and city officials. To date, around 70 percent of the US population lives in areas regulated by these codes—both for commercial and residential buildings (Iaconangelo 2021).
- In 2019, the City of Santa Rosa, California passed a reach code that requires all new residential buildings (of three stories and below) to be all-electric (City of Santa Rosa Government 2021).
- In 2018, Argentina launched the “Energy Efficiency and Renewable Energy in Social Housing” standard. This is the first national standard for building energy performance that applies to social housing (IEA 2021).
- The municipality of Sao Paulo, in Brazil, launched its own certification system—the EDIF Seal—in 2018. It defines minimum mandatory actions—as well as optional ones—for the incorporation of environmental criteria and energy efficiency, among others.
- The Mexican government—with support from the German Agency for International Cooperation (GIZ)—has developed a rating system of energy performance for office buildings based on the Energy Star methodology (EM Magazine 2018).
- In Brazil, the “Programa de Desempenho Energético Operacional” (Operational Energy Performance Program) recently released a benchmarking platform where building owners can compare their energy performance against similar buildings (GlobalABC 2020).
- Argentina’s IRAM 11603 standard divides the country into five bioclimatic regions and specifies seasonal climatic data for the verification of thermal quality in buildings (GlobalABC 2020). Based on microclimate conditions, it provides recommendations regarding building orientation and design—including ventilation, thermal insulation, and glazing (Iriarte 2018).

Box 1 (continued). Best practices to reduce operational carbon in buildings

- In 2017, the Chilean government signed a memorandum of understanding with the United Kingdom to promote BIM protocols in public projects, training, and planning processes (British Embassy Santiago 2017). More recently, the Chilean government mandated BIM for all public projects starting in 2020 (Bnamericas 2019). Brazil followed suit and has established the mandatory use of BIM for public projects starting January 2021 (Planbim 2021).
- Torre Mayor in Mexico City—which holds a LEED Gold Certification—is a leading example of best practices in operations and maintenance. It is an intelligent building that provides an efficient work environment through the optimization of the structure, systems, services, and administration. A Lutron Intelligent System controls the lighting of the lobby, commercial areas, and parking lot, which enables considerable energy savings (USGBC 2018).
- New York recently painted 1 million m² of ‘cool roofs’ with a novel white painting (made up of barium sulphate) that can cool surfaces by up to 4.5°C (World Economic Forum 2021).

Technologies to Reduce Carbon from Appliances and Systems

According to the International Energy Agency, a sustainable development scenario requires improvements of up to 35 percent in the energy performance of heating devices across the region by 2030 (IEA 2020b). Although heating demand is generally low across Latin American countries (due to predominantly warm climates), countries that do have heating demand need to improve their heating intensity efficiency. **Heating technologies**—such as heat pumps and modern biomass stoves and boilers—can enable reductions in energy consumption (GlobalABC 2020).

While heating technologies are necessary for the medium-term, complete decarbonization of space heating and cooling is paramount to achieving net-zero buildings. This could be achieved through renewable energy systems, fuel substitutions away from fossil fuels, and renewable district systems. The primary strategy to reduce emissions from space heating is the deployment of **air-source heat pumps (ASHPs)**. ASHPs are powered by electricity and move heat from outdoor air to indoor air. When powered by zero-carbon electricity, ASHPs provide space heating with almost zero carbon emissions. These devices are suitable technologies for Latin American countries since they have proven to be particularly effective in mild climates (Kaufman et al. 2019).

As mentioned before, the demand for cooling systems is expected to grow across the region (IEA 2019a). Therefore, cooling technologies must operate efficiently to reduce energy demand and limit the amount of carbon released into the atmosphere. On top of appropriate passive design strategies

that minimize the need for cooling, **hybrid cooling technologies**—such as evaporative cooling and ventilate cooling—can deliver improved efficiency (GlobalABC 2020). Natural ventilation is the least expensive and most energy-efficient way to cool buildings. While natural ventilation may suffice for cooling, it usually needs to be supplemented with spot ventilation, ceiling fans, and window fans (US DOE 2021e). Evaporative coolers are also an efficient approach to cooling buildings. These devices cost about one-half as much to install as central air conditioners and use around one-quarter as much energy (US DOE 2021b).

Lighting technologies can improve the quality of light, enable energy efficiency, and reduce costs (GlobalABC 2020). To date, the light-emitting diode (LED) is one of the most energy-efficient lighting technologies. High-quality residential LED light bulbs consume 75 percent less energy and last 25 times longer than incandescent lighting (US DOE 2021c).

Policies to Reduce Carbon from Appliances and Systems

Lighting, appliances, and equipment systems offer significant opportunities for emissions reductions in new and existing buildings. Across the region, many standard appliances—including refrigerators, washing machines, and air conditioners—have **mandatory energy performance standards (MEPS)**, endorsement labels, or rating systems in place (GlobalABC 2020). However, these standards should be expanded to all countries and revised regularly to ensure enhanced performance. Testing protocols and enforcement mechanisms are also essential for MEPS to work effectively. The existence of MEPS would gradually eliminate the most inefficient appliances—in terms of energy utilization—from the market (Ravillard et al. 2019). Some countries have already incorporated MEPS at the national level. As of June 2020, Brazil has prohibited the manufacturing, import, and marketing (by both wholesalers and retailers) of non-compliant air conditioners (GlobalABC 2020).

While increased efficiency in buildings' appliances and systems is an adequate strategy in the medium term, the complete electrification of household and commercial appliances is needed to achieve net-zero buildings by 2050. Governments in Latin America should aim to establish national **zero-emission appliance manufacturing standards** covering space heating and cooling, water heating, and cooking. Appliance electrification policies could mirror electric vehicle mandates (such as California's ZEV program), requiring appliance manufacturers to sell an increasing fraction of electric products while allowing emissions trading among them. Alternatively, electrification policies could take the form of clean energy standards, where emissions per product are required to decline over time until they reach zero (NASEM 2021).

Mandatory product labels provide relevant information by specifying the performance, energy demand, carbon emissions, and cost of operation of an appliance during its entire lifecycle. This information allows consumers to make better choices when acquiring appliances and enables the implementation of incentives, MEPS, and phase-out programs (GlobalABC 2020). Although most Latin American countries have appliance labeling to some extent, these programs are not mandatory in all countries and cover different appliances and equipment. In Mexico, labels apply to domestic electric

equipment, air conditioning, heating, and bulb lighting (Ravillard et al. 2019). While labeling programs in Mexico and Central America align with those of the US, most countries in South America are aligned—to some extent—with European programs. Achieving harmonization may be difficult due to countries' different economic structures, diverse commercial linkages, and conflicting national interests (Braungardt and Göthner 2017). However, product labels for main appliances should become universal and mandatory before 2030 (GlobalABC 2020).

Public and private entities can contribute to phasing out inefficient systems and appliances through **green procurement**. The term green procurement refers to the acquisition of products and services “with smaller-than-average environmental footprints.” Labeling and certification programs—such as Energy Star—can be leveraged to identify green products and services (Fischer 2010). While government agencies could incorporate green procurement policies as part of their operations at the national and local levels, international financial institutions could implement green procurement policies at the project level. Since these policies could be harder to enforce in the private sector, governments should publicly encourage firms to adopt voluntary sustainability standards. Firms would have to perform well in all aspects of purchasing social responsibility (PSR) to keep their reputation intact (Appolloni et al. 2014).

Financial and non-financial incentives should be escalated to encourage the purchase and manufacture of efficient systems and appliances, as well as to promote energy conservation in buildings. On one hand, utilities, local governments, and state agencies could offer incentives programs—such as rebates, tax incentives, and loans—to contribute to making energy efficiency a more affordable option (Energysage 2019). On the other hand, expedited product approvals and permits can accelerate the deployment of efficient appliances by encouraging private investment. Nudge policies are excellent non-financial incentives that encourage energy conservation. Some electric bills include information about the energy use of customers' neighbors, which creates social pressure and competition—thus encouraging consumers to reduce their energy consumption relative to their neighbors (Cleary and Palmer 2020). National governments could mandate electric utilities the implementation of such programs.

Other Strategies to Reduce Carbon from Appliances and Systems

Cooling as a Service (CaaS) is a financial instrument and market model that aims to reduce energy consumption for air conditioning. CaaS is a pay-as-you-go model that enables customers to make investment decisions on the lifecycle cost rather than on the purchase price of the equipment. This model lowers the upfront cost of efficient devices—such as HVAC systems, fans, and air conditioners—to make it easier for households to acquire them (SE4ALL 2020). A technology provider installs, maintains, and owns the cooling equipment, and recovers the cost through end users' periodic installments. The providers are also responsible for paying for the energy used, which incentivizes them to install highly efficient technologies (GlobalABC 2020).

The digitalization of electric appliances represents an additional opportunity to improve energy efficiency. Appliances such as air conditioners, heating systems, washers and dryers, dishwashers, and televisions can become more efficient by reducing standby losses and connectivity energy use. The use of sensors, controls, and automation systems can enable low-power modes, load balancing, and remote programming (GlobalABC 2020).

Box 2. Best practices to reduce carbon from appliances and systems

- In Mexico, the “Hipoteca Verde” (“Green Mortgage”) and “Esta es tu casa” (“This Is Your House”) programs have provided families with supplemental finance to cover the incremental cost of energy-efficient appliances in new dwellings (CONAVI 2012).
- In Buenos Aires, Argentina, the “Pasate a LED” (“Change to LED”) program has delivered more than 740,000 lamps across 162,757 households. Beneficiaries of the program have achieved significant reductions in energy consumption—around 14 percent less energy on average. By the end of the project, 325,000 homes will be reached with total estimated energy reductions of 45.2 GWh. This is equivalent to the consumption of 13,627 homes per year and represents a reduction of 43,000 tons of CO₂ equivalent (C40 Cities 2020).
- In Mexico, the installation and operation of high efficiency chillers over a period of seven years resulted in a reduction of 18,000 tons of CO₂—the equivalent to the energy use of 1,945 homes in a year (The Lab 20201).

VI. Action Items to Reduce Embodied Carbon in Buildings

Construction materials for new and renovated buildings (such as steel, cement, and wood) are linked to energy demand and carbon emissions in every stage—from extraction and production to transport and construction. Reducing embodied carbon in buildings requires a range of actions both inside the building sector (such as lowering material) and outside the building sector (such as enhancing energy efficiency in material manufacture processes) (Energy Transitions Commission 2018a). Inside the building sector, the reuse and recycling of construction materials can significantly reduce the embodied carbon of buildings.

Policies and Climate Instruments inside the Building Sector to Reduce Embodied Carbon

Lifecycle assessments (LCAs) are powerful tools to estimate embodied carbon in buildings. Since the availability and adoption of LCAs in Latin America are minimal, countries should move toward a legislative adoption of LCAs for the building sector (GlobalABC 2020). These assessments include the environmental impacts of construction materials throughout the whole lifecycle of buildings—from material extraction and manufacturing to decommissioning and disposal. While LCAs are emerging as a functional assessment tool, there are some limitations to their use. For instance, there are few financial incentives for LCA adoption (Bayer et al. 2010). Another limitation is incomplete or deficient databases. Reliable databases containing information on the embodied carbon of materials will be necessary at the national and regional levels to undertake comprehensive analyses of buildings design (GlobalABC 2020).

Building passports could incentivize reductions in embodied carbon by informing relevant stakeholders on all building-related data at every stage of a building's lifecycle. Local experts in Latin America believe that building passports should incorporate information on materials, embodied energy, systems, and maintenance schedules by 2030. Similarly, they should include energy efficiency and clean energy measures by 2040 (GlobalABC 2020). Similar to building operations, **benchmarking and disclosure** practices should become widespread—and eventually mandatory—at the national level to monitor progress and understand best practices. The benchmarking and disclosure of environmental impacts and materials can help to inform policymaking and enforce regulations (GlobalABC 2020). Data disclosure could build upon building passports and other initiatives like the Carbon Disclosure Project—a global system for investors, companies, cities, states, and regions to manage their environmental impacts (CDP 2021).

Building codes should incorporate **minimum environmental standards** detailing the performance of building materials and promoting the use of low-carbon products. Currently, few countries in Latin America have developed building codes that incorporate minimum environmental standards for building materials (GlobalABC 2020). The stringency of building codes should increase over time and minimum environmental standards should eventually become mandatory for all materials in order to achieve net-zero buildings by 2050.

Governments should develop **local and national decarbonization strategies** by setting targets for embodied carbon in building projects. Such strategies should rely on comprehensive data collection and the implementation of tools and benchmarks to assess embodied carbon. Specific targets should be defined for materials like cement and steel while promoting the adoption of nature-based solutions as substitutes for—or complements to—conventional building materials (GlobalABC 2020). Public procurement should incorporate requirements for minimum recycled content and reusability of materials. Finally, decarbonization strategies could encourage reductions in floor space per capita by shifting to shared approaches (particularly in office buildings) (Energy Transitions Commission 2018b).

Governments should put in place and scale up **financial and non-financial incentives** to increase the adoption and use of sustainable materials in buildings. To date, there are few incentives in place for

materials with higher environmental standards across Latin America (GlobalABC 2020). Incentives should nudge both the public and private sectors towards adopting minimum performance specifications and procurement rules for sustainable products. Financial incentives can also drive new construction techniques that enable embodied carbon reductions (GlobalABC 2020). In particular, the use of low-carbon alternative materials—such as clinker substitutes for cement production or timber instead of steel—should be strongly encouraged and incentivized.

Additional Strategies inside the Building Sector to Reduce Embodied Carbon

The design of buildings should incorporate measures aimed at lowering lifecycle environmental impacts. Industry experts believe that up to 20 percent of materials are wasted during the construction of buildings (Energy Transitions Commission 2018b). Therefore, buildings should be designed in the context of a **circular economy**. A circular economy approach consists of adopting more efficient resources, reusing materials, and reducing waste (Munaro, Tavares, and Bragança 2020). Structural elements—particularly steel and concrete elements—could be reused in refurbishments and even new buildings (Energy Transitions Commission 2018b). Developing guidelines for circular economy implementation and choosing circular economy indicators should be done in the early stages of a project and based on LCAs and material flow analyses (Stephan and Athanassiadis 2017). National and local governments should develop waste management plans to reduce construction and demolition waste by specifying alternatives to recover, reuse, or recycle building materials (GlobalABC 2020).

The use of efficient materials and low-carbon strategies could significantly reduce embodied carbon at the project level. Cost-effective actions to reduce the embodied carbon of materials include reducing material demand through optimized design, adopting optimized construction techniques, and reusing scrap materials. Some optimization strategies are **precast concrete, 3-D printing, and building information modeling (BIM)**. Other efficiency strategies include reducing cement content in concrete and lowering the clinker-to-cement ratio. While efficiency measures and low-carbon strategies should be encouraged, they should incorporate precautionary steps to prevent unanticipated effects. For instance, sustainable forest management should meet the higher demand for timber (GlobalABC 2020).

Box 3. Best practices inside the building sector to reduce embodied carbon in buildings

- Finland, France, and the Netherlands are moving toward legislative adoption of lifecycle assessments (LCA) requirements for the construction industry, which could serve as a catalyst for wider penetration of environmental product declarations (EPDs) (GlobalABC 2020).

Box 3 (continued). Best practices inside the building sector to reduce embodied carbon in buildings

- In 2017, the Argentinian government partnered with a range of stakeholders to fast-track the construction of 100,000 timber houses through a value chain that incorporates sustainable forest management. In addition, the Argentina Housing Bicentennial Credit Program (PROCREAR) has partnered with the National Housing Fund to promote the use of timber products in the construction of dwellings and schools (GlobalABC 2020).
- HENIA, an Argentinian private company, utilizes straw bales from crop residues to manufacture panels. Besides mitigating carbon emissions (from reusing the straw), this novel material has thermal insulation seven times greater than double-hollow brick walls. The panels are also fire- and earthquake-resistant (HENIA 2021).
- The Uruguayan non-profit Tagma—in partnership with Earthship Bioteecture—is creating a network of sustainable public schools in Latin America. It deployed the first sustainable public school in Uruguay in 2016. Around 60 percent of the school is made up of recycled materials—including plastic and glass bottles, tires, cans, and cardboard (El País 2016). To date, Tagma has also deployed sustainable schools in Chile and Argentina (Tagma 2021).
- Colombia and the US use fly ash (from thermoelectric power plants) to reduce the amount of cement during the production of concrete. The use of fly ash in Portland cement concrete has many benefits and improves concrete performance in both the fresh and hardened state. Fly ash use in concrete improves the workability of plastic concrete and the strength and durability of hardened concrete. It is also a cost-effective approach (US DOT 2017).

Strategies outside the Building Sector to Reduce Embodied Carbon in Buildings

Material labeling provides useful data on products' sustainability (including information on embodied carbon) across the whole lifecycle of materials. Yet, the use of labels for environmental impacts of materials is minimal across the region (GlobalABC 2020). **Environmental Product Declarations (EPDs)** can also provide information on products' lifecycle embodied carbon. EPDs are independently verified and registered documents that communicate transparent information on the lifecycle environmental impact of materials in a credible way (EDP 2021). These labeling systems allow stakeholders to make better decisions regarding the design, acquisition, and operation of buildings. It is important to underscore that the foundation of an EPD is a lifecycle assessment.

Increasing energy efficiency in the manufacturing processes of construction materials is a necessary first step to reduce embodied carbon. The **best available technologies (BATs)** should be developed and promoted to maximize energy efficiency. Specific indicators to monitor energy use in production processes should be established, tracked, and compared against BATs. Additional measures to improve energy efficiency include making energy management systems (EMS) compulsory, promoting industry networks to share best practices, and facilitating access to sustainable manufacturing technologies (GlobalABC 2020). Cement substitutes (such as fly ash or slag) can achieve up to 20 percent reductions in embodied carbon emissions from concrete buildings (Gan et al. 2017). In steel manufacture, the injection of green hydrogen into blast furnaces can reduce carbon emissions by up to 20 percent (Hoffmann, Hoey, and Zeumer 2020). However, if countries are serious about net-zero targets, all industrial processes must undergo complete electrification. To date, producing steel from an electric arc furnace with recycled steel scrap as feedstock can reduce the embodied carbon buildings by up to 60 percent (Gan et al. 2017).

While energy efficiency measures may be adequate over the medium term, the **decarbonization of production processes** will be necessary over the long run. Tracking embodied carbon in construction materials could incentivize manufacturers to shift to cleaner energy mixes and even develop circular approaches (such as using biofuels) in production processes. These strategies hold great potential for the cement and steel industries—two of the largest sources of embodied carbon in buildings. For instance, the HYBRIT technology will replace coking coal—traditionally used in steel manufacture—with renewable electricity and hydrogen to bring the first fossil-free steel to the market by 2026 (SSAB 2021). Ultimately, governments could penalize companies that use materials with high contents of embodied carbon and companies that incur unsustainable practices during the extraction and processing of materials.

The use of renewable energies and the electrification of industrial processes should be encouraged through financial and non-financial incentives. Similarly, disincentives should be implemented to phase out fossil fuels. In this sense, ending fossil fuel subsidies will be paramount. However, the rollback of fossil fuel subsidies should be coupled with targeted welfare policies to mitigate potential socioeconomic impacts among vulnerable populations. When assessing the costs and benefits of fossil fuels vis-à-vis renewable energies, all the environmental and health costs of fossil fuel use should be considered (GlobalABC 2020).

VII. Conclusions

The decarbonization of the building sector is a crucial step towards achieving the tenets of the Paris Agreement. International Financial Institutions—including the IDB—are uniquely suited to help countries develop and adopt a range of policies, technologies, and additional measures to reduce both operational and embodied carbon in buildings. However, effective collaboration among several stakeholders—including policymakers, urban planners, architects, construction companies, materials

suppliers, utility companies, developers, and investors—will be critical at the regional, national, local, and project levels.

The IDB could promote and prioritize strategies with the potential to curb both operational and embodied carbon in buildings. At the national level, the adoption of mandatory building codes that include both operational energy requirements and embodied carbon specifications will be particularly relevant to attain carbon-neutral buildings by 2050. At the project level, building passports and lifecycle assessments could incentivize reductions in both operational and embodied carbon by informing relevant stakeholders on relevant data at every stage of a building's lifecycle. Ultimately, the IDB could help Latin American countries to outline effective long-term decarbonization strategies, NDCs, and climate plans at the national and local levels.

Although significant reductions in carbon emissions can be achieved inside the building sector (e.g., through the electrification of appliances, increased efficiency in systems, improved construction techniques, and the reuse/recycle of construction materials), it is important to highlight that actions outside the building sector are also crucial to achieve a complete decarbonization of the building sector. To this end, the IDB should promote efficiency and electrification strategies—as well as benchmarking and disclosure of information—in industrial processes, particularly for the cement and steel industries.

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