Report

Building Green

Sustainable Construction in Emerging Markets

OCTOBER 2023

IFC International Finance Corporation
WORLD BANK GROUP

About IFC

IFC—a member of the World Bank Group—is the largest global development institution focused on the private sector in emerging markets. We work in more than 100 countries, using our capital, expertise, and influence to create markets and opportunities in developing countries. In fiscal year 2023, IFC committed a record $43.7 billion to private companies and financial institutions in developing countries, leveraging the power of the private sector to end extreme poverty and boost shared prosperity as economies grapple with the impacts of global compounding crises. For more information, visit www.ifc.org.

Building Green

Sustainable Construction in Emerging Markets

IFC International Finance Corporation WORLD BANK GROUP

ACKNOWLEDGEMENTS

This report was prepared under the guidance of Susan Lund, Vice President of Economics at IFC. Denis Medvedev (Director, CERDR, IFC), Roumeen Islam (Senior Economic Advisor to the CEO, IFCMD, IFC), Vivek Pathak (Director, CBDDR, IFC), and Jamie Fergusson (Director, CBDDR, IFC) provided research leadership. Lucio Castro (Senior Economist, CERER, IFC) was the lead author managing the team. Working team members include Imtiaz Ul Haq (Economist, CERER, IFC), Juliana Somerville (Consultant, CERER, IFC), Gabriel Michelena (Consultant, CERER, IFC), Samuel Asuquo Edet (Economist, CERER, IFC), Edgar Salgado (Economist, CERER, IFC), Maty Konte (Senior Economist, CERER, IFC), and Ariana Tamara Volk (Associate Economist, CERER, IFC). Li Tu (Senior Investment Officer, CMGMF, IFC), John Anagnostou (Senior Industry Specialist, CMGMF, IFC), Marek Stec (Senior Industry Specialist, CMGMF, IFC), and Jinhuan (Ursula) Sun, (Associate Investment Officer, CMGMF, IFC) co-authored Chapter 3, while Imtiaz Ul Haq and Juliana Somerville co-authored Chapter 4. Dominique van der Mensbrugghe (Director and Research Professor, Purdue University) and Maksym Chepeliev (Senior Research Economist, Purdue University) developed the model and produced the projections presented in this report, jointly with Lucio Castro and Gabriel Michelena. R. Balaji (Chief Industry Specialist, CMGMF, IFC), John Anagnostou and Marek Stec provided invaluable expertise and support on construction materials, and Hania Dawood (Practice Manager, SCCFE, World Bank), Corinne Figueredo (Senior Operations Officer, CBDSB, IFC), Prashant Kapoor (Chief Industry Specialist, CBDSB, IFC), Ommid Saberi (Senior Industry Specialist, CBDSB, IFC), Sandeep Singh (Operations Officer, CBDSB, IFC), Naz Beykan (Consultant, CBDGB, IFC), and Smita Chandra Thomas (Consultant, CBDGB, IFC) on green buildings. Jean Pierre Lacombe (Director, CGRDR, IFC), Veronica Navas (Senior Economist, CGRDR, IFC), and Julio Flores Salvatierra (Senior Economist, CGRDR, IFC) provided detailed comments on the prospects for steel decarbonization in emerging markets. We also thank Kruskaia Sierra-Escalante (Senior Manager, CBFNP, IFC) and Elizabeth T. Burden (Operations Officer, CBFNP, IFC) for their invaluable help with the concessional and blended finance data, and Diep Nguyen-Van Houtte (Senior Manager, CBDSB) for her comments on the report. Peter Gumbel and William Shaw were the editors and Irina Sarchenko (Communications Officer, CCOCO, IFC) served as the graphics editor. Brian Beary (Communications Officer, CCOCO, IFC) and Chris Vellacott (Senior Communications Officer, CCOCO, IFC) played an invaluable role in editorial production. Nadya Saber (Senior Communications Officer, CCOIC, IFC), Monica de Leon (Communications Officer, CCOIC, IFC), and Nicolas Douillet (Senior Communications Officer, CCOIC, IFC) led the dissemination efforts. Adama Badji (Executive Assistant, CERDR, IFC), Irina Tolstaia (Program Assistant, CERDR, IFC), and Gleice Zanettin (Program Assistant, CERDR, IFC) provided administrative support.

We thank the peer reviewers Tom Farole (Lead Economist, SCADR, IBRD), Stephan Hallegatte (Senior Climate Change Adviser, GGSVP, IBRD), Seema Jayachandran (Professor of Economics and Public Affairs, Princeton University) and Juan Pablo Rud (Professor of Economics, Royal Holloway, University of London) for their insightful comments.

We especially thank the Facility for Investment Climate Advisory Services (FIAS) for the financial support provided for the report. FIAS supports World Bank Group projects that foster open, productive, and competitive markets and unlock sustainable private investment in business sectors that contribute to growth and poverty reduction. Supported by nearly 20 development partner countries and donor institutions, co-financed by the World Bank Group, and managed and implemented by IFC, FIAS is one of the oldest and largest multi-donor trust funds in the World Bank Group. For more information, see the FIAS website at www.thefias.info.

Fias | THE FACILITY FOR INVESTMENT CLIMATE ADVISORY SERVICES

CONTENTS

Foreword ... **6**

Main Findings ... **8**

Executive Summary ... **10**

CHAPTER 1: Prospects for Reducing Carbon Emissions from Construction ... **27**
1.1. Summary ... 28
1.2. Construction value chains are a major contributor to global CO^2 emissions, particularly from emerging markets. ... 28
1.3. Emissions from construction are set to rise and are off track to meet construction climate commitments. ... 36
1.4. A combination of available and emerging technologies and policy actions can reverse the growth in construction value chain emissions. ... 42
1.5. $1.5 trillion in investment in emerging markets is needed to achieve the emissions-reduction goal in construction. ... 47
1.6. Decarbonizing construction value chains entails short-term trade-offs for long-term benefits. ... 50

CHAPTER 2: Building Green in Emerging Markets ... **55**
2.1. Summary ... 56
2.2. The environmental and financial advantages of green buildings. ... 56
2.3. Decarbonizing buildings in the next decade. ... 60

CHAPTER 3: Technological Solutions for Decarbonizing Construction Materials ... **71**
3.1. Summary ... 72
3.2. Reducing emissions from the production of construction materials is challenging. ... 72
3.3. The construction materials industry is well-positioned to decarbonize. ... 72
3.4. More needs to be done to decarbonize construction materials. ... 76
3.5. Opportunities and challenges for investments in green cement and steel. ... 85

CHAPTER 4: Financing the Green Construction Transition in Emerging Markets ... **87**
4.1. Summary ... 88
4.2. Emerging markets are not mobilizing enough green private finance to decarbonize their construction value chains. ... 88
4.3. Market failures largely explain the paucity of green finance for construction in emerging markets. ... 89
4.4. Concerted action by private investors and policymakers will be required to overcome market failures and reduce emissions from construction value chains. ... 93

CHAPTER 5: Ways Forward ... **111**

Annexes ... **117**
Annex 1: The General Equilibrium—Circular Economy (CGE-CE) Model ... 118
Annex 2: Supplementary Tables and Figures ... 122
Annex 3: Methodology for Green Building Finance and Policy Tools ... 130

References ... **137**

EXHIBITS

EXHIBIT 1 .... **29**
Construction Generates About 40 Percent of Global Carbon Emissions

EXHIBIT 2 .... **30**
Cement and Steel Account for About 50 Percent of Carbon Emissions from Construction Materials

EXHIBIT 3 .... **32**
Cement Is the Most Carbon-Intensive Activity Globally

EXHIBIT 4 .... **33**
Construction-Related Emissions in Emerging Markets, 2022

EXHIBIT 5 .... **34**
Emerging Markets Account for About 90 and 70 Percent of Global Cement and Steel Production

EXHIBIT 6 .... **35**
Construction Materials Production Is More Carbon Intensive in Emerging Markets Than in High-Income Countries

EXHIBIT 7 .... **37**
Dissemination of Green Building Measures by the Private Sector Has Been Limited Outside High-Income Countries and Large Emerging Markets

EXHIBIT 8 .... **39**
Global Construction Emissions Are Projected to Grow

EXHIBIT 9 .... **40**
South Asia Will Be Driving the Increase in Construction Emissions in Emerging Markets

EXHIBIT 10 .... **43**
Global Construction Emissions Could Decline by 13 Percent Below the 2022 Level by 2035 with Decisive Action in Construction Value Chains

EXHIBIT 11 .... **46**
Emerging Markets Will Account for Most of the Expected Reduction in Construction-Related Emissions

EXHIBIT 12 .... **48**
Investment Needs for Building Green Will Amount to $1.5 Trillion in Emerging Markets in the Next Decade

EXHIBIT 13 .... **49**
Investment in Building Green Would Be Largest in Residential Housing

EXHIBIT 14 .... **59**
Upfront Capital Costs and Payback Periods of Green Buildings Vary Widely

EXHIBIT 15 .... **60**
Green Buildings Can Have Lower Operating Costs and Higher Asset Value

EXHIBIT 16 .... **65**
Expected Costs and Abatement Potential of Decarbonization Options in Construction

EXHIBIT 17 .... **67**
District Cooling Systems Can Reduce Energy Consumption up to 40 Percent

EXHIBIT 18 .... **77**
Abatement Potential and Economic Costs of Technological Solutions

EXHIBIT 19 .... **82**
Use of Alternative Fuels for Cement Production is Limited in Low-Income Regions

EXHIBIT 20 .... **91**
Global Private Green Debt Finance to Build Green Increased Twentyfold, and About 70 Percent Flowed into Green Bonds

EXHIBIT 21 .... **92**
Emerging Markets Issued Only 10 Percent of Global Domestic and Foreign Private Green Debt Finance for Construction Decarbonization

EXHIBIT 22 .... **93**
Latin America and the Caribbean Accounts for More Than 50 Percent of Private Green Debt Issuance for Construction Decarbonization in Emerging Markets Outside China

EXHIBIT 23 .... **94**
Emerging Markets Are Increasingly Using Sustainability-Linked Instruments for Green Construction Financing

EXHIBIT 24 .... **97**
Sustainability-Linked Finance Can Help Decarbonize Hard-to-Abate Construction Materials

EXHIBIT 25 .... **100**
Fundraising by Green REITs Increased More Than Fortyfold in the Last Four Years

EXHIBIT 26 .... **104**
Carbon Taxes Have Been Introduced in Only a Few Emerging Markets

EXHIBIT 27 .... **105**
Regional, National, and Subnational Emissions Trading System (ETS) Initiatives Implemented

EXHIBIT 28 .... **109**
Latin America and the Caribbean and Sub-Saharan Africa Receive About Half of Concessional and Blended Finance

EXHIBIT 29 .... **110**
Multilateral Development Banks Raised About $16 Billion in Bonds Supporting Building Green in Emerging Markets in 2017–2022

ABBREVIATIONS AND ACRONYMS

BF-BO	Blast Furnace – Basic Oxygen Furnace
CCUS	Carbon Capture, Utilization, and Storage
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CGE-CE	Computable General Equilibrium – Circular Economy model
CO_2 kg eq.	Kilograms of carbon dioxide equivalent
DFIs	Development Finance Institutions
EAF	Electric Arc Furnace
EBRD	European Bank for Reconstruction and Development
EDGE	Excellence in Design for Greater Efficiencies
EF	Environmental Finance
EFTA	European Free Trade Association
ENVISAGE	Environmental Impact and Sustainable Applied General Equilibrium model
ESG	Environmental, Social, and Governance
ETS	Emissions Trading System
EU	European Union
GCCA	Global Cement and Concrete Association
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IEA	International Energy Agency
IEA PAMS	IEA Policy and Measures database
IFC	International Finance Corporation
IMF	International Monetary Fund
IMF WEO	IMF World Economic Outlook
KPIs	Key Performance Indicators
MAGC	Market Accelerator for Green Construction
MDBs	Multilateral Development Banks
$MtCO_2$ eq.	Metric tons of carbon dioxide equivalent
NDCs	Nationally Determined Contributions
OECD	Organization for Economic Co-operation and Development
$PM_{2.5}$	Particulate Matter Pollution
R&D	Research and Development
REITs	Real Estate Investment Trusts
UNFCCC	United Nations Framework Convention on Climate Change

Foreword

Construction value chains, including the construction and operation of buildings as well as production of materials such as steel and cement, account for approximately 40 percent of energy and industrial-related CO_2 emissions globally. Two-thirds of this can be attributed to emerging markets, and this contribution will grow substantially as growing populations, urbanization, and rising incomes drive demand for better housing and commercial buildings.

How developing countries meet their rising building needs will be pivotal to the world's climate future. The good news is that the projected emissions growth in construction value chains can be reduced significantly with the application of existing technologies, new financing instruments, and the implementation of appropriate policies. Even as emerging economies meet the rising demand for residential and commercial buildings, it is possible to reduce total emissions from the sector below today's level by 2035. To avoid perpetuating the status quo, decisive action is needed by policymakers, developers, construction material producers, financiers, and international development institutions.

IFC is launching this report to guide international efforts to decarbonize construction value chains. *Building Green: Sustainable Construction in Emerging Markets* was prepared through close collaboration between IFC economists, investment officers, and building and construction sector specialists. The report provides a comprehensive analysis of the challenges of reducing carbon emissions from construction value chains in developing countries, but also the considerable opportunities that will come from mobilizing the estimated $1.5 trillion of investment required for this transition.

The report also offers important recommendations on financial instruments, technical assistance, standards, technologies, and capacity building to channel more financing into green buildings and materials and address the market failures hampering further progress on building green. IFC's own green buildings program and sustainability-linked finance facilities offer proven models on how such initiatives can be accomplished at scale.

Realizing the potential outlined in this report will require coordinated efforts by stakeholders across regions and industries. IFC is committed to working with policymakers, businesses, and investors on seizing the climate opportunity in building green and turning today's challenges into opportunities for a greener, more resilient world.

Susan M. Lund

Vice President, Economics and Private Sector Development, IFC

Main Findings

Global climate goals will not be achieved without a substantial reduction in emissions from the construction sector. This poses a particular challenge to emerging markets: their economic development depends significantly on construction activity, but they already generate about two-thirds of global construction-related emissions.

This report analyzes the investments and policy actions needed—and the economic trade-offs they imply—to reduce carbon emissions in construction value chains in emerging markets, including the construction and operation of buildings and the production of construction materials such as cement and steel. It explores the costs and availability of technological solutions that could help reduce emissions, and it considers potential sources for financing these solutions as well as the policy interventions needed to channel private investment into mitigation and adaptation efforts in emerging markets. The report examines the alternative policy options and available and novel technologies for building green in emerging markets, considering each region's income level, technological and policy readiness, and dependence on fossil fuels. Key findings and messages include:

Construction value chains today account for about 40 percent of energy and industrial-related CO_2 emissions globally, according to this report's estimates. Without additional mitigation and adaptation efforts, emissions are likely to increase by about 13 percent by 2035, this report estimates, which would equal the total construction-related emissions of the United States in 2022. The share of construction-related emissions generated in emerging and developing economies, currently two-thirds of the global total, is also likely to rise by 2035. This is because these markets have the largest stock of brown buildings (not adapted for energy or emissions reduction), use relatively more carbon-intensive construction methods and materials, and their investment in construction is likely to grow faster than in high-income economies.

Technologies that already exist can significantly reduce construction's environmental footprint with moderate economic costs. For buildings operation, these technologies include electrification of buildings with non-fossil fuels, and use of specific materials to reduce energy consumption, like reflective painting for rooftops and film coating for windows, among others. For new buildings, energy-efficient and resilient designs and systems, renewable energies, and district cooling and heating systems, are some of the possible mitigation and adaptation options. For construction materials, especially cement and steel, improving energy-efficiency, and switching to low-emission processes, raw materials, and fuels, can also reduce emissions now. In the future, potentially deploying nascent technologies such as carbon capture and storage and green hydrogen, among others, can all serve to reduce emissions, but these levers are only expected to become commercially available without fiscal support by 2035 and beyond.

For all emerging markets, incorporating resilience into new green buildings will be paramount in the next decade, especially in countries affected by frequent hazardous climate events. Climate change-induced disasters are already causing significant damage to people and assets around the world. Between 2008 and 2018, on average 24 million people per year were internally displaced because of climate disasters, of which 85 percent involved storms and floods.

Investments in electrification of brown buildings with cleaner energy, energy-efficient new buildings, and low-emission materials, and the adoption of adequate policy frameworks could reduce global construction value chain emissions by 2035 to about 23 percent below the level they are projected to reach without any mitigation efforts—and 13 percent below today's levels—this report estimates. Emerging markets would account for about 55 percent of this projected reduction in construction emissions. The decline in global construction emissions would also entail a drop in total global emissions—including construction and other economic activities—of about 20 percent in comparison to a scenario without any mitigation investments and measures. These results emphasize the importance of starting to decarbonize hard-to-abate activities now, such as building operations and materials, to meet the climate goals set in the Paris Agreement.

With proper policies and regulations in place, adopting these commercially available technologies in construction value chains would generate new private investments of $1.5 trillion in greener buildings and materials in emerging markets over the next decade, according to this report's estimates. Private investors have yet to take advantage of this opportunity. Global private debt financing for decarbonizing construction using 'green' financial instruments reached a record high in 2021 of about $230 billion, but emerging markets only issued about 10 percent of that total, this report estimates.

This report examines two possible pathways for reducing carbon emissions in construction value chains in the next decade in emerging markets. One pathway involves accelerating the attainment of the net zero emissions target set by the Paris Agreement by 2050 by boosting investments in green buildings and materials through widespread carbon pricing and fiscal support measures. This pathway would more than double investments in green construction by 2035 globally but would entail significant short-to-mid-term output losses due to early retirement of productive assets and other transition-related costs. Another pathway would achieve a similar reduction in construction emissions but at lower costs by supporting the adoption of 'low-hanging fruit' technologies, like the electrification of buildings with cleaner energy mixes and energy-efficient buildings and materials, among others.

Based on these estimates, the report stresses the need for a flexible strategy for decarbonizing construction value chains geared toward minimizing economic costs for emerging markets by deploying the most efficient sequencing of adaptation and mitigation policies and technologies, adapted to each country's conditions, and from a long-term perspective.

Policymakers can support the green construction transition and crowd in private financing by creating an adequate business and regulatory environment. It is critical to address the market failures which limit green construction in emerging markets through green building codes and standards, greening government buildings and public procurement, and in the mid-term, wider adoption of carbon pricing and fiscal support measures.

The pace of adoption of these technologies and measures will depend on each country's income level, access to finance, technological and policy readiness, and dependence on fossil fuels. Countries with sufficient fiscal space may be able to move faster in deploying relatively costly policies, like carbon pricing, stricter environmental regulations, retrofitting brown plants and buildings, and providing fiscal incentives to novel green technologies non-economically viable today. In other countries, early action could be taken by seizing 'low hanging fruit', including the adoption of commercially available technologies for electrification of buildings with cleaner energies and energy-efficient buildings and materials. Low-income economies can begin their journey in the green construction transition with technical and financial support from the international community.

Decarbonizing construction value chains in emerging markets will entail relatively small short-term negative costs for long-term benefits. Construction-specific measures and the cost of incentives to adopt commercially available technologies geared towards fostering energy-efficient buildings and materials powered with cleaner energies would reduce global GDP growth by 0.03 percentage points per year between 2022 and 2035, this report estimates. Most of this output loss will occur in countries with the largest construction sectors today, mostly high-income and some upper-middle economies. The majority of middle-income countries would be able to meet their rapidly growing construction needs with lower economic costs. Output losses among low-income countries would be smaller still. These reductions pale in comparison with the loss in human welfare over the next decades if insufficient efforts are made to address climate change.

Executive Summary

Construction value chains in emerging markets are a major contributor to global CO_2 emissions, and the problem is set to get worse by 2035.

Construction value chains account for about 40 percent of energy and industrial-related CO_2 emissions globally.[1,2] These value chains comprise the construction and operation of buildings and the production of materials. This report estimates that operation of buildings explains about 20 percent of global carbon emissions, followed by the supply of materials (19 percent), and construction services (0.3 percent) (Exhibit A). About 85 percent of total construction emissions globally come from the use of fossil fuels in buildings and materials plants while the remaining 15 percent comes from process or industrial emissions related to the production of construction materials.[3]

Emerging markets generate two-thirds of construction-related global emissions, with about three-fifths of these emissions from China, because of their dominant share both of "brown" buildings and the global production of materials, their use of more carbon-intensive construction methods and materials than in high-income countries, and their rapid growth in income per capita, which increases construction demand.[4]

Without additional mitigation efforts, global construction-related emissions would increase by about 13 percent between 2022 and 2035, according to this report's estimates. This 13 percent increase relative to today's levels, driven by increasing emissions from emerging markets would be equivalent to the total emissions from the construction value chain in the United States in 2022. Global climate goals are unlikely to be achieved without a reduction in emissions from the construction and operation of buildings. Thus, an important challenge facing the global community is how to ensure the integration into construction value

1 This report includes only scope 1, 2, and 3 CO_2 emissions resulting from energy combustion and economic activity in agriculture, manufacturing, and services. Emissions of other greenhouse gases (e.g., methane) and other CO_2 emissions (e.g., from changes in land use) are not considered due to data limitations. Emissions are calculated based on the location where they were produced, not where they are consumed. Industrial or process emissions are the by-product of processes that convert raw materials to chemical, mineral or metal products such as cement and steel, among others.

2 This estimate roughly aligns with recent calculations from IEA (2021) and UNEP (2021) in which construction accounts for 36 percent of global final energy consumption and 37 percent of energy related CO_2 emissions.

3 IFC calculations based on Global Trade Analysis Project data.

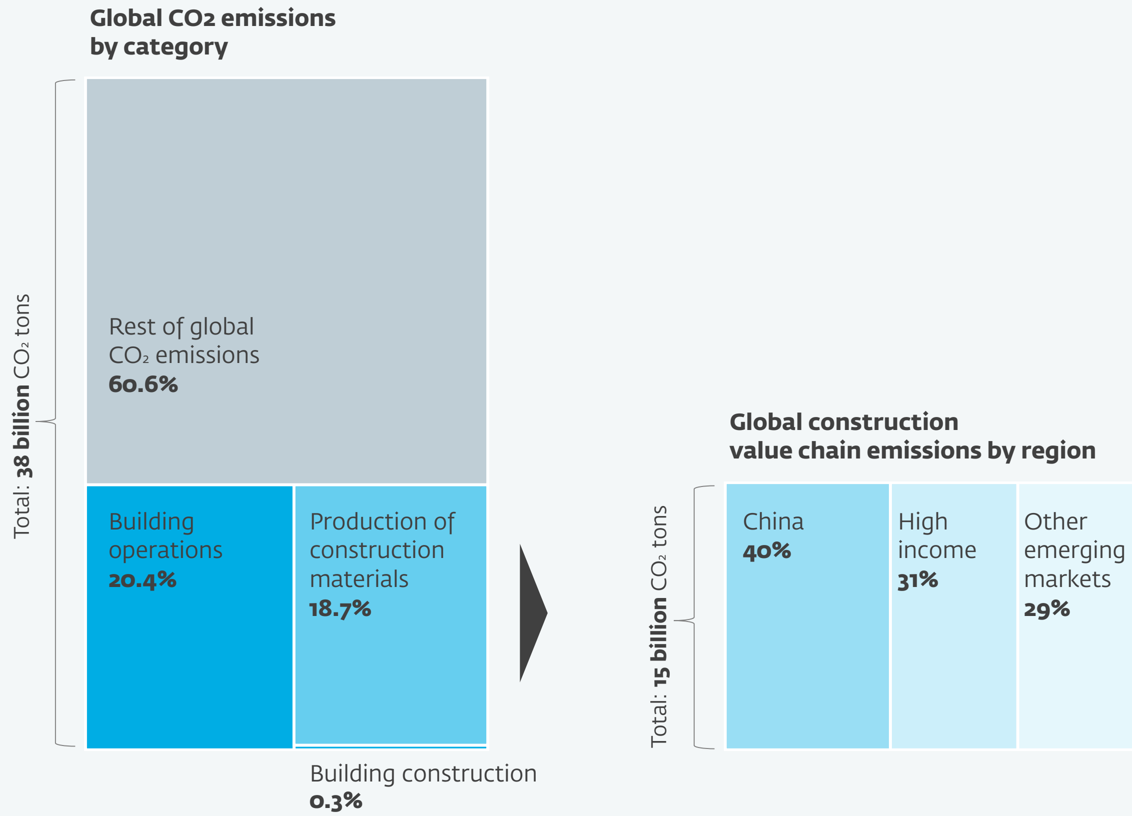
4 "Brown" refers to conventional buildings and materials in which no energy or emission-reduction measures or technologies have been adopted.

chains of commercially available green technologies that could substantially reduce carbon emissions in the next decade. Some promising technologies with high abatement potential, like green hydrogen and carbon storage, among others, are likely to only become commercially available without fiscal support by 2035 and beyond. Deploying already available technologies will therefore be a priority in emerging markets in the next decade.

The level of economic and policy effort required to reduce emissions from construction value chains will necessarily vary across regions in the next decade. Countries with greater fiscal and financial resources

EXHIBIT A

Construction Generates About 40 Percent of Global Carbon Emissions



Notes: This report includes only scope 1, 2 and 3 CO2 emissions coming from energy combustion and economic activity in agriculture, manufacturing, and services. Emissions from other greenhouse gases (e.g. methane) and other CO2 emissions (e.g., from changes in land use) are not considered due to data limitations. Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the firm. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the firm's value chain. Other emerging markets category includes Sub-Saharan Africa. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from the Global Trade Analysis Project (2022).

may be better positioned to deploy more rapidly relatively costly policies—carbon pricing, tighter environmental regulations, and fiscal support—and new technologies with significant abatement potential but high economic costs today. Middle-income countries, in turn, can accelerate the pace of adoption of green construction codes, standards, and readily available technologies and practices. Low-income economies can begin their green construction transition with financial and technical support from the international community.

This summary of the report provides, first, an overview of technologies that are either being deployed or are anticipated in the near future. Increased resources will be needed to support the green construction transition, and the report provides rough estimates of the magnitude of the private investment required. Governments will also be required to mitigate the market failures prevailing in construction value chains and green financial markets by establishing an appropriate policy framework, under which companies in construction value chains can adopt emerging and commercially available technologies. The final section of this summary discusses policies that could encourage companies to undertake more green construction and private investors to commit more resources to these activities.

Construction and operations of buildings and other structures.

The menu of available options to decarbonize buildings ranges from measures with high abatement and adaptation potential but prohibitive economic costs today to measures with more moderate emission-reduction potential but lower costs. Emerging

BOX A

Some Examples of the Climate and Business Benefits of Green Buildings

Energy savings. The Menarco Tower office in Manila, the Philippines, achieved 41 percent energy savings through variable speed drives in the air handling units, a higher-efficiency cooling system and appliances, energy-saving lighting in corridors, common and external areas, and occupancy sensors in bathrooms along with other passive measures.

Lower carbon emissions. In Gujarat, India, a district cooling system has been installed in the Gujarat Finance Tec-City, a joint-venture financial center. The system distributes thermal energy in the form of chilled water from a central source to multiple buildings through a network of underground pipes for use in space cooling. The system aims to reduce power demand and make air conditioning more energy efficient, reducing CO_2 emissions.

Financial benefits. Residential green developers like Signature Global (India) and Capital House (Vietnam), have reported faster sales resulting in stronger cash flows for them. In South Africa, International Housing Solutions reports that its low-income renters save an entire month's rent each year from lower utility bills, and its green homes' occupancy rates are higher than for similar conventional homes that it owns. Lower operating costs and higher occupancy thus make green buildings a more profitable asset.

countries will have to choose among these alternatives depending on country conditions, available financing and policy and regulatory frameworks in place in the next decade.

Deep retrofitting "brown" buildings and materials plants through replacing inefficient energy and thermal electrical and mechanical systems or reconstructing building envelopes, among other measures, can significantly reduce buildings' emissions. Due to its high costs today, however, this option is likely to be affordable only for few countries with the fiscal and policy space required to start deep retrofitting or implementing early retirement of stranded brown buildings and plants now.

Electrification, or replacing fossil fuels for cooking, water heating and cooling with electric systems powered with renewable energies, is an attractive complement to deep retrofitting because of its relatively low costs and the expected greening of electricity generation over the coming decade. However, electrification alone cannot achieve the needed reductions in emissions given the economic unfeasibility of completely removing fossil fuels from the energy mix in most countries in the next decade.

Economies for which complete retrofitting is likely to remain out of reach in the near future, including middle-income countries undergoing rapid population and economic growth, can invest in electrification as well as construction of new green buildings and material plants to respond to their swelling housing needs in the years to come. And for all emerging markets, incorporating resilience into green construction will be critical in the next decade, especially in countries affected by catastrophic climate events.

Green buildings, buildings with energy-efficient designs, cleaner energy-mixes, and low-emission materials, offer multiple opportunities to significantly reduce carbon emissions in construction value chains while offering a business opportunity for private investors. Passive measures related to the design of green buildings achieve energy savings through the building's orientation to the sun, external shading, and reduced window size. Such measures are particularly effective in managing heat gain or loss during the day as well as reducing construction costs. Active measures in green buildings related to more efficient electrical and mechanical systems also lower energy consumption. For instance, ceiling fans, thermostatic valves, and heat valves can achieve high levels of energy efficiency. The use of eco-friendly refrigerants also enables emissions savings. Incremental costs, payback periods and emission reduction potential of green buildings relative to conventional alternatives are contingent on climate zones, country conditions and types of buildings. Box A provides some examples of the climate and financial benefits of green buildings and systems.

One important aspect of green building measures, like renewable energy technologies, passive cooling and heating systems, water recycling, or rainwater collection solutions, is that they improve resilience of buildings to hazardous events. Resilience needs to be integrated into construction of new green buildings to ensure longer life cycles and avoid unnecessary land carbon emissions related to the reconstruction process. Countries with sufficient fiscal space can also employ fiscal incentives to integrate resilience into retrofitted buildings.

With supportive policies, the use of specific materials, such as reflective painting for rooftops and film coating for windows, can enhance thermal efficiency in existing as well as new buildings with relatively moderate costs. In specific large projects, like renovation of urban areas or construction of university or medical campuses, district cooling technologies can reduce energy consumption by setting a centralized cooling system for an interconnected group of new or completely renovated buildings and structures.

Greater reliance on digital technology could also contribute to reducing construction emissions. Using "smart" internet-connected devices to enhance the energy efficiency of large appliances, like air conditioners, refrigerators, washing machines, and cookstoves, can significantly reduce emissions from buildings operations. Increasing the use of this technology may require regulatory measures, and in some cases, depending on country conditions, policy incentives. 3D-printed construction can reduce waste (and thus lessen embodied carbon) and construction time, improve energy efficiency, and lower labor costs but can only be applied today in relatively small housing and commercial projects. Across all project stages, digitalization could increase materials' efficiency by integrating life-cycle emissions in the construction process, using, for instance, 3D building information modeling, enhancing collaboration through management apps on mobile devices, and monitoring sites with drones for scanning.

Improving the use of space and infrastructure through flexible design and undertaking climate-smart building that emphasizes the importance of resilience would extend lifetimes of new buildings. This would reduce the demand for cement and steel, as well as construction-related CO_2 emissions. Deep retrofitting old buildings to be more carbon efficient can achieve similar or higher energy savings than construction of new green buildings, but its high cost makes it unlikely to be a priority in most emerging countries in the next decade.

Many other approaches exist to reduce the carbon footprint of building construction and operation. For example, increasing reliance on renewable energies and district systems for heating and cooling could significantly reduce emissions from buildings operation. Local emissions from construction sites could be addressed using electric vehicles and biomass-powered machinery. Some of these options may only be feasible in middle- or high-income countries, but the international community can contribute to gradually disseminating and supporting them in low-income economies.

Construction Materials

Cement and steel are the two major materials used in construction, and for both, technological solutions to reduce their emissions intensity are already available or being developed. By 2035 and beyond, novel technologies with high abatement potential but non-commercially available today, such as carbon capture and storage and green hydrogen, are likely to still need significant fiscal support, even in advanced economies. Deep retrofitting or early retirement of existing brown plants will also remain out of reach for most emerging economies in the next decade.

Over the next 10 years, the priority should therefore be promoting commercially available abatement and adaptation levers, particularly in emerging markets undergoing rapid economic and population growth.

Piloting some of these technologies and measures, with the support of the international community, could also contribute to reducing emissions in cement and steel production.

For example, replacing carbon-intensive clinker, cement's main input, with alternative natural materials and industrial by-products can significantly reduce process emissions. Using alternative fuel sources such as biomass, waste, and industrial residues, combined with wind and solar renewable energies, among others, rather than coal can reduce emissions from production of cement by 20 percent. Taking energy and resource efficiency measures can save up to 30 percent in electricity plant needs. Adaptive and self-learning technologies can also optimize fuel management and material blending. These options can have relatively short payback periods with adequate financing and regulatory frameworks.

By 2035 and beyond, green hydrogen is expected to offer a promising (but not now commercially viable) solution for decarbonization in the cement

BOX B

Some examples of the use of already available and novel decarbonization technologies in cement and steel plants

Biomass and recycled materials. Sococim, a subsidiary of French cement maker Vicat S.A, will replace part of its clinker lines in its Senegal plant with more fuel-efficient facilities, utilizing up to 70 percent alternative fuels (biomass and recycled tires). The project will reduce greenhouse emissions by 312,000 tons of CO_2 equivalent per year by 2030, enabling it to produce one of the lowest-emission cements in the world. IFC is supporting the project with its first green loan for materials in Africa.

Recycled scrap. Rider Steel, a rolling mill operator, is investing in a greenfield manufacturing plant in the Kumasi area in Ghana. The new plant will save 332,000 tons of carbon dioxide annually by entirely using steel scrap as input (283,200 tons per year). The plant also operates an energy-efficient induction furnace with a significantly lower carbon intensity than existing blast furnaces. IFC supported the project through a $12 million loan in 2020.

Green hydrogen. In 2021, Compañía Siderúrgica Huachipato launched in Chile a pilot of a green hydrogen mill that is expected to be completed by 2023. CEMEX is already implementing hydrogen technology at its San Pedro de Macoris cement plant in the Dominican Republic.

Carbon capture and storage. Anhui Conch Cement developed in 2017 a cement with carbon capture plant in Wuhu, China. In India, Dalmia Cement Limited and Carbon Clean Solutions are developing the largest cement plant with carbon capture in the global cement industry. The plant is expected to capture 500,000 tons of CO_2 per year.

industry.[5] Carbon capture, utilization, and storage—which captures CO_2 from industrial emissions and either recycles it for further industrial use or stores it safely underground—is another technological innovation that could potentially almost halve CO_2 emissions but also will also require subsidies and tax incentives, at least before 2035, and possibly beyond.

In the steel industry, injecting pure oxygen into blast furnaces can lower emissions by 15–20 percent, by reducing the use of coal as a reductant agent for iron oxide. When sourced from renewable resources, biomass can also substitute for coal, while increasing the share of high-quality scrap in electric arc furnace steelmaking can lower the use of carbon-intensive iron. Green hydrogen could improve the performance of conventional blast furnaces and produce direct reduced iron to be further processed into steel. As with cement, green hydrogen and carbon capture technologies, among others, combined with renewable electricity generation, hold the promise of carbon-neutral steelmaking in the longer term but they will not be economically viable without fiscal support by 2035 and beyond.

Box B summarizes the experiences of companies which are implementing some of these existing and novel decarbonization technologies in cement and steel plants in emerging markets.

Deploying these technologies could reverse projected emissions growth from construction value chains, requiring $3.5 trillion in global investment between 2022 and 2035.

Integrating readily available technologies, like electrification of brown buildings with cleaner energies and energy-efficient buildings and materials, among other technologies, into construction value chains combined with compliance with the NDC targets could reduce construction-related emissions to well below today's levels. Results from the computable general equilibrium–circular economy dynamic model[6] employed in the report suggest that, taken together, these measures (the "energy efficiency scenario" in Exhibit B) would reduce global construction-related emissions in 2035 to about 13 percent below the level in 2022, or about 23 percent below the level that would be reached in 2035 in the absence of additional mitigation efforts (the "no mitigation" scenario in Exhibit B). The 13 percent reduction relative to today's levels is equivalent to the total emissions from the construction sector in the United States in 2022. Emerging markets would account for more than half of this reduction in emissions.

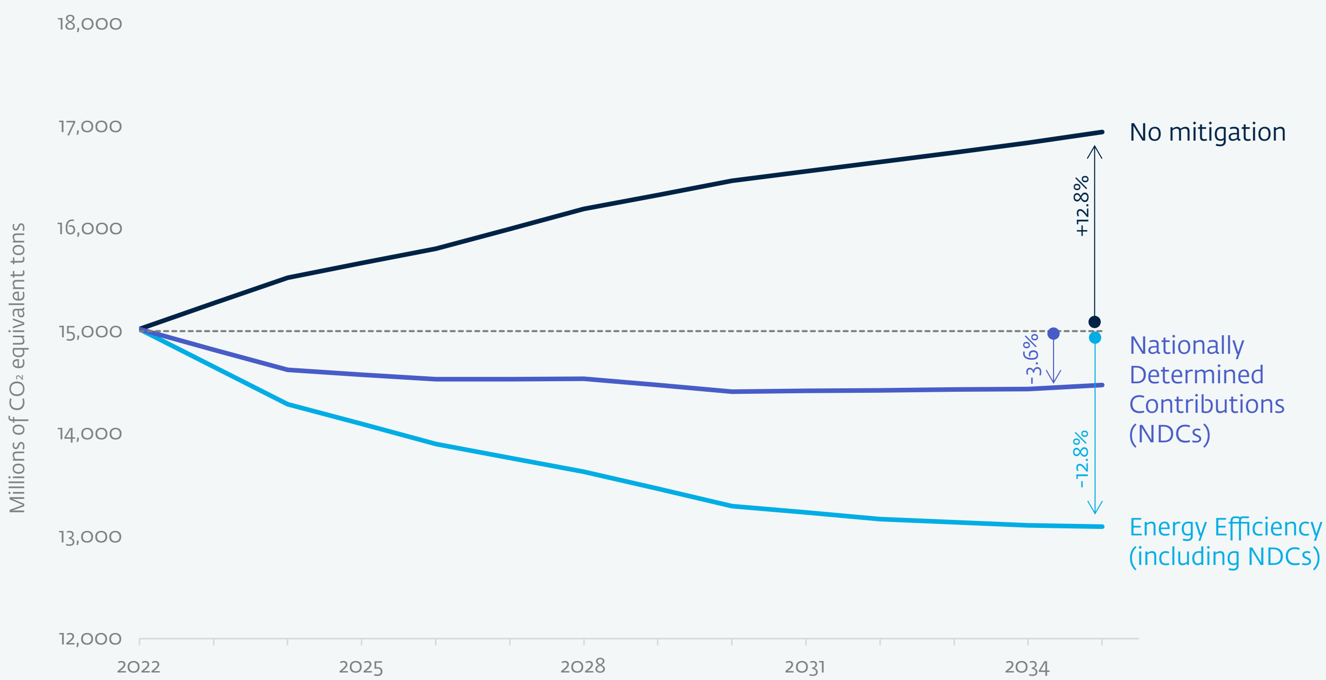
On average, global construction-related emissions decline by about 2 percentage points per year in the energy efficiency scenario relative to the no mitigation scenario. Of this, 1.4 percentage points

5 Green hydrogen is hydrogen produced by splitting water into hydrogen and oxygen using renewable electricity. Hydrogen gas is extracted from water by a technique known as electrolysis, which involves running a high electric current through water to separate hydrogen and oxygen atoms. The electrolysis process is expensive because it involves high energy expenditure.

6 Global dynamic computable general equilibrium models provide an indication of some plausible paths of economic growth and carbon emissions under alternative policy scenarios rather than precise numerical estimates. These models, however, allow us to examine the effects of these policies on the global economy taking into the account the interactions between countries, economic sectors and economic agents based on a consistent and analytical robust theoretical framework and detailed input-output, balance of payments and fiscal accounts data. See Box 2 and Annex 1 for a detailed explanation of model and simulations presented in this report.

EXHIBIT B

Global Construction Emissions Could Decline by 13 Percent Below the 2022 Level by 2035 with Decisive Action in Construction Value Chains

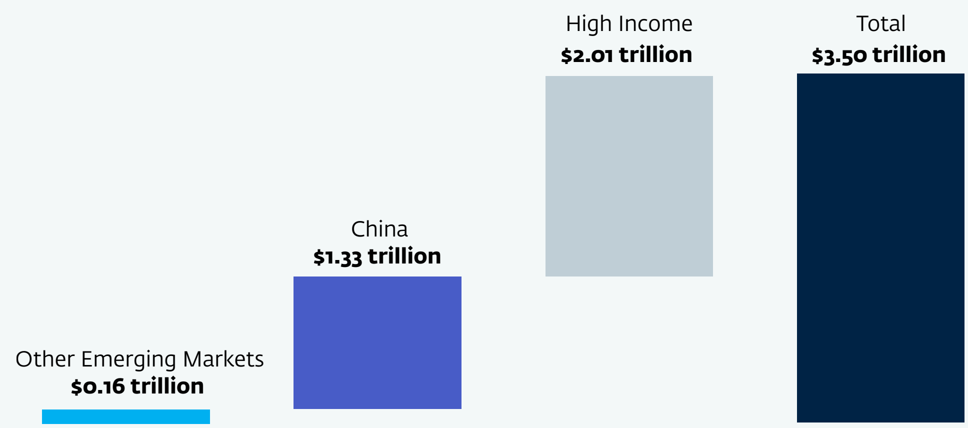


Notes: The exhibit shows the results of the simulations for the no mitigation, Nationally Determined Contributions (NDCs), energy-efficiency and net zero-aligned scenarios described in Box 2 and Annex 1. Castro et. al mimeo simulates alternative scenarios. The NDC scenario simulates the effects of complying with the NDCs emission-reduction targets set in the Paris Agreement. The energy-efficiency scenario simulates the effects of sector-specific measures geared towards cleaning the energy mix and improving the energy efficiency of buildings and materials plus compliance with the NDCs. The net zero-aligned scenario simulates the impacts of widespread carbon pricing on brown buildings and materials and subsidies to green alternatives plus compliance with the NDCs. The drop in emissions in the net zero-aligned scenario is similar to the decline in emissions in the energy efficiency scenario and it is therefore not shown here. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from the Global Trade Analysis Project (2022) and Global Climate Change Alliance (2021).

EXHIBIT C

Investment Needs for Building Green Will Amount to $1.5 Trillion in Emerging Markets in the Next Decade



Notes: Investment needs are calculated as the difference between investments in electrification of brown buildings with renewable energies and new buildings and materials powered with low-emission energies in the no mitigation scenario and the energy efficiency scenario. See Box 2 for an explanation of the model and scenarios. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from Global Trade Analysis Project, Global Climate Change Alliance, International Energy Agency and other sources.

come from reductions in energy intensity of buildings and materials, while 0.6 percentage points come from a decline in carbon intensity. Construction demand would only experience a minor drop of 0.04 percentage points per year.[7]

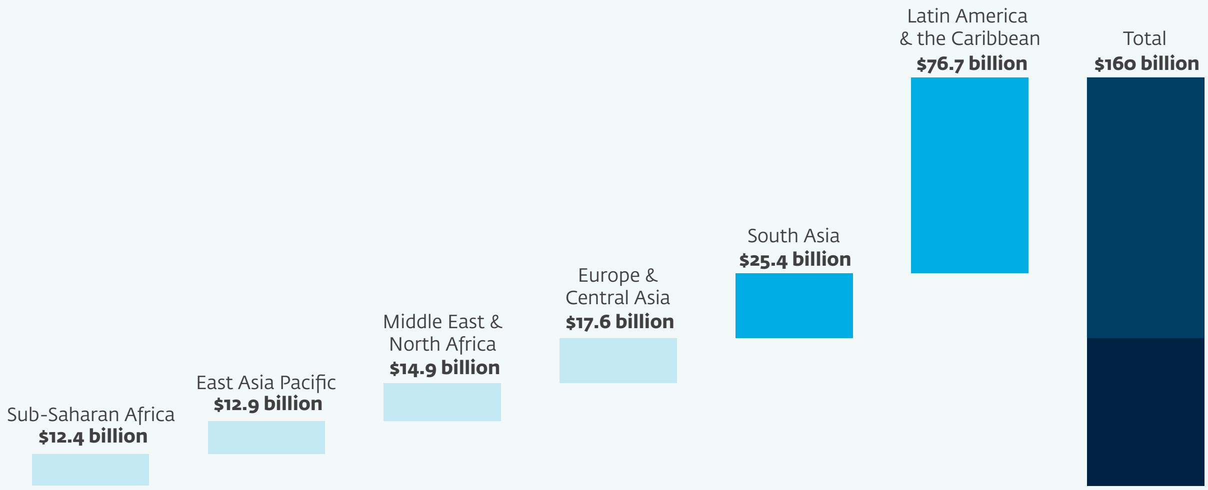
The simulations also suggest that the drop in construction emissions achieved through the electrification of brown buildings with renewable energies and energy efficient buildings and materials (the energy efficiency scenario in Exhibit B) would result in a decline in total global emissions, including construction and all other sectors, of about 19.8 percent by 2035, compared with the no mitigation scenario.[8] These results emphasize the need to pave the way now for decarbonizing hard-to-abate activities, such as construction and operation of buildings and materials, in the next decades to meet

7 IFC calculations based on Global Trade Analysis Project (2022). Energy intensity refers to the unit of energy used per unit of construction output and carbon intensity refers to the unit of CO_2 metric ton per unit of energy consumed in construction. Castro et. al, mimeo present a detailed decomposition of these carbon and energy intensity and total demand effects. The 2 percent average yearly drop in emissions refers to the 23 percent decline in construction-related emissions in the energy-efficiency scenario relative to the no mitigation scenario between 2022 and 2035.

8 IFC calculations based on Global Trade Analysis Project (2022).

EXHIBIT D

A Third of the Investment Needs in Emerging Economies Outside China Would Be in Latin America and the Caribbean and South Asia



Notes: The exhibit shows the results of the simulations of the cumulative investment needs for the energy efficiency scenario described in Box 2 and Annex 1 relative to the no mitigation scenario. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on Global Trade Analysis Project (2022).

the climate goals set in the Paris Agreement.

The results of the model also suggest that the global cumulative investment needed from 2022 to 2035 to achieve this reduction in construction emissions in the energy efficiency scenario could amount to $3.5 trillion.[9] The investment needs in emerging markets would amount to almost $1.5 trillion, of which $1.3 trillion would be from China. (Exhibit C).

Most of the $1.5 trillion investment needs in emerging markets would be channeled to electrification of brown buildings, new energy efficient buildings, and materials powered with cleaner energies. Around 75 percent of investment would be funneled into cleaning the energy mix and improving the energy-efficiency of buildings. Increased supply of less carbon-intensive cement, steel, and other materials would absorb about 20 percent of the required investment. The remaining 5 percent would finance built environment-related services on and off construction

9 Investment refers to gross fixed capital investment in the Global Trade Analysis Project database. See Annex 1.

sites.[10] These financing needs would require a marked rise in domestic and international green private debt finance for decarbonizing the construction value chain in emerging markets, which amounted to about $23 billion in 2021.

Of the additional $160 billion in green construction investment in emerging markets other than China between 2022 and 2035, Latin America and the Caribbean, South Asia and Europe and Central Asia would account for about $77 billion, $25 billion, and $18 billion. In the Middle East and North Africa and East Asia and the Pacific, the investment would amount to about $15 billion and $13 billion. Green building investment would amount to $12 billion in Sub-Saharan Africa (Exhibit D). About 86 percent of the investment would be directed to residential buildings (a half of that in Latin America and the Caribbean), especially in single-family detached housing.

The results of the model employed in this report also suggest that an alternative scenario geared towards accelerating the pace to achieve net zero-construction by 2050 by boosting the stock of green buildings and materials through widespread carbon pricing and fiscal support measures (the net zero-aligned scenario described in the notes of Exhibit B) would attain a similar drop in construction emissions by 2035 as the energy-efficiency scenario but with markedly higher investment needs. Bringing down construction emissions by about 23 percent with this policy mix would require investments in new green buildings and materials amounting to $6 trillion globally, almost twice the investments needed in the energy efficiency scenario, but also would come at a much higher cost in foregone output as the construction value chain undergoes a more rapid transition to net zero emissions.

Decarbonizing construction value chains entails short-term trade-offs for long-term benefits.

Combining compliance with NDCs with construction value chain-specific mitigation and adaptation measures and readily available technologies geared towards cleaning the energy mix and improving the energy efficiency of buildings and materials would likely have only a limited impact on economic growth rates by 2035. The model employed in this report suggests that compliance with the NDCs (without measures specific to the construction sector) would reduce global construction emissions by 3.6 percent and total global emissions, including construction and the rest of the economic activities, by 13.04 percent for a decline in yearly global GDP growth of 0.02 percentage points by 2035.

Pursuing construction-specific mitigation policies to promote cleaning the energy mix and improving the energy-efficiency of buildings and materials in addition to compliance with NDCs (the energy efficiency scenario in Exhibit B) would reduce global construction emissions by 13 percent and total global emissions, including construction and all other economic activities, by 19.8 percent relative to the no mitigation scenario for a decline in yearly global GDP growth of 0.03 percentage points. However, this short-term loss would be more than compensated by long-term gains in reduced damages from climate change to infrastructure, growth, and human welfare.

10 IFC calculations based on Global Trade Analysis Project (2021); and GCCA (2021).

An alternative policy mix of applying carbon taxes to brown buildings and materials, subsidizing green alternatives, and complying with NDC targets (the "net zero-aligned" scenario described in Exhibit B) would achieve a similar reduction in global emissions as the energy efficiency scenario. It would also contribute to putting construction more rapidly on the path to net zero by 2050 by boosting the stock of greener buildings and materials in construction value chains.

The net zero-aligned scenario would bring down global carbon emissions, however, at significantly higher costs than the energy efficiency scenario. The 19.8 percent reduction in global total emissions, including construction and the rest of the economic activities, in this scenario would entail a drop of 0.4 percentage points in average yearly growth globally by 2035, more than 10 times the output losses of the energy efficiency scenario.

This larger output loss in the net zero-aligned scenario relative to the energy efficiency scenario is explained by the crucial importance of construction value chains in global investment.[11] As most buildings and materials are brown today,[12] imposing taxes on conventional construction would cause a marked drop in total construction investment that is unlikely to be offset in the next decade by the expansion of green alternatives, even with fiscal support measures, at least until technologies with the highest abatement potential become commercially available by 2035 and beyond.

These results suggest that relatively few countries with available fiscal space may be in a position to offset the decline in private investment in conventional construction due to carbon taxes on brown buildings and materials through increased public investment and fiscal support measures. For other emerging markets, promoting the adoption of 'low hanging fruit' technologies, like the electrification of buildings with cleaner energies and energy-efficiency, would be a more pragmatic and feasible pathway to reducing emissions in construction value chains in the next decade, until horizon technologies, like carbon capture and storage and green hydrogen, become widely available at scale.

By 2050, the cost in terms of foregone output stemming from the emissions reduction scenarios in this report is likely to be more than offset by reduced damages to infrastructure, productivity, and growth from global temperature increases. Recent simulations using similar models to the model employed in this report, for instance, suggest that the economic benefits of reducing the growth in global temperatures by 2050, particularly related to lower mortality and morbidity rates, would exceed by 1.4 to 2.5 times the output costs of reducing carbon emissions in this decade.[13]

Emerging markets receive only a small share of domestic and foreign green finance for decarbonizing construction.

Several financial tools are, or can be, used to channel

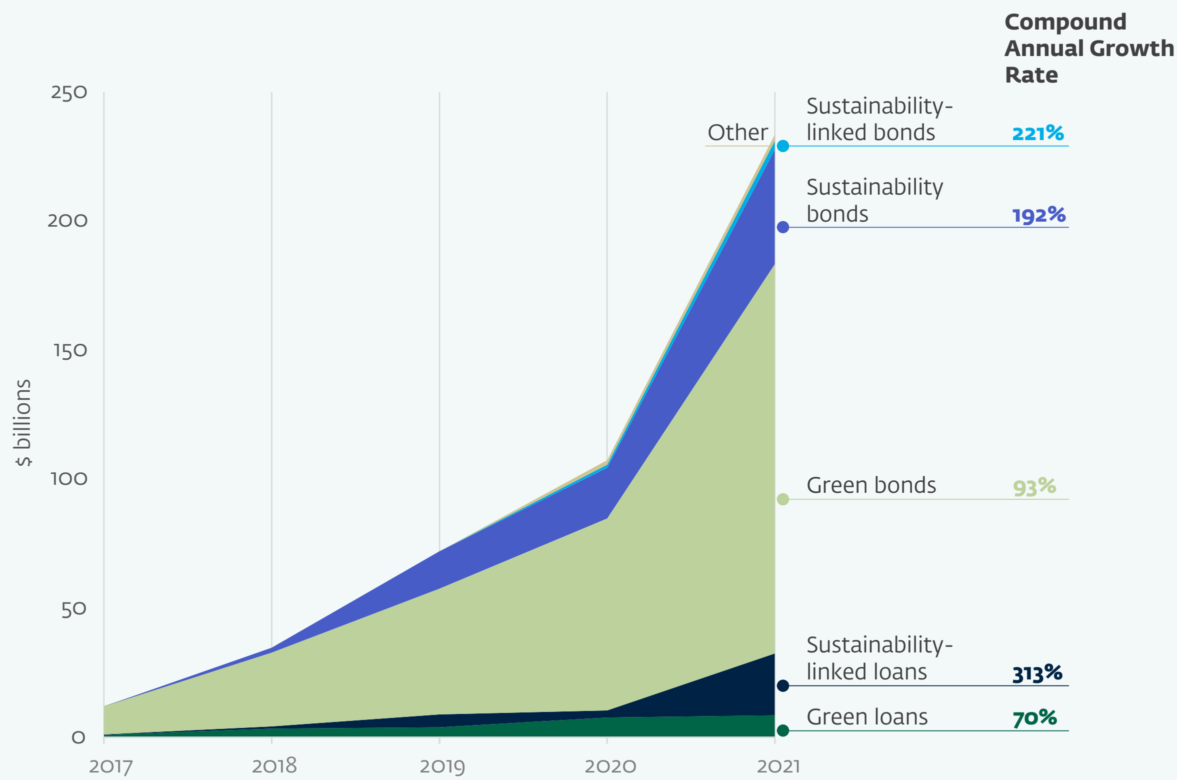
11 Construction accounts for about half of total fixed capital investment globally (IFC calculations based on Global Trade Analysis Project, 2022).

12 Only about 7 percent of the stock of buildings is green today globally, according to IFC calculations based on the Global Trade Analysis Project.

13 See, for instance, Markandya et al. (2018).

EXHIBIT E

Global Domestic and Foreign Private Green Debt Finance for Construction Decarbonization Increased Twentyfold in the Last Five Years



Notes: Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material sectors and used for decarbonization. 'Other' includes transition bonds and sustainability loans. See Annex 3 for more details on the methodology. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from Environmental Finance and Bloomberg (2022).

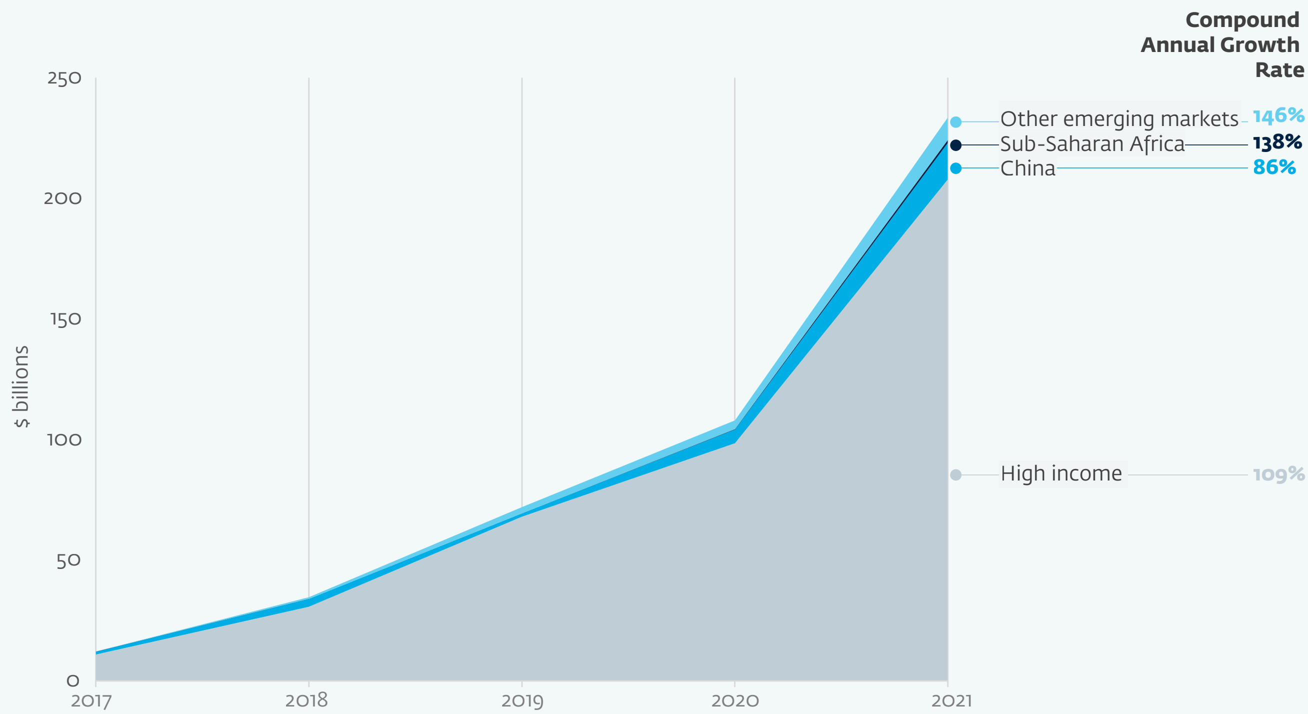
domestic and foreign private funds to greening construction value chains. These include:

- Sustainability-linked debt can mobilize private investment for decarbonizing hard-to-abate construction materials by aligning financial incentives between investors and material producers to reduce emissions;[14]

14 Sustainability-linked finance includes loans and bonds in which compliance with a set of pre-determined sustainability targets triggers reductions in financing costs.

EXHIBIT F

Only 10 Percent of Global Domestic and Foreign Private Green Debt Finance for Construction Decarbonization Was Issued in Emerging Markets



Notes: Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material sectors and used for decarbonization. Volumes shown by income and region are based on the location of headquarters and/or country of risk (determined by the firm's geographical exposure to operations) of the issuing entity. Compound annual growth rates are calculated using the first year of issuance as base year: 2018 for Sub-Saharan Africa and other emerging markets, and 2017 for high income countries. See Annex 3 for more details on the methodology. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from Environmental Finance and Bloomberg (2022).

- Green mortgages can drive consumer demand for investments in net-zero buildings;
- Performance contracts and leasing can offer off-balance sheet financing from local energy providers for energy-efficiency investments in buildings and materials that can be repaid through energy savings over time;
- Green funds and real estate investment trusts can inject equity finance in new or retrofitted green buildings and materials;
- Venture capital funds can finance or co-finance game-changing decarbonization construction

technologies; and,

- Carbon transition bonds and carbon retirement portfolios can contribute to decarbonizing or decommissioning brown construction assets.

Of these green financial instruments, green bonds have attracted most of the domestic and foreign private financing for green construction between 2017 and 2021, although sustainability-linked debt instruments experienced the highest growth rates (Exhibit E).[15,16] Equity instruments are less commonly used for such financing, though Real Estate Investment Trusts have the potential to scale financing of green building construction and operations. The volume of other innovative green finance tools, such as transition bonds or carbon retirement portfolios, is quite small and almost non-existent in emerging markets.

Emerging markets issued only 10 percent of total domestic and foreign private green debt finance for construction decarbonization in 2021 (Exhibit F). Of that share, China accounts for 6 percent of the global total and the rest of the emerging economies for the remaining 4 percent. Private green debt financing for construction is also heavily skewed toward green buildings, with decarbonization of construction materials attracting only 9 percent of the issuance globally.

Concerted action by private investors and policymakers will be required to reduce emissions from construction value chains.

The low level of investment for green construction largely stems from market failures that make green buildings more expensive than they should be, since in the absence of carbon pricing the social benefit from building green is not reflected in their market price. Other market failures, such as the limited information on default rates and monetary benefits of green building investments, coupled with high screening and monitoring costs of emission-reduction targets, further restrict finance for green construction. These failures compound with other market failures, the decentralized structure of construction value chains, and fragmented regulations and policies at the national and sub-national level. Depending on country conditions and fiscal and policy resources, policymakers can take action to mitigate the market failures in construction value chains and remove the bottlenecks to private investment. Measures can include the following:

- Improving the efficiency, transparency, and depth of local financial markets through improved macroeconomic management and prudential regulations is paramount to expanding funding for building green;
- Electrification, or replacing fossil fuels for cooling, heating and cooking with cleaner energies, can contribute to reducing emissions from building operations;
- Green building codes and standards and other regulations can contribute to enticing private finance into green construction;

15 IFC (2020) provides a broader analysis of the green bond market.

16 Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material companies and used for decarbonization. See Annex 3 for more details on the methodology.

- Governments should take the lead on construction decarbonization through greening public buildings and public procurement, as well as encouraging the adoption of carbon transition bonds and carbon retirement portfolios for decarbonizing and decommissioning brown plants;
- Carbon pricing can help internalize emissions externalities by providing an economic incentive to emitters to either green their production and lower their emissions or continue emitting and pay the price for their emissions. It can also encourage consumers to switch from brown to green construction products;
- Compulsory or voluntary carbon markets can unlock domestic and foreign private sector investment in construction decarbonization;
- Green banks can play a role in mobilizing finance for small-scale green building projects that may not otherwise be widely available in the market; and,
- Subsidies (e.g., grants, below-market-rate loans, and direct transfers) and tax incentives (e.g., tax breaks) can contribute to financing technologies for construction decarbonization and incentivize the decarbonization or decommissioning of brown materials' plants. However, more empirical evidence is needed on the effectiveness and efficiency of such tools. Many emerging markets also lack the fiscal resources and policy readiness to manage efficiently these measures, in particular in low-income countries.

Development finance institutions have critical roles to play in construction value chain decarbonization.

Development finance institutions can play an important role in promoting financing toward construction value chains decarbonization in emerging markets. They can help to mobilize significant volumes of domestic and international private and public funds through investing in green bonds and loans and other financial instruments, support innovative green financial instruments for decarbonizing brown buildings, provide technical assistance for the adoption of green codes, regulations, and standards, serve as an anchor investor, provide concessional and blended financing, and operationalize various supranational climate funds.

Concessional finance deployed by development finance institutions can provide financial products to de-risk private investments through subordinated loans, equity, and guarantees. Blended finance utilizes limited pools of concessional funds to mobilize larger sums of private sector financing toward development goals, often with climate-related objectives; thereby it can provide more impact per dollar than pure grants while reducing potential misallocation of capital.[17] Concessional and blended finance for building green will need to be scaled up in the poorest countries.

How this report is structured

Emerging markets encompass a heterogeneous group of countries. Their capabilities for adopting and implementing mitigation and abatement policies in

17 IFC (2021).

construction, therefore, vary widely. These countries also differ in their reliance on fossil fuels for driving economic growth and diverge in the carbon intensity of the production of materials and the construction and operation of buildings.

The report focuses on the prospects for reducing emissions in construction in emerging markets in the next decade, a period where some of the technologies with the largest abatement potential are unlikely to become commercially available without supportive policies. This approach also emphasizes the most plausible path for adopting carbon pricing programs in emerging markets over the next 10 years based on the existing NDCs, rather than simulating the hypothetical carbon prices required to limit emissions below the levels established in the Paris Agreement by 2050. Other recent reports analyze the impacts of global warming and abatement policies on economic growth in the next decades by 2050 and beyond.[18]

This report is organized as follows. The first chapter details the size, source, and prospects for reducing carbon emissions from construction value chains. The second chapter considers technological improvements that would reduce carbon emissions from the construction and operation of buildings, while the third chapter addresses technologies to reduce emissions from the production of building materials. The fourth chapter outlines the finance now available for green construction, the measures required to improve incentives for green construction, and measures to channel the increased domestic and foreign private financing to emerging markets to achieve a significant reduction in carbon emissions from construction value chains. The last chapter summarizes the main recommendations for policymakers, private investors, and other stakeholders for making a reality of the opportunity for building green in emerging markets in the next decade.

18 See, for instance, IMF (2022), Chapter 3; and Acemoglu et. al. (2012). IEA (2020) explores the effects of investments and policies promoting energy efficiency on global warming by 2050.

CHAPTER 1:

Prospects *for* Reducing Carbon Emissions *from* Construction

1.1. Summary

Emerging markets generate about 70 percent of construction-related emissions globally and that share is projected to increase by 2035. Technologies are available or emerging that can reduce emissions across construction value chains, both from the operation of buildings and from the production of construction materials. The speed of the green construction transition will depend on each country's income level, technological and policy readiness, available fiscal and financial resources, and dependance on fossil fuels. This chapter examines scenarios for construction-related emissions reduction in emerging markets and the amount of investment that these efforts would require. It also estimates the implications for economic growth in emerging markets over the next decade and beyond.

1.2. Construction value chains are a major contributor to global CO_2 emissions, particularly from emerging markets.

Construction value chains—that comprise construction and operation of buildings and production of construction materials—account for about 40 percent of CO_2 emissions globally (Exhibit 1).[19,20] Box 1 describes what is meant by a construction value chain in this report. The operation of buildings is highly energy- and resource-intensive, generating about 20 percent of global emissions. The supply of materials accounts for about 19 percent of global emissions, mainly from the fossil fuel-powered and energy-intensive processes used to produce these materials. The construction process itself accounts for only 0.3 percent of global emissions, as it relies heavily on relatively less carbon- and resource-intensive activities like off-site and on-site construction services. About 85 percent of total construction emissions globally come from the use of fossil fuels in buildings and materials plants while the remaining 15 percent comes from process or industrial emissions related to the production of cement, steel, and other construction materials.[21]

The contribution of the operation of buildings to global emissions accrues over the buildings' lifetime from the use of energy-intensive and fossil fuel-powered systems, like cooling, heating, and lighting, and large appliances, like refrigerators and cookstoves. Inefficient envelope insulation and design features (e.g., building placement and exposure to sunlight, window size and rooftops' heat absorption, and air circulation) in conventional buildings further increases heating, cooling, and lighting systems' energy loads.[22] Retrofitting is extremely expensive today; brown buildings[23] account for most of the stock of buildings

19 This report includes only scope 1, 2 and 3 CO_2 emissions coming from energy combustion and economic activity in agriculture, manufacturing, and services. Emissions from other greenhouse gases (e.g. methane) and other CO_2 emissions (e.g., from changes in land use) are not considered due to data limitations. Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the firm. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the firm's value chain.

20 This estimate roughly aligns with recent calculations from IEA (2021) and UN (2021) in which construction accounts for 36 percent of global final energy consumption and 37 percent of energy-related CO_2 emissions.

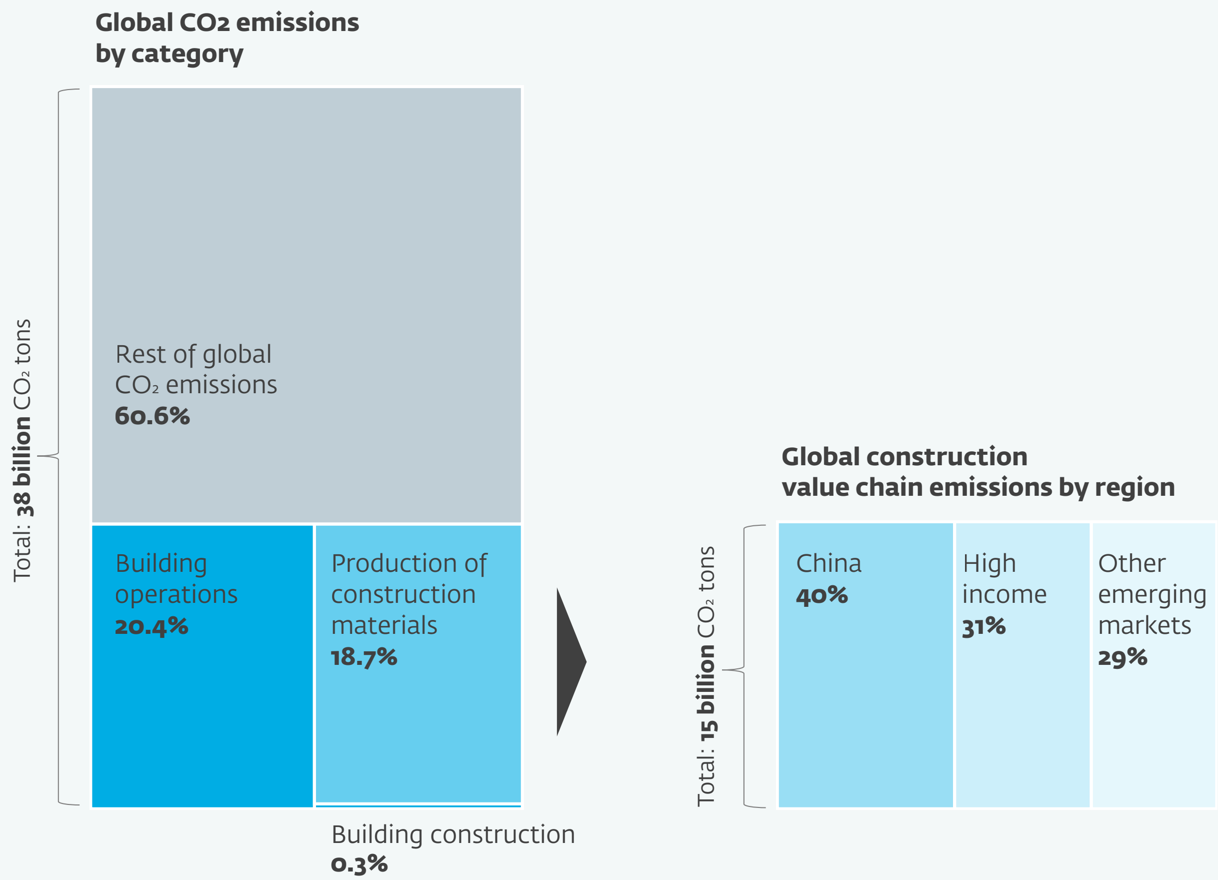
21 IFC staff calculations based on Global Trade Analysis Project data.

22 IEA (2021).

23 Brown buildings refer to buildings not designed or adapted for energy or emissions reduction.

EXHIBIT 1

Construction Generates About 40 Percent of Global Carbon Emissions

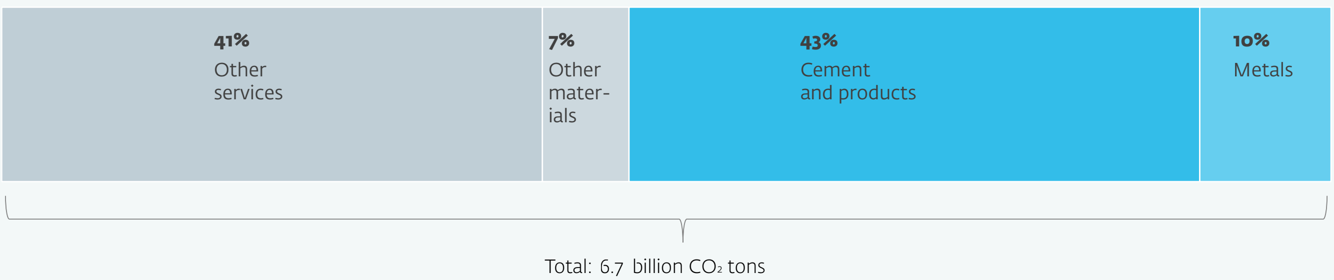


Notes: This report includes only scope 1, 2 and 3 CO2 emissions coming from energy combustion and economic activity in agriculture, manufacturing, and services. Emissions from other greenhouse gases (e.g. methane) and other CO2 emissions (e.g., from changes in land use) are not considered due to data limitations. Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the firm. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the firm's value chain. Other emerging markets category includes Sub-Saharan Africa. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from the Global Trade Analysis Project (2022).

EXHIBIT 2

Cement and Steel Account for About 50 Percent of Carbon Emissions from Construction Materials



Notes: About 50 percent of demand for steel comes from construction (World Steel Association, 2020). About 99 percent of cement production goes to construction (GCCA, 2020). Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project and GCCA.

globally, even in high-income economies.[24] Given the average lifetime of a building is about 50 years, the stock of brown buildings will keep the contribution of building operations to global carbon emissions high and it will increase as new brown buildings are built in the absence of additional mitigation and adaptation efforts.[25]

About 56 percent of the global emissions from buildings' operation originates in emerging markets. This sizable contribution is explained by the prevalence of brown buildings and appliances in emerging markets relative to high-income countries. China accounts for about 45 percent of those emissions, while other emerging countries, particularly in Europe and Central Asia, Middle East and North Africa, and South Asia, explain the rest with about 55 percent of global buildings' operation-related emissions.[26]

Materials and construction today generate only 22 percent of the emissions of a typical building during its average 50-year lifespan.[27] Most of these embodied carbon emissions are associated with production materials, with around half of these emissions generated by cement and steel.[28] Embodied carbon refers to the carbon emissions associated with the

24 See Sections 2.2. and 3.3 on the current landscape and prospects for retrofitting buildings.

25 IEA (2020).

26 IFC staff calculations based on Global Trade Analysis Project.

27 WBCSD/ARUP (2021) Exhibit 1 measures emissions from manufacturing construction materials in the base year 2022 rather than emissions resulting from the materials' production over the building's lifespan.

28 Material Economics (2018).

BOX 1

What Is a Construction Value Chain?

The construction value chain is a complex network with multiple stages and stakeholders. The diagram shows that the value chain of construction and operation of buildings and other infrastructures comprises three main stages with varying duration: (a) materials and construction (3–5 years); (b) operations (up to 50 years); and (c) end of life (demolition).

Three main decision makers intervene over the life cycle of buildings and other constructions: (a) material manufacturers; (b) developers; and (c) users. Government regulations play a key role in shaping the availability and emission-intensity of materials and the design and specifications of construction. Users determine emission intensity and waste generation in the operation phase. Financial institutions and investors influence the supply of materials and construction, while architects, engineers and other specialists can affect design and construction specifications.

The construction value chain plays a crucial role in the global economy. Investment in construction accounts for 15 percent of global GDP and about 10 percent of the GDP in emerging markets.* Construction is the main component of investment in most economies. Therefore, it is a key driver for aggregate demand and economic growth. Construction is also a labor-intensive activity, generating millions of low-skilled jobs in emerging markets. The value chain also encompasses some of the main industrial activities, like cement and steel, along with an extended network of downstream on-site and off-site services like logistics and transportation, among others.

* IFC calculations based on Global Trade Analysis Project and WEO.

Schematic Representation of the Construction Value Chain

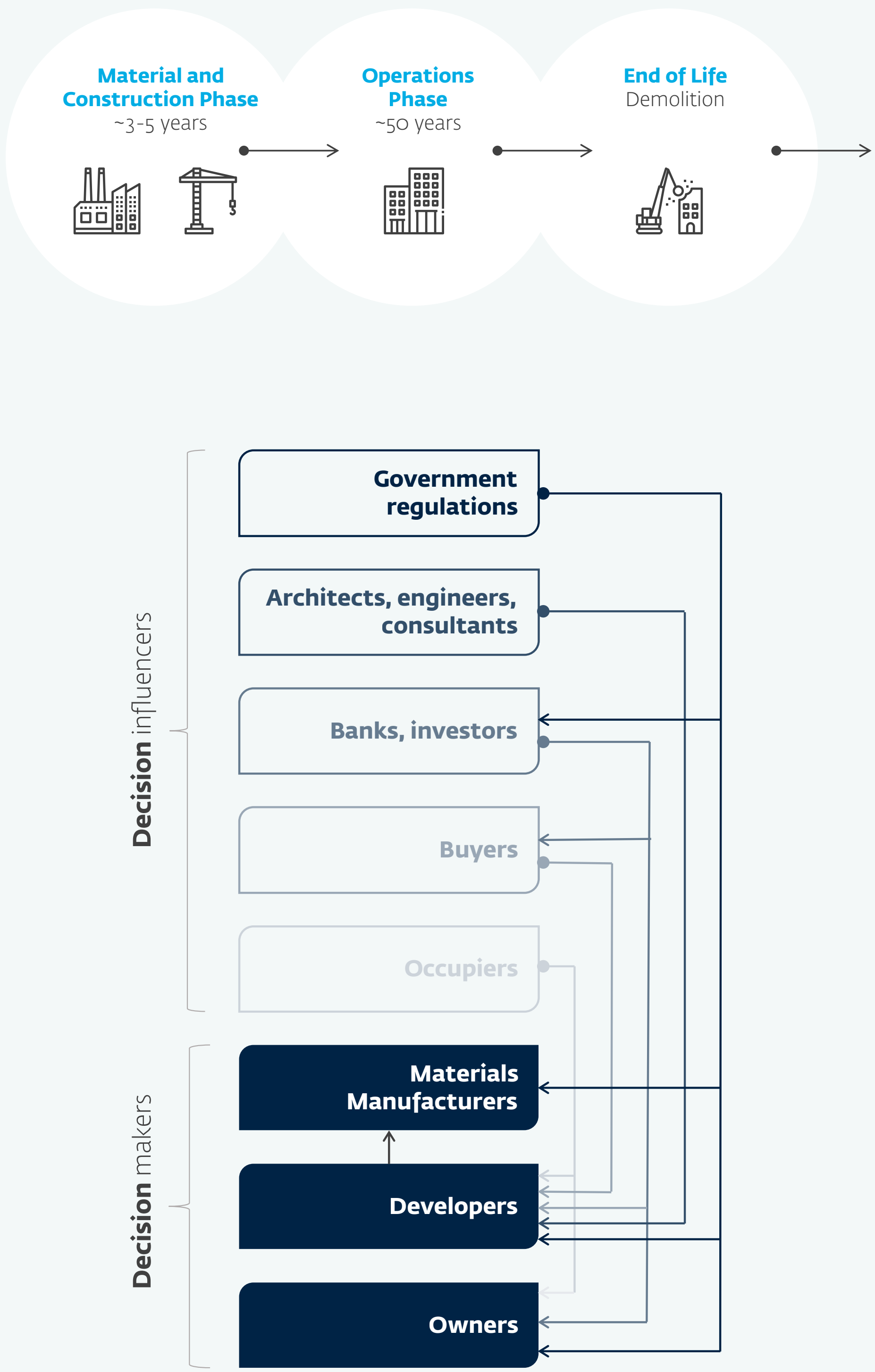
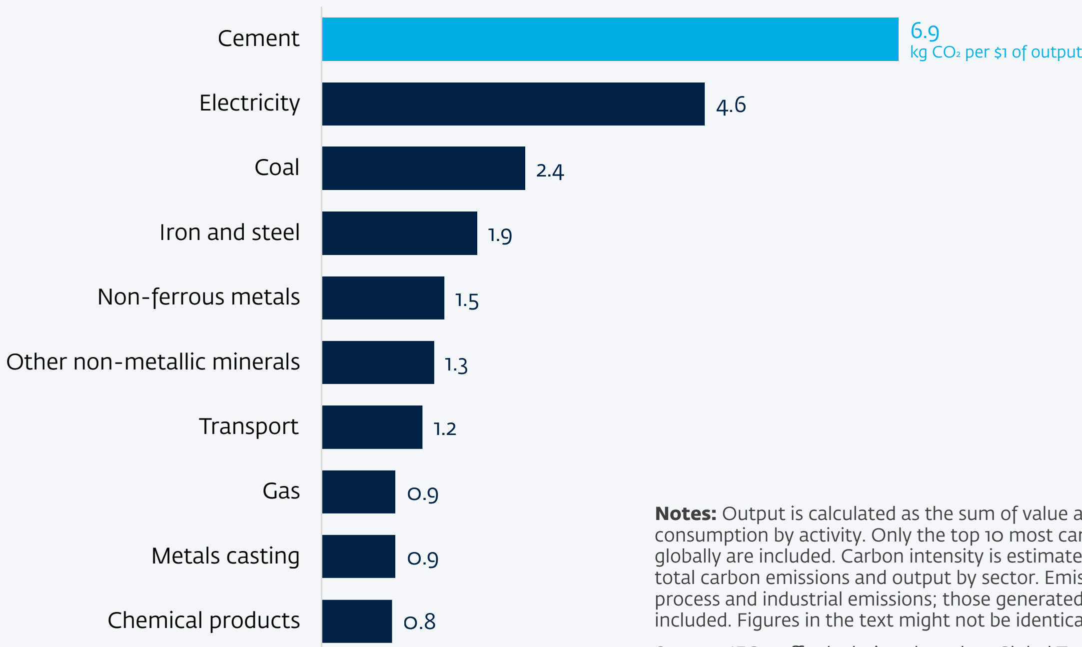


EXHIBIT 3

Cement Is the Most Carbon-Intensive Activity Globally



Notes: Output is calculated as the sum of value added and intermediate consumption by activity. Only the top 10 most carbon intensive activities globally are included. Carbon intensity is estimated as the ratio between total carbon emissions and output by sector. Emissions only include process and industrial emissions; those generated by methane are not included. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project and GCCA.

materials and construction processes throughout the whole life cycle of a building or infrastructure. It includes material extraction, transport to the manufacturer, manufacturing, transport to site, construction, use phase (e.g., concrete carbonation but excluding operational carbon from, for example, energy use of the building or infrastructure), maintenance, repair, replacement, refurbishment, deconstruction, transport to end-of-life facilities, processing, and disposal.[29]

The contribution of construction materials to global emissions is, in turn, mostly due to the production of cement and steel. The construction industry consumes almost all the world's cement and nearly half the steel produced.[30] Cement and concrete production generate about 43 percent of the emissions from materials, steelmaking about 10 percent, and other materials about 7 percent.[31] Construction materials are also heavy users of other highly carbon-intensive activities, mainly electricity, transportation, and other services,

29 Material Economics (2018).

30 Karlson et. al (2020).

31 About 50 percent demand for steel comes from construction (World Steel Association, 2021). About 99 percent of cement production goes to construction (GCCA, 2021).

which account for the remaining approximately 40 percent of emissions (Exhibit 2).

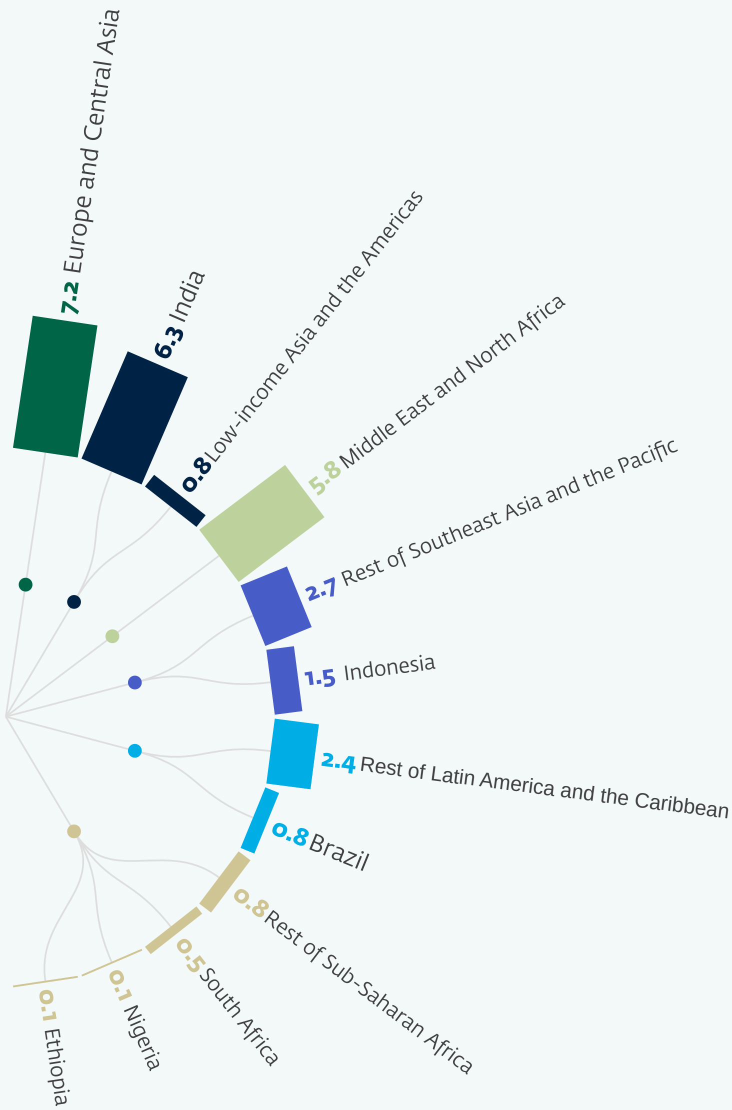
According to this report's calculations, cement is the most carbon-intensive activity globally (about 7 CO_2 kg eq per $1 of output), and steelmaking (iron and steel) is the fourth most intensive (about 2 CO_2 kg eq per $1 of output). Other materials and activities heavily used in construction, such as electricity, carbon, non-ferrous metals, other non-metallic minerals, transport, metal casting and chemical products, are also among the top 10 most carbon intensive (Exhibit 3). The carbon intensity of cement and steel derives in part from the massive amounts of energy needed to generate the high temperatures required to produce these materials. This energy is still mainly dependent on fossil fuels, especially in emerging markets. The chemical processes involved in producing these materials are also a large source of emissions.[32]

Against this backdrop, emerging markets generate more than 70 percent of total construction-

EXHIBIT 4

Construction-Related Emissions in Emerging Markets, 2022

Percent of total, excluding China



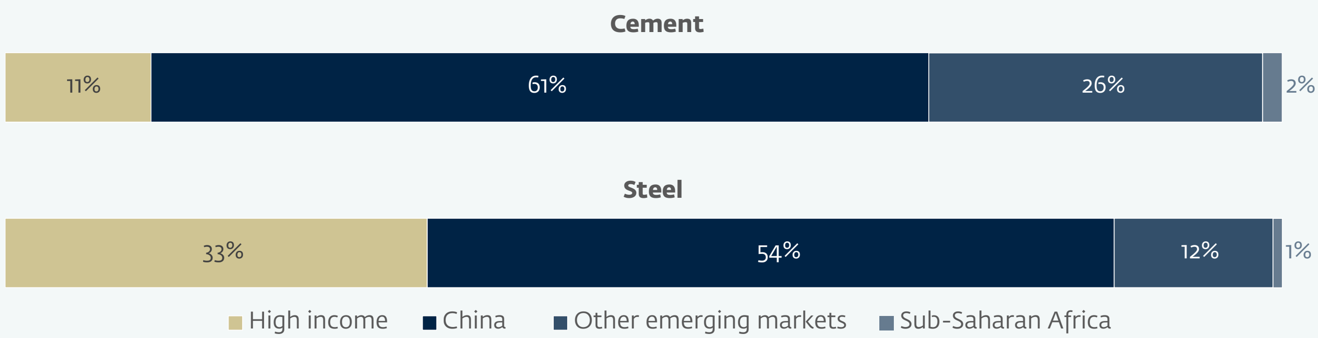
Notes: Only the largest countries measured by population are reported due to data limitations. Color of categories corresponds to the official World Bank Group regions. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project and GCCA.

32 Hasanbeigi (2021). See Box 4 in Chapter 3 for an explanation of how cement and steel are produced.

EXHIBIT 5

Emerging Markets Account for About 90 and 70 Percent of Global Cement and Steel Production



Notes: Figures in the text might not be identical due to rounding

Source: IFC staff calculations based on Global Trade Analysis Project and GCCA.

related emissions globally today. China is the largest contributor, accounting for about 40 percent of the world's construction-related emissions. Other emerging markets contribute about 30 percent (Exhibit 1).[33]

In other emerging markets excluding China, Central Asia and Europe accounts for about 7 percent of global construction emissions, and India and the Middle East and North Africa follow with about 6.3 percent and 5.8 percent, respectively. In Sub-Saharan Africa, South Africa is the largest emitter (0.5 percent of global construction-related emissions), followed by Ethiopia and Nigeria (both with 0.1 percent). In Southeast Asia and the Pacific, Indonesia contributes the largest share of global construction emissions (1.5 percent). Brazil is the largest emitter in Latin America and the Caribbean, with about 0.8 percent of global construction emissions (Exhibit 4). Table 2.3 in Annex 2 shows the projected contribution of each country to construction-related emissions by country grouping, region and globally between 2022 and 2035.

33 Other emerging markets includes Sub-Saharan Africa unless stated otherwise.

Within construction value chains, emerging markets account for about 83 percent of global carbon emissions generated by the production of construction materials. For instance, China generates about 68 percent of cement emissions and about 62 percent of steel emissions globally. Other middle-income emerging markets account for 26 percent of global emissions from construction materials.[34] The contribution of low-income countries is marginal.

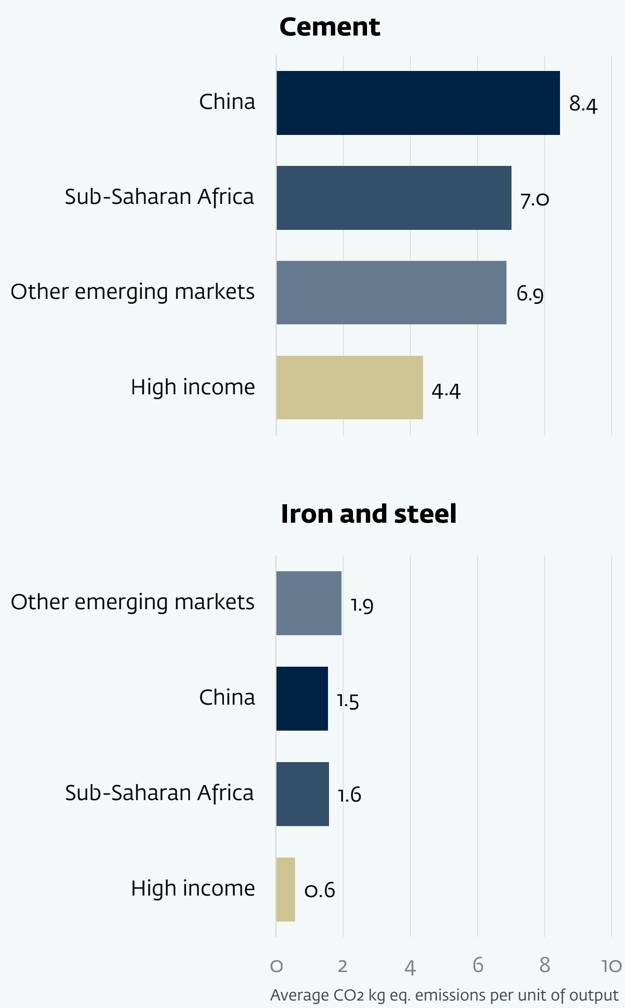
This disproportionate contribution of middle-income emerging countries in part reflects their decisive role in the supply of these materials globally. They account for about 90 percent of the world's cement production and about 67 percent of steel. China explains about half of that, but other large emerging markets such as India, Indonesia, Brazil and other South Asian and East Asian countries have been rapidly expanding production, driven by their rising per capita incomes, growing urbanization, and increased investments in buildings and infrastructure. Emerging markets excluding China produce about 26 percent of cement

34 IFC staff calculations based on Global Trade Analysis Project.

EXHIBIT 6

Construction Materials Production Is More Carbon Intensive in Emerging Markets Than in High-Income Countries

Average CO_2 kg eq. emissions per unit of output



Notes: Output is calculated as the sum of value added and intermediate consumption by sector. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project and GCCA.

and about 12 percent of steel globally. Sub-Saharan Africa has a minor participation in the supply of both materials. High-income countries only account for about 11 percent of the global supply of cement and about 33 percent of steel (Exhibit 5). Table 2.1 and 2.2 in Annex 2 shows the contribution of each country by region to the production of cement and steel in these country groupings and globally.

The significant contribution of large emerging markets to the emissions from construction materials also reflects reliance on relatively more carbon-intensive production methods. For instance, emerging markets produce steel with almost three times more emissions per unit of output than developed economies (Exhibit 6). Similarly, cement production in emerging markets is much more carbon-intensive than in high income countries. Use of more polluting energy sources, like heavy fuel oils and coal, and more energy- and resource-intensive equipment mainly account for these large differences in carbon-intensity of cement and steel production between developing and developed economies.[35]

Finally, high levels of construction emissions by emerging markets also reflect the rapid growth of investment in new buildings and materials in these countries, particularly in middle-income economies.[36] Today, emerging markets account for about half of the global investment in construction (China alone has about a quarter of the global total), up from about 30 percent in 2000. By contrast, the share of high-income countries in construction investment declined from more than 70 percent to less than 50 percent over the same period. Overall, investment in construction and materials accounts for about 20 percent of the combined GDP of emerging markets.[37]

1.3. Emissions from construction are set to rise and are off track to meet construction climate commitments.

The Paris Agreement calls for every building to be net-zero carbon (highly efficient and powered from renewable energy sources, with any emissions offset) by 2050. Only 5 percent of new buildings, however, are net-zero and less than 1 percent of these buildings are built with zero-carbon specifications today.[38]

As the expected life span of buildings constructed today is about 50 years, the construction methods of today determine emissions and energy consumption of buildings for the foreseeable future. Non-carbon-neutral buildings will also need to be retrofitted in the next 30 years.[39] Retrofit rates are insufficient, however, as average annual retrofit rates in buildings amount to less than 1 percent of the buildings stock per year in most major markets, even in high income countries. Because of its high costs, moving aggressively in deep retrofitting or decommissioning brown buildings, however, will be challenging for most economies and it

35 World Bank, mimeo.

36 Investment in this report refers to gross fixed capital investment in the construction sector in the Global Trade Analysis Project database. See Annex 1.

37 IFC staff calculations based on Global Trade Analysis Project.

38 A zero carbon ready building is highly energy efficient and either uses renewable energy directly or uses an energy supply (e.g., electricity or district heating) that will be fully decarbonized by 2050. IEA (2020).

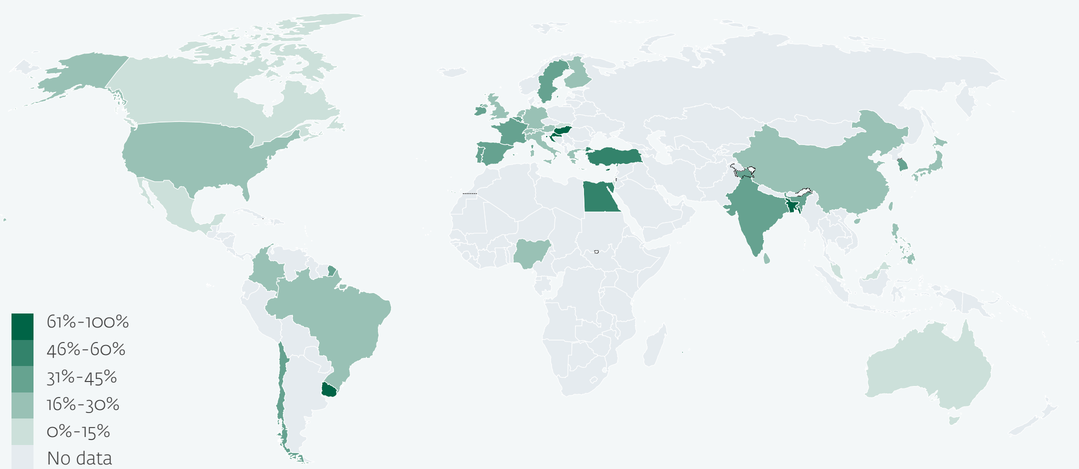
39 IEA (2020).

EXHIBIT 7

Dissemination of Green Building Measures by the Private Sector Has Been Limited Outside High-Income Countries and Large Emerging Markets

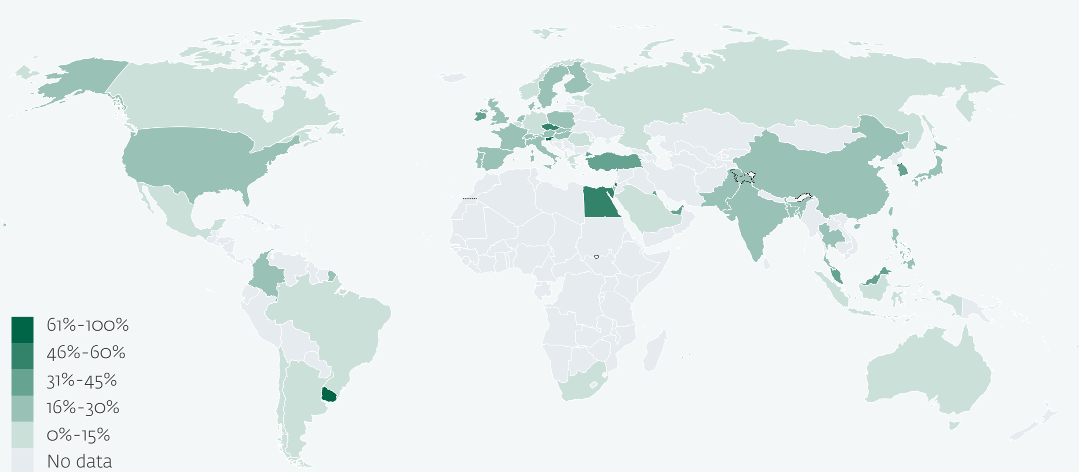
2015: Positive sentiments share related to 'Green Building Certification'

share of positive documents by country



2021: Positive sentiments share related to 'Green Building Certification'

share of positive documents by country



Notes: Analysis based on identifying selected keywords on green building certifications and construction methods in company's documents using artificial intelligence text-recognition methods, natural language processing, and machine learning. Algorithms assess the tone of a transcript on a spectrum of positive to negative. The scale measures the share of company's documents registering positive "sentiment" by country. The data only includes company's documents in English.

Source: IFC and IBRD DEC based on Facset https://www.factset.com/solutions/data-solutions.

will therefore most likely not be a priority for middle- and low-income countries in the years to come.

More than 110 countries lacked mandatory building energy codes or standards in 2021, meaning that more than 2.4 billion square meters of floor space were built last year without meeting any energy-related performance requirements—the equivalent of Spain's entire building stock.[40]

Lack of adequate building codes, insufficient green financing, and the dearth of technical and enforcement capabilities explain the sparsity of low-emission buildings and materials in least developed economies, and some middle-income economies. The highly local and decentralized organization of the construction industry also makes designing and enforcing consistent green building regulations and standards challenging in many emerging markets, especially in some Latin American and Southeast Asian economies.[41]

This report employs a computable general equilibrium dynamic-circular economy model to analyze alternative scenarios for construction value chains decarbonization in emerging markets by 2035 (See Box 2 and Annex 1 for a detailed description of the model and the scenarios). Computable general equilibrium models provide an indication of plausible paths of construction carbon emissions and the economic effects of alternative policy options rather than precise numerical estimates. These models offer valuable guidance to policymakers and private investors for the design and deployment of mitigation and adaptation measures and the identification of potential investment opportunities. The summary of results of the simulations of the model employed in this report are presented in the following paragraphs.

In the absence of additional efforts to reduce emissions (the no mitigation scenario described in Box 2), the results of the model suggest that total construction-related emissions would increase by about 13 percent between 2022 and 2035 globally. About 45 percent of this increase reflects the rapid investment in conventional carbon-intensive buildings and construction materials in emerging markets other than China, driven by fast urbanization and economic growth in India, East Asia and the Pacific, the Middle East and North Africa and Sub-Saharan Africa. China's contribution to the increase in emissions will be moderate due to the existing excess supply of cement, steel, and other materials as well as the already massive stock of buildings (Exhibit 8). Low-income economies would make only a marginal contribution. Table 2.3 in Annex 2 provides the projected trajectory of construction-related emissions by country and region. Only the major countries measured by purchasing power parity-adjusted GDP are displayed there due to data limitations.

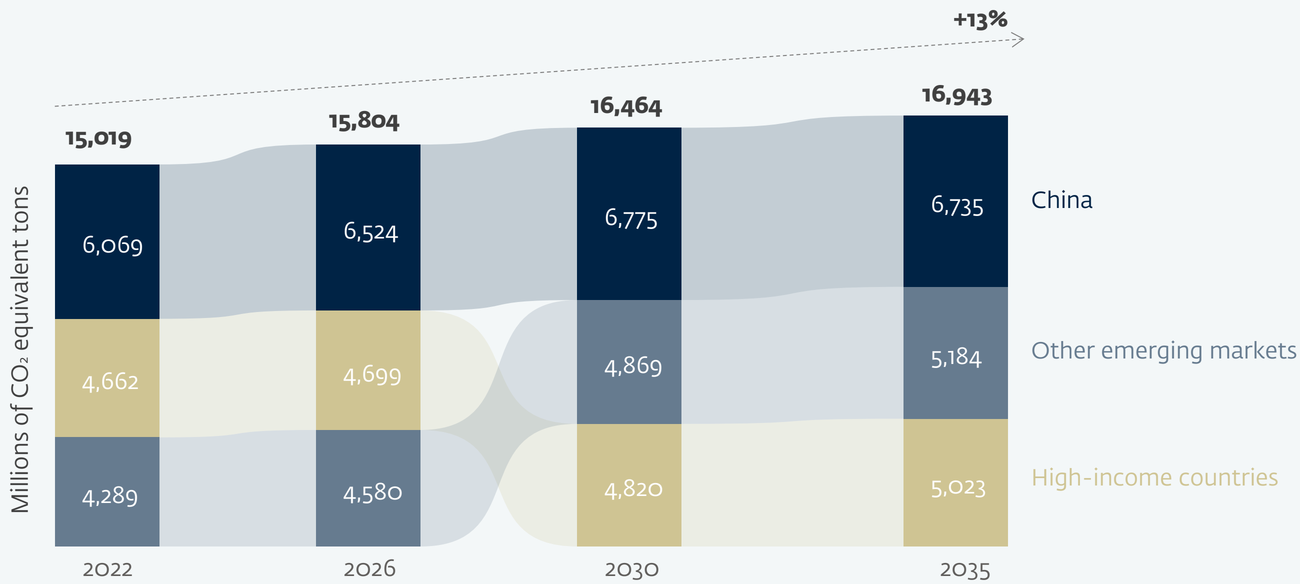
The operation of buildings will account for most of the projected rise in construction-related emissions. Its contribution will increase from about 50 percent of construction emissions in 2022 to about 60 percent by 2035. In the absence of vigorous mitigation efforts (the no mitigation scenario in Box 2), this will be mainly propelled by the construction of new brown buildings, and therefore, by the expansion of the stock of

40 IEA (2021).

41 World Bank (mimeo); and IEA (2020).

EXHIBIT 8

Global Construction Emissions Are Projected to Grow



Notes: See Box 2 and Annex 1 for a description of the model used for the projections. Other emerging markets include Sub-Saharan Africa. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project.

carbon- and energy-intensive buildings.[42] Retrofitting is costly, and the construction of new energy-efficient buildings, and the expected progressive greening of the energy grid, is unlikely to offset the emissions coming from conventional brown buildings without decisive additional mitigation efforts in the next decade.[43]

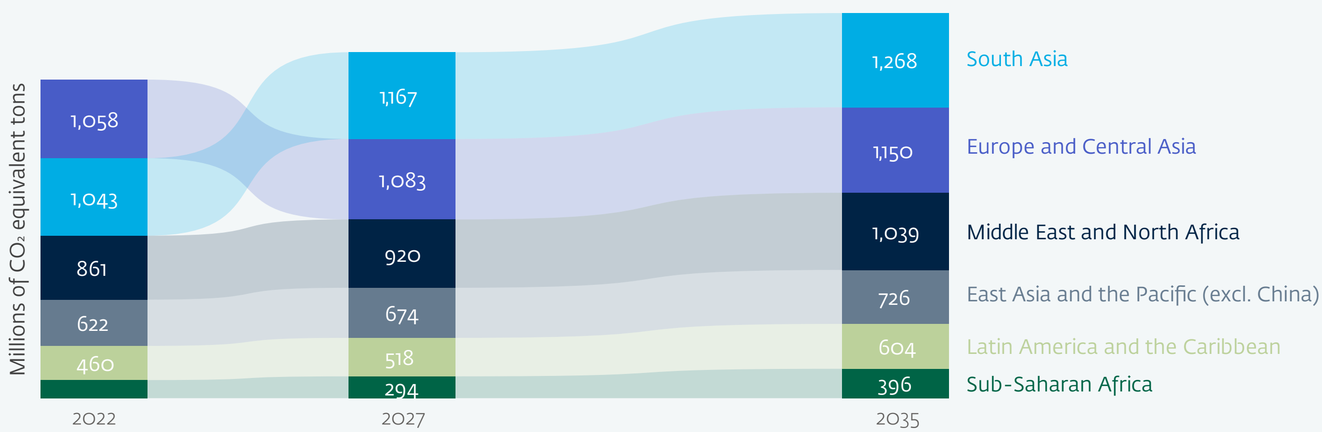
Against this backdrop, in the next decade, advanced economies will most likely concentrate their policy efforts on scaling up carbon pricing programs, adopting stricter green codes and standards, and promoting novel mitigation and adaptation technologies not commercially viable today through fiscal incentives. Most middle- and low-income economies are likely to focus more on seizing 'low-hanging-fruit' measures with moderate costs like green codes, regulations and standards and already commercially available technologies. With financial and technical support from development finance institutions, some upper-middle income countries could also accelerate the piloting of promising

42 IFC staff calculations based on Global Trade Analysis Project.

43 IEA (2020). See Chapters 2 and 4.

EXHIBIT 9

South Asia Will Be Driving the Increase in Construction Emissions in Emerging Markets



Notes: See Box 2 and Annex 1 for a description of the model used for the projections. Only the major countries measured by GDP adjusted by purchasing power parity are displayed here due to data limitations. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project.

technologies with high abatement potential like green hydrogen.[44]

Looking at the regional distribution in the simulations, the model's results suggest that, in the absence of additional mitigation efforts (the no mitigation scenario in Box 2), rapid population and economic growth in South Asia and East Asia and the Pacific, especially in India and Indonesia, and to a lesser extent, in Europe and Central Asia, would drive the increase in global construction emissions. The Middle East and North Africa would follow in importance due to the presence of economies with abundant and intensive use of fossil fuels in the operation of buildings and production of materials. Latin America and the Caribbean, and especially Sub-Saharan Africa, would only make a minor contribution (Exhibit 9).

The growth in construction activity will be mainly propelled by expansion in building floorspace in emerging markets, especially in high growth South Asian and East Asian countries, like India, Indonesia, and Malaysia. Building floorspace is expected to increase by a factor of two to three in developing

44 See Chapter 4.

BOX 2

Modeling Alternative Scenarios for Construction Investment and Emissions by 2035

Given the complexity of construction value chains in their interactions with the broader economy and the environment, IFC has partnered with the Global Trade Analysis Project (GTAP) at Purdue University, which developed for this report a computable general equilibrium–circular economy (CGE-CE) model. The model aggregates information on national accounts, balance of payments, and input-output matrices in a consistent representation of the dynamic inter-dependencies across sectors, agents, and markets.

To analyze the effects of economic and population growth and alternative mitigation policies on emissions and other environmental indicators, the CGE-CE model incorporates an explicit representation of production technologies (e.g., primary, secondary, and recycling activities) and materials (e.g. steel, cement, glass, fossil fuels, minerals, among others). By capturing changes in both supply and demand, the model simulates adjustments in the economy following the implementation of a policy shock.

For instance, if carbon pricing is adopted, this leads in the model to higher prices in brown primary and secondary activities, reduced demand for brown goods, as well as shifts in the supply mix by increasing the share of low-carbon activities in output and employment. Carbon prices also induce changes in carbon and energy intensity of total output. These demand and energy- and carbon-intensity effects cause, in turn, changes in total emissions.

The model represents the economy as a circular flow in which firms acquire factors (e.g., labor, capital, materials, energy, etc.) to produce goods and services. Households, in turn, receive income from firms (e.g., wages, capital gains, etc.), and demand goods and services produced by firms. Equality of supply and demand determines equilibrium prices for factors, goods, and services. Using the economic and environmental data described above, the model is calibrated to this theoretical representation of the economy for the baseline year of 2022 and solved as a sequence of comparative static equilibria where inputs are linked over time.

For this report, the model simulates four scenarios: a) no mitigation, which assumes continuation of the current climate policies without additional mitigation measures; b) NDC, which assumes countries comply with their Nationally Determined Contributions (NDCs); c) energy efficiency, that includes compliance with the NDCs, and electrification of brown buildings with cleaner energies and decarbonization of construction materials and new buildings with non-fossil fuels and improved energy efficiency; and d) net-zero-aligned that includes compliance with NDCs, and direct taxation of brown buildings and materials and subsidies to green alternatives. Scenario b) is simulated by applying carbon taxes on all sectors to achieve NDC targets. Scenario c) is simulated by applying carbon taxes on electricity generation for buildings operations and construction materials, and assuming improvements in the use of energy. Scenario d) is simulated by applying taxes directly on the stock and flow of brown buildings and materials and direct subsidies to low-emission alternatives (Annex 1).

The simulations focus on a time span (the next decade, 2022-2035) when most of the technologies with the largest abatement potential, like green hydrogen and carbon storage, are unlikely to become widely adopted without supportive policies (IEA, 2023). This approach also emphasizes the most plausible path for adopting carbon pricing in emerging markets based on the existing NDCs, instead of simulating the hypothetical carbon prices required to limit emissions below the levels established in the Paris Agreement. Annex 1 provides the carbon prices by country and region used in the simulations, considering the expected differences in the level and velocity of adoption of carbon pricing programs between high-income economies and emerging markets. It also provides further details about the model employed in the report.

countries by 2060.[45] According to this report's calculations using the model described in Box 2 and Annex 1, emerging markets could account for about half of global construction investment by 2035 in the no mitigation scenario.

Despite the expected deceleration of its economy,[46] China is still likely to account for a quarter of the world's construction investment because of the combination of new investments and the need to maintain the existing stock of buildings and other structures. The contribution of other emerging markets is expected to rise to about 25 percent, with most of the construction occurring in India and other Asian economies.

The share attributable to Sub-Saharan Africa and low-income economies in other regions would be relatively small, at 3 percent, despite the region more than doubling its construction investment in absolute terms. In contrast, the construction investment share of high-income economies is likely to decline from 50 percent in 2022 to 48 percent by 2035 due to decelerating population and economic growth.[47]

1.4. A combination of available and emerging technologies and policy actions can reverse the growth in construction value chain emissions.

Compliance with the NDCs and construction-specific mitigation policies and novel and available technologies could bring down construction emissions to well below today's levels. Chapters 2 and 3 discuss these existing and emerging technologies and Chapter 4 examines the policies and financing required to achieve the projected reduction in global construction emissions.

The model employed in this report focuses on two alternative, but not necessarily exclusive, pathways or scenarios for reducing carbon emissions in construction value chains by 2035 (See Box 2 and Annex 1). One pathway involves accelerating the attainment of the net zero emissions target set by the Paris Agreement by 2050 by boosting the stock of green buildings and materials through widespread carbon pricing and fiscal support measures (the net zero-aligned scenario in Box 2). Another pathway involves fostering the adoption of 'low-hanging fruit' technologies, such as electrification of brown buildings, energy-efficient buildings and materials, and cleaner energies through measures with moderate economic costs (the energy efficiency scenario in Box 2).

These scenarios entail tradeoffs between accelerating now the decarbonization of hard-to-abate sectors and the potential costs in terms of foregone output and investment required by 2035. When and how emerging markets start down these pathways towards construction decarbonization would depend on country conditions, available financing, technological and policy readiness, and dependence on fossil fuels. The simulations of the model described

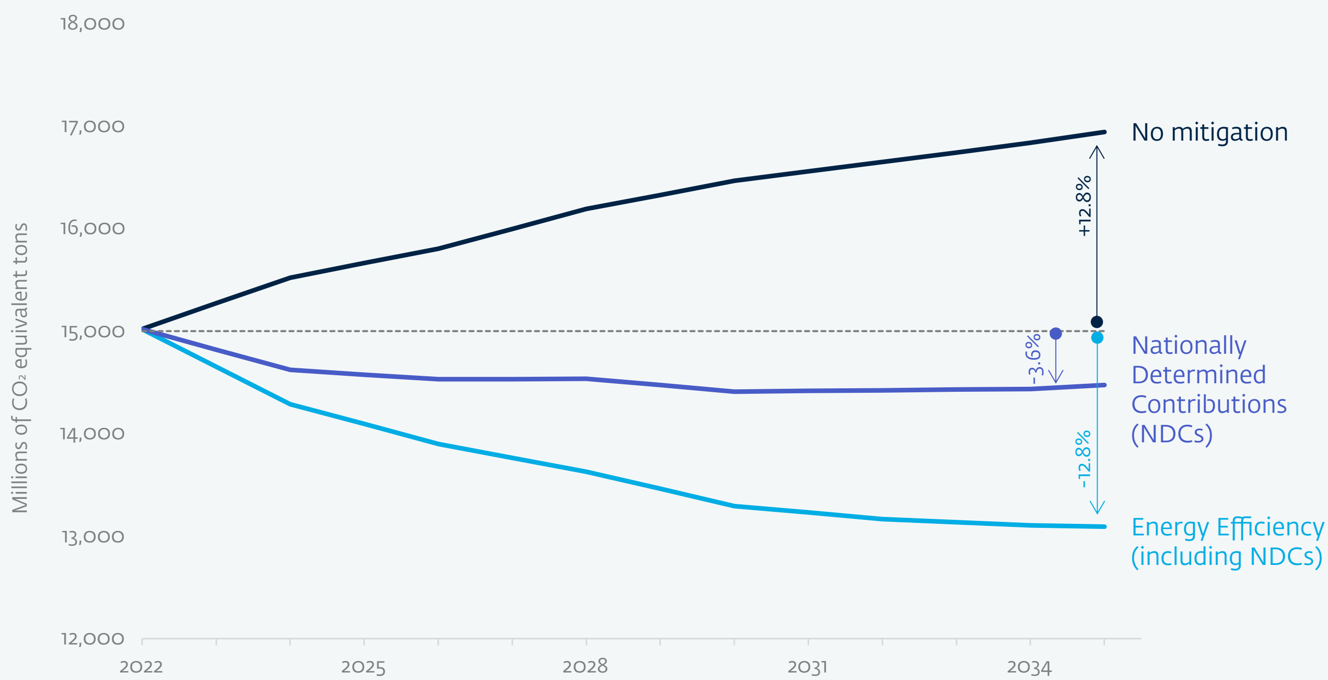
45 UN Environment and IEA (2017).

46 China's GDP growth is expected to decelerate from an average 6 per cent per year in 2014–2022 to 4 percent in 2022–2035 (Global Trade Analysis Project model calculations based on near-term outlook in WEO (2022).

47 IFC staff calculations based on Global Trade Analysis Project (2022).

EXHIBIT 10

Global Construction Emissions Could Decline by 13 Percent Below the 2022 Level by 2035 with Decisive Action in Construction Value Chains



Notes: The exhibit shows the results of the simulations for the no mitigation, Nationally Determined Contributions (NDCs), energy-efficiency and net zero-aligned scenarios described in Box 2 and Annex 1. Castro et. al mimeo simulates alternative scenarios. The NDC scenario simulates the effects of complying with the NDCs emission-reduction targets set in the Paris Agreement. The energy-efficiency scenario simulates the effects of sector-specific measures geared towards cleaning the energy mix and improving the energy efficiency of buildings and materials plus compliance with the NDCs. The net zero-aligned scenario simulates the impacts of widespread carbon pricing on brown buildings and materials and subsidies to green alternatives plus compliance with the NDCs. The drop in emissions in the net zero-aligned scenario is similar to the decline in emissions in the energy efficiency scenario and it is therefore not shown here. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from the Global Trade Analysis Project (2022) and Global Climate Change Alliance (2021).

in Box 2 and Annex 1 explore these potential tradeoffs. Section 1.4 presents the results of the model for the investment needed to reduce construction emissions in the next decade, while Section 1.5 presents the results pertaining to foregone output under the two scenarios.

Exhibit 10 shows the simulated trajectories of total construction-related emissions globally under the no mitigation scenario and the energy efficiency scenario, using the model depicted in Box 2 and Annex 1. According to the simulations, construction emissions would not only decline in the energy efficiency scenario by about 13 percent globally with respect to 2022—equal to about 1.9 billion CO_2 equivalent tons —but they would also fall by about 23 percent, about 3.8 billion CO_2 equivalent tons, relative to the no mitigation scenario (Exhibit 10). The 13 percent reduction relative to today's levels is equivalent to the total emissions from the construction value chain in the United States in 2022; when compared with the decline relative to the no mitigation scenario in 2035, it would be equivalent to the combined emissions of the United States, the European Union, and the rest of the OECD countries.[48]

The simulations also suggest that by 2035 global total carbon emissions, including construction and the rest of the economic activities, would decline by about 19.8 percent in the energy efficiency scenario compared with the no mitigation scenario due to the drop in construction emissions.[49] These results emphasize the need to pave the way now for decarbonizing hard-to-abate activities, such as construction and operation of buildings and materials, to meet the climate goals set in the Paris Agreement.

These results also suggest that buildings and construction materials will not decarbonize in the years to come without decisive policy action, private sector investment, and widespread adoption of existing abatement technologies and practices.[50] Novel technologies hold the promise of net zero buildings and materials, but they are expected to remain non-economically viable without fiscal support by 2035 and beyond.[51]

The speed and depth of the policies required to promote the adoption of these existing and novel technologies will vary across countries in the next decade. Countries that have already made significant progress in decarbonizing activities with lower marginal abatement costs, such as energy supply and transportation, and that possess adequate fiscal space may be able to move faster in deploying carbon pricing and promoting technologies that are non-commercially available today. With adequate policy and regulatory frameworks and international financial and technical support, middle-income economies could be able to reap the benefits of already commercially available technologies, and the piloting of novel mitigation and adaptation technologies. Low-income countries will need assistance to start walking the path towards building green in the years to come (See Chapter 4).

48 IFC staff calculations based on Global Trade Analysis Project (2022).

49 IFC calculations based on Global Trade Analysis Project (2022).

50 Castro et. al, mimeo.

51 IEA (2023).

The results of the simulations suggest that the operations of buildings would account for about three quarters of the 23 percent projected decline in global construction emissions by 2035 in the energy efficiency scenario compared to the no mitigation scenario (Box 2). This would occur through the electrification of brown buildings with renewable energies, the construction of new net-zero carbon and resilient buildings, and other mitigation and adaptation alternatives. The increased supply of cleaner cement and steel, spurred by the increased use of renewable energy, low-emission raw materials, and improved energy and thermal efficiency, would account, in turn, for about 25 percent of the projected drop in emissions. Greening the construction activity itself would only have a marginal contribution as it relies on relatively less carbon- and energy-intensive activities like off-site and on-site construction services.[52]

On average, global construction-related emissions decline by about 2 percentage points per year in the energy efficiency scenario relative to the no mitigation scenario. Of this, 1.4 percentage points come from reductions in energy intensity of buildings and materials, while 0.6 percentage points come from a decline in carbon intensity. Construction output would experience only a minor deceleration (a drop of 0.04 percentage points per year).[53]

Depending on the expected abatement costs and emission-reduction potential of alternative technologies,[54] the results of the model suggest that the road towards building green in emerging markets would require sequencing the decarbonization of construction value chains by 2035. Reducing the energy and carbon intensity of new buildings and materials or electrifying the stock of brown buildings with cleaner energies, for instance, could contribute to reducing emissions with moderate economic costs in the next decade (See Section 1.6).

Commercially available measures and technologies, such as improving thermal and energy efficiency and switching to less carbon intensive inputs and non-fossil fuels, can also contribute to reducing emissions from construction materials now. Retrofitting brown plants or buildings could potentially yield sizeable reductions in global emissions, but the high costs are likely to limit substantial progress in this area in the next decade in most emerging markets (See Chapter 3). In the longer term, widespread adoption of carbon pricing and technologies with high abatement potential, but not commercially available now, could further decrease construction emissions (See Chapter 4).

Against this backdrop, emerging markets would account for more than half of the approximately 23 percent decline in global construction-related emissions in the energy efficiency scenario relative to the no mitigation scenario (Box 2). According to the projections, China's contribution to the drop in emissions would be 10.3 percentage points, while other emerging markets and Sub-Saharan Africa would

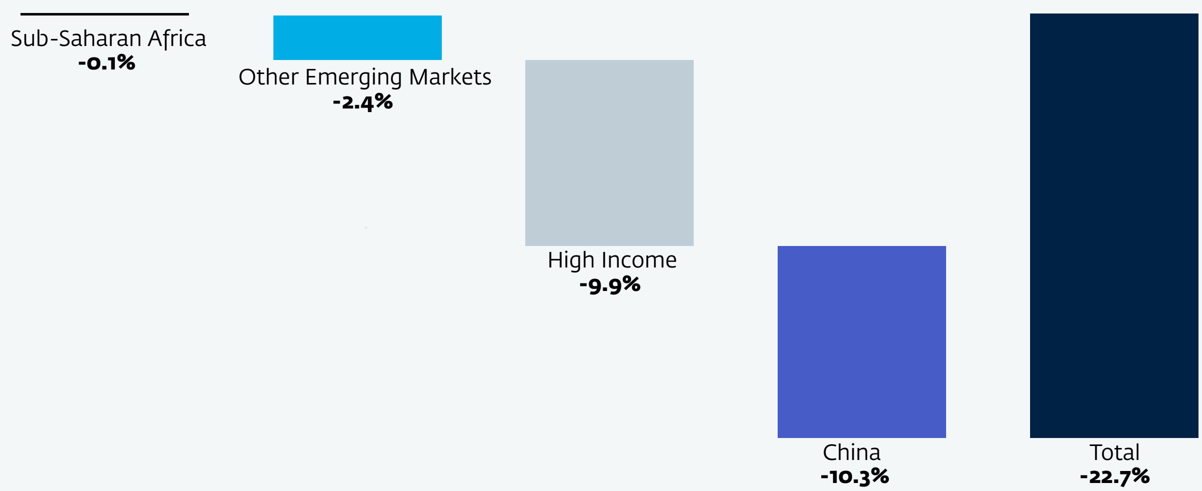
52 IFC staff calculations based on Global Trade Analysis Project.

53 Energy intensity refers to the unit of energy used per unit of construction output, while carbon intensity refers to the unit of CO_2 metric ton per unit of energy consumed in construction. Castro et. al, mimeo present a detailed decomposition of these carbon and energy intensity and total demand effects The 2 percent average yearly drop in emissions refers to the decline in emissions of about 23 percent in the energy-efficiency scenario compared to the no mitigation scenario between 2022 and 2035.

54 Chapters 2 and 3 analyze the economic costs and abatement potential of alternative technologies and measures for buildings and materials, respectively.

EXHIBIT 11

Emerging Markets Will Account for Most of the Expected Reduction in Construction-Related Emissions



Notes: The exhibit depicts the contribution of each region to the change in construction-related emissions in the policy scenario relative to the no mitigation scenario (See Box 2 and Annex 1). The contribution is calculated by multiplying the share in global emissions in the base year by the percentage change in emissions for each region. Castro et. al, Forthcoming explore alternative scenarios and assumptions for the simulations. Figures in the text might not be identical due to rounding.

Source: IFC based on Global Trade Analysis Project and GCCA.

contribute 2.4 and 0.1 percentage points, respectively, to the decline (Exhibit 11).

Emissions from middle- and low-income economies are set to experience a more moderate decline in construction emissions because of their expected higher growth rates, less developed carbon pricing and regulations,[55] and more carbon and energy-intensive construction and operation of buildings and construction materials, even in the energy efficiency scenario.

The results of the model also suggest that the net zero-aligned scenario (Box 2) would achieve a similar 13 percent reduction in global construction emissions as the energy efficiency scenario and also place construction value chains closer to the goal of net zero emissions set by the Paris Agreement by 2050 by increasing the relative importance of green buildings and materials in total construction investment. This alternative would, however, entail significantly higher investment needs and economic costs by 2035

55 See Section 4.4 for an analysis of carbon pricing programs in emerging markets. Annex 2 provides the assumed carbon prices used in the simulations employing the model described in Box 2. Construction value chains emissions reductions by country/region in the "energy efficiency" and "net-zero-aligned" scenarios are roughly proportional to the reductions in the NDC scenario.

than the energy efficiency scenario, particularly for emerging markets, as shown in the next two sections.

1.5. $1.5 trillion in investment in emerging markets is needed to achieve the emissions-reduction goal in construction.

According to the model described in Box 2 and Annex 1, reducing construction-related emissions by 13 percent between 2022 and 2035 would require cumulative investments in electrifying brown buildings with cleaner energies and energy efficient new buildings and materials of about $3.5 trillion globally (Exhibit 12),[56] supported by complementary policy reforms.[57]

The simulations also suggest that the alternative path to reduce construction emissions by shifting construction investment towards greener alternatives through widespread carbon pricing and fiscal incentives (the net zero-aligned scenario in Box 2 and Annex 1) would be a much costlier solution. This path would require cumulative investments of about $6 trillion globally by 2035, about twice the investment required for electrifying conventional buildings and new energy-efficient buildings and materials powered by cleaner energies (the energy efficiency scenario in Box 2).[58]

Emerging markets offer more cost-effective opportunities to reduce carbon emissions in construction value chains through investments in electrification, energy efficiency and renewable energies than developed economies. According to the model described in Box 2, in emerging markets excluding China, investments in cleaner brown buildings and new green buildings would amount to $160 billion in the next decade, compared to $2 trillion in high-income economies in the energy efficiency scenario in comparison with the no mitigation scenario. Investment in China would amount to $1.3 trillion (Exhibit 12).

Construction practices and technologies in emerging markets are more carbon intensive than in high-income countries, especially in fast-growing economies with higher shares of fossil fuels in the energy mix.[59] More importantly, the expected faster pace of both population and economic growth in emerging markets over the next decade could allow for available energy-efficient technologies to be embedded in existing and new buildings rather than deeply retrofitting or retiring existing brown assets.[60]

The results of the simulations of the energy efficiency scenario using the model depicted in Box 2, suggest that most of the $1.5 trillion investment needs in emerging markets would be channeled to electrification of brown buildings and new, more energy efficient buildings and materials, powered with cleaner energies. Around 75 percent of investment would be funneled into cleaning the energy mix of brown buildings and new green buildings with lower energy and water consumption, less polluting waste management systems, low-carbon embodied

56 Investment refers to gross fixed capital investment in the construction sector in the Global Trade Analysis Project database. See Annex 3.

57 Chapter 4 examines in detail the policies and financing required for incentivizing investment in green construction in emerging markets.

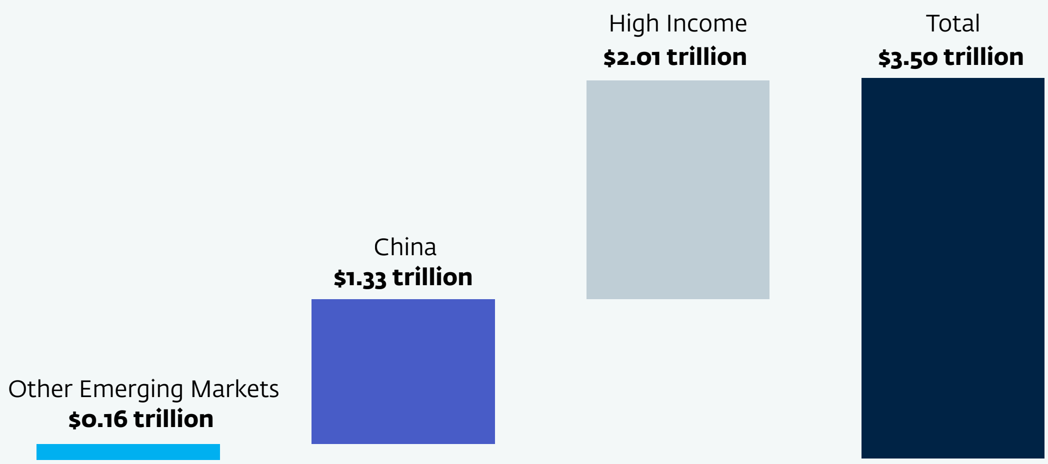
58 IFC calculations based on Global Trade Analysis Project (2022).

59 IEA (2020).

60 IEA (2021).

EXHIBIT 12

Investment Needs for Building Green Will Amount to $1.5 Trillion in Emerging Markets in the Next Decade



Notes: Investment needs are calculated as the difference between investments in electrification of brown buildings with renewable energies and new buildings and materials powered with low-emission energies in the no mitigation scenario and the energy efficiency scenario. See Box 2 for an explanation of the model and scenarios. Figures in the text might not be identical due to rounding.

Source: IFC calculations based on data from Global Trade Analysis Project, Global Climate Change Alliance, International Energy Agency and other sources.

materials, carbon offsets and use of renewable energies. Increased supply of less carbon-intensive cement, steel, and other materials would absorb about 20 percent of the required investment for decarbonizing construction value chains in emerging markets by 2035.[61] The remaining 5 percent would finance built environment-related services on and off construction sites.[62]

Employing the model described in Box 2, Exhibit 13 further disaggregates the projected investment in electrified brown buildings and green buildings with renewable energies and improved energy efficiency for emerging markets by region, assuming that the construction materials and services are already embedded in the buildings. Section 3.5 analyzes some specific investment opportunities in green cement and steel.

Of the additional $160 billion in green construction investment in emerging markets other than China between 2022 and 2035, Latin America and the

61 IFC calculations based on Global Trade Analysis Project (2021); and GCCA (2021).

62 IFC calculations based on Global Trade Analysis Project (2021); and GCCA (2021).

EXHIBIT 13

Investment in Building Green Would Be Largest in Residential Housing

Investment needs by region and building type, 2022–2035, $ billion

	Europe & Central Asia	Sub-Saharan Africa	Middle East & North Africa	Latin America & the Carribean	East Asia Pacific	South Asia	Total
Office	0.4	0.5	0.5	1.1	0.4	0.7	3.6
Retail	0.8	0.4	0.4	1.2	0.4	1.0	4.3
Education	1.0	1.1	0.8	3.4	0.4	0.6	7.3
Healthcare	0.4	0.4	0.5	0.8	0.1	0.2	2.4
Hotels & Restaurants	0.3	0.1	0.2	0.7	0.2	0.4	1.8
Institutional/Assembly	0.3	0.3	0.4	0.3	0.1	0.2	1.5
Warehouse	0.2	0.3	0.2	0.5	0.1	0.2	1.5
Total Commercial	**3.4**	**3.0**	**3.0**	**8.1**	**1.7**	**3.2**	**22.4**
Single-Family Detached	10.4	8.1	8.9	47.9	5.8	12.8	94.0
Multi-Unit Residential	3.9	1.3	3.0	20.7	5.4	9.4	43.6
Total Residential	**14.3**	**9.4**	**12.0**	**68.6**	**11.2**	**22.2**	**138**
Grand Total	**17.6**	**12.4**	**14.9**	**76.7**	**12.9**	**25.4**	**160**

Notes: Investment in materials and construction services are already embedded in the investment by type of building and structure. The coloring is comparing building types within a region. Within a region, the building type with the highest value has the brightest blue color. These forecasts differ from the estimates presented in IFC, 2019 because the model used in this report considers the dynamic effects of investments in green buildings on investment in conventional alternatives as well as the effects of the latter on other markets and sectors and the entire global economy between 2022 and 2035. See Box 2 and Annex 1 for an explanation of the model and scenarios. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Global Trade Analysis Project and IFC (2019).

Caribbean, South Asia and Europe and Central Asia would account for about $77 billion, $25 billion, and $18 billion. In the Middle East and North Africa and East Asia and the Pacific, the investment would amount to about $15 billion and $13 billion. Green building investment would amount to $12 billion in Sub-Saharan Africa. About 86 percent of the investment would be directed to residential buildings (a half of that in Latin America), especially in single-family detached housing.

This amount of investment implies a major scale-up in funding for investment in building green in emerging markets. According to IFC calculations, local and foreign private green debt finance—bonds and loans—for decarbonizing the construction value chains amounted globally to $230 billion in 2021, with only $23 billion issued in emerging markets. Less than half of this amount was issued in emerging markets outside China (See Chapter 4).

In the next decade, new buildings and plants will still have to be built, and therefore, investment will have to be financed in emerging markets. Financial markets offer an opportunity to channel domestic and international capital to investments in green construction in emerging markets with the adequate policy and regulatory framework in place (See Chapter 4). Concessional and blended finance will also have to be stepped up for building green in the poorest countries in the next decade. In 2022, multilateral climate funds issued $1.79 billion in grants and $1.39 billion in concessional and blended climate finance. Development finance institutions provided $3.06 billion in grants and $16.81 billion in concessional and blended climate finance.[63]

1.6. Decarbonizing construction value chains entails short-term trade-offs for long-term benefits.

Climate change action entails facing the trade-offs between short-term adverse effects on economic growth and long-term positive impacts on productivity and human welfare. Recent publications suggest that adoption of ambitious mitigation targets now could have relatively small economic costs in the next decade that would be more than compensated by the benefits of taming global warming by 2050 and beyond. [64] Against this backdrop, this section examines these trade-offs using the model described in Box 2 to simulate the economic and environmental effects of alternative adaptation and mitigation policies in construction value chains.

Existing evidence indicates that without reductions in high-emission activities, climate change is expected to have an increasingly negative impact on the global economy, particularly in the period after 2050. Rising temperatures caused by increasing emissions dampen agricultural productivity, workers' health, land availability, hydropower capacity, and labor productivity, and increase the frequency and magnitude of adverse climatic events, hampering economic growth. Besides its effects on human systems, climate change hinders biodiversity, water quality, and natural habitats.[65]

Against this background, the most cost-efficient solution to start decarbonizing construction value chains in emerging markets now will be to foster the adoption of 'low-hanging fruit' technologies, particularly switching the energy mix towards non-fossil fuels and improving the energy efficiency of new and existing buildings and the supply of materials (the energy efficiency scenario in Box 2), through policies with relatively moderate economic costs, like green construction codes, energy efficiency regulations and green building standards (See Chapter 4), at least until high-abatement technologies, like green hydrogen and carbon storage, become commercially available (IEA, 2023, and Chapters 2 and 3).

The alternative pathway to reduce construction emissions in the next decade through widespread taxation of brown buildings and materials and subsidies to green alternatives (the net zero-aligned scenario in Box 2) would come with greater costs to

63 There is no disaggregated data by use of proceeds for concessional and blended finance. See Chapter 4.

64 See, for instance, IMF (2022).

65 IMF (2022) and Chepeliev et.al (2022).

short-to-medium term economic growth than the energy efficiency scenario. The carbon intensity of construction value chains would require imposing significantly higher carbon taxes on buildings and materials than in relatively easier to decarbonize sectors, like electricity generation, at least until technologies with high abatement potential become commercially available by 2035 and beyond. Given the importance of construction in total global investment,[66] deploying carbon taxes directly on predominantly brown buildings and materials would therefore entail a larger decline in economic growth rates compared to measures geared towards cleaning the energy mix and improving the energy efficiency of construction value chains.

The results of the simulations of the model described in Box 2 suggest that direct taxation of brown buildings and materials (the net zero-aligned scenario) would result in a 0.4 percentage points deceleration in global yearly growth through 2035 with about a 20 percent drop in global total emissions, including construction and other activities, in comparison to the no mitigation scenario. Emerging markets would experience relatively larger output losses than high income economies because their construction value chains are more carbon intensive. Novel technologies with high abatement potential are also extremely expensive today and would therefore require massive subsidies which are unlikely to be attainable for most emerging economies, at least without significant concessional support or direct transfers from high-income countries.

These output losses are not likely to be offset fully by the expansion of low-emission construction activities over the next decade. Workers' reallocation from high- to low-emission activities could involve significant costs due to inter-sectoral skills mismatches and other frictions in labor markets.[67] Shifting capital to low-emission activities can also face substantial obstacles due to financial market imperfections.[68] As the result of these frictions in capital and labor markets, contraction of high-emission sectors caused by carbon taxes could result in lower economic growth rates than in a counterfactual scenario in which no additional mitigation measures are undertaken—until the damages from rising temperatures start to increase rapidly in the second half of the century.

Against this background, the results of the model described in Box 2 and Annex 1 suggest that the alternative pathway of promoting the adoption of 'low hanging fruit' technologies -electrification of buildings, cleaner energy supply and energy-efficiency- (the energy efficiency scenario) would achieve a similar drop in global carbon emissions than the 'net zero-aligned' scenario but with much more moderate output losses.

The total cost of reducing global total emissions —including construction—by about 13.04 percent through compliance with the NDCs (with no construction-specific mitigation measures) would

66 Construction accounts for about half of total fixed capital investment globally (IFC calculations based on Global Trade Policy Project, 2022).

67 Policies required to facilitate the reallocation of workers from high to low-emission activities (e.g., reskilling, labor support programs, among others) are out of the scope of this report, and not analyzed here.

68 See Chapter 4.

amount to 0.02 percentage points in annual GDP growth by 2035 in comparison with the no mitigation scenario. Promoting energy-efficient buildings and materials powered with cleaner energies (the energy efficiency scenario) would reduce total global emissions, including construction and other sectors, by about 20 percent, like the net zero-aligned scenario, but with output losses amounting to 0.03 percentage points in yearly global growth relative to the no mitigation scenario. The results of the simulations under this scenario align with the Climate Action Tracker (CAT) pathways, the main reference for climate-related simulations using similar computable general equilibrium models to the model employed in this report (Annex 1).

According to the simulations of the model described in Box 2, upper-middle income countries would experience the largest output losses in the energy efficiency scenario amounting to minus 0.06 percent in yearly growth by 2035, in comparison with the no mitigation scenario. Lower-middle income countries would experience the lowest output losses amounting to about minus 0.01 percentage points in yearly growth. Low-income economies in Sub-Saharan Africa would experience a similar decline.[69]

These results suggest that emerging markets facing rising housing demands in the next decade, driven by high economic and population growth, have an opportunity to build green with moderate economic costs by promoting 'low-hanging fruit' mitigation and adaptation technologies for buildings electrification, improved energy-efficiency and cleaner energy supply through adequate policy and regulatory frameworks, and international technical and financial support.[70]

These results also suggest that decarbonizing construction value chains in emerging markets is likely to require a sequential strategy in the years to come. Early action could be taken on electrifying buildings with renewable energies, and on switching the energy mix and processes of material plants to less carbon-intensive fuels and raw materials. Improved energy and thermal efficiency and resilience of new and existing buildings and plants, and adoption of other readily available technologies, should also be priorities for emerging markets. In the longer term, retrofitting brown buildings and plants, accelerating the pace of greening materials and the readiness of novel technologies with high abatement potential but non-commercially viable today without fiscal incentives through widespread carbon pricing programs and fiscal support measures, will also be required to reach the net zero carbon targets set in the Paris Agreement by 2050.

The modalities and pace of this integral and sequential approach will depend on each economy's conditions: available fiscal and financial resources, technological and policy readiness, and dependence on fossil fuels. Countries with sufficient financial and policy capabilities, such as high-income economies and perhaps some upper-middle income countries, could begin now the deep decarbonization of buildings and materials through carbon pricing and fiscal support

69 IFC calculations based on Global Trade Analysis Project (2022).

70 IFC calculations based on Global Trade Analysis Project. See more details on the model in Box 2 and Annex 1. Chapters 2 and 3 detail the available mitigation and adaption technologies and measures. Chapter 4 discusses alternative policy options for fostering building green in emerging markets.

measures at the expense of assuming higher output loses. Most middle-income economies should prioritize the adoption of some readily available technologies and regulations with moderate economic costs. Low-income economies can begin their journey in the green construction transition with technical and financial support from the international community and development finance institutions.[71]

In the longer term, the results of similar computable general equilibrium-circular economy dynamic models to the model employed in this report (See Box 2 and Annex 1) show that these costs in terms of foregone output will be more than offset by reduced damages from global temperature increases by 2050 with the adequate policy framework in place. Recent simulations, for instance, show that the economic co-benefits of lower global temperatures by 2050, particularly related to lower mortality and morbidity rates, would exceed by 1.4 to 2.5 times the output costs of reducing carbon emissions this decade.[72]

Conclusions

As we have seen, the construction sector is a major source of global emissions, with developing countries contributing the largest share. And the world is far off track from achieving the Paris Agreement target that every building on the planet should be net-zero carbon by 2050. Indeed, in the absence of additional mitigation efforts, emissions from the construction sector are expected to grow significantly over the next decade. However, by meeting the NDCs, combined with strong efforts to reduce carbon emissions in construction value chains, emissions could fall substantially.

The technology required to achieve a significant reduction in construction-generated emissions is available now but technologies with highest abatement potential would only become commercially available by 2035 and beyond. Investment opportunities for building green are significant but require decisive public and private action to materialize. Decarbonizing construction value chains will demand an integral strategy that includes the most efficient sequencing of measures and technologies. The specific modalities of this strategy would vary across emerging markets depending on their income level, carbon intensity of construction value chains, and policy and technological readiness. Potential technological improvements to reduce emissions are outlined in the next two chapters. At the same time, sufficient domestic and international financial resources must be mobilized to achieve the transition to lower emissions in emerging markets, and policymakers need to support net-zero carbon construction through finance and changes in incentives. These efforts are described in Chapter 4.

71 Chapter 4 analyses these policy options and the role of development finance institutions.

72 Markandya et al. (2018).

CHAPTER 2:

Building Green *in* Emerging Markets

2.1. Summary

Green buildings, which feature energy efficient designs, low-emission materials, and use renewable energy, could make a significant contribution to reducing carbon emissions from construction value chains and constitute a business opportunity for private investors. The technology to achieve new zero-carbon buildings or to electrify brown buildings with cleaner energies already exists. Emerging markets, particularly middle-income countries, can build green now to respond to rapid population and economic growth in the next decade. In low-income countries, adequate financial and technical support could contribute to paving the way for greening buildings. Retrofitting of brown buildings is unlikely to become a priority because of its high costs, but some relatively simple steps can be taken to reduce energy consumption in existing buildings. This chapter examines both passive and active measures relating to the design, construction and operation of buildings that can reduce emissions by, among others, energy-efficient designs and electrical and mechanical systems, electrification with renewable energies, improving building resilience, enhancing the efficiency of materials used, modifying building practices, exploiting digital technologies and smart devices and appliances, and extending the life of buildings.

2.2. The environmental and financial advantages of green buildings.

Green buildings feature energy-efficient designs, low-emission materials, and renewable energy. These buildings minimize negative impacts on the environment and climate. Green buildings that incorporate recycling can reduce waste output by 90 percent and use 30 percent less energy. In financial terms, this equates to a 5 percent increase in net operating income compared to traditional buildings. Green buildings use technologies with a longer anticipated lifespan and/or more durable components (such as LED lights), reducing maintenance costs.[73]

Key considerations for building green include the physical features and operating systems of buildings, the embodied carbon of buildings which is determined through the choice of materials, and the energy efficiency and waste levels of design and construction practices. For instance, natural cross ventilation can reduce the need for air conditioning and supplies fresh air during the seasons when external temperatures are comfortable.

More efficient mechanical and electric systems can also reduce energy consumption in green buildings. For instance, the Menarco Tower office in Manila, the Philippines, achieved 41 percent energy savings through variable speed drives in the air handling units, higher-efficiency cooling systems and appliances, energy-saving lighting in common and external areas, and occupancy sensors in bathrooms along with other passive measures.[74] Embedding resilience into the design of buildings can also limit emissions by reducing the need for new buildings (Box 4).

73 IFC (2021).

74 IFC staff analysis.

Some evidence suggests that green buildings can offer discernable financial advantages in addition to creating social value. Depending on the type of building, the passive and active measures undertaken, and country conditions, green buildings can have, for instance, relatively low incremental upfront costs and short payback periods. Data from IFC EDGE-certified projects suggest that the average incremental capital expenditure for some green buildings can range from 1 to 10 percent. Savings in utility costs relative to a traditional building can also result in short payback periods of two to three years in some residential projects. Costs can be low enough for green measures to be attractive even for some low-income housing projects in certain country conditions, climate zones, and types of buildings.

India's Tata Realty & Infrastructure Ltd, for instance, reported incremental costs of 2 percent for its green residential projects. Joyville Shapoorji Housing Pvt. Ltd., an Indian affordable housing developer, has managed to keep these incremental costs to under 1 percent by focusing primarily on passive design features which create energy savings of up to 45 percent. According to Aavas Financiers Limited, an Indian housing financing company, construction costs for green homes are about 2 percent more than for a traditional home, while the savings for homeowners are very tangible with payback periods of just two to three years.[75]

Incremental upfront costs and payback periods can vary across type of building, countries, climate zones, and resource and energy efficiency. According to a sample of IFC EDGE's project data, for instance, the ratio of incremental cost to conventional cost is largest, at 5 percent, for retail buildings and smallest for hospitals (with hospitality, home, and offices falling somewhere in between). Hospitals also had the shortest payback period (at almost two-and-a-half years), while homes had the longest payback period at up to five years (Exhibit 14).

Payback periods and incremental costs also vary substantially by country. Projects in Kenya and Vietnam had the longest payback periods, each over six years, while projects in Indonesia, Jordan, and Peru were among the lowest periods (all under two years). On the other hand, Malaysia and Peru had the highest incremental costs (both over 10 percent), while projects in the Philippines and Vietnam had some of the lowest.[76] These variations are explained by differences in design, building codes and other regulations, costs of labor and other services, the availability of technology and materials, and climate.[77]

Green buildings can have lower operating costs and can also have higher asset values than traditional buildings. A recent survey,[78] for instance, suggests that green buildings can have an average of 10 to 17 percent lower operating costs and asset values that can be more than 9 percent higher than comparable conventional buildings (Exhibit 15).

75 For more details on Aavas Financiers Limited's experience, with direct testimonies from Indian homeowners, see: https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/green-buildings-in-india-are-reducing-emissions?deliveryName=DM170723

76 IFC based on EDGE internal project data.

77 UN Environment Program (2021).

78 Dodge Data and Analysis (2022).

BOX 3

What Is a Green Building?

Green buildings produce significantly lower carbon emissions than conventional buildings. While some definitions include a variety of other requirements (including preservation of biodiversity and the physical and psychological wellbeing of occupants), most focus on energy, water, and waste treatment efficiency, and use of renewable energies. IFC has established three criteria for identifying a basic green building:

- Certification under a robust governance system, such as IFC Excellence in Design for Greater Efficiencies (EDGE).
- Ambitious performance levels, including at least 20 percent lower energy use in operations than conventional buildings; and,
- Ability to quantitatively report impact, such as energy and water savings, and reductions in greenhouse-gas emissions.

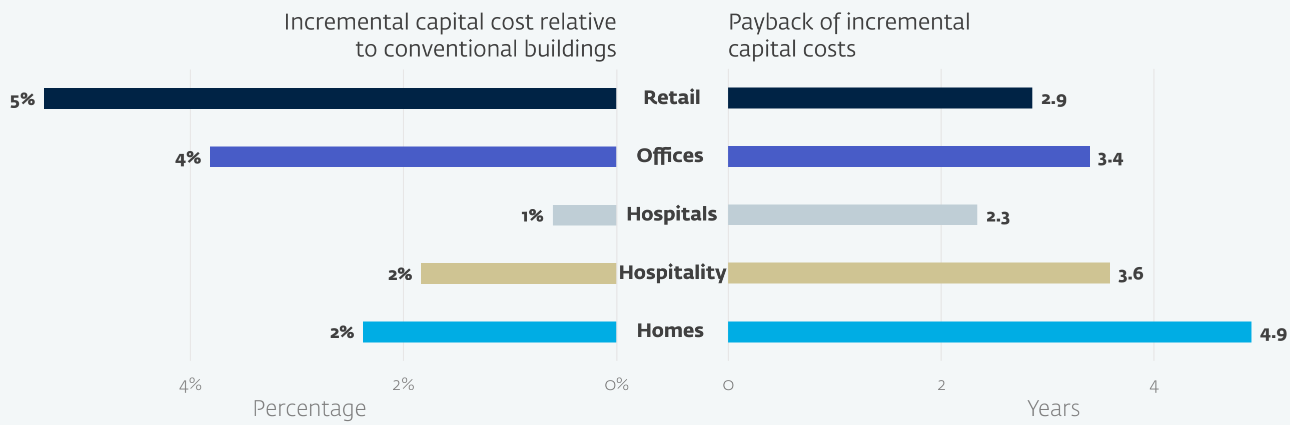
Green buildings can reduce emissions through passive and active measures. Passive measures relate to fixed physical features, and active measures involve mechanical or electrical systems and the use of renewable energy measures to reduce reliance on fossil fuels. Passive measures - the orientation of a building to the sun, natural ventilation, external shading, and reduced window size are the most cost-effective and reliable means to ensure higher energy efficiency. These measures cost less than many active measures to implement, and their efficacy does not depend on how the building is managed. They are particularly effective to manage heat gain or loss through the year. For instance, a smaller window area reduces the heating energy need that is associated with heat losses in cold climates and the cooling energy demand due to heat gains in hot climates, and also reduces construction costs.

Active measures involve mechanical or electrical systems. For example, ceiling fans are a more efficient way to provide comfort than air-conditioning. Most commercial buildings, from offices to warehouses, target improving the efficiency of their cooling and lighting systems. In cold climates, radiators' thermostatic valves to control heating in each room reduce energy consumption. Both cooling and heating can be addressed by heat pumps.

In the future, adoption of net-zero carbon building standards could create incentives for industrial producers of steel, cement, glass, and other inputs to decarbonize their production processes. These standards could also foster complete electrification of green buildings with renewable energies and more ambitious energy reduction targets than existing green building standards and regulations.

EXHIBIT 14

Upfront Capital Costs and Payback Periods of Green Buildings Vary Widely



Notes: Incremental capital costs are the ratio of incremental cost over typical construction costs.

Source: IFC based on a sample of IFC EDGE internal project data.

For instance, residential developers, like Signature Global (India) and Capital House (Vietnam), have reported faster sales resulting in better cash flows for them. In South Africa, International Housing Solutions reports its low-income renters save a whole month's rent each year from lower utility bills, and its green homes occupancy rates are higher than similar conventional homes it owns.

Several emerging market countries have begun implementing green building policies, or are planning on doing so, to encourage the private sector to invest in green construction. Colombia in 2015, for instance, as the first Latin American country to adopt a mandatory green building code, followed by policies to incentivize voluntary certification, which yielded immediate results (Box 4).

Despite its financial and climate benefits and supportive regulations, however, the construction of new green buildings faces stringent challenges. Construction is a fragmented sector and highly localized; customary building use and construction practices vary widely. Most of the companies are small and medium-sized and therefore lack scale and access to financing to deploy new technologies with uncertain returns.[79]

79 World Bank, mimeo.

EXHIBIT 15

Green Buildings Can Have Lower Operating Costs and Higher Asset Value

	Average reduction in operating costs in the next 12 months	Average reduction in operating costs in the next 5 years	Average perceived increase in asset value
New Green Buildings	10.5 percent	16.9 percent	9.2 percent
Green Renovation/Retrofit	11.5 percent	17.0 percent	9.1 percent

Notes: Survey of over 1,200 respondents from 79 countries.
Source: Dodge, 2022.

No single solution is appropriate for all contexts, and significant awareness-raising and capacity building are essential to foment change. Split incentives and information asymmetries are among the industry challenges. While design decisions lie with developers and building sponsors, the benefits of lower utility costs go to the end-users such as home buyers or tenants. The lack of skilled construction workers with adequate knowledge about how to build with lower emissions further limits the potential for green construction. Moreover, while developers know what resource-efficiency measures lie behind the façade, the buyer or investor may not have the expertise to evaluate claims of higher efficiency or resilience (the financial implications of these issues are explored in Chapter 4).

2.3. Decarbonizing buildings in the next decade.

In addition to the green building measures already in use, other practices and emerging technologies can further reduce the carbon footprint of construction and operation of buildings. A new generation of green buildings needs to be fostered in the next decade. The embodied carbon of green buildings can be reduced through less use of high-emission cement and steel. This can be accomplished in several ways, including technologically driven abatement practices that improve energy efficiency in the production of these materials (See Chapter 3), construction practices that reduce the need for, and the waste of, these materials, and substitution with other materials. Electrification—substitution of fossil fuels for renewable energies in cooking, cooling, and heating—can also be a cost-effective measure to reduce emissions in buildings' operation.

The further development of these technologies and their widespread adoption would require appropriate policies, including regulations, carbon pricing, and fiscal incentives, to encourage green construction. How, which and when these levers are adopted will depend on income level, policy and technological readiness and

BOX 4

In Colombia, Public Policy and Private-Sector Investment Have Made the Country a Leader in Green Construction

In 2015, the Colombian government enacted the first mandatory green building code in Latin America. This includes minimum requirements for the construction of new residential and commercial buildings aimed at ensuring lower energy and resource consumption than conventional buildings. By establishing clear direction for public policy, the government raised awareness in the industry and successfully unleashed a wave of private-sector investment in green buildings totaling $9 billion to date, according to IFC estimates.

Policies included tax incentives for green technologies and certified green projects. This enabling environment gave banks confidence to launch green construction finance and green mortgages.

In 2016, Bancolombia became the first bank in Latin America to finance green buildings by raising $400 million in three bond issuances. In 2017 the Colombian Chamber of Construction (CAMACOL) started an aggressive educational program with its members to promote EDGE certification. By 2021, five banks were offering green building finance products—mainly green mortgages: Bancolombia, Davivienda, BBVA, Banco Bogotá, and Caja Social.

In 2021, about 20 percent of Colombian new construction was certified as green, from virtually no green buildings in 2017. CAMACOL is now pushing members toward zero-carbon construction. Banks meanwhile are increasing their product offerings for green construction: BBVA, for instance, plans to launch preferential financing for EDGE Advanced buildings (higher resource efficiency).

the support of the international community, especially in low-income countries (See Chapter 4). Here, we explore in detail these decarbonization levers.

Fostering a new generation of zero carbon buildings.

The technology to achieve zero-carbon buildings already exists. The next frontier for green buildings is to have net-zero emissions. Net-zero buildings are highly efficient buildings that use only renewable energy or carbon offsets.[80] In 2017, there were 2,500 net-zero buildings worldwide that were recognized through a green building certification or adhered to an official standard. Some of these achieved self-sufficiency in operational energy by generating as much renewable energy as they consume annually.[81] In addition, some low-carbon materials are already available to address embodied emissions to reduce the emissions from construction. A push by the public sector could mainstream the adoption of approaches

80 IFC (2021).

81 IFC staff estimates.

already tried and tested by industry leaders, especially in middle-income economies (See Chapter 3).

Some buildings in developing countries are already zero carbon. Francis Kere, the first African to receive architecture's coveted Pritzker award, is well known for his mastery of passive design. Within the cadre of EDGE Zero Carbon certified buildings, offices dominate, for instance, the Ufficio BJX office in Mexico, and the Arthaland Century Pacific Tower in Philippines. A wide range of highly efficient buildings are being constructed in various markets using commercially available technology. As of June 30th, 2022, over 9.7 million square meters of floor space had been EDGE Advanced certified in 55 countries.[82]

Improving energy efficiency primarily through passive measures and decarbonizing energy demand should be the key priority for the next generation of green buildings. The former is the cheapest way to reduce emissions, resulting in less energy demand and less need for heating, ventilation, and air conditioning and renewable energy generation systems, all of which have their own carbon footprint as well as cost.[83] More financial and technical support will be needed from development finance institutions in the next decade to encourage and support the construction of net zero buildings. In some specific construction projects, like housing for lower income households, blended finance and other concessional finance, or fiscal incentives will be needed, especially in low-income economies (See Chapter 4).

Integrating resilience into new net-zero buildings and existing brown buildings.

Resilience needs to be integrated into construction of both new green buildings and existing buildings to ensure longer life cycles and avoid unnecessary carbon emissions related to the reconstruction process, especially in regions affected by increasingly frequent catastrophic climate events, like South Asia and some Caribbean economies. Green building measures like renewable energy technologies, passive cooling systems, water recycling, or rainwater collection solutions can improve resilience to these hazardous events.[84]

Climate change-induced disasters are already causing significant damage to assets and people around the world. Any new building or retrofit must consider the potential impacts from extreme weather events. When structural integrity and climate resilience are not considered, damaged or entirely lost properties need to be rebuilt, especially as the frequency and intensity of climatic disasters increase. On average, 24 million people per year were internally displaced between 2008 and 2018 because of climate disasters, of which 85 percent involved storms and floods.[85,86]

82 IFC staff estimates based on EDGE project data.

83 IFC (2019).

84 IDMC (2019).

85 IDMC (2019).

86 IDMC (2019).

A striking example is the 2017 Hurricane Maria's impact on Dominica in the Caribbean. About 38 percent of the hurricane's damages was in the housing sector; 15 percent of the country's housing stock was destroyed and 75 percent partially damaged.[87] The disaster's damage to properties and infrastructure alone was estimated to be around 200 percent of Dominica's GDP.[88]

Electrifying buildings with cleaner energies.

Electrification, or replacing fossil fuels for cooling, cooking, and heating with technologies that draw electricity from renewable energies, is a low-hanging fruit for decarbonizing building operations. Natural gas, for instance, accounts for around 44 percent of the energy mix used in cooking, cooling, and heating globally. In emerging countries, about 60 percent of the energy employed in cooking comes from traditional biomass. Other fossil fuels, such as natural gas, LPG, and kerosene, are also widely used, especially in low-income economies.[89]

Large appliances, like air conditioners, refrigerators, washing machines, cookstoves, among others, are one of the fastest growing sources of energy demand, driven by emerging markets with growing populations and economies, and high temperatures.[90] Together, these appliances account for 40 percent of global electricity demand and annual emissions equivalent to the current level of emissions from the United States.[91]

Commercially available electric technologies for heating and cooking, such as electric hot water heaters, electric heat pumps, and electric stoves powered with cleaner energies, can help to reduce emissions from buildings operation. Stimulating the demand for electric, renewable and energy efficient heating, cooling, and cooking systems through developing, supporting, and enforcing minimum energy requirement standards, energy labels, fiscal support programs, and energy efficient public procurement systems will therefore be essential to reduce emissions from the operation of buildings in the next decade.

Technologies and practices to further reduce emissions from the construction and operation of buildings.

Exhibit 16 summarizes the expected costs and abatement potential of some of these measures in the next three decades. Material efficiency offers the largest abatement potential with more than 1,000 tons of carbon dioxide equivalent, followed by switching to low-emission materials with 500–1,000 tons of carbon dioxide equivalent. The rest of these technologies offer similar abatement potential with less than 500 tons of carbon dioxide equivalent.

87 GFDRR (2017).

88 GFDRR (2017).

89 BP (2023).

90 IEA (2018).

91 IEA (2021).

The potential costs of these technologies are rather low, but widespread adoption in emerging markets has been so far limited mainly due to lack of regulatory and technological readiness, especially in low-income countries but also in some middle-income economies, combined with the fragmented market structure and highly localized regulations of construction value chains and split incentives between developers, financiers and owners (See Chapter 4). Here, we analyze these technologies in detail.

Improvements in material efficiency.

World Bank estimates show that improving material efficiency in the construction of new buildings and other structures alone could cut embodied construction emissions by 2050 in half, while not significantly affecting the cost of construction.[92] This would be achieved by reducing the amount of cement and steel used in construction that exceeds the amount needed to meet standards, among other measures. Achieving this depends on how much steel and concrete demand can be reasonably reduced. To illustrate, estimates of excess structural steel range from 20–46 percent.[93]

Substitution of high-emission with low-emission materials.

Replacing concrete and steel with low CO_2 primary materials can reduce embodied construction emissions. In the case of steel, optimized design would customize the size of each structural beam to its specific location in the building, moving away from uniform steel beams. Computer-driven designs could handle the increased complexity of design and prevent construction errors.

Replacing carbon-intensive refrigerants and heating materials can also significantly contribute to reducing emissions from the operation of buildings. For instance, in Eastern Europe, older supermarkets that have high leakage rates in fridges and freezers can save the same level of carbon emissions as from reducing electricity by using eco-friendly refrigerants.

Another option would be to substitute cement and steel for less carbon-intensive materials. For instance, timber can be used as an alternative to steel in buildings under 12–18 stories in both residential and commercial settings. The use of timber has been deemed one of the most greenhouse gas-abating uses of biomass when used instead of steel and cement.[94] However, the cost of timber is highly dependent on local availability and can be 10–20 percent above the price of a comparable concrete frame. The increased use of timber in construction also raises issues around sustainable sourcing and deforestation and will require changes in the design and construction phases. The use of other materials, such as engineered wood products and rammed earth, to reduce carbon emissions also should be explored.[95]

Building techniques to enhance thermal efficiency.

92 World Bank (Mimeo).

93 C40 Cities (2019).

94 World Bank (2022).

95 World Bank (2022).

EXHIBIT 16

Expected Costs and Abatement Potential of Decarbonization Options in Construction

Measures and Technologies	Abatement Potential *Tons of CO_2 equivalent in 2050*	Cost
Material efficiency	>1,000	Low <$50/Tons of CO_2 equivalent
Material substitution	500–1,000	
Enhanced building utilization	<500	
Digital construction	<500	
Modular construction	<500	

Source: World Bank (forthcoming).

According to the International Energy Agency (IEA), energy use for space cooling has doubled since 2000—from 1,000 terawatt-hours to 1,945 terawatt-hours—due to hotter weather, rapid urbanization, increased ownership of air conditioners, and use of inefficient air conditioners.[96] Space cooling is responsible for significant energy use and emissions, contributing around 1 gigaton of CO_2 and nearly 5 percent of total energy consumption worldwide in 2020.[97]

Against this background, reflective painting and film coating can enhance thermal efficiency in existing as well as in new buildings. For instance, reflective roofs could save more than $20,000 per year in electricity bills relative to a conventional building in one-floor warehouses in Bogota, Colombia. Utility savings from tinted windows could reach up to $2,000 per year in three-floor retail buildings in Jakarta, Indonesia.[98]

Centralized cooling systems.

For large projects, such as renovated or new urban areas, industrial parks, and health and university campuses, among others, using a "district" centralized cooling system for an interconnected group of new or renovated buildings can reduce energy consumption dramatically (See Exhibit 17 for a diagrammatic representation). For example, Keppel Industries develops and operates district cooling systems for industrial and commercial parks in Singapore and China, enabling energy savings of up to 40 percent through use of solar panels, innovative thermal energy storage technologies, and smart optimization systems.[99]

96 IEA (2021).

97 IEA (2021).

98 IFC (2022) based on EDGE simulations.

99 "Introduction to Keppel". Presentation prepared for IFC. October, 2022.

In Gujarat, India, a district cooling system has been installed in the Gujarat International Finance Tec-City, a joint-venture financial center. The system distributes thermal energy in the form of chilled water from a central source to multiple buildings through a network of underground pipes for use in space cooling. The system aims to reduce power demand and make air conditioning more energy efficient, reducing CO_2 emissions.[100]

The Energy Center for the Olympic Park in London, United Kingdom, reduced emissions by more than 20 percent and enabled energy savings in energy consumption, compared to conventional facilities, by adopting district cooling systems.[101] District Clima, located in a renovated urban area in Barcelona, Spain, has achieved reductions in fossil fuel consumption by 63 percent through district cooling systems.[102]

IFC has partnered with UAE-based cooling system company Tabreed to set up Asia's first greenfield platform to invest in sustainable district cooling solutions for commercial and retail developments. Its primary focus is on India, followed by other Southeast Asian countries. India has a growing demand for cooling infrastructure, and the use of district cooling technology is at an early stage. The project will assist market creation by establishing proof of concept for district cooling technology, economic and commercial viability, and sustainable energy efficiency.

Improving building design and construction practices.

Thoughtful design can reduce the amount of concrete, metal, or glass in a building, for example, by reducing glazing, using hollow concrete blocks and 'filler' in floor slabs. Design for disassembly is another example of life-cycle design thinking. Improvement in the design and construction process can include prefabricating components and structures at centralized facilities, and reducing vehicle emissions at sites, for example through using electric vehicles and biomass-powered machinery.[103] Zero-emission construction sites (which also have spillover benefits relating to noise and pollution reduction) are also within reach. For instance, around 14.5 percent of fine particulate matter pollution (PM2.5) in London is estimated to be due to construction sites.[104]

Having systems in place to measure and track embodied carbon will be key, and cradle-to-cradle analysis must be mainstreamed to meet net-zero carbon goals. Many material manufacturers now declare their carbon footprint through Environmental Product Declarations. Products undergo a Life Cycle Analysis which may report carbon emissions from cradle-to-gate (from primary material extraction to the factory gate), cradle to grave (material extraction to end-of-product life), or cradle-to-cradle (material extraction to recycling of product components into more products).

100 Patel (2017).

101 See: https://www.power-technology.com/projects/olympic-park-energy-centre/

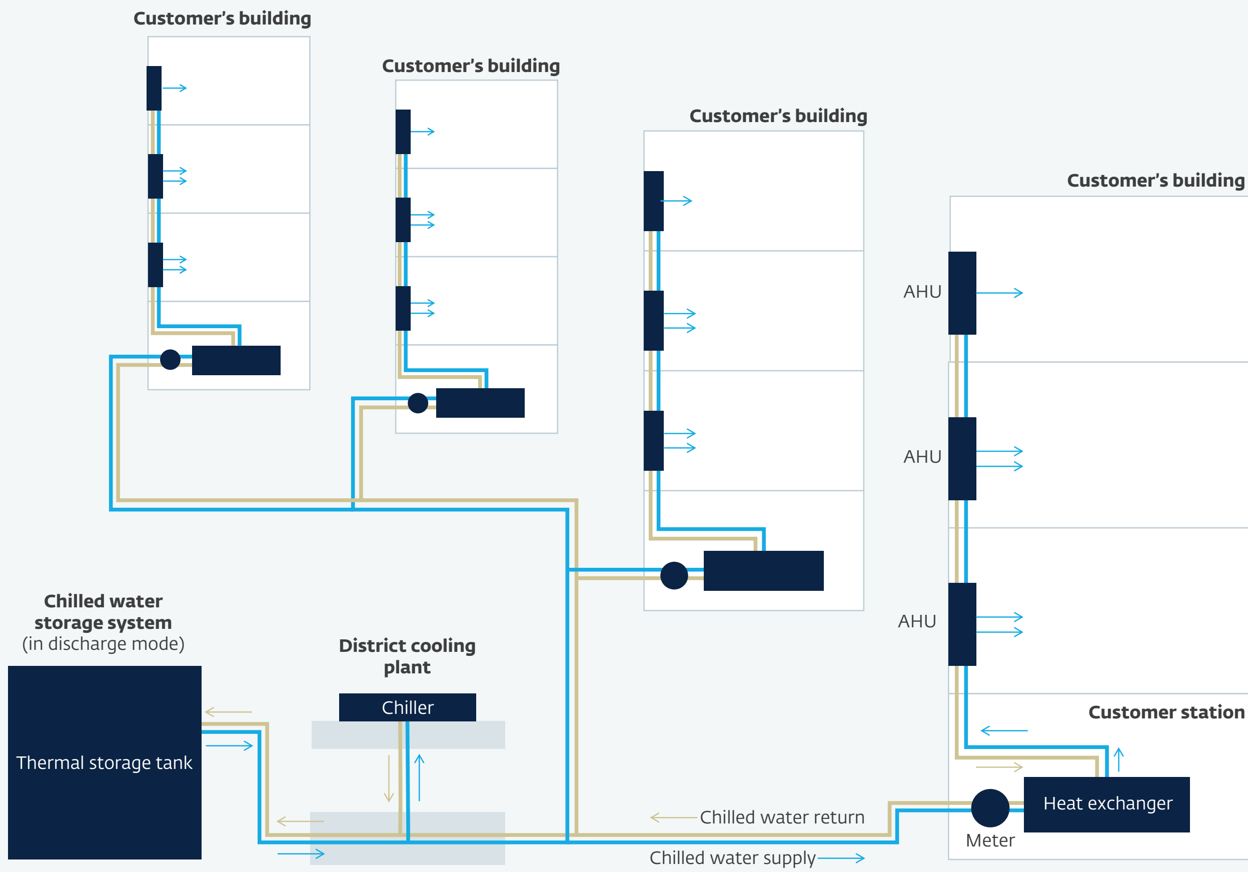
102 IFC staff calculations.

103 Oslo Kommune (2020).

104 Oslo Kommune (2020).

EXHIBIT 17

District Cooling Systems Can Reduce Energy Consumption up to 40 Percent



Source: Keppel (2022).

Cradle-to-cradle analysis[105] is key to promoting the regenerative loops necessary for a circular economy, however it is difficult to execute.[106] Manufacturers typically provide cradle-to-gate data. Nevertheless, cradle-to-cradle analysis, which recognizes the value of long product life, recyclability, reusability, and the

105 Cradle to cradle can be defined as the design and production of products of all types in such a way that at the end of their life, they can be truly recycled (upcycled), imitating nature's cycle (Sherrat, 2013).

106 EU (2021).

minimization of waste, must increase to meet the Paris Agreement goals. Of course, the biggest impact comes from repurposing a whole building rather than demolishing it.

Recycling.

Embodied carbon of green buildings can also be reduced via 'secondary substitution', i.e., recycling building components (for example, using old steel beams in a new building). In the city of Medellin, Colombia, for instance, construction companies, producers of cements and concrete mixtures, firms producing pavements, and quarries are recycling and reusing construction waste in their construction materials and works.[107]

Elongating the life of steel and cement components via recycling requires 'construction for deconstruction', or thoughtful design around how input materials can eventually be reused. These emerging solutions must be implemented at scale. Low- and middle-income countries are, however, unlikely to identify material efficiency and recycling as a policy priority due to the need for encouraging building and infrastructure construction for development purposes.

Helping buildings live longer.

Design for refurbishment over new construction can be another route to reduce emissions from constructing new buildings. Encouraging efficient use of space and infrastructure through flexible design could extend building lifetimes. Possible reductions in the demand for new buildings in the future range from 10 to 20 percent.[108] This measure can also reduce the demand for steel and cement for new buildings, reducing embodied construction emissions. Extending a building's lifespan could reduce CO_2 construction-related emissions by 50 percent in countries like China, where the average residential lifespan is about 25 years, compared to 100 years in the European Union and the United States.[109]

Efficient use of space can be particularly important for developing countries, where most investment in new buildings and construction is expected to happen in the next decade (See Chapter 1). Efficient use of space can also generate savings in construction, depending on the type of building (e.g., commercial, or residential), building design, and local regulations and materials availability.[110]

Retrofitting existing buildings.

Green retrofit practices to reduce energy consumption include thermal insulation of the building envelope, increased natural or mechanical ventilation when outdoor temperatures are at comfortable level, replacement of windows and doors, improved lighting systems, water-saving faucets, ultraviolet-disinfected or filtered air circulation systems, and the installation of energy-efficient heating and air conditioning

107 UN Environment Program (2021).

108 C40 Cities (2019).

109 Hertwich et al. (2019)

110 C40 Cities, (2019).

systems.[111] Given the long operational life of a typical building, retrofitting can achieve similar or higher energy savings than construction of new green buildings.[112] Typical building retrofits reduce energy use by up to 25 percent while deep retrofits can sometimes save more than 50 percent.[113]

The retrofit market is estimated to have grown at a compound annual growth rate of 8 percent from 2018 to 2023, mainly driven by demand from high income economies.[114] Energy efficiency retrofits have shown attractive returns on investment, even for short-term investors. This is because, in addition to generating direct cost savings, these measures positively affect the overall value of buildings.[115] ABN AMRO and ING have financed retrofits as a way of accessing the green bond market, complying with stricter emission regulations, and reducing their exposure to carbon-intensive assets in their portfolios. In some European countries, like Germany, governments are providing tax breaks for improving the energy efficiency of existing buildings through replacing the heating system, fitting new windows, or insulating roofs and external walls.[116]

In emerging countries, however, the dissemination and adoption of retrofitting practices, especially deep retrofitting, remains limited because of the high costs of replacing energy inefficient mechanical and electrical systems, and modifying building envelopes, especially in lower-middle- and low-income countries. Limited fiscal resources further restrict the use of tax incentives and subsidies to promote retrofitting of commercial and residential buildings.

Innovative construction technologies.

Buildings can already be 3D printed. This is an automated process that can produce complex wall structures using fast-curing viscous material layer-by-layer. It minimizes construction waste and achieves higher energy efficiency due to seamless construction, while decreasing labor costs. The process is fast and has the potential to use local low-carbon inputs, such as soil.

For instance, the developer 14Trees in Kenya built an IFC EDGE Advanced 3D printed sustainable home, the first of its kind in Africa. The 3D printing process uses minimal materials, only printing exactly what is needed for the structure of the house. 14Trees hoped to not only save energy and water during the construction process, but also during the operational phases, which led the company to certify the houses with EDGE.

Prefabricated wall panels can be manufactured in a factory to precise dimensions and assembled on site. Advantages are like those of 3D printing: reduced waste; better energy efficiency; faster construction; and decreased labor costs. Prefabricated panels have less embodied carbon and yet have tested as more

111 IFC (2019).

112 Hills et al (2016).

113 IFC (2021).

114 IFC staff estimates.

115 IFC (2021).

116 See: https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2019/20191016-altmaier-tax-breaks-for-retrofitting-buildings-benefit-both-climate-change-mitigation-and-local-craft-workers-and-jobs.html

typhoon resistant than traditional hollow concrete blocks.[117] This technology can be cost competitive with existing construction processes, but this is highly dependent on transport costs.[118]

Climate-smart building strategies.

A climate-smart building strategy should also recognize the importance of building both green and resilient. The resource efficiency and resilience of a building is largely locked in at the design stage. Retrofitting is financially far less attractive than constructing a new building with optimal efficiency because it usually involves demolition and replacement of existing features. Moreover, effective passive measures are best incorporated at the design stage. Nevertheless, retrofitting is essential given the long operational life of a typical building, as most buildings built today are expected to be in use for the next 50 years or more.[119] At the same time, extreme weather events are becoming more severe and frequent.

Digital technology and smart appliances.

Across all project stages, digitalization could increase materials' efficiency by integrating life-cycle emissions, using 3D building information modeling, enhancing collaboration in the construction process through management apps on mobile devices, and monitoring sites with drones for scanning. Paper-based work practices, cost increases, and technological illiteracy are, however, likely to represent key barriers in developing countries, especially in low-income and fragile countries and middle-income economies with construction sectors characterized by the large presence of informal and small construction companies.[120]

Internet-connected appliances can help reduce energy consumption by enabling the use of dynamic electric pricing and time-of-use tariffs. These smart appliances, along with energy efficient management retrofit systems, can reduce energy consumption by 20 to 30 percent.[121] The Super-Efficient Equipment and Appliance Deployment Initiative, led by the International Energy Agency, for instance, provides support to more than 20 governments to implement energy efficient policies for appliances and equipment and identify and promote the adoption of innovative smart devices and systems.[122]

117 See: https://www.connovate.com/technology

118 McKinsey & Company (2017).

119 UNEP (2021).

120 World Bank (Mimeo).

121 IEA (2021).

122 IEA (2021).

CHAPTER 3:

Technological Solutions *for* Decarbonizing Construction Materials

3.1. Summary

Construction materials include some of the most carbon-intensive and hard-to-abate industrial activities globally. This chapter focuses on the two key materials for the industry, cement and steel, and explores a range of technologies and other options for both that could sharply reduce their carbon intensity and emissions. These include commercially available alternatives such as improving energy and resource efficiency, switching to alternative, lower-carbon feeder materials and using alternative non-fossil fuels. Nascent technologies, including green hydrogen and carbon capture, utilization, and storage, hold the promise of net zero cement and steel but they are likely to remain non-economically viable without substantive fiscal support by 2035 and beyond.

3.2. Reducing emissions from the production of construction materials is challenging.

Cement and steel are considered some of the hardest industrial sectors to abate. Production is extremely energy intensive (Box 5): process-related emissions generate about 60 percent of total carbon emissions in the global cement industry, and about 86 percent of carbon emissions from steelmaking.[123] Cement and steel are highly capital- and scale-intensive activities, and changing production processes entails massive investments. Plants have an average operational life of over 50 years, making it even harder to replace existing technologies or production processes and underlining the risk of stranded polluting assets. In the absence of carbon price programs[124] or regulations that internalize the social costs of carbon emissions, producers often do not have an incentive to invest in expensive and still uncertain decarbonization technologies, particularly as demand is sensitive to both price and quality, or to offload plants in operation.[125] Demand from environmentally-responsible developers and owners is also limited by the lack of widely accepted standards and regulations that determine what low-emission materials are, and regulate how they should be employed in construction.

3.3. The construction materials industry is well-positioned to decarbonize.

The construction materials industry has made significant progress and important commitments to decarbonize. For instance, resource recycling and more energy-efficient production processes have reduced carbon emissions in the supply of steel and cement. Both private-sector companies and governments are moving to put in place measures to further decarbonize construction materials.

This section focuses on the cement and steel industries' current decarbonization efforts. These two materials are responsible for about 80 percent of the embodied emissions in buildings and other structures.[126] Critically, there are no cost-effective and scalable alternatives today for these materials in

123 World Bank, mimeo.

124 Chapter 4 analyzes alternative carbon price programs, like taxes, markets, and regulations, in emerging markets. Castro et al, mimeo explore the impacts of carbon tariffs in high income countries on the steel industry in developing countries.

125 Envirotech Online, 2019.

126 See Chapter 1.

construction value chains. Cement is also the most consumed good in construction in the world, while steel can be found not only in buildings and other structures but also in other crucial activities such as aviation or automobiles. Even technologies that are driving decarbonization, like wind turbines and solar panels, require cement and steel.[127]

Decarbonizing cement and steel can, therefore, have a decisive impact on reducing carbon emissions in the entire global economy beyond construction value chains. Box 6 provides some examples of IFC recent experience in supporting private manufacturers of cement and steel in emerging markets on their path to decarbonization.

Existing technologies are already helping to decarbonize cement.

Between 1990 and 2020, global emissions per ton produced of cement fell by about one fifth. Manufacturers achieved these savings mainly by improving production energy efficiency, utilizing waste as a fuel, and substituting clinker with industrial byproducts, such as fly ash from power generation plants and blast furnace slag from steel plants.

Concrete is well-positioned to become carbon neutral. This material is durable, can be 100 percent recycled and uses other industry wastes directly (through recycled aggregates) or indirectly (through cement). Except for the embodied carbon of cement, concrete has very low embodied carbon compared to alternatives.

Major cement industry associations have announced plans to meet the carbon neutrality ambition. The World Cement Association recently issued a statement supporting accelerating changes to achieve full decarbonization. The Global Cement and Concrete Association has also issued a set of sustainability guidelines and an ambitious roadmap to cut CO_2 emissions by a quarter by 2030, and to achieve net-zero CO_2 emissions by 2050.[128] CEMBUREAU, which represents the European cement industry, has set a goal of reducing gross CO_2 emissions by 30 percent for cement and by 40 percent for the clinker-cement-concrete-construction-carbonation value chain by 2030 and achieving carbon neutrality by 2050.[129]

In the European and North American markets, investor scrutiny and regulatory pressure to reduce carbon emissions are likely to intensify. The European Union's ambitious Green Deal and its package of measures, including the introduction of a carbon border adjustment mechanism for cement, could reduce carbon emissions across the entire region.[130] In North America, decarbonization efforts are promoted through state- and country-wide initiatives, such as Canada's 2019 implementation of the Carbon Pricing Backstop program. [131]

Steel is one of the most recycled materials.

Steel is among the most highly recycled materials in use today, and about 30 percent is produced with

127 UNIDO (2022).

128 GCCA (2020).

129 European Cement Association (2022).

130 EU (2022).

131 IEA (2020).

recycled scrap. Steel recovery rates are estimated at 90 percent for automotive and machinery, 85 percent for construction, and 50 percent for electrical and domestic appliances. A total of 1,085 million tons of steel is recycled per year.[132] Recycled steel saves raw materials, energy consumption, and emissions: recycling one ton of steel scrap saves 1.5 tons of CO_2, 1.4 tons of iron ore, 740kg of coal, and 120kg of limestone.[133]

In the future, recycled steel production could rise as more steel-made products reach the end of their life cycle in emerging markets. However, scrap-based steel is unlikely to satisfy the industry's need for raw materials because of the growth in demand and the lack of availability of quality scrap metal and developed recycling value chains, especially in low-income countries. Steelmakers are adopting similar technologies and measures as cement producers for decarbonization.

Some major steel producers and business associations have made important commitments to decarbonize the industry. China

132 The World Counts (2022).

133 World Steel Association (2022).

BOX 5

How Are Cement and Steel Produced?

Cement and concrete are essential construction materials. As the principal ingredient of concrete, cement acts as the binder between aggregates (fine and coarse rocks) in the formation of concrete. In the cement-manufacturing process, raw materials—limestone and a few other natural materials, including clay or shale—are heated to a temperature of up to 1450°C in a kiln in a fuel-intensive process. This process and the resulting chemical reactions lead to the formation of the material that in the industry is referred to as clinker. Once cooled, the small round clinker nodules are ground to a fine powder and combined with other ingredients like gypsum to produce cement.

Cement production is a local industry with plants usually located near limestone deposits. Given its performance characteristics and the plentiful supply of limestone, cement (and therefore concrete) is likely to remain the construction material of choice globally and is part of the future of development and urbanization.

Steel offers the most economical and the highest strength-to-weight ratio of any building material and serves as an integral material for virtually all aspects of our built environment. Steel is produced via two main routes: the blast furnace-basic oxygen furnace (BF-BOF), and electric arc furnace (EAF). The BF-BOF route predominantly uses iron ore, coal, limestone, as raw materials, while the EAF route uses mainly recycled steel and electricity. In the production process, these ingredients turn into liquid steel through a series of chemical reactions at a temperature of up to 1700°C. The heat is generated by coking coal, which is made from coal in furnaces.

The addition of elements such as chromium or titanium can produce alloys that are more able to absorb energy (toughness), easier to cast, scratch resistant (hardness), or rust-resistant (corrosion-resistance, such as in stainless steel). Huge rollers and molds help to shape the metal while it is still hot, with further processing potentially incorporating protective coats, color, or other additions. Steelmaking is a truly global industry, and raw materials (such as iron ore and scrap) and steel products are traded globally.

BOX 6

IFC Experience Supporting Cement and Steel Decarbonization

IFC has been a long-time investor in the cement and steel industries in emerging markets. IFC is supporting the adoption of the best available technologies and international environmental and social standards in order to strengthen sustainability. IFC has enabled its clients to improve energy efficiency (via measures such as waste heat recovery), resource efficiency (via measures such as waste recycling), and value chain integration. Here, we include some recent examples of IFC projects supporting decarbonization in cement and steel in emerging markets.

CIMAF. Ciments de l'Afrique, a subsidiary of Omnium des Industries et de la Promotion Group, a leading cement producer in Morocco and West Africa, is investing in the best available technologies in cement production in Ghana, Mali, and Senegal. The project will reduce annually up to 332,000 tons of carbon dioxide by entirely using steel scrap as input. IFC provided €165 million debt financing for the project since 2021. The IDA19 Private Sector Window Blended Finance Facility also provides up to €7.5 million to support the project in Mali.

NCCL. Kenya's largest domestic cement producer invested in 2019 in reducing fuel consumption, achieving energy savings, and reduced carbon emissions through lower clinker-to-cement production, use of reactive pozzolana, and a waste heat recovery unit, which will be the first of its kind for cement in East Africa. IFC supported NCCL in two rounds: $55m loan and $7.5m equity investment in 2014, and in 2019 with $25m IFC loan, and $103m in syndications between 2019 and 2020.

Rider Steel. The company, a rolling mill operator, is investing in a greenfield manufacturing plant with best available technologies in the Kumasi area in Ghana, with a total production capacity of 240,000 tons per year. The new plant will save 332,000 tons of carbon dioxide annually by entirely using steel scrap as input (283,200 tons per year). The plant also operates an energy efficient induction furnace that achieves much less carbon intensity compared to existing blast furnaces. IFC supported the project through a $12 million loan in 2020.

Baowu Group and Luxembourg-based ArcelorMittal, two of the world's largest steelmakers,[134] for instance, have committed to becoming carbon neutral by 2050.[135] The World Steel Association published a recent report indicating that total direct emissions from iron and steel would need to fall by more than 50 percent by 2050 relative to 2019, and the emissions intensity of crude steel production would need to decline by 58 percent, to be in line with the goals of the Paris Agreement.[136]

134 World Steel Association, (2022).

135 ArcelorMittal (2020); China Baowu Group (2021).

136 World Steel Association (2021).

3.4. More needs to be done to decarbonize construction materials.

There are three principal approaches to deeply decarbonize the cement and steel industries, including operational advances, alternative construction inputs and fuels, and technological innovations. Adoption of best-available-technologies can already reduce energy and resource intensity and consumption. Replacing carbon-intensive materials, like iron in steelmaking and clinker in cement, for readily available greener organic or recyclable alternatives can also cut process-emissions today. Switching from fossil fuels to biomass, waste, or recycled alternatives is already technologically feasible for cement and steel plants, enabling the reduction of emissions relating to energy consumption.

In the future, new technologies, like carbon capture, utilization, and storage and green hydrogen, could contribute to making cement and steel production carbon neutral but it is not economically viable and will most likely remain so until 2035 and beyond.[137] Carbon capture, storage, and utilization is a process through which carbon dioxide is captured and then transported to storage or for further industrial use. Green hydrogen is hydrogen produced by splitting water into hydrogen and oxygen using renewable electricity. Hydrogen gas is extracted from water by a technique known as electrolysis, which involves running a high electric current through water to separate hydrogen and oxygen atoms. The electrolysis process is expensive because it involves high energy expenditure.[138]

Technological readiness, abatement potential, and economic costs vary significantly across these decarbonization levers. Novel technologies, like carbon capture and green hydrogen, for instance, offer the highest abatement potential (500 to 1,000 tons of carbon dioxide equivalent by 2050) in most applications, but their costs today are still extremely high (ranging from $50 to more than $100/ton of CO_2) for both cement and steel production. These technologies are expected to remain non-economically viable without fiscal support in the next decade, and potentially beyond.[139] In contrast, biomass and waste fuels are already economically feasible, but their abatement potential is relatively more limited (Exhibit 18).

This chapter focuses separately on these technologies for the cement and steel industries in detail, given their specific technical, regulatory, and economic challenges. We examine their abatement potential, economic costs, and technological and process applications. The further development of these technologies and their widespread adoption by private companies would require establishing an appropriate policy framework to encourage green construction and mitigating market failures in construction value chains and green finance (See Chapter 4).

137 IEA (2023).

138 IRENA (2020). While there are other types of hydrogen like blue and grey hydrogen, this report focuses on green hydrogen given the potential of this lever for the cement and steel industry. IFC (2023) provides an in depth-analysis of these alternative types of hydrogen and how green hydrogen is produced.

139 IEA-IFC (2023).

EXHIBIT 18

Abatement Potential and Economic Costs of Technological Solutions

	Expected Technology Costs (current $/ton of CO_2)		
Abatement potential (tCO_2 in 2050)	***High* (>$100/$tCO_2$)**	***Medium* ($50–100/$tCO_2$)**	***Low* (<$50/$tCO_2$)**
***High* >1,000 tCO_2**	Top-gas recycling in steel blast furnace with CCUS	Cement-specific CCUS options	Alternative non-clinkered cements
***Medium* 500–1,000 tCO_2**	Hydrogen and electrification in cement	Smelting reduction for steel production with CCUS	Alternative clinkered cements
***Low* <500 tCO_2**	Hydrogen in steel blast furnace	Hydrogen direct reduction in steel	Biomass and waste fuels for cement Iron ore electrolysis for steel production

Notes: CCUS—carbon capture, utilization, and storage.

Source: World Bank (forthcoming).

Cement.

The cement industry has several options to reduce emissions in the next decade. Some of them are already available, while others are still in the pilot phase with high economic and financial costs. Here, we analyze three commercially available options for cement decarbonization: improving energy and resource efficiency; reducing and replacing clinker, cement's main input, for less-polluting alternatives; and increasing the use of alternative fuels to fossil energies. We also examine the prospects of the technologies with the highest abatement potential in the cement industry but that are not expected to be commercially available until 2035 and beyond: the use of green hydrogen fuel and adopting carbon capture, utilization, and storage; and recycling construction and demolition waste for concrete production.[140]

Improving energy and resource efficiency.

Further energy efficiency measures are possible, including integrating waste heat recovery systems, which can generate up to 30 percent of overall plant

140 Lorea et al (2022) provides a list of green cement projects announced worldwide.

electricity needs,[141] and investing in state-of-the-art equipment, such as multistage preheaters and pre-calciners and high-efficiency coolers that can reduce kiln heat requirements. Multistage preheaters and pre-calciners make use of the waste heat from the kiln and clinker cooler to pre-heat and pre-process the kiln feed, and thereby allow for considerable energy savings.[142]

Installation of long kilns that recover heat from the clinker heating unit can reduce emissions by 7 percent.[143] Energy intensity can be reduced through better plant utilization and increasing equipment effectiveness. Advanced analytics can create adaptive, self-learning models to enable higher levels of automation and optimization of kilns and mills fuel management and material blending.[144] Future cement plants could further reduce carbon emissions by combining digital technology and more sustainable operations.[145]

This is particularly important for emerging markets where most of the global demand for new cement plants will originate in the next decade, driven by increased economic growth, population, and investment in buildings and infrastructure. In those countries, there is therefore an opportunity to adopt state of the art or best available low-emission energy and resource efficient equipment in new cement plants. In contrast, the future for decarbonization in countries with substantial installed capacity will mainly lie in either engaging in expensive retrofitting or offloading existing plants.

Substitution of clinker with alternative materials.

CO_2 emissions are directly proportionate to the amount of clinker used in cement production. Clinker can be substituted by alternative materials, such as limestone, natural and calcined pozzolans,[146] and industrial by-products, such as fly ash[147] and blast furnace slag,[148] for producing blended cement. Limestone calcined clay cement, for instance, a new type of cement that is based on a blend of limestone and calcined clay, can help reduce CO_2 emissions in the production process by up to 40 percent.[149] Alternative natural or recycled non-clinkered cements can achieve zero or negative cost abatement, with a significant emissions reduction potential of nearly 2,000 tons

141 IFC (2014).

142 Institute for Industrial Productivity (2022).

143 Schorcht et al. (2013).

144 For instance, advanced analytics can be used for controlling and monitoring rates of fuels to ensure consistent burning; optimizing the grinding circuit to increase throughput and secure consistent output quality, while also lowering energy consumption; and ensure cement is blended in the right proportions, which is essential to ensuring specifications and quality of products.

145 World Bank (mimeo).

146 A natural pozzolan is a raw or calcined pozzolan that is found in natural deposits. A material is referred to as "calcined" when it has been heated below the temperature of fusion to alter its composition or physical state. ACI (2022).

147 Fly ash is the fine ash produced at coal-fired power plants that develops cementitious properties when mixed with cement and water.

148 Slag cement is a hydraulic cement formed when granulated blast furnace slag is ground to suitable fineness and is used to replace a portion of Portland cement. It is a recovered industrial by-product of an iron blast furnace.

149 Construction World (2021).

of carbon dioxide equivalent by 2050. This could represent a reduction of nearly 90 percent in carbon emissions generated by cement production in non-OECD countries.[150]

One challenge to switching to non-clinkered alternatives is the lack of availability of these materials. For instance, the quantity of blast-furnace slag and fly ash is expected to decline as the industries decarbonize in high-income countries but also in upper middle-income emerging markets. Natural reserves of pozzolans are limited to specific regions close to volcanic regions, such as northeast Argentina, Chile, China, Germany, Greece, Italy, and Peru, among others, and have not yet been assessed at scale. Stringent local cement regulations also hamper piloting and adopting natural and industrial clinker substitutes.[151]

Despite these challenges, some global companies are already substituting clinker with natural and recycled materials, given the high abatement potential and relatively moderate costs of this solution. For instance, the Mexican-based building-material company CEMEX has developed a clinker-free cement that enables carbon emission reductions of 40 percent relative to conventional concrete.[152]

Increasing use of alternative non-fossil fuels.

Alternative fuels only supply about 8 percent of total thermal energy used in heating cement kilns globally, and this technology is little used in emerging markets.[153] Alternative fuels refer to fuels that can be used instead of conventional fossil fuels such as coal, oil, and natural gas. Some alternative fuels commonly used in the cement industry are residue oil and solvents, contaminated wood and process waste from wood, used tires and rubber waste, plastic waste, thermal fraction of domestic waste, sewage sludge, and animal meal, among others.[154]

A shift to less carbon-intensive alternative fuels for heating cement kilns could reduce CO_2 emissions by around 12 percent by 2050.[155] Producers today face no technical limitations on increasing the share of alternative fuels. However, the feasibility of this shift depends on the availability of alternative fuels. The development of local supply chains and domestic regulations also plays a critical role in enabling firms to switch to alternative fuels. For instance, regulation of the waste management value chain can induce the use of waste as an energy source.[156] Adoption of this alternative fuel also requires investments in technology and equipment to turn waste into fuel and incorporate it into the cement manufacturing process.

150 World Bank (mimeo).

151 World Bank (mimeo).

152 CEMEX (2021).

153 Energy Transition Commission (2022).

154 Chinyama (2011).

155 IEA (2018).

156 World Bank (Mimeo).

IFC estimates that using biomass and natural and industrial waste in cement plants with capacities of more than 5 tons per hour involves a capital expenditure investment of between $5 million and $18 million and results in an operating expenditure of between $5 and $25 per ton of cement, representing a relatively small additional cost.[157] As a result, recycled and biomass fuels have increased in cement production in developed countries and some of the main producing countries in Latin America, but are lagging in Sub-Saharan Africa and other low-income regions. (Exhibit 19).

Some companies are already investing in the production of low-carbon cement with biomass and reused materials in emerging markets. For instance, Sococim, a subsidiary of French cement maker Vicat S.A, will replace part of its clinker lines in its Senegal plant with more fuel-efficient facilities, utilizing up to 70 percent alternative fuels (biomass and recycled tires). The project will reduce greenhouse emissions by 312,000 tons of CO_2 equivalent per year by 2030, enabling it to produce one of the lowest-emission cements in the world. IFC is supporting the project with its first green loan for materials in Africa.

Green hydrogen for heating cement kilns.

In the mid-to-long term, green hydrogen offers a promising abatement solution (500–1,000 tons of carbon dioxide equivalent by 2050) but it is expected to remain non-commercially viable without fiscal support in the next ten years and possibly beyond.[158] This technology can eliminate direct emissions from heating the cement kiln, which account for around 35 percent of total emissions in cement production. Adoption is contingent on availability and costs, which currently are high at more than $100 per ton of CO_2.

Some companies in developed countries, with support from government agencies and business associations, are already piloting this technology. In 2021, a cement kiln was successfully operated in the United Kingdom using hydrogen technology for the first time.[159] High costs and implementation challenges have so far impeded efforts to pilot the use of green hydrogen for heating cement kilns in emerging markets.

Some companies in emerging markets are nonetheless already piloting this technology, while others have announced plans to deploy it soon. In 2021, Compañía Siderúrgica Huachipato, for instance, launched in Chile a pilot of a green hydrogen mill that is expected to be completed by 2023.[160] Chile's solar and wind resources can produce green hydrogen with the lowest costs in the world.[161]

CEMEX announced in 2021 that it will extend the use of green hydrogen from its plants in Europe to its operations in Africa, Asia, the Caribbean, Central America, Mexico, South America, and the United States. For instance, the company is already

157 IFC (2017).

158 IEA (2023).

159 MPA (2021).

160 See CAP S.A.: https://www.capacero.cl/cap_acero/noticias/ejecutivos-de-cap-presentan-a-ministerio-de-energia-proyecto-de/2021-11-03/115628.html

161 See World Bank: https://worldbankgroup.sharepoint.com/sites/news/pages/Betting-on-Green-Hydrogen-for-Sustainable-Growth--17072023-120542.aspx

implementing hydrogen technology at its San Pedro de Macoris cement plant in the Dominican Republic.[162]

Carbon capture, utilization, and storage technologies.

On the horizon by 2050 are carbon capture, utilization, and storage technologies, which capture CO_2 from industrial emissions and either recycle it for further industrial use or store it safely underground. Once captured, a wide variety of potential uses for CO_2 could be possible, such as in the production of plastics, minerals, or synthetic fuels. Carbon capture is still expensive at $50–$100/ton of CO_2 and it is expected to remain so by 2035 and beyond, but it offers the largest abatement potential among the decarbonization levers for cement production (Exhibit 18).

There are several carbon-capture pilots underway by large cement players, although still with high costs and often ample government assistance. For instance, Anhui Conch Cement developed in 2017 a cement with carbon capture plant in Wuhu, China. In India, Dalmia Cement Limited and Carbon Clean Solutions are developing the largest cement plant with carbon capture in the cement global industry. The plant is expected to capture 500,000 tons of CO_2 per year.[163]

The progress of extensive decarbonization will depend on the economic viability of this carbon capture technology, as well as the availability of CO_2 marketplaces through which the captured CO_2 can be traded. These conditions are not prevalent in many emerging markets, which also lack the regulatory and implementation capacity and the green finance needed to pilot this high-risk technology with still uncertain benefits.

Recycling construction and demolition waste.

One way to introduce circularity into the cement value chain is by recycling construction and demolition waste to produce concrete. In the United Kingdom, for instance, recycled material from construction and demolition waste is increasingly being used to replace aggregates in concrete. Some companies are also engaging in the production of recycled concrete. For instance, Holcim operates the Geocycle Recycling Center in Retznei, Austria, which processes 130,000 tons of construction and demolition waste per year. About 35 percent of this waste is co-processed in the company's cement, while 35 percent is used as recycled aggregates by construction companies. The remaining unrecyclable 30 percent is used as backfilling material for the cement plant quarry.[164]

Other solutions include introducing new materials that can be easily deconstructed and reused in other buildings once the original building is torn down and expanding the use of carbon calculators such as EC3 or third-party auditors or environmental, social, and governance (ESG) rating agencies to give visibility to the embodied carbon emissions in a construction

162 See CEMEX: https://www.cemex.com/-/cemex-successfully-deploys-hydrogen-based-ground-breaking-technology

163 Global CCS Institute (2019).

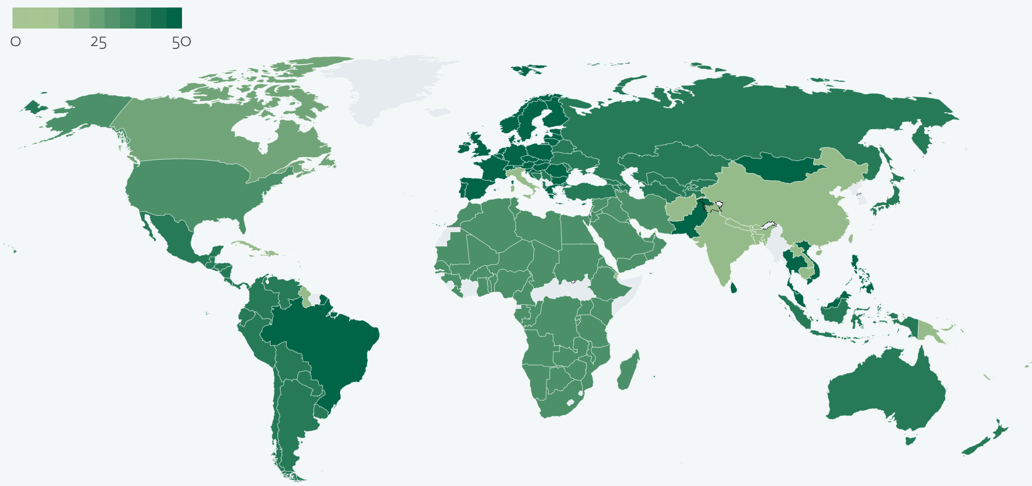
164 See Holcim: https://www.holcim.com/who-we-are/our-stories/building-again-construction-and-demolition-waste

EXHIBIT 19

Use of Alternative Fuels for Cement Production is Limited in Low-Income Regions

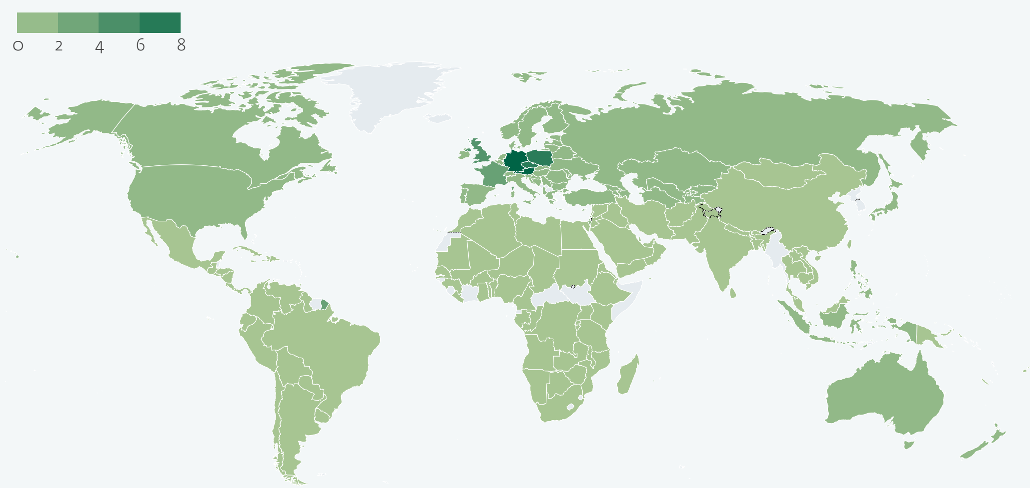
Biomass utilization in cement fuel consumption

as percentage of total consumption



Alternative fuels utilization in cement fuel consumption

as percentage of total consumption



Source: IFC staff calculations based on GCCA (2022).

project at the design and procurement phases.[165] This would allow building owners, green building certification programs, and policymakers to assess supply chain data to establish requirements and set embodied carbon limits at the project stage.

Steel.

In steelmaking, the decarbonization options that are already commercially available include enhancing energy and thermal efficiency, increasing the use of scrap to substitute iron, steel's main input, and substituting coal and heavy fuel oils with biomass fuels. Like in the cement industry, adoption of innovative technologies such as carbon capture and green hydrogen, among others, hold the promise of net zero steelmaking but these levers are expected to remain non-economically viable by 2035 and beyond. As with cement, we analyze the specific application of some of these technologies for the steel industry.[166,167]

Increasing the share of scrap-based electric arc furnace steelmaking.

The main feedstock for electric arc furnace steelmaking is steel scrap, but it can also smelt solidified iron or sponge iron. The heat necessary for melting the metal comes from an electric arc that arises when the electrodes contact the metal (Box 5). This technological option seeks to maximize secondary flows and recycling by melting more scrap in electric arc furnaces. However, this lever can be limited in regions with an inadequate supply of high-quality scrap, making the use of other abatement technologies a must. Increasing demand for high-quality scrap will also lead to extra cost for the electric arc furnace-based steel production.

Improving furnace efficiency.

Furnaces that use this technology produce iron from iron ore, and then a basic oxygen converter turns iron, with some additions of scrap, into steel (Box 5). Production relies on a chemical process called reduction to separate iron from oxygen. Carbon in the form of coal is needed, as a reducing agent. In the process, the carbon combines with the oxygen and forms carbon dioxide. This use of carbon makes CO_2 emissions unavoidable in this process.

Decarbonization options include optimizing the blast furnace burden mix by maximizing the iron content in raw materials to decrease the usage of coal as a reductant, using coke oven gas in the furnace as an energy source, and increasing the use of fuel injection through, for example, pulverized coal injection, natural gas, plastics, or biomass. Pulverized coal injection is a process that involves blowing large volumes of fine coal granules into the blast furnace. This provides a supplemental carbon source to speed up the production of metallic iron, reducing the need for coke production. These options help decrease CO_2 emissions, yet do not offer fully carbon-neutral steel production. Near pure oxygen can also be injected into existing blast furnaces to improve efficiency and

165 The Embodied Carbon in Construction Calculator (EC3) tool is a tool that allows benchmarking, assessment, and reductions in embodied carbon, focused on the upfront supply chain emissions of construction materials. See https://carbonleadershipforum.org/ec3-tool/

166 IFC (2023) analyzes other emerging technologies for steel decarbonization and provides further detail on the economic costs and potential abatement potential of steel decarbonization levers.

167 Lorea et al (2023) provides a tentative mapping of green steel projects announced worldwide.

lower overall emissions intensity by approximately 15-20 percent.[168]

Use of biomass in integrated steelmaking.

Biomass can be used in integrated steelmaking as a source of fuel or reductant, substituting coal or other fuels in the sintering process, as a blend component in the production of coke, as a direct replacement for coke or as an injectant to replace injected pulverized coal in the blast furnace, and as a source of carbon in the steelmaking process (Box 5). When sourced from renewable resources, biomass has the potential to reduce emissions intensity by as much as 50 percent across the integrated steelmaking process.[169] However, biomass may not become a widespread abatement lever due to a lack of availability of sustainable sources of biomass in some regions[170] and competing demand from other industries.

Despite these challenges, some producers are already conducting steelmaking trials using biomass in emerging markets. Aço Verde do Brasil (Green Steel of Brazil), for instance, is piloting the production of 600,000 tons per year of low carbon steel in its mill in the northern Maranhão state of Brazil. The trial employs hot metal production based on eucalyptus charcoal, replacing traditional coking coal. The company has 50,000 hectares of eucalyptus planted for sustainable charcoal and captive pig iron production.[171]

Hydrogen-based steelmaking.

There are generally two ways to use green hydrogen in steelmaking: as alternative injection material to pulverized coal to improve the performance of conventional blast furnaces, which can reduce carbon emissions by up to 20 percent;[172] and as an alternative reductant to produce direct reduced iron that can be further processed into steel using an electric arc furnace.[173] Based on the use of green hydrogen as well as renewable electricity from wind, solar, or water, this technology can enable nearly carbon-neutral steelmaking.[174]

However, the main challenges and uncertainties for the scalable commercial adoption of this technology are related to the costs of hydrogen generation and running the electric arc furnace on affordable sources of renewable energy. Today, the costs of green hydrogen are still high (\$50–\$100/ton of CO_2), despite its large abatement potential (Exhibit 18).

Some global steelmakers are exploring this technology

168 BHP (2020).

169 BHP (2020).

170 See Exhibit 19 for data on biomass availability for the cement industry.

171 See AVB's announcement: https://avb.com.br/en/brazils-avb-receives-carbon-neutral-steel-certificate/

172 McKinsey & Company (2020).

173 Direct reduced iron is iron ore in the form of lumps, fines or pellets that have had the oxygen removed by using hydrogen and carbon monoxide. Typical sources of carbon monoxide are natural gas, coal gas, and coal. Other energy inputs into the production process often include oil and electricity.

174 McKinsey & Company (2020).

in emerging markets. In South Africa, for instance, Sasol and ArcerlorMittal in 2022 launched a joint venture that will assess the use of green hydrogen to convert captured carbon from ArcelorMittal South Africa's Vanderbijlpark steel plant into sustainable fuels and chemicals.[175]

Carbon capture, utilization, and storage.

Carbon capture, utilization, and storage can be integrated in existing steelmaking plants but requires carbon transport and storage infrastructure. Depending on the configuration, carbon capture has the potential to reduce emissions intensity of the integrated steelmaking process by up to 60 percent.[176] The first commercial steel carbon capture project has been launched by Al Reyadah and Emirates Steel at a gas-based, direct reduced iron plant in Abu Dhabi, United Arab Emirates.

In India, Tata Steel has commissioned a 5 ton-per-day carbon capture plant at its Jamshedpur Works. The carbon capture technology extracts carbon dioxide directly from blast furnace gas for onsite reuse. The company plans to scale up this technology in other facilities.[177] As with cement, carbon capture technologies for now are not economically viable (Exhibit 18).

Green hydrogen and carbon capture technologies in steelmaking are today up to 30 percent more expensive than their commercially available counterparts in the absence of carbon pricing programs.[178] Gas-based direct reduced iron with carbon capture and hydrogen-based direct reduced iron are highly sensitive to the cost of natural gas and electricity and the policy environment.[179] However, it is expected that carbon capture and green hydrogen will provide competitive options for steelmakers by 2040-2050 globally.[180]

3.5. Opportunities and challenges for investments in green cement and steel.

The prospects for greening cement and steel production in emerging markets hinge on the availability and carbon content of alternative fuels and raw materials, the average capacity of plants, and policy and regulatory readiness. Here, we briefly examine some of the regional and country investment opportunities and challenges, with a focus on commercially available technologies.[181]

Within emerging markets, China and India offer the largest potential for cleaner cement and steel production. In China, several factors could encourage investment in low-emissions cement and steel over the next decade. These include the recent deployment

175 See Sasol's announcement: https://www.sasol.com/media-centre/media-releases/sasol-arcelormittal-south-africa-partner-decarbonise-and-reindustrialise-vaal-saldanha-through

176 BHP (2020).

177 IFC (2023).

178 IFC (2023).

179 IEA (2020).

180 McKinsey & Company (2021).

181 Chapter 4 analyzes in detail the policy framework and financing required for decarbonizing construction, including cement and steel.

of carbon-trading programs at the provincial level, and their planned scale up nationwide, tighter environmental regulations, and the large scale of the cement and steel plants, which can more easily bear the higher costs of green technologies relative to conventional alternatives.[182] The Chinese government, for instance, has recently announced plans to put a price on cement emissions.[183]

In India, recent policy measures, like the Performance Achieve and Trade Scheme, the Steel Scrap Recycling Policy, and Draft National Resource Policy, will incentivize decarbonization in cement and steel.[184] Blast furnace-basic oxygen furnaces, which could potentially switch to low-carbon technologies, contribute 65 percent of India's steel capacity. The country has available iron ore reserves and massive potential for renewable energy sources. India's government, for instance, requires thermal power plants to be 5-10 percent co-firing with biomass. India is also the second largest cement market in the world, and its production is expected to more than double in the next decade.[185] This offers an opportunity for investing in greening existing cement plants and investing in new net-zero facilities. Yet, restrictive regulations impede the use of low-carbon non-clinkered materials, hindering the commercial viability of one of the readiest decarbonization levers in cement.[186]

Besides China and India, Brazil offers significant investment opportunities in green steel in Latin America and the Caribbean. It has the largest supply of renewable energy in Latin America and ample iron ore reserves. It is the only country in South America with carbon storage facilities (two out of three are in operation). There is also one green hydrogen plant under construction and four others will be ready by 2030.[187] Half of the cement used in Brazil is still hand-mixed, pointing to the need for investments in speeding up the transition to bulk cement and concrete-ready mixes.[188] Substantial investment opportunities for green cement and steel also exist in Türkiye and South Africa.[189] Other emerging markets, some in Sub-Saharan Africa, present the potential for investing in new zero-emissions steel and cement plants to respond to increasing construction demand.[190]

182 IFC staff analysis, IFC (2023) and IEA (2022c).

183 IEA (2022c).

184 IFC (2023a) and IEA (2018).

185 IFC based on Global Trade Analysis Project and WEF (2022).

186 IFC (2023b).

187 IFC (2023a) and IEA (2018).

188 IFC (2017b).

189 IFC (2023a) and IFC staff analysis.

190 IFC staff analysis and McKinsey & Company (2022).

CHAPTER 4:

Financing *the* Green Construction Transition *in* Emerging Markets

4.1. Summary

Emerging markets that put adequate policies in place could represent a major investment opportunity for building green. Emerging markets, however, issued only 10 percent of the $230 billon in domestic and foreign green private debt finance for building green in 2021. This chapter examines approaches to directing a greater volume of private finance to building green in emerging markets, including green codes, regulations and standards; mandatory and voluntary carbon markets; and financial tools including sustainability-linked finance and venture capital funds, among others. Some of these instruments represent an investment opportunity for domestic and foreign investors. The capability to foster and adopt these tools will vary across emerging markets depending on each economy's income level, technological and policy readiness, and dependence on fossil fuels.

4.2. Emerging markets are not mobilizing enough green private finance to decarbonize their construction value chains.

Domestic and foreign private finance is increasingly flowing into greening construction globally. In the last four years, green debt financing increased twentyfold, from about $10 billion in 2017 to a record high of about $230 billion in 2021. Green bonds accounted for about 70 percent of that financing, but some emerging debt instruments, like green sustainability bonds and loans, have been growing at a faster pace (Exhibit 20).[191] Equity instruments are less commonly used for such financing, though Real Estate Investment Trusts (REITS) hold the potential to scale financing of green building construction and operations. Other innovative green finance tools, such as transition bonds or carbon retirement portfolios, are almost non-existent in emerging markets.[192]

Emerging markets are mostly missing out on these increasing flows of private green finance for decarbonizing construction. Since 2017, they have issued just 10 percent of total global green debt financing, and China accounted for about 60 percent of that. Relative to total green debt private finance, for all purposes, debt finance for net-zero buildings and materials amounted to only 20 percent in emerging markets, compared with about 30 percent in high-income countries.[193]

Yet, there is some promise: private green debt finance for building green has been growing faster in other emerging markets, including Sub-Saharan Africa, although such finance remains at extremely low levels (Exhibit 21). In addition, about 90 percent of this financing in 2021 globally went to green buildings rather than to hard-to-abate construction materials such as steel and cement, which account for about 19 percent of global carbon emissions.[194]

191 Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with green buildings in the use of proceeds or issued by construction material sectors and used for decarbonization. See Annex 3 for more details on the methodology.

192 Section 4.5 analyzes in detail each of these instruments, and their use in greening construction in emerging markets.

193 IFC staff calculations based on Environmental Finance and Bloomberg. Total green debt finance includes sustainability, sustainability-linked, and transition debt issued in 2021 for all purposes, including green buildings and materials.

194 IFC staff calculations based on Environmental Finance, Bloomberg and Global Trade Analysis Project.

Of the total private green debt finance for building green issued in emerging markets outside China, about 54 percent of domestic and foreign debt was issued in Latin America and the Caribbean, followed by East Asia and the Pacific (19 percent), and Europe and Central Asia (12 percent). The Middle East and North Africa, South Asia, and Sub-Saharan Africa together issued about 15 percent of total green debt financing for building green (Exhibit 22). Within Sub-Saharan Africa, South Africa accounts for most of the private green debt financing issued for construction decarbonization (75 percent).[195]

Looking at the use of climate finance instruments by region, about 90 percent of green bonds and loans for decarbonizing construction were issued by high-income countries and China between 2017 and 2021. Sustainability bonds were issued mainly in those economies, but Sub-Saharan Africa and other emerging markets also use some of those financial instruments, accounting for about 7 percent of the total (Exhibit 23).

Sustainability-linked green debt instruments exhibit the highest use by emerging markets of green construction financial instruments, with 20 percent of the total bonds and 10 percent of the total loans (Exhibit 23).

4.3. Market failures largely explain the paucity of green finance for construction in emerging markets.

The low levels of domestic and foreign private capital for building green in emerging economies are partly explained by market failures in green finance and construction value chains. These market failures are often more pronounced and pervasive in emerging economies, especially in low-income countries.

For instance, the fragmented structure of construction value chains, highly localized regulations, the presence of informational asymmetries between the segments of the value chains and policymakers, and the prevalence of small and medium-sized construction companies restricts finance for building green. Financial decisions often involve multiple stakeholders, including investors, developers and owners, architects and other professionals, and materials producers, with split incentives (Box 1). Investors cannot also easily identify investment opportunities in green construction in the absence of green codes, regulations, and standards. Small and medium-sized developers, especially in economies with high levels of informality, also face financial restrictions for building green. The lack of skilled workers in sustainable construction techniques further limits the potential of investments in green buildings or materials.

Green construction alternatives also appear more expensive than they ought to be because today's market prices do not reflect the social costs imposed by emissions from brown buildings and materials, reducing expected returns for green construction projects. Consumers and investors can be unwilling or unable to pay an up-front premium for green buildings of about 1–5 percent relative to brown alternatives, especially in affordable housing targeted at lower-income households. This is more challenging in low-income and fragile countries, where there are few

195 IFC staff calculations based on Environmental Finance and Bloomberg (2022).

commercially viable green building investments.

Limited information about default rates and the monetary benefits of green building investment portfolios also reduces investment in green construction. Climate risk, related to issues such as economic losses arising from climate hazards, tends to be underpriced by financial markets.[196] For example, residential property values often do not fully reflect the risks of extreme climate events, even when such information is public.[197] This increases the capital costs for green and resilient buildings relative to traditional alternatives. This problem can be more severe in emerging markets exposed to frequent catastrophic events and lacking well-developed financial and insurance markets.[198]

Carbon markets can, in principle, mitigate some of these differences in market prices between green and brown buildings and materials. [199,200] However, these markets remain underdeveloped, especially in emerging markets. For instance, only three emerging economies have launched carbon markets: China, Kazakhstan, and Mexico.[201] This is partly explained by the lack of legal frameworks and institutional capabilities. Carbon pricing can also increase consumer prices of brown construction materials and buildings, limiting the appetite for these systems, especially in low-income countries.[202] Restrictions on international trading of carbon permits also limit channeling capital from carbon markets in developed countries to green construction projects in emerging markets.[203]

Private investors can face high costs for measuring and monitoring environmental performance in green construction projects, especially in hard-to-abate materials like cement and steel. These costs are especially high in emerging markets because of poor governance and disclosure standards, lower transparency, weaker regulations, and limited technical capabilities for issuing and regulating green financial instruments.[204]

Emerging markets may also face supply constraints. There are often fewer commercially viable green projects in construction value chains to finance in these markets.[205] This may be due to the absence of innovation, limited green technical capacity for

196 Hong et al. (2019); Hino & Burke (2021).

197 Ibid.

198 See Chapter 3 for a discussion on resilient green buildings in emerging markets.

199 Note that carbon taxes can achieve a similar effect by imposing a cost on carbon, forcing firms to internalize the social costs generated due to emissions. Taxes also face similar concerns of potentially higher consumer prices and erosion of competitiveness, though implementation capacity issues are less of a problem. The primary difference is in the setting of the carbon price: it is determined by market forces in carbon markets and by the government in the case of taxes. Hence for the former, there may be some uncertainty around costs for firms, and it is possible that the cost of abatement exceeds the estimated benefits (Frank, 2014). However, carbon taxes are subject to uncertainty around the impact on total level of emissions (relative to carbon markets where caps can be set). (Frank 2022).

200 IFC (2019b).

201 World Bank (2022).

202 IFC (2019b).

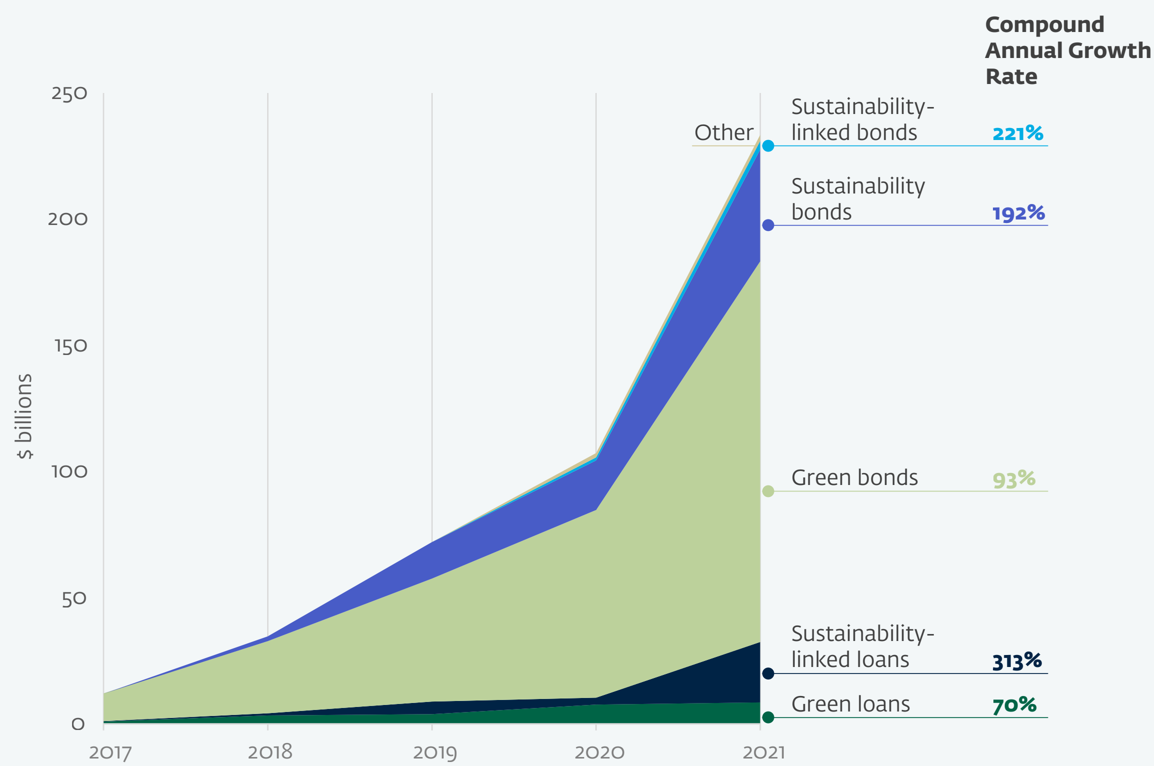
203 World Bank (2021a).

204 IFC and Amundi (2019).

205 World Economic Forum (2022a).

EXHIBIT 20

Global Private Green Debt Finance to Build Green Increased Twentyfold, and About 70 Percent Flowed into Green Bonds

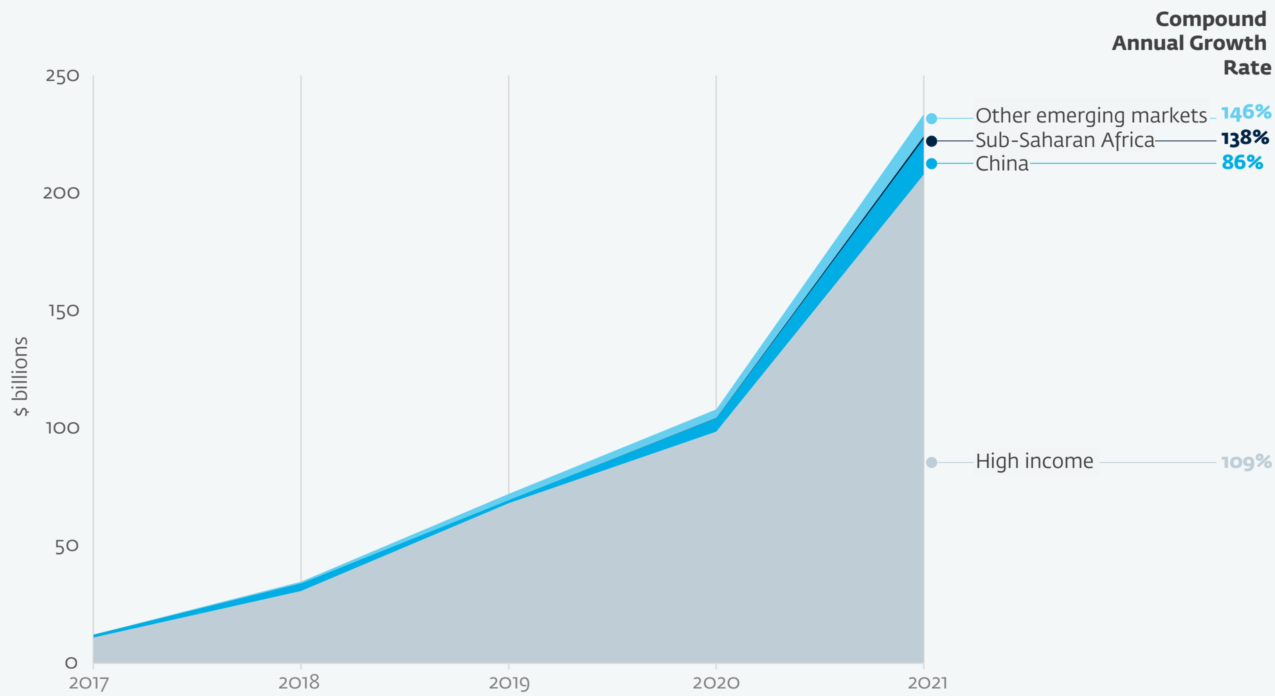


Notes: Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material sectors and used for decarbonization. See Annex 3 for more details on the methodology. 'Other' includes transition bonds and sustainability loans. See Annex 3 for more details on the methodology. Figures in the text might not be identical due to rounding.

Source: IFC based on Environmental Finance and Bloomberg (2022)

EXHIBIT 21

Emerging Markets Issued Only 10 Percent of Global Domestic and Foreign Private Green Debt Finance for Construction Decarbonization



Notes: Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material sectors and used for decarbonization. Income and region volumes are based on the location of headquarters and/or country of risk (determined by the firm's geographical exposure to operations) of the issuing entity. Compound annual growth rates are calculated using the first year of issuance as base year: 2018 for Sub-Saharan Africa and other emerging markets, and 2017 for high income countries. See Annex 3 for more details on the methodology. Figures in the text might not be identical due to rounding.

Source: IFC based on Environmental Finance and Bloomberg.

implementation, lack of economies of scale, and limited concessional finance resources.[206] Regulatory, macroeconomic, currency, and political risks and volatility can also increase costs, making green construction investments less profitable.

4.4. Concerted action by private investors and policymakers will be required to overcome market failures and reduce emissions from construction value chains.

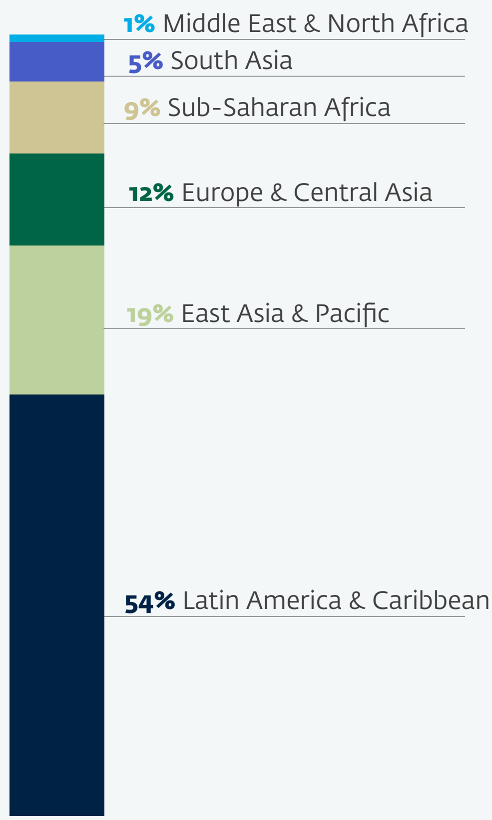
A range of solutions that already exist or are emerging can address some of these challenges for financing green construction in emerging markets in domestic and international capital markets. Some solutions are purely financial, while others are based on carbon-trading and pricing systems, or government regulations. Some of these financial tools are already available, like sustainability-linked finance and equity funds; others are still nascent and require further support, like green mortgages, transition bonds, and carbon retirement portfolios.

206 Chatterton and De Vautibault (2021); Loukoianova et al. (2022).

EXHIBIT 22

Latin America and the Caribbean Accounts for More Than 50 Percent of Private Green Debt Issuance for Construction Decarbonization in Emerging Markets Outside China

Percent of emerging markets excluding China by region, 2017–2021



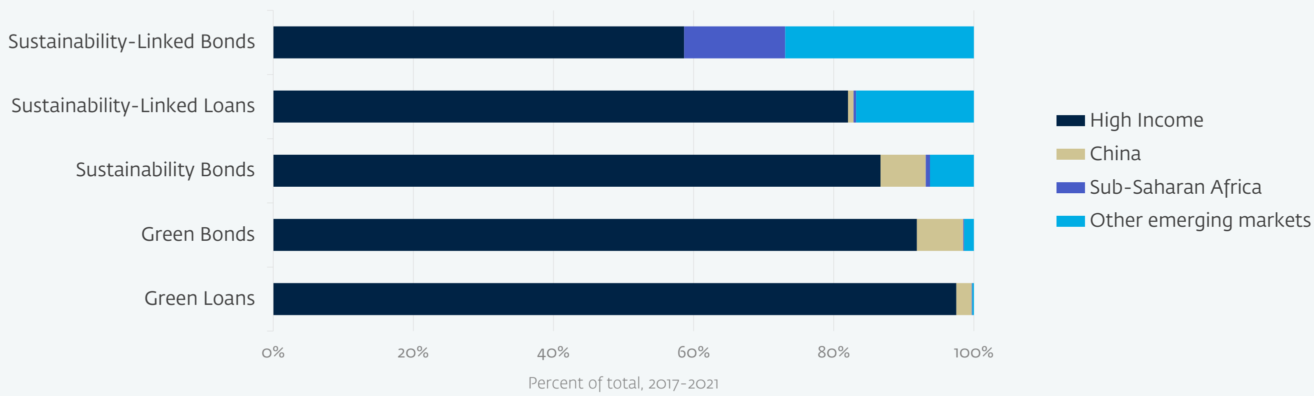
Notes: Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material sectors and used for decarbonization. Income and region breakouts are based on the location of headquarters and/or country of risk (determined by the firm's geographical exposure to operations) of the issuing entity. South Asia comprises solely India (no other country recorded any issuances). Middle East & North Africa includes Egypt (63 percent) and Lebanon (38 percent). Latin America and the Caribbean comprises Mexico (66 percent), Brazil (8 percent), Costa Rica (7 percent) and Guatemala (7 percent), among others. Europe and Central Asia includes Türkiye (88 percent), Russia (10 percent) and Armenia (2 percent). East Asia and Pacific includes Philippines (41 percent), Malaysia (26 percent) and Indonesia (25 percent), among others. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Environmental Finance and Bloomberg (2022).

EXHIBIT 23

Emerging Markets Are Increasingly Using Sustainability-Linked Instruments for Green Construction Financing

Accumulated sustainability finance by region. Percent of total, 2017–2021



Notes: Calculations only consider green, sustainability, sustainability-linked, and transition bonds and loans with "green buildings" in the use of proceeds or issued by construction material sectors and used for decarbonization. Income and regional breakouts are based on location of headquarters and/or country of risk (determined by the firm's geographical exposure to operations) of the issuing entity. 'Other emerging markets' sustainability-linked bonds are composed solely of issuances from India. Figures in the text might not be identical due to rounding.

Source: IFC based on Environmental Finance and Bloomberg

These instruments would open a $1.5 trillion business opportunity for both domestic and international investors in electrified brown buildings with cleaner energies and lower-emission new buildings and materials than conventional alternatives in emerging markets in the next decade (See Chapter 1). The sources of funding—domestic, foreign and/or multilateral—as well as the type of provider—private, public, and/or multilateral—and the potential financial instruments for financing these decarbonization levers, including off-balance sheet, debt, equity, and venture capital, among others, along with some examples of recent investments in emerging markets are discussed here and detailed in Table 2.4 in Annex 2.

The appropriate mix of financial and policy instruments for building green will vary across emerging markets, depending on the country's income level, the size and depth of the domestic financial system, and the public sector's regulatory and enforcement capabilities. Reliance on fossil fuels in the local economy and carbon- and energy-intensity of the construction sector will also affect the prospects and the speed of adoption of some of these tools.

A range of private green financing instruments is available or emerging to support investments in greening construction value chains.

Building green in emerging markets will require a combination of existing and novel green financial instruments, depending on the type of investment and country conditions. Some of these tools will be mainly provided by local financial institutions, especially in residential real estate. International and domestic investors can contribute with other debt and equity instruments, such as green bonds and loans or REITs. Off-balance sheet financing can also be supplied by local energy-service providers, via performance contracts or leasing. Voluntary carbon markets can, in turn, help to channel domestic and international capital into green construction. Here, we analyze some of these tools.

Using sustainability-linked debt for decarbonizing hard-to-abate construction materials.

By reducing screening and monitoring costs for lenders, sustainability-linked finance—that is, loans and bonds in which compliance with a set of pre-determined sustainability targets triggers reductions in financing costs—can, at least in principle, contribute to aligning incentives of investors and brown construction companies to reduce carbon emissions. To be effective in reducing emissions, sustainability-linked finance requires well-developed regulatory, prudential, and sustainability frameworks, and domestic financial markets.

The case of India's largest cement producer, Ultra Tech, illustrates the potential of this instrument. In 2021, the company issued a sustainability-linked bond that raised $400 million in domestic and international capital markets. The bond's rate is linked to compliance with the company's self-determined target of reducing its carbon emissions by 22 percent by 2030. If the target is missed, the interest rate will rise by 75 basis points.[207]

In 2021, sustainability-linked finance for greening construction registered a record high of about $27 billion globally, and about 70 percent of that went to decarbonization of construction materials. Cement and steel each received about half of total sustainability-linked finance for construction materials globally, but the share of steel has been growing more rapidly since 2019. Loans are the most popular linked instrument for financing the decarbonization of construction materials, accounting for about 86 percent of total financing, but bond issuance increased seven-fold in 2019–2021.[208] (Exhibit 24).

Driving demand for green construction with green mortgages.

As with traditional mortgages, domestic financial institutions are the primary provider of green mortgages in most countries. This type of debt instrument demands long-term finance in local currency not commonly offered directly to borrowers by international banks or other investors.[209] However, debt and equity issuances in global capital markets, along with conventional and concessional finance from development finance institutions, are becoming

207 See Ultra Tech Cement's announcement: https://www.ultratechcement.com/about-us/media/features/ultratech-cement-raises-usdollar-400-million-through-india-s-first-sustainability-linked-bonds

208 IFC staff calculations based on Environmental Finance and Bloomberg.

209 IEA (2021).

an important source of finance for this asset class for mortgage providers in middle-income economies.

Against this backdrop, green mortgages offer consumers preferential conditions, such as lower interest rates and/or longer duration, to purchase properties with lower energy consumption and carbon emissions. Green mortgages may have lower down payments than conventional alternatives because green buildings consume less energy, and thus have lower utility bills, which may count as borrower's income.

Outside the European Union and United States, use of green mortgages has been limited by high due diligence costs for green buildings and the lack of information on default rates of these instruments for local financial institutions.[210] That is not the case everywhere, however. In 2016, Bancolombia, Colombia's largest commercial bank, issued a $400 million green bond in three tranches. This financing was used to build a pipeline of green construction projects and offer green mortgages in local currency with a discount rate of 65 basis points.[211] In Peru, IFC is supporting BBVA, one of the largest local financial institutions, to finance homebuyers' green mortgages also issued in domestic currency, and is providing advisory and certification services through EDGE, IFC's green building certification program.[212]

As in the case of sustainability-linked finance, green mortgages require demanding regulatory and prudential capabilities, adequate sustainability frameworks, deep local financial markets and thriving demand from sustainability-oriented owners and investors. With financial and technical support from development finance institutions, these financial instruments are therefore more likely to blossom in middle-income economies than in low-income countries.

Energy-performance contracts and leasing for building green.

Off-balance sheet finance can be an effective tool to incentivize and fund investments in new and retrofitted net-zero buildings and materials. Through performance contracts and leasing, energy-service providers can offer financing for energy-efficiency investments that can be repaid through energy savings over time. Off-balance sheet energy-performance contracts can also be used to finance waste heat recovery in cement plants,[213] and could be used to fund energy-efficiency upgrades in steel plants.

According to the IEA, about 25 percent of global clean energy investments (e.g., energy- efficiency improvements, carbon capture, and alternative low-emission fuels) in the industrial sector, including cement and steel, is financed today through performance contracts or leasing. Combined with equity and debt financing, off-balance sheet finance might become an even more important source of capital for construction decarbonization. It is estimated, for instance, that about 20 percent of

210 IFC (2019a).

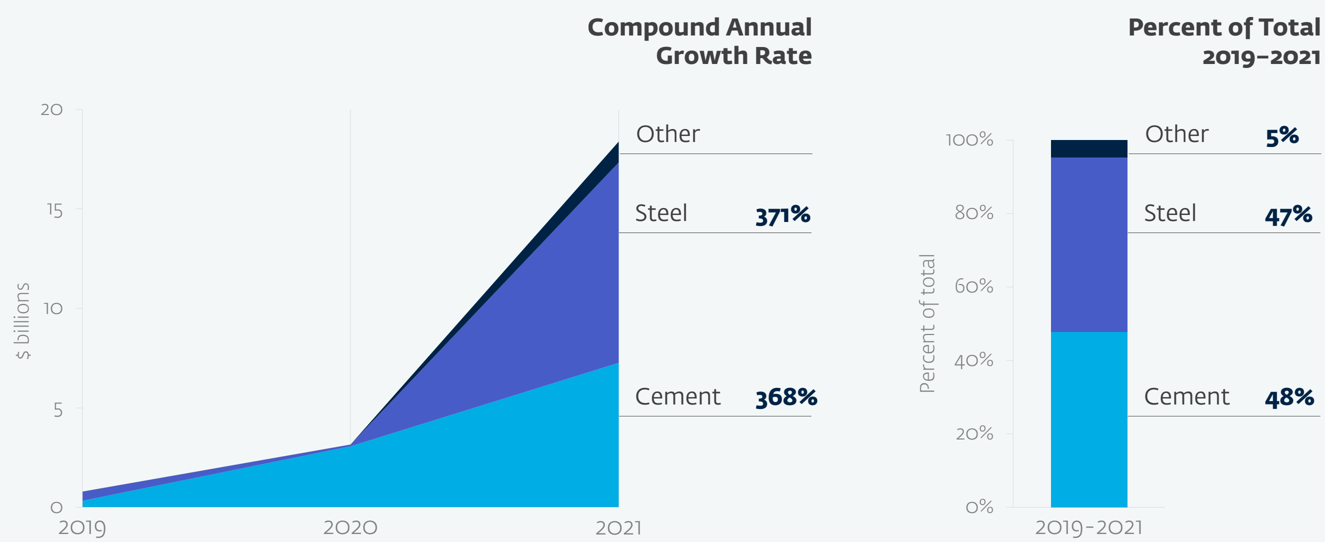
211 Ibid.

212 IFC (2022).

213 IFC (2014).

EXHIBIT 24

Sustainability-Linked Finance Can Help Decarbonize Hard-to-Abate Construction Materials



Notes: 'Other' comprises sustainability-linked bond issuances from a provider of wood-based solutions for construction and sustainability-linked loan issuances from a provider of sustainable facades. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Environmental Finance and Bloomberg.

financing for green buildings will occur through energy-performance contracts or leasing in the next decade.[214] Given its relatively low regulatory demands compared to sustainability-linked finance and green mortgages, off balance sheet contracts could become a powerful tool to promote building decarbonization not only in middle-income economies, but also in some low- income countries with adequate regulations in the energy sector and financial and technical support from the international community.

Channeling equity finance into green buildings in emerging markets with green funds and REITs.

Green REITs inject equity finance into net-zero construction through investments in green real estate and mortgages. This instrument raised about $28 billion in 2021 globally through bonds and loan issuance, up from $0.7 billion in 2017 (Exhibit 25). There is no detailed information on emerging markets, but green REITs show potential to finance building green

214 IEA (2021).

by diversifying investors' risk in a portfolio of brown and carbon-neutral properties.

For example, Kimco Realty, the largest operator of open-air shopping centers in North America, used $365 million from a green bond issued in 2020 to finance the acquisition of green residential and commercial buildings and invest in energy-efficiency upgrades in 123 of its existing properties. This transaction enabled 7,200 tons of carbon dioxide equivalent savings in greenhouse gas emissions for the company.[215]

Like green REITs, green equity funds can invest in companies that design, build, manage, and operate green buildings. Some funds also invest in decarbonization of cement and steel companies.[216] Green equity funds are among the prominent options for investors to invest in sustainable companies in emerging markets,[217] though they are mostly domiciled in advanced economies.[218]

Green funds are relatively new. For instance, the first Exchange Traded Fund for green buildings was launched in 2021. This passive fund tracks the MSCI Global Green Building Index, which focuses on the entire global construction value chain, including emerging markets.[219] Recent evidence suggests that actively managed green equity funds can identify green firms with potentially high-risk adjusted results, reducing screening and monitoring costs for investors relative to green equity passive funds.[220]

Green equity could become a powerful instrument to foster construction decarbonization in emerging markets in the years to come. This asset class, however, remains nascent even in most high-income economies and requires relatively sophisticated policy and oversight capabilities in the public sector. Green construction equity funds are therefore more suitable for middle-income economies with substantial policy capabilities. In low-income countries, development finance institutions could support some equity-based construction-related investment, possibly with blended finance, with the aim of sowing the seeds for green equity markets in the years to come.

Financing innovative technologies with venture capital.

Venture capital markets can help finance game-changing technologies for construction material decarbonization and energy, as well as resource-

215 Business Wire (2022).

216 Naqvi et al. (2021).

217 Naqvi et al. (2021).

218 IMF (2021).

219 Johnson (2021).

220 Revelli & Viviani (2014).

efficient buildings and infrastructures. They can also be critical in building a pipeline of commercially viable green construction technology investments. However, since 2013, only 4 percent of $88 billion invested by venture capital funds in green technologies globally went to green buildings and materials.[221] Moreover, venture capital investing in emerging markets is limited because of weak protections for intellectual property rights, a lack of long-term investors, and the dearth of exit options because of underdeveloped capital markets.[222]

Venture capital holds promise for promoting novel mitigation and adaptation technologies for construction decarbonization in countries with relatively sophisticated domestic financial markets and venture capital investors operating in other sectors, like Brazil, India, or South Africa. Realizing this potential will require, however, strengthening financial regulations and support from development finance institutions. In low-income economies, the international community can collaborate to lever venture capital investments into small innovative green construction projects through blended finance and other concessional tools as well as technical support.

Funding building green in emerging markets through voluntary carbon markets.

These markets allow investors to trade carbon permits against investments in green projects without government oversight or regulation. For now, they have financed green construction projects in only 10 emerging economies since 2006, and mainly in green buildings rather than in hard-to-abate construction materials. Low-income countries have received investments in green buildings, while middle- and high-income countries have invested in energy efficiency retrofits and waste heat recovery in cement and steel plants.[223] High-income economies could support construction decarbonization in emerging economies by fostering the development of voluntary carbon markets specialized in trading carbon permits against green construction projects in those countries. Development finance institutions could provide financial and technical support and blended finance for such efforts in lower-middle income and low-income economies.

Carbon transition bonds and carbon retirement portfolios for decarbonizing or retiring brown construction assets.

These bonds do not require borrowers to be completely green but to become greener over time, thereby reducing negative screening by investors of hard-to-abate and carbon-intensive steel, cement, and glass companies.[224] This tool is relatively new, with only about $4 billion issued to date for the

221 Johnson (2021).

222 Groh et al. (2016).

223 IFC staff calculations based on Berkeley Voluntary Registry Offsets Database (July 2022).

224 Negative screening refers to the process of finding and excluding stocks of companies, whose operations are seen as "unsustainable" from an environmental, social or a governance (ESG) standpoint.

construction sector. Transition bonds have not yet been issued in emerging markets.[225]

The first transition bond issued by a steelmaker globally illustrates the potential of this instrument. In 2022, JFE Holdings, Japan's largest steelmaking company, issued a $230 million transition bond. Proceeds have been used for investments in research and development (R&D) of innovative technologies, including carbon recycling blast furnaces, hydrogen-based steelmaking, carbon capture, storage, and utilization technology, and electric arc furnaces. The funds have also been used to increase the use of renewable energies and scrap metal in the steelmaking process.

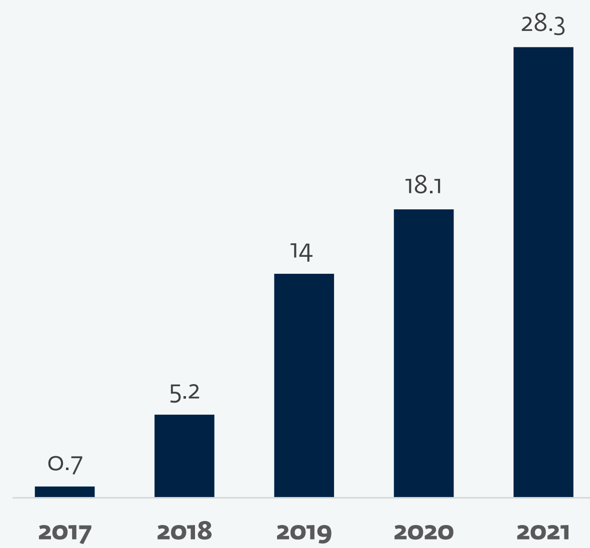
In the future, carbon retirement portfolios could also contribute to decarbonizing cement and steel. These portfolios, which are not yet commercially viable, might enable investments to phase down outdated plants and to decarbonize plants still in operation, diversifying and reducing investors' risks.[226]

Development finance institutions could provide technical and financial support to the development of these novel financial instruments in emerging markets. Given the high cost of decommissioning or retrofitting brown steel and cement plants and buildings, and the need for fiscal support, these efforts should be focused on countries with relatively large cement and steel sectors and developed domestic financial markets. These efforts could be oriented towards some pilot projects to contribute to paving the way for further decarbonization in the longer term.

EXHIBIT 25

Fundraising by Green REITs Increased More Than Fortyfold in the Last Four Years

$ Billion



Notes: Fundraising refers to debt issuances only. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Environmental Finance

Policymakers' action is required to support the growth of green construction financial markets.

Policymakers can use a range of tools to mobilize domestic and international green finance in emerging markets. These measures include strengthening local

225 IFC staff calculations based on Environmental Finance and Bloomberg.

226 World Economic Forum (2021).

financial markets, carbon taxes and markets, fiscal incentives, building codes and regulations, as well as concessional and blended finance, among others. To date, the most popular tool used in emerging countries has been regulation, especially minimum energy performance standards, compared with high income countries that mainly resort to fiscal tools such as carbon taxes and incentives (Annex 2). Here, we analyze how these policy instruments can be used to channel more investments in building green in emerging markets, considering differences in fiscal resources, government capabilities, reliance on fossil fuels, and carbon intensity of materials, construction, and operation of buildings.

Green building codes and standards and other regulations as a tool for enticing domestic and international private finance into green construction.

Codes and energy-efficiency standards for materials and buildings can be effective mechanisms for attracting more green funding for construction value chains. Building codes and standards force developers and other participants to meet certain standards from the get-go, applying them to the design, construction, use, and maintenance of built structures. Minimum energy-efficiency standards include mandatory labeling and/or certification of energy performance for buildings and appliances. Universal green building codes can reduce the incremental costs of green building projects relative to standard buildings which previously came under no regulation.[227]

Governments can also increase investor appetite and spur innovation by requiring all publicly-owned buildings to meet certain green standards. This has a knock-on effect in terms of developing skills among designers, engineers, and workers—ensuring a growing technical capacity which can spill over into the private sector.[228] However, today only about 80 countries have mandatory or voluntary building energy codes at the national or subnational level, of which just over half, 43 countries, have mandatory codes at the national level for both residential and non-residential buildings.[229]

Codes can incentivize private investment by increasing the risk of stranded assets in portfolios that hold conventional buildings (making investments in green buildings more attractive by comparison).[230] Large fines for buildings that do not meet regulatory criteria can lessen underpricing of climate risk, reducing the risk-return portfolio of standard buildings. Other regulatory benefits for green building, like density bonuses (additional height allowances for eligible green buildings) and expedited permitting, can also make green building investments more attractive.

Against this backdrop, emerging markets tend to rely more on regulatory tools than fiscal tools to foster decarbonization in construction. Due to limited fiscal space, regulation is a popular tool among these governments (See Table 2.4 in Annex 2 for more details). However, in emerging markets where

227 IFC (2019a).

228 Steuer and Troger (2022).

229 IEA (2021).

230 IFC (2019a).

regulations such as building codes do exist, they may not be comprehensive or fully enforced. Weak institutional and enforcement capabilities, combined with high risk of corruption, may limit the effectiveness of these tools and increase the risk of greenwashing.

Strengthening domestic capital and financial markets for building green.

All over the world, private investments in construction, especially residential housing, are mainly funded by domestic financial institutions in local currency.[231] Volatile macroeconomic and political conditions, combined with weak regulatory and implementation capabilities, hamper the expansion and deepening of financial markets in many emerging economies.

In low-income countries, for instance, domestic credit to the private sector only amounts to about 13 percent of GDP compared to about 160 percent in high-income countries.[232] Similarly, stock market capitalization hovers around 80 percent of GDP in low- and middle-income countries, while it is about 170 percent in high-income economies on average.[233] Public financing or co-financing for construction also faces stiff restrictions in emerging markets. Government gross debt to GDP, for instance, only amounts to about 64 percent of GDP in low-income countries compared to more than 100 percent in advanced economies.[234]

Adopting policies geared toward improving the efficiency, transparency, and depth of local capital markets, through improved macroeconomic conditions, prudential regulations, and other measures, is thus necessary to unlock the capital required for building green, especially in the poorest and more unstable developing countries. [235]

Improving environmental, social, and governance (ESG) disclosure regulations.

In addition to strengthening local capital markets, governments can increase ESG reporting requirements, which can facilitate financing green construction. Regulations on environmental disclosure can improve transparency in the market for sustainable financing instruments, serving to reduce informational asymmetries. Currently, high screening costs due to greenwashing concerns can discourage investors and lead to inefficient allocation of capital, especially for carbon-intensive companies such as concrete and steel producers.

More standardized and comparable disclosure regulation can serve to improve the quality of ESG information that is reported and reduce screening costs for investors. This would allow financiers to better navigate around firms with substantial climate risk (for both financial and non-financial reasons), and instead allocate more capital to greener firms that

231 IFC (2019).

232 Aggregate figures sourced from the World Bank Open Data portal.

233 Aggregate figures sourced from the World Bank Open Data portal.

234 Government gross debt figures sourced from World Economic Outlook data portal.

235 See World Bank (2020) for a detailed policy discussion on capital market development.

will thrive in an increasingly sustainability-focused economic context.[236]

Improving these regulations should become a priority in all emerging markets. To foster the use of novel and sophisticated financial instruments for construction decarbonization like sustainability-linked finance, green equity funds, and more in the future, carbon retirement portfolios and transition bonds, middle-income as well as low-income economies should strengthen and expand the reach of their ESG disclosure regulations.

Emissions Trading Systems (ETS).

These systems can help mobilize domestic and foreign private capital to invest in green buildings and net-zero carbon materials in emerging countries. Emissions trading systems provide incentives to invest in green alternatives by pricing the social costs of emissions from brown construction activities.[237] The United Nations-run Clean Development Mechanism (CDM) is a system that certifies and regulates carbon credits generated in emerging countries. These credits are then allowed to be sold to high-income countries and firms that are regulated by emissions caps. The CDM has certified more than 12 million credits in green buildings, 23 million in net-zero carbon cement, 54 million in steel and iron, and about 40,000 in glass. Most of the cement and steel decarbonization projects originated in China and India.[238] Outside those countries, development finance institutions and government agencies from high-income countries should contribute to broaden the use of carbon credits for decarbonization projects in emerging markets through fiscal support -tax incentives or subsidies-, blended finance, and technical assistance, especially in lower middle- and low-income economies.

Emissions trading systems can generate government revenues that can co-finance piloting technologies for greening construction value chains that might be too risky for private investors. For instance, ArcelorMittal, the world's largest steelmaker, is using a combination of carbon offsets, funding from the EU Green Deal, and grants from the EU ETS Innovation Fund to finance investments in green technologies.[239] Similar programs could be used to foster piloting new technologies in emerging markets with support from development finance institutions, development government agencies of high-income economies or the EU.

The potential to implement emissions trading systems in emerging markets remains constrained by weak legal frameworks and implementation capabilities. Carbon pricing can increase consumer prices and impair the competitiveness of domestic producers, which further reduces the appetite for this tool in emerging economies.[240] Some solutions for making

236 Steuer and Troger (2022).

237 McKinsey & Company (2022).

238 IFC staff calculations based on CDM data from 2006–2022. Figures include all projects in the respective 'cement', 'steel & iron', and 'glass' categories as classified by the CDM UNFCC database, not only those specific to buildings. See methodology for detailed explanation.

239 The EU Innovation Fund raises revenue through the EU ETS and has been commissioned to provide funding to highly innovative low-carbon technologies (Greenovate Europe, 2019). The EU Green Deal is an economic plan aimed to help the EU reach carbon neutrality by 2050 and will be financed via the EU's seven-year budget and the Next Generation EU Recovery Plan (European Commission, 2019).

240 IFC (2019b).

EXHIBIT 26

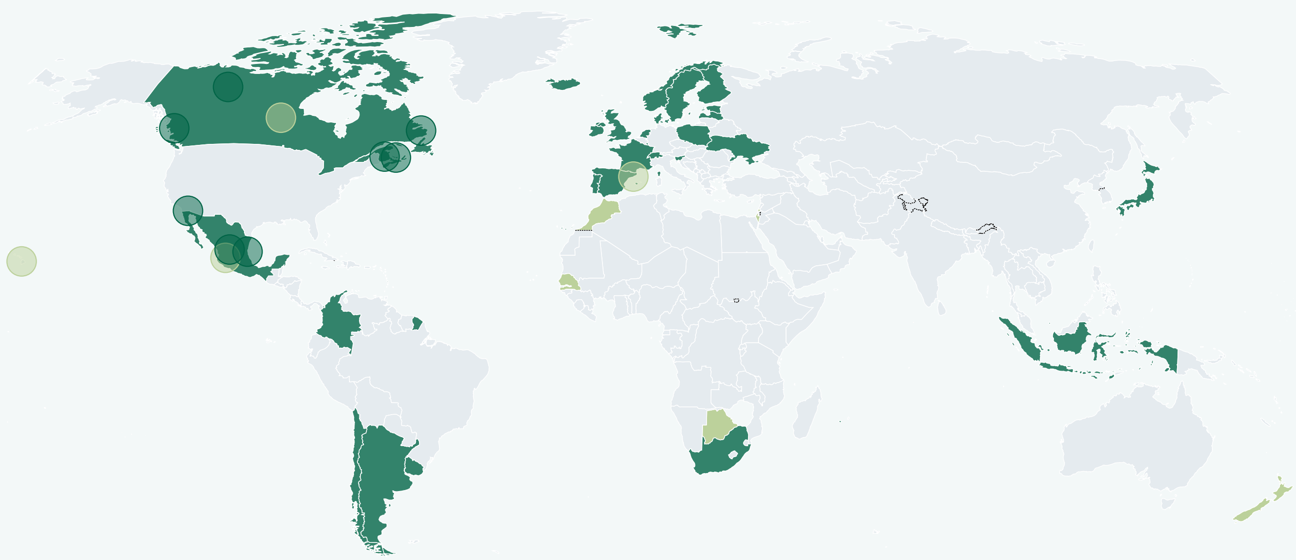
Carbon Taxes Have Been Introduced in Only a Few Emerging Markets

National and regional carbon tax systems

- under consideration
- implemented or scheduled for implementation

Subnational carbon tax systems

- under consideration
- implemented or scheduled for implementation



Source: World Bank Group Carbon Pricing Dashboard. Accessed July 2022.

carbon markets more attractive to policymakers may include using revenues for pro-poor policies.[241] Development finance institutions should help to mitigate these potentially adverse distributional effects through provision of financial and technical support. Because of these hurdles, only a few emerging markets have implemented emissions trading systems to date (Exhibit 27).

Using carbon taxes to promote green construction.[242]

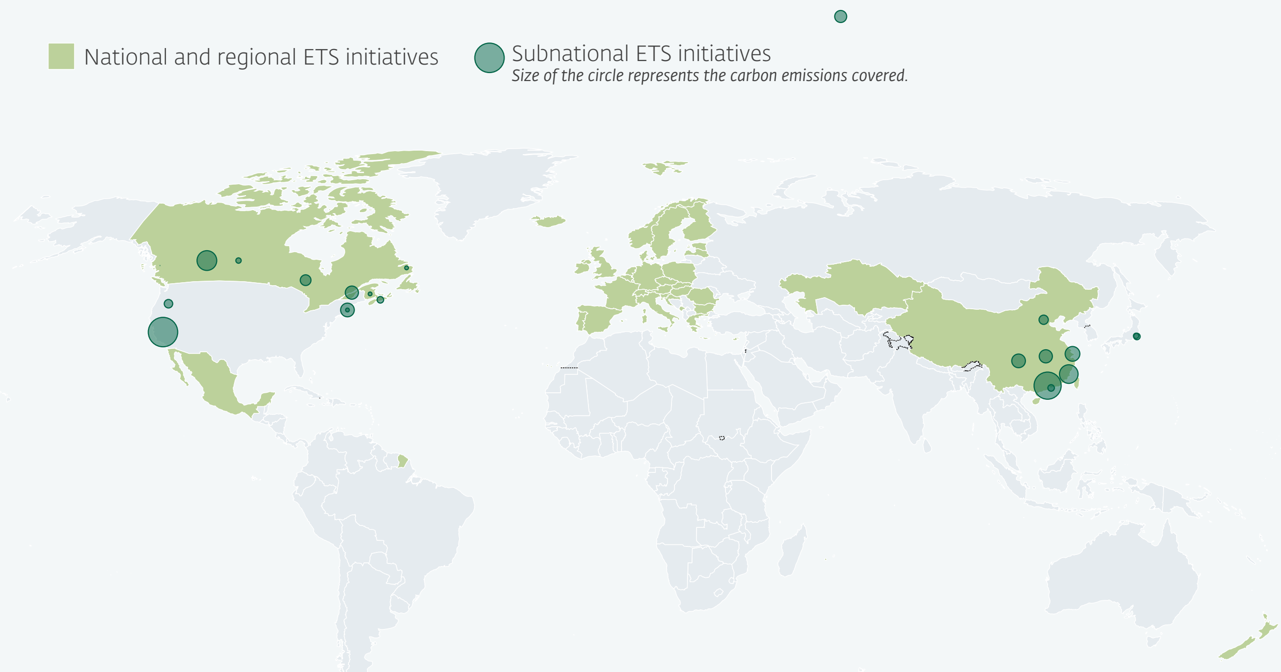
Carbon taxes can contribute to internalizing the social

241 IFC (2019b).

242 The analysis of potential risk of leakages of carbon pricing programs in steel given its high international tradability is beyond the scope of this report. Yet, available evidence from the European Union Trading System suggests there are no significant leakages stemming from these programs (Branger, Quirion, and Chevallier 2017).

EXHIBIT 27

Regional, National, and Subnational Emissions Trading System (ETS) Initiatives Implemented



Source: World Bank Group Carbon Pricing Dashboard. Accessed July 2022.

costs of brown construction in manufacturers and developers' prices, increasing the demand for greener alternatives. One of the key benefits of carbon taxes is that they generate revenues that can be used to compensate for their potential distributional effects. Carbon taxes are easier to implement than market-based carbon pricing systems and provide a clearer price signal to consumers and producers. These characteristics may make them better suited for middle-income countries. However, setting the right price is critical to maximize effectiveness and may require complex analysis. Another benefit of carbon taxes is that they can be increased gradually over time, allowing companies to adjust their cost structures gradually.

Carbon taxes can also be applied to different segments of construction value chains, from fossil fuels providers to builders and consumers, to encourage green

BOX 7

What Is Concessional and Blended Finance?

Concessional finance from development finance institutions can provide a range of below-market-rate financial products to the green building and green construction material sectors, correcting for some market failures. Concessional finance can include subsidized loans and grants, as well as guarantees and equity. While grants are usually one-time transfers of money with no expectation of repayment, subsidized loans are loans offered to firms at below-market-rate interest rates.

Concessional equity is an ownership stake in a company with return expectations below the market rate. This equity tool can be advantageous as it may provide credit-constrained buildings and building material firms with upfront funding and does not require recipients to make loan payments. This may be helpful for cash-strapped firms in low-profit margin, capital-intensive sectors like steel and cement, which require substantial capital upgrades to reduce emissions. This form of financing can also mitigate risk associated with senior debt—borrowed money that a company must repay first if it goes out of business—by improving coverage ratios and, unlike concessional senior debt, it does not crowd out private bank participation.

Concessional guarantees and risk-sharing facilities transfer all or part of the financial risk of a loan to the guarantor, with fees charged at below-market rates (e.g., first-loss guarantees, partial credit guarantees). While this tool does not solve the liquidity constraints of green building developers and commercial bank lenders, it can directly address the underlying portfolio risks and uncertainties around the future value of green projects, particularly innovative ones, and hence help to unlock private capital. Additionally, it can also address the issue of currency risk for local currency financing in emerging markets.

Blended finance utilizes limited pools of concessional funds to mobilize larger sums of private sector financing toward development goals, often with climate-related objectives. The concessional component can be used to increase the commercial viability of projects via risk mitigation and improvement of the risk-return profile of cutting-edge investments. The donor elements of these transactions tend to be structured as co-investments (primarily as debt, but also as equity, risk-sharing, or guarantee products) with expectation of reflows for future investments or other uses. Blended finance can provide more impact per dollar than pure concessional financing, as a relatively small amount of concessional funds can unlock substantial amounts of private capital. This also means there is less risk of misallocation of capital compared to standard grants and subsidies.

construction.[243] In principle, carbon taxes should be targeting those segments with the highest abatement potential. For instance, taxing construction materials could become relatively more important than taxing building use-related activities in the next decades as the power industry decarbonizes and buildings increasingly rely on electricity in their operations.[244] Taxing consumers or producers would depend, in

243 IFC (2019).

244 IFC (2019).

turn, on the potential distributional implications and political feasibility, especially in lower middle- and low-income countries.

Alternatively, carbon taxes could be applied to the entirety of construction projects to spread out their costs over the entire value chain instead of on a particular set of stakeholders. Carbon taxes are mainly used today for the raw materials and manufacturing of building products as well as the repair, replacement and refurbishment of buildings, and operational stages.

The results of the simulations employing the model described in Box 2 presented in Section 1.3. suggest, however, that direct taxation of brown buildings and materials now could have significant negative impacts on economic growth in the short-to-medium-term, especially in emerging markets, at least until the technologies with the highest abatement potential become commercially available by 2035.

As of 2022, there were 36 carbon pricing initiatives implemented, covering 28 national jurisdictions, and regulating approximately 6 percent of total global greenhouse gas emissions. These include not only national programs, but also eight subnational systems (which are mostly located in North America). An additional eight carbon tax initiatives are underway, in emerging markets such as Botswana, Indonesia, Morocco, and Senegal (Exhibit 26). While carbon tax programs appear to be extending to new regions, they are becoming a relatively smaller piece of the equation as other carbon-pricing mechanisms gain in popularity. For example, 2021 was the first year in which revenues from emissions trading systems surpassed those from carbon taxes.[245]

Fiscal support for decarbonizing and decommissioning materials plants and funding low-income green residential housing.

Subsidies (e.g., grants, below-market-rate loans, and direct transfers) and tax incentives (e.g., tax breaks) are commonly used policies to finance construction decarbonization, especially in developed economies (Annex 3). Given the risks associated with such measures, for example subsidies where the desired result is not effectively monitored or would have occurred in the absence of support, there is a need for more empirical evidence on the effectiveness and efficiency of such tools, particularly in comparison to regulatory approaches.

Yet, following the example of the United States and the European Union with carbon-powered facilities,[246] fiscal support will likely be needed to decommission or decarbonize brown cement and steel plants. Given the high costs of decommissioning or retrofitting stranded material plants, this lever will most likely remain a longer-term priority for most emerging markets. Fiscal incentives will also be required to incentivize construction of green residential housing targeted to low-income households that might not be available in fiscally constrained economies without international support.

245 World Bank (2022).

246 See IEA (2021).

Green Banks.

Green banks can play a role in mobilizing domestic and international finance for small-scale green building projects. These types of banks, often funded by national or subnational governments, specialize in providing mission-driven green financial products that may not otherwise be widely available on the market. Products include green construction loans, mortgages, and first loss guarantees. However, two-thirds of green banks are in high-income countries. Expansion of green banks in emerging markets is limited by the availability of finance, technical capacity, and political and regulatory factors.41 Nonetheless, these entities are becoming more popular and currently exist in India, Malaysia, and South Africa.

Development finance institutions.

Development finance institutions can play a critical role in mobilizing local and international private capital toward green construction, serving as an anchor investor, providing market-rate and concessional financing, and operationalizing supranational climate funds. For green buildings specifically, IFC invested and mobilized nearly $4.4 billion from 2014 to 2019.[247] According to IFC client survey data, loan disbursements for green building projects have grown from only $226,000 in 2015 to reach a high of approximately $495 million in 2019.[248]

Concessional and blended finance can be particularly effective in channeling funding to financial

BOX 8

IFC Experience in Promoting Green Buildings Using Concessional and Blended Finance

Since 2018, IFC has funded green construction projects in Latin America, Sub-Saharan Africa, Middle East and North Africa, South Asia, and East Asia for $15.4 million using concessional and blended finance through the Market Accelerator for Green Construction (MAGC) program. Co-funded with the United Kingdom's Department for Business, Energy & Industrial Strategy (BEIS), MAGC seeks to boost the uptake of greener practices and technologies focused on developing countries' construction markets through four main components: (a) firm-level technical assistance and blended finance to financial institutions; (b) country-level capacity building; (c) IFC's EDGE certification platform, maintenance, operations and improvements; and (d) Green building performance report and dissemination.

About 60 percent of MAGC's funds has gone to developers to afford the extra costs of green buildings, and the remaining financing to support green mortgages through private financial institutions. For instance, IFC provided blended finance and technical support to help open the green home market in South Africa in 2017. IFC invested $21 million in a $300 million fund managed by a large equity investor in South Africa's affordable housing sector, called HIS. Of the total $21 million investment, $10 million was funneled to the HIS through a concessional equity investment using donor funds from the Global Environmental Fund.

247 Figure is referenced from IFC EDGE 'Creating Markets: IFC's Green Buildings Market Transformation Program'.

248 IFC calculation based on IFC Climate Assessment for Financial Institutions Database. Coverage is limited as client survey response rate is approximately 70 percent. See Annex 3 for more details.

institutions looking to expand their green building and construction materials' portfolio, addressing liquidity constraints and funding bottlenecks. The concessional component of blended finance is often supported by bilateral or multilateral climate funds. Similarly, bilateral, and multilateral funds could support blended and concessional finance to support construction decarbonization in low-income and fragile countries. Box 7 explains what concessional and blended finance is.

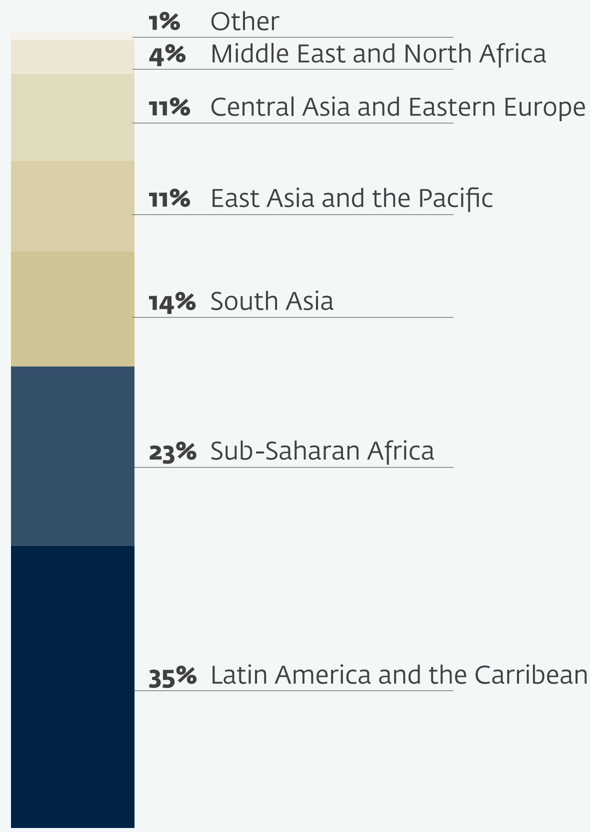
Concessional and blended funds have become an important source of climate finance for emerging markets. In 2020, multilateral climate funds issued $1.79 billion in grants and $1.39 billion in low-cost project debt for climate finance, including green buildings. Development Finance Institutions provided $3.06 billion in grants and $16.81 billion in low-cost project finance. Box 8 illustrates the recent experience of IFC in fostering green construction in emerging markets through concessional and blended finance.

Bilateral and multilateral institutions are also key contributors of low-cost project debt, while governments provide substantial climate finance through grants. The bulk of low-cost funds issued by development finance institutions using concessional and blended finance went to Latin America and the Caribbean, and Sub-Saharan Africa (Exhibit 28).

More co-financing with the private sector will be needed from development finance institutions in the next decade to reduce carbon emissions in construction value chains, especially in hard-to-abate and carbon-intensive construction materials. Since 2017, development finance institutions for instance, have raised about $16 billion for green buildings in

EXHIBIT 28

Latin America and the Caribbean and Sub-Saharan Africa Receive About Half of Concessional and Blended Finance



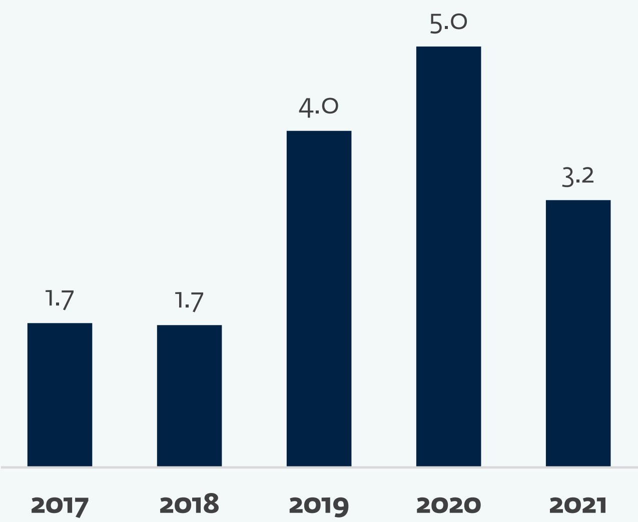
Notes: 'DFIs' include multilateral, bilateral, and national DFIs. 'Other' (1 percent) includes Transregional and Western Europe. Western Europe debt is composed solely of national DFI issuance. No detailed data on concessional and blended funds for green buildings is available. Figures in the text might not be identical due to rounding.

Source: Climate Policy Initiative, Global Landscape of Climate Finance 2021.

EXHIBIT 29

Multilateral Development Banks Raised About $16 Billion in Bonds Supporting Building Green in Emerging Markets in 2017–2022

$ Billion



Notes: Includes all green, sustainability-linked, and sustainability bonds used for green building issued by the following multilateral development banks: ADB, EBRD, European Investment Bank, IADB, IBRD, IFC, Nordic Investment Bank, West African Development Bank. See Annex 3. Figures in the text might not be identical due to rounding.

Source: IFC staff calculations based on Environmental Finance (2022).

emerging markets through sustainability bonds (Exhibit 29).

Blended finance will also be required to support ongoing efforts for the development of novel technologies with high abatement potential like green hydrogen. The World Bank, for instance, recently approved a $150 million loan that establishes a blended finance fund and risk mitigation instruments to accelerate green hydrogen projects in Chile. The project will also provide technical assistance, including capacity building—regulations, certification processing and enabling environment—and boosting local demand. IFC is also currently supporting the pre-investment stages of green hydrogen projects. IFC projects these could mobilize more than $2 billion in private investments in Chile.[249]

249 See World Bank: https://worldbankgroup.sharepoint.com/sites/news/pages/Betting-on-Green-Hydrogen-for-Sustainable-Growth--17072023-120542.aspx

CHAPTER 5:

Ways Forward

The findings of this report indicate that limiting the global rise in temperatures to well below 2 degrees Celsius, and thus avoiding the worst effects of climate change, as committed in the Paris Agreement, will not be possible without a substantial reduction in emissions from the construction sector in the next decade.

Achieving that goal will require the integration of existing and novel abatement technologies into construction value chains. Some of the critical technologies for reducing construction emissions are commercially feasible today, while others are likely to come on stream over the next few years. But the challenge of greening construction value chains goes well beyond the availability of technologies.

In the long term, the major issue is that the financial return on green activities is too low, because it does not reflect the benefits to society of providing a product or service with lower emissions. As green production technologies tend to be more expensive than brown alternatives (in the absence of carbon prices or their equivalents), companies wishing to build green may find it difficult to compete with companies that are less concerned with their carbon footprint. They may also face difficulties in attracting investors. Given the higher market prices of green goods and services, consumers also lack incentives for substituting brown products with green products. Other market failures related to the availability of information, as well as screening and monitoring costs, further restrict domestic and international private finance for green construction investments.

These market failures compound the problems stemming from the decentralized market structure, informational asymmetries, lack of specialized skills, resources, and scale, and fragmented and rigid regulations of construction value chains in emerging markets. Absent or weakly enforced green codes and standards and insufficient public awareness efforts reduce the incentives of environmentally minded households and companies for buying or renting green buildings. The lack of regulations and standards certifying the carbon content of construction materials also hampers the use of net zero materials in new buildings by developers. Rigid construction regulations also limit the use of alternative materials and non-fossil fuels to produce cement and steel with lower emissions. Construction services are also often dominated by small and medium-sized companies with limited resources and adequately skilled workers to adopt environmentally friendly materials and sustainable construction techniques and practices, especially in low-income countries but also in some fast growth middle-income economies.

Achieving the needed reduction in emissions from construction value chains will therefore require urgent efforts by policymakers to address these market failures in construction value chains and green financial markets. At least in developing countries with adequate capabilities, governments will also need to ensure that construction companies and materials producers absorb the social cost of their operations and can earn an adequate return by choosing green, and that consumers switch consumption from brown to green construction products and services.

The findings of this report emphasize the need for policymakers to take decisive steps toward establishing the appropriate business, policy, and regulatory frameworks that will facilitate the green construction transition. This framework will be pivotal to mobilize domestic and international investments toward net-zero buildings and materials in emerging markets in the next decade. The report also emphasizes the need to focus policy efforts on promoting the adoption of readily available technologies with moderate economic costs until the technologies with the highest abatement potential, but prohibitive costs today, like green hydrogen and carbon storage, become available by 2035 and beyond.

The report also stresses the need for an integral strategy to decarbonizing construction value chains that considers the interaction between the segments of the value chain, other sectors, and technological changes, and that seeks to minimize costs to economic output. This strategy will also require careful sequencing of mitigation and adaptation actions and technologies, adapted to the specific conditions of each country, and from a long-term perspective.

Under supportive policy frameworks, early action can be taken at relatively low costs and with significant reductions in construction emissions by deploying readily available technologies for electrifying brown buildings, improving the energy efficiency of new and existing buildings and plants, and integrating cleaner energies and raw materials. Supporting the development and piloting of new technologies with high abatement potential, like green hydrogen and carbon storage, is also feasible in the next decade but with fiscal support that it is unlikely to be attainable for most emerging markets. The gradual deployment of carbon pricing programs should also pave the way for net zero construction by 2050.

This integral strategy should also contemplate the interaction between technologies with differing costs and time horizons. Electrification of brown buildings with renewable energies will require investments in new transmission lines, energy storage, and energy efficient cooking, heating, and cooling appliances, and systems. New buildings with improved energy and thermal efficiency and powered with cleaner energies, or net zero buildings, will also require similar investments and the gradual decarbonization of materials and construction services. Deploying biomass-derived fuels measures will also interact with the deployment of non-commercially available technologies today, like carbon storage and capture.

This report suggests a wide range of policies that governments in emerging markets can undertake to encourage green construction. These include regulatory policies, namely green codes and standards that require companies to adopt practices that limit their carbon emissions. They also include measures to promote contributions to green construction activities from the financial markets, reducing market failures that limit private domestic and international investment and establishing the appropriate financing infrastructure to encourage green financial instruments. Other policies outlined in the report include promotion by governments of green construction through their own building operations and fiscal support for the decommissioning of stranded brown materials plants as well as the construction of green residential housing for low-income households. The report also highlights the establishment of frameworks that impose quantitative limits on, or increase taxes on, firms' emissions.

How and when policymakers deploy these measures will vary depending on country conditions, available fiscal and financial resources, and technological and policy readiness. For most middle-income countries, the focus over the next decade is likely to be on actions with moderate economic costs and policy efforts, like green codes and standards, green public buildings, and green construction procurement, and on mobilizing green private finance into net zero buildings and materials. High-income economies and possibly some upper-middle-income countries with sufficient fiscal space and adequate regulatory capacity may be able to move faster, deploying relatively costlier policies like carbon pricing programs, stringent environmental regulations, and providing fiscal support to technologies with high abatement potential but that are non-commercially available today, like green hydrogen and carbon storage. Low-income countries could begin walking the path towards green construction now with international financial and technical support.

Development finance institutions can play an important role by providing resources, particularly at concessional terms with focus on low-income economies. They could also mobilize greater private sector investment by promoting the adoption of innovative green financial tools and adequate regulations, especially in middle-income countries with well-developed domestic financial markets. Here, we summarize the main recommendations of the report.

Regulation and Standards.

Supporting and strengthening green construction regulations and standards would be the option of choice for most emerging markets. With adequate technical and financial support, middle-income and some low-income countries could accelerate the pace of green construction in the next decade with moderate economic costs and policy efforts through these policy tools.

Governments can adopt green building codes that govern the design, construction, use, and maintenance of built structures. Minimum energy-efficiency standards can be imposed, supported by mandatory labeling and/or certification of energy performance. Additional height allowances and expedited permitting for eligible green buildings can reduce incremental capital costs for private builders at minimal or zero fiscal costs.

Effective green building codes, enforced by substantial fines for noncompliance, can improve the competitiveness of green construction. Regulations, particularly minimum energy performance standards, are more commonly used in emerging markets to support green construction than fiscal tools are. However, many emerging markets with such regulatory practices need to strengthen their institutional and enforcement capabilities to ensure the effectiveness of such standards.

Other regulations can be modified to increase the feasibility of green construction. For example, easing stringent local cement regulations, while ensuring consumers' safety, could encourage piloting and adopting natural and industrial clinker substitutes, especially in middle-income countries. And regulation of the waste management value chain can promote the use of waste as an energy source. These measures have negligible fiscal costs and therefore could be widely adopted in many emerging markets with financial and technical support from development finance institutions.

Financial Markets.

Financial innovation is important to channel the financial resources needed for the massive investments in green construction required over the next decades. Particularly in the poorest countries, improving the efficiency, transparency, and complexity of local financial markets through improved macroeconomic conditions and prudential regulations is critical for an expansion of finance for green construction. Establishing more reliable and standardized environmental disclosure regulations could reduce the high screening costs of green buildings and materials projects, particularly in emerging markets, that make it difficult to attract investment in green construction. Thus, efforts to strengthen governance and regulatory frameworks, particularly environmental, social, and governance disclosure by private firms, and to improve technical capabilities for issuing and regulating green financial instruments would help channel greater financing to green construction.

The financial industry can also play a role in improving standards, for example through publishing green finance guidelines, providing third-party environmental audits, suggesting harmonized environmental frameworks, and promoting the use of ESG rating providers. Such information can encourage green construction and help mobilize finance by enhancing transparency, reporting, and monitoring of sustainability impacts in linked finance, transition bonds, and carbon retirement portfolios.

Government Buildings and Procurement.

Governments have a large carbon footprint, and changes in their own operations can make a significant contribution to green construction. Requiring that all publicly owned buildings meet certain green standards would directly reduce emissions; encourage innovation in green construction; increase the economy-wide supply of designers, engineers, and craftsmen with knowledge of green building techniques; and (if done well) provide examples that could encourage imitation by private sector firms. Greening public procurement in construction can also help foster the demand for green buildings and materials from private companies and consumers.

Carbon Taxes and Emissions Caps.

Taxing carbon emissions so that prices fully reflect their environmental costs, or imposing limits on firms' or regions' carbon emissions (in conjunction with programs to allow the trading of emissions rights) provide an economic incentive to companies to green their production and induce consumers to switch from brown to green products. However, while the bulk of emissions over the next decade are expected to be generated by emerging markets, only seven have implemented carbon pricing initiatives, with additional carbon tax initiatives underway in eight emerging markets. Only three emerging market governments have established mandatory emissions trading systems.

The potential to implement emissions trading systems in emerging markets could be improved by strengthening legal frameworks that are not adequate to establish reliable carbon markets, and by improving the implementation capabilities of the government agencies involved. There is also a concern that imposing higher energy prices would impair the competitiveness of domestic producers in industries exposed to international competition. This issue underlines the importance of international coordination of carbon pricing and emissions caps.

Carbon taxes can be a useful alternative to emissions trading, particularly in low- and middle-income countries, because they generate revenues that can be used to compensate for their potential distributional effects, are easier to implement than market-based carbon pricing, provide a clearer price signal to consumers and producers, and can be increased gradually over time to allow firms time to adjust. However, setting the right tax rate is critical to maximize effectiveness and may require complex analysis. Carbon taxes could be targeted to segments of the value chain with the highest abatement potential (for example, increasing reliance on taxation of construction materials as their importance in emissions increases relative to building operations over the next decade).

Fiscal Support.

Subsidies (e.g., grants, below-market-rate loans, and direct transfers) and tax incentives are commonly used policies to finance construction decarbonization, especially in developed countries, and some large developing economies. Following the example of the United States and European countries with carbon-powered facilities, fiscal support will be needed to encourage decommissioning of stranded brown plants, and construction of green residential housing targeted to low-income households. Along with these incentives, policymakers will also need to encourage the development and adoption of innovative financial instruments, such as carbon transition bonds and carbon retirement portfolios, for decarbonizing or decommissioning brown plants.

Given the risk of ineffective fiscal programs, for example subsidies where the desired result is not effectively monitored or would have occurred in the absence of support, there is a need for more empirical evidence on the effectiveness and efficiency of such tools, particularly in comparison to regulatory or carbon pricing approaches.

Development Finance Institutions.

Development finance institutions can also make an important contribution to mobilizing local and international private capital for green construction. Their potential roles include serving as an anchor investor, providing market-rate and concessional financing, and operationalizing supranational climate funds. Concessional and blended finance can be used to increase funding for financial institutions looking to expand their green building and construction materials portfolio, addressing liquidity constraints and funding bottlenecks.

Other areas where development finance institution support could be particularly useful include the construction of affordable green housing, the retrofitting of buildings, new and retrofitted low-emission cement and steel plants, and piloting new decarbonization technologies. Increasing the availability of finance for these activities could encourage greater investments by venture capital funds in technological innovations for greening construction value chains. Carbon retirement portfolios may also require incentives to become operational. Finally, co-financing with private-sector financiers will be an essential tool over the next decade to reduce emissions in construction value chains, especially in hard-to-abate and carbon-intensive construction materials.

ANNEXES

Annex 1:
The General Equilibrium—Circular Economy (CGE-CE) Model

IFC has partnered with Global Trade Analysis Project (GTAP)-Purdue University who developed for this report a computable general equilibrium – circular economy (CGE-CE) model. CGE-CE aggregates information on national accounts, balance of payments, and input-output matrices in a consistent representation of the dynamic inter-dependencies across sectors, agents, and markets.

To analyze the effects of economic and population growth and alternative mitigation policies on emissions and other environmental indicators, the CGE-CE model incorporates an explicit representation of production technologies (e.g. primary, secondary, and recycling activities) and materials (e.g. steel, cement, glass, fossil fuels, minerals, among others). By capturing changes in both supply and demand, the model simulates adjustments in the economy following the implementation of a policy shock.

For the report, a new database was developed covering 141 countries and 98 sectors. The database also incorporates detailed information on the share of green buildings and production of low-emission material by country. Information from IFC projects on detailed cost structures of abatement costs for cement and other materials as well as incremental capital costs of green buildings relative to conventional alternatives was also included.

The database was coupled with the global recursive-dynamic CGE model ENVISAGE for the 2022–2035 period. The model nests energy demand in the simulations, assuming energy preferences are agent-specific and providing a representation of alternative generation technologies. The model also assumes preference shifts and technological changes over time relating to decreasing cost of renewables; increasing preferences toward renewable energy; increasing electrification rates; increasing share of services; energy efficiency improvements; and increasing energy efficiency of new green buildings. Finally, the model incorporates the following dynamics: exogenous labor growth; capital growth (as a function of savings); and exogenous land, energy, and trade productivity. The model also assumes trajectories for carbon prices varying by country and region (Table 1.2.).

TABLE 1.1

Details the New Sectors That Were Developed for the Report

	GTAP	New sector	Description
1	oxt	nmn	Non-metallic minerals mining
2		mio	Mining of iron ores
3		mao	Mining of aluminum ores
4		mco	Mining of copper ores
5		moo	Mining of other ores
6	rpp	rbr	Rubber products
7		plp	Plastic products – primary
8		pls	Plastic products – secondary
9		plr	Recycling - plastics
10	nmm	cmc	Cement conventional
11		cmg	Cement 'green'
12		nmx	Other mineral products
13	i_s	isp	Iron and steel – primary
14		iss	Iron and steel – secondary
15		ris	Recycling - iron and steel
16		isc	Iron and steel casting
17	nfm	app	Aluminum – primary
18		aps	Aluminum – secondary
19		ral	Recycling - aluminum
20		cpp	Copper – primary
21		cps	Copper – secondary
22		rcp	Recycling - copper
23		mpp	Other metals – primary
24		mps	Other metals – secondary
25		rom	Recycling - other metals
26		nfc	Non-ferrous metals casting
27	cns	cnc	Construction conventional
28		cng	Construction 'green'

Source: IFC staff calculations based on Global Trade Analysis Project

The CGE-model simulated four scenarios: a) no mitigation, which assumes continuation of the current climate policies without additional mitigation measures; b) NDC, which assumes countries comply with their Nationally Determined Contributions (NDCs); c) energy efficiency, that includes compliance with the NDCs, and electrification of brown buildings with cleaner energies and decarbonization of construction materials and new buildings with non-fossil fuels and improved energy efficiency; and d) 'net-zero-aligned', that includes compliance with NDCs, and direct taxation of brown buildings and materials and subsidies to green alternatives.

Two additional policy scenarios simulating alternative revenue recycling programs carbon taxes were carried out as a sensitivity check without significant changes relative to the main scenarios (b) and (b) and therefore those scenarios are not reported: reducing labor taxes and boosting investment in green construction activities.

Investment needs were calculated as the difference between the investment in electrification with non-fossil fuels and improvements in energy efficiency in existing and new buildings in the no mitigation scenario and the energy efficiency scenario. Investment needs were similarly calculated as the difference between investment in new green buildings and materials in the no mitigation scenario and the net zero-aligned scenario.

The global scenarios simulated for this report align with the Climate Action Tracker (CAT) pathways, the main reference for climate-related simulations using similar CGE models to ENVISAGE employed here.[250] CAT quantifies and evaluates climate change mitigation targets, policies, and actions. It also aggregates country action to the global level, determining likely temperature increases during the 21st century using the MAGICC climate model.

This global pathway of CAT is then used as input to a reduced-complexity carbon-cycle / climate model (MAGICC7) which is calibrated against data from complex general circulation models (GCMs), including climate sensitivity and carbon cycle information. The MAGICC emulations reflect the complex model response ranges for the assessed scenarios in the calibration datasets, in particular the Representative Concentration Pathways (RCPs). MAGICC7 is run multiple times to obtain a probability distribution of outcomes such as global mean temperature, CO_2 concentration, and total greenhouse gas concentration. These distributions are used for deriving the central median estimate of e.g. the global mean warming in 2100 and corresponding temperature exceedance likelihoods over the 21st century.

250 For more information on CAT, see: https://climateactiontracker.org/

TABLE 1.2

Assumed Carbon Prices, $/Ton of CO_2

Country/region	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
EU-27+EFTA	69	82	95	107	120	132	145	157	162	167	172	177	182
Rest of OECD	23.2	28.6	33.9	39.3	44.7	50	55.4	60.7	63.7	66.9	70.3	73.8	77.5
High-income Asia	3.9	9.2	14.5	19.7	25	30.7	36.5	42.2	44.3	46.5	48.9	51.3	53.9
Japan	3.9	9.2	14.5	19.7	25	30.7	36.5	42.2	44.3	46.5	48.9	51.3	53.9
China	9.5	10.5	11.6	12.9	14.3	15.8	17.5	19.3	20.3	21.3	22.3	23.5	24.6
Middle East and North Africa	3.1	5.6	8.1	10.5	13	15.1	17.1	19.2	20.2	21.2	22.2	23.3	24.5
United States	2.2	4.4	6.6	8.7	10.9	13	15.1	17.2	18.1	19	19.9	20.9	22
Brazil	1.9	3.7	5.5	7.4	9.2	10.9	12.6	14.3	15	15.8	16.6	17.4	18.3
Rest of Latin America and Caribbean	1.9	3.7	5.5	7.4	9.2	10.9	12.6	14.3	15	15.8	16.6	17.4	18.3
Europe and Central Asia	1.3	2.7	4.1	5.5	6.9	8.3	9.7	11.1	11.7	12.2	12.8	13.5	14.2
India	1.4	2.4	3.4	4.5	5.5	6.4	7.3	8.2	8.6	9	9.5	10	10.5
Indonesia	1.4	2.4	3.4	4.5	5.5	6.4	7.3	8.2	8.6	9	9.5	10	10.5
Low-income Asia and the Americas	1.4	2.4	3.4	4.5	5.5	6.4	7.3	8.2	8.6	9	9.5	10	10.5
Rest of Southeast Asia and Pacific	1.4	2.4	3.4	4.5	5.5	6.4	7.3	8.2	8.6	9	9.5	10	10.5
Sub-Saharan Africa	0.6	1.1	1.6	2	2.5	2.9	3.3	3.7	3.9	4.1	4.3	4.5	4.7

Source: IFC staff calculations based on Global Trade Analysis Project

Annex 2:
Supplementary Tables and Figures

TABLE 2.1

Cement Output by Country and Region, 2022

Percent of Total

		Global Output	Regional Output
China	China	61%	100%
High Income	EU-27+EFTA	4.9%	42.3%
	United States	2%	17.5%
	Japan	1.8%	15.5%
	High-income Asia	1.7%	14.7%
	Rest of OECD	1.1%	10%
Other Emerging Markets	India	6.9%	26.7%
	Middle East and North Africa	4.8%	18.6%
	Rest of Southeast Asia and Pacific	3.8%	14.5%
	Europe and Central Asia	3.6%	14%
	Rest of Latin America & Caribbean	3.1%	11.8%
	Indonesia	1.4%	5.5%
	Brazil	1.5%	5.8%
	Low-income Asia and the Americas	0.8%	3.2%
Sub-Saharan Africa	Ethiopia	0.5%	32.5%
	Nigeria	0.3%	20.6%
	Rest of Sub-Saharan Africa	0.4%	26%
	South Africa	0.3%	21%

Source: IFC based on Global Trade Analysis Project, GCCA, IEA and other sources. Only the largest countries measured by GDP are reported for each region.

TABLE 2.2

Steel Output by Country and Region, 2022

Percent of Total

		Global Output	Regional Output
China	China	54%	100%
High Income	EU-27+EFTA	9.3%	28.1%
	United States	5.1%	15.4%
	High-income Asia	6.4%	19.3%
	Japan	10%	30.2%
	Rest of OECD	2.3%	6.9%
Other Emerging Markets	Middle East and North Africa	1.6%	13%
	India	2.7%	22.2%
	Europe and Central Asia	3.6%	29.5%
	Rest of Latin America and the Caribbean	1.3%	10.3%
	Rest of Southeast Asia and Pacific	0.8%	6.8%
	Brazil	1.7%	13.8%
	Indonesia	0.3%	2.1%
	Low-income Asia and the Americas	0.3%	2.4%
Sub-Saharan Africa	Ethiopia	0.3%	38.4%
	Nigeria	0.1%	11.7%
	Rest of Sub-Saharan Africa	0.2%	28.4%
	South Africa	0.2%	21.48%

Source: IFC based on Global Trade Analysis Project, GCCA, IEA and other sources. Only the largest countries measured by GDP are reported for each region.

TABLE 2.3

Simulated Trajectory of Construction-Related Emissions by Country and Region in the No-Mitigation Scenario

Millions of CO_2 Equivalent Tons

		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
China	China	6,069	6,240	6,411	6,467	6,524	6,612	6,701	6,738	6,775	6,762	6,748	6,740	6,731	6,735
High Income	EU-27+EFTA	936	903	871	849	826	808	789	773	757	752	747	742	738	734
	High-income Asia	427	434	442	452	462	471	480	490	499	508	517	527	536	545
	Japan	491	491	491	493	495	497	499	500	502	503	504	505	506	507
	United States	2,262	2,284	2,305	2,330	2,356	2,386	2,416	2,446	2,476	2,504	2,532	2,558	2,584	2,611
	Rest of OECD	547	548	550	555	561	567	573	580	586	593	601	609	617	626
Other Emerging Markets	Brazil	111	112	113	117	122	123	125	127	128	130	131	133	134	136
	Europe and Central Asia	1,058	1,060	1,061	1,066	1,070	1,083	1,095	1,105	1,114	1,123	1,131	1,138	1,145	1,150
	Indonesia	218	224	230	231	232	235	239	242	245	248	250	254	257	260
	India	927	967	1,008	1,015	1,021	1,037	1,053	1,065	1,077	1,088	1,099	1,109	1,119	1,129
	Low-income Asia and the Americas	117	121	125	126	128	130	131	133	134	135	136	137	138	139
	Middle East and North Africa	861	869	877	890	903	920	937	953	970	984	999	1,012	1,026	1,039
	Rest of Latin America and the Caribbean	349	352	356	371	386	395	403	412	421	431	441	451	460	468
	Rest of Southeast Asia and the Pacific	404	415	427	430	434	439	444	448	451	454	457	460	463	467
Sub-Saharan Africa	Sub-Saharan Africa	244	250	255	270	284	294	305	317	328	341	354	368	382	396

Source: IFC based on Global Trade Analysis Project, GCCA, IEA and other sources. Only the largest countries measured by GDP are reported for each region.

TABLE 2.4

Construction Decarbonization and Potential Finance Providers and Instruments

	Energy Efficiency	
Segment of Construction Value Chain	Buildings	Materials
Type of Technologies and Examples	Energy efficient lighting and air conditioning, reflective paint, air sealing, building envelope design	Waste heat recovery systems, improving furnace-basic oxygen furnace (BF-BOF) efficiency, optimizing thermal efficiency in cement kilns
Type of Providers	Private capital, DFIs, public finance	Private capital, DFIs, public finance[251]
Type of Instruments	Debt (e.g., green mortgages, green bonds and loans, sustainability-linked bonds and loans, transition bonds)[252] and equity (e.g., green REITS), off-balance sheet (via energy service contracts or leasing), tax incentives[253]	Debt (e.g., green bonds and loans, sustainability-linked bonds and loans, transition bonds) and equity, off-balance sheet financing (via energy service contracts or leasing[254]), tax and subsidy-based incentives, grants
Origin of Financial Provider	Primarily domestic	Domestic and international
Examples of Potential Providers	U.K.-IFC Market Accelerator for Green Construction, Bancolombia Green Mortgage Program, Infonavit Green Mortgage Program, Kimco Realty (green REIT)	The EBRD's Green Transition Bonds (allocated through its Green Transition Portfolio), U.K. Department of Business, Energy & Industrial Strategy (BEIS)[255]
Examples of Projects	The Infonavit Green Mortgage Program in Mexico provides households seeking mortgages for green homes an additional credit on top of their standard mortgage, which can be used to cover the cost of eco-friendly technology upgrades (i.e., roof insulation, energy-saving lamps, solar water heaters). Sixty percent of mortgage customers are low-income[256]	In 2019, IFC provided both debt and equity investments to NCCL, Kenya's largest cement producer. These investments have helped NCCL to increase its energy efficiency through utilizing a lower clinker-to-cement production ratio and a waste heat recovery plant—the first of its kind in East Africa. In 2019, the EBRD issued a transition bond and allocated funds toward its Green Transition Portfolio, which includes efficiency in cement and steel manufacturing and buildings renovation

251 For example, the UK Department of Business, Energy & Industrial Strategy (BEIS) announced up to 18 million pounds of grant funding to support industrial heat recovery projects.

252 In 2019, the EBRD issued a transition bond, allocating funds towards its 'Green Transition Portfolio', which includes buildings renovation (IEA, 2021).

253 For example, the U.S. government provides federal income tax credits for energy-efficient new homes, as well as home and commercial building upgrades.

254 IEA (2021).

255 BEIS (2020).

256 Word Habitat Awards, Mexico 2012 Winner.

	Alternative Fuels	
Segment of Construction Value Chain	Buildings	Materials
Type of Technologies and Examples	Substitution of clinker in cement-making (i.e., clinker free cement), use of construction & demolition waste to replace aggregates in concrete, scrap based EAF steelmaking	Use of biomass in integrated steelmaking, use of alternative fuels for heating cement kilns
Type of Providers	Private capital, DFIs, public finance	Private capital, DFIs, public finance
Type of Instruments	Debt (e.g., green bonds and loans,[257] sustainability-linked bonds and loans, transition bonds), equity, carbon credits,[258] off-balance sheet finance[259]	• Debt (e.g., green bonds and loans, sustainability-linked bonds and loans, transition bonds), equity, • off-balance sheet finance
Origin of Financial Provider	Domestic and international	Domestic and international
Examples of Potential Providers	Government of France	U.K. Department of Business, Energy & Industrial Strategy (BEIS)
Examples of Projects	Hoffman Green Cement, the world's first producer of clinker-free cement, was initially funded with help from the French government (unclear if via debt or equity). The company later raised €75 million on Euronext market (in equity).[260] It also sells carbon credits to other firms looking to offset their emissions	Heidelberg Cement has operated a cement kiln on a net zero fuel mix composed of tanker-delivered hydrogen and biomass components (i.e., 'grey hydrogen') as a demonstration trial. The trial received grant funding from BEIS as part of its Industrial Fuel Switching Competition[261]

257 For example, expenditures toward the substitution of clinker is listed as an eligible project in CEMEX's green financing framework (CEMEX, 2022).

258 For example, Hoffman Green Cement, the world's first producer of clinker-free cement, sells carbon credits.

259 IEA (2021).

260 Hoffman Cement webpage, accessed (2023).

261 Heidelberg Cement (2021).

	Carbon Capture, Utilization, and Storage
Segment of Construction Value Chain	Materials
Type of Technologies and Examples	Used in both the cement (e.g., capturing and storing CO_2 emissions for exhaust cases produced during lime production)[262] and steel industries (e.g., capturing and storing CO_2 emissions form the blast furnace process).
Type of Providers	Private capital, DFIs, public finance
Type of Instruments	• Primarily balance sheet and equity finance initially, with likely a growing role for debt (e.g., green bonds and loans,[263] sustainability-linked bonds and loans, transition bonds) and project finance as technologies develop a track record[264]. • Other instruments include special purpose vehicles and joint ventures, state-owned enterprise investments, public grants,[265] and tax incentives.[266]
Origin of Financial Provider	Primarily domestic
Examples of Potential Providers	• Climate Funds (Green Climate Fund, Global Environment Facility) • EU Emissions Trading System Innovation Fund • CCUS Trust Funds (ADB, World Bank) • Norwegian government[267]
Examples of Projects	The first commercial steel CCUS project was launched by Al Reyadah and Emirates Steel at a gas-based, direct reduced iron plant in Abu Dhabi, United Arab Emirates. The capital investment of $15 billion was provided by the Abu Dhabi government.[268]

262 European Commission (2022).

263 These instruments may not be available to all CCUS projects given the high-emission nature of the industry (IEA, 2021).

264 IEA (2021).

265 SPV/JV, SOE investments, and public grants all commonly used instruments for financing CCUS (IEA, 2021).

266 For example, the U.S.-based 45Q tax credit for CO_2 storage, computed per metric ton of qualified carbon oxide sequestered.

267 Reuters (2023).

268 Scottish Carbon Capture & Storage (2023).

	Green Hydrogen
Type of Technologies and Examples	Can be used in the cement industry (e.g., to fuel cement kilns[269]) and the steel industry (i.e., as an alternative reductant to produce direct reduced iron that is processed into steel).
Type of Providers	Private capital, DFIs,[270] public finance[271]
Type of Instruments	• Primarily balance sheet and equity finance initially, with likely a growing role for debt (e.g., green bonds and loans,[272] sustainability-linked bonds and loans, transition bonds) and project finance as technologies develop a track record. • Other instruments include special purpose vehicles and joint ventures, state-owned enterprise investments, public grants, and tax Incentives.
Origin of Financial Provider	Domestic and international
Examples of Potential Providers	• SDG Namibia One Fund[273] • The World Bank Hydrogen for Development Partnership (H4D)[274]
Examples of Projects	In South Africa, for instance, Sasol and ArcerlorMittal launched in 2022 a joint venture that will assess the use of green hydrogen to convert captured carbon from ArcelorMittal South Africa's Vanderbijlpark's steel plant into sustainable fuels and chemicals.

269 Green hydrogen in this context is not yet implemented as it is currently not cost-effective.

270 For example, the EBRD has committed to providing a $80 million loan to Egypt Green to fund the nation's first green hydrogen plant.

271 Public finance will have a key role in the beginning, especially as a mechanism for credit enhancement (e.g., via guarantees) (IEA, 2021).

272 These instruments may not be available to all CCUS projects given the high-emission nature of the industry (IEA, 2021).

273 The SDG Namibia One Fund is a blended finance platform used to accelerate the green hydrogen sector in Namibia.

274 World Bank H4D is a partnership intended to raise and utilize low-carbon hydrogen production in developing countries.

TABLE 2.5

Number of Countries Using Public Sector Decarbonization Tools

Tools	High-Income Countries	Emerging Markets
Carbon Taxes	24	5
Tax Breaks (credits, rebates, other policies with a tax-based component)	13	2
Grants	33	4
Regulation	39	44
Minimum Energy Performance Standards	25	37
Building Codes and Standards	22	10
Carbon Trading: ETS	6	3

Notes: Carbon tax figures do not include subnational carbon taxes: three subnational carbon tax systems exist in Mexico, while all other subnational carbon tax systems are in advanced countries. ETS figures do not include subnational systems (Japan and the United States both have subnational ETS systems but not national systems, and hence are not counted in figures). Figures do include the regional EU ETS, which is counted as an advanced country. Data for voluntary markets is not included, as cross-border markets make it difficult to associate markets to specific countries.

Source: Carbon taxes and ETS data comes from World Bank Group Carbon Pricing Dashboard. All other data are IFC calculations based on IEA PAMS database.

TABLE 2.6

Total Certified Emission Reduction (CER) Credits Issued for CDM Green Building and Cement, Glass, Steel Projects 2006–2022

First Issuance Year of Project	Green Building	Cement	Glass	Steel & Iron	Other Building Materials
Total, 2006–2022	12,139,107	23,910,704	41,087	54,302,943	731,907

Notes: CERs are generated by climate-friendly projects, with each CER representing one metric ton of CO_2 reduced. CERs are then sold to investors and companies in developed economies regulated by emission caps.

Source: IFC staff calculations based on CDM and UNFCCC

Annex 3:
Methodology for Green Building Finance and Policy Tools

The green building label was introduced by the International Capital Market Association Green Bond Principles in 2017—hence all data on debt markets is reported from 2017 onwards. All data uses World Bank region and income definitions for regional and income breakouts.

All financing volumes (except those from Bloomberg) presented are geographically assigned by domicile of firm headquarters. Note that actual expenditure of funds may be different in practice, especially for multinational firms; however, it is not possible to track these given data limitations. For Bloomberg figures, volumes are assigned by country of risk, which is determined by geographical exposure of operations.

Green loans are a form of debt financing that enables borrowers, such as real estate developers, to fund projects which have a significant positive environmental impact. These products are typically financed by commercial banks, but also sometimes institutional investors, and can be earmarked for green building projects such as the construction of energy-efficient buildings and energy-efficient retrofits of existing buildings. Green loans can also be issued by construction material producers looking to implement decarbonization or other green eligible projects. Similar to green loans in design, sustainability loans are used to finance projects with a combination of environmental and social objectives, such as affordable energy-efficient homebuilding. However, these products are less frequently used and constitute a relatively small segment of the total sustainable debt market.

Green bonds are like conventional, fixed-income bonds except funds raised are intended to be used to finance specific green projects. Recent research has shown that green bonds command an 'issuer premium', meaning borrowers may benefit from a competitive advantage in the form of lower interest rates when issuing green bonds versus conventional bonds. Sustainability bonds are similar to green bonds except funds can also be allocated toward social objectives.

While green and sustainability loans are ring-fenced for specific projects and typically fund the underlying green asset, sustainability-linked finance is used to improve the borrower's overall sustainability profile. Sustainability-linked finance consists of loans and bonds in which compliance with a set of pre-determined sustainability targets triggers reductions in interest rates. By reducing screening and monitoring costs for lenders, these products can, at least in principle, contribute to aligning incentives of investors and brown construction companies for reducing carbon emissions. Furthermore, the ability to use proceeds for general business purposes provides additional flexibility to such borrowers where green projects may not be currently or concretely identifiable.

Bonds

Environmental Finance

Environmental Finance (EF) collects data on social, green, sustainability, sustainability-linked, and transition bonds. All social bonds were excluded from the data analysis, as were all bonds issued outside of the 2017–2021 range. The EF database includes information on head office of the issuer (for each bond and loan issuance). This variable is used to provide regional and country-level categorizations in bond figures shown in the draft.

EF uses in-house analysis to identify use of proceeds and key performance indicator (KPI) information for each bond issuance listed in their database. However, there are some instances of missing information. Not all bonds had 'use of proceeds' or KPI data available (15 percent missing). For bonds with both variables missing, correlations were used from available data to extrapolate green building issuance in the real estate sector, addressing 10 percent of missing data.

Most green, sustainability, and transition debt instruments have multiple uses of proceeds, and most sustainability-linked debt instruments have multiple KPIs. A small percentage of sustainability-linked products have use of proceeds information instead of KPIs, and a small percentage of green and sustainability products have KPI information instead of the use of proceeds (or, have both). In all cases, bonds were included in relevant green building figures if they had green buildings listed in either the use of proceeds or KPI categories.

EF provides classification by issuer type, including 'corporate', 'financial institution', 'agency', 'municipal', 'sovereign', and 'supranational'. Bonds earmarked for green building that were issued by financial institutions were manually reclassified to include central state banks and state-owned financial institutions in the government figures (and likewise to exclude these from the private sector figures). However, financial institutions with minority or majority (but not whole) state ownership (e.g., Bank of China) are included in private sector figures. 'Corporates' include both private and state-owned enterprises, as manual reclassification was not possible because of the volume of issuances. As such, all corporates (including all types of state-owned enterprises) have been included in the private sector figures as opposed to the public sector figures.

Government figures in graphs include municipals, public financial institutions, sovereigns, the EU (originally classified within the 'supranational' category), as well as some agencies (including U.S.-based Fannie Mae). Among the 'agency' category, local development finance institutions which primarily invest domestically were included in government figures, while bilateral institutions that invest abroad were excluded from government figures. Multilateral development bank figures are composed of all issuers in the 'supranational' category, apart from the EU.

EF does not have loan issuer type categories (akin to the bond issuer type categories used to separate public and private entities). Instead, manual analysis of 213 green building loans was conducted, combined with assumptions made using the available borrower sector information. For example, all REITs are assumed to be private, whereas firms categorized as financial, energy, industrial machinery and engineering, healthcare, logistics, public transportation, and real estate development and management were manually investigated. Only six loan issuances were determined to be public sector.

For the decarbonization analysis, the EF database includes issuer sector (as well as the use of proceeds and KPI information), which were used, alongside manual identification, to determine bonds issued by the glass, steel, and cement firms to fund decarbonization efforts. Cement and glass firms were identified among the 'real estate – construction and construction materials' sector, while steel firms were identified among the 'mining/metals' and "manufacturing – other' categories. Other building material firms outside these three specific industries were identified among both the 'real estate – construction and construction materials' and 'manufacturing – other' sectors. To determine if funding was going to decarbonization efforts specifically, a combination of the use-of-proceeds information, KPI information, and bond type information was used. Of the sixteen relevant bonds, six were sustainability-linked bonds, of which five had 'carbon/GHG emissions intensity – other/unspecified' listed in the KPIs. The remaining sustainability-linked bond had missing KPI information, but outside research revealed the bond was tied to CO_2 emissions intensity. There were three sustainability bonds, which all had renewable energy or energy efficiency listed in KPIs (among other environmental and social categories). Finally, there were seven green bonds, of which three had 'green buildings' listed in use of proceeds (one with 'energy efficiency' listed as well), an additional three had either 'energy efficiency' or 'renewable energy' listed, and one had 'pollution prevention and control' listed. All 16 bonds were included in the figures.

Loans

Environmental Finance

EF collects data on social, green, sustainability, and sustainability-linked loans. All social loans were excluded from the data analysis, as were loans issued outside of the 2017–2021 range. A small subset of loans was classified by EF as both 'green' and 'sustainability-linked' – these are categorized as sustainability-linked loans in all figures.

The EF database includes information on head office of the issuer (for each bond and loan issuance). This variable is used to provide regional and country-level categorizations in the green building loan figures shown in the draft. However, the building material decarbonization figures are sourced from Bloomberg, where 'country of risk' was provided instead. 'Country of risk' is a proprietary Bloomberg value which is driven by four core factors: country of domicile, country of listing, country of largest revenue, and reporting currency. In these figures, the 'country of risk' variable is used for all regional and country-level categorizations.

EF uses in-house analysis to identify use of proceeds and KPI information for each loan issuance listed in their database. However, there are some instances of missing information. Not all loans had 'use of proceeds' or KPI data available (5 percent missing). Correlations were used from available data to extrapolate green building issuance in the real estate sector addressing 30 percent of missing data.

Bloomberg

Bloomberg data were used for the analysis of sustainability-linked loan issuance in the decarbonization sector because of superior loan coverage compared to EF. However, Bloomberg's data has not been used for the green building loan analysis, in part because its database does not utilize a specific 'green building' use-of-proceeds category, but a 'building & infrastructure' category. While the first sustainability-linked loan was issued in 2017, Bloomberg coverage is from 2018 onwards. According to Bloomberg's database, no green or sustainability loans were issued for the decarbonization of cement, steel, or glass for buildings. Hence, we have only shown figures for sustainability-linked loans.

Bloomberg data include issuer sector and project KPI categorizations which were used, alongside manual identification, to determine loans issued by glass, steel, and cement firms to fund decarbonization efforts. Steel firms were identified among the 'metals & mining' sector classification, while cement and other building materials firms were identified among the 'construction materials manufacturing' sector classification. Additional building material firms were also identified within the 'home improvement' sector classification. One glass-packaging firm was identified among the 'containers & packaging' category, but no glass firms were identified among the 'construction materials manufacturing' sector. After identifying all loans issued by relevant sectors, KPI metrics were analyzed to isolate only those where loan funding was used to finance decarbonization efforts.

Bloomberg provides a variable called 'Tier 1 sustainability performance indicators' which classifies the loan as either being based on 'metrics' (31 loans) or 'ESG score' (3 loans) or 'unknown' (2 loans). 'Tier 2 metric categories' provides further details, with all relevant loans classified as 'metrics' also classified as 'environmental' under this variable.

- Of the three 'ESG score' loans, one was classified as 'general ESG rating' and the two others had missing information. Based on manual investigation, one of these loans with missing information was manually reclassified as 'general ESG rating' based on online research. It was not possible to identify more information on the other loan with missing information issued by Formosa Ha Tinh Cayman Ltd. All three of these loans were thus excluded from figures given that specific environmental indicators were not listed and/or found online.
- The two loans classified as 'unknown' under the 'Tier 1 sustainability performance indicators' had no additional useful information under 'Tier 2 metric categories.' Based on outside research, the loan issued by Wienerberger AG was manually reclassified as 'general ESG rating', while no other information was found on the 'unknown' loan issued by BEWI Invest AS. Both loans were thus excluded from figures, given that specific environmental indicators were not listed and/or found online.

Among the 31 loans listed as 'environmental' under 'Tier 2 metric categories', 23 had GHGs listed under 'Tier 2 metric categories' – many of which also had 'other E', 'renewable energy', or 'energy efficiency' listed as well. An additional four loans had other E' solely listed and an additional loan had 'water' solely listed, and thus were excluded. An additional two 'environmental' loans issued by CEMEX with missing 'Tier 2 metric categories' data were manually classified as 'GHGs' based on outside research (including reference to other CEMEX loans with complete data listed as 'GHGs').

Multilateral Development Banks (MDBs)

The EF Green, Social, and Sustainability Bonds database was used to estimate the total green building bond issuance of MDBs. In alignment with the private and government debt figures, all bonds issued by MDBs with 'green building' listed in either the use of proceeds or KPI categories were included in figures. In all cases, bonds were classified as 'green building' alongside other use of proceeds or KPI categories. There were no relevant loans in the EF database issued by MDBs, so only MDB bond figures are shown.

In addition to bond data, figures are also shown which come directly from IFC and the EBRD publicly published sources. For example, according to IFC data, as of 2019 IFC had invested and mobilized nearly $4.4 billion in green buildings since 2014. This included $387 million of direct investment from IFC in 2019. The EBRD also reported €24 billion in green building projects.

Additionally, Climate Assessment for Financial Institutions data—anonymized internal IFC client data on green building projects—is utilized. Figures are based on IFC defined green building categories. To note, coverage is not complete, with about 70 percent of IFC clients responding to the relevant surveys. Data includes both the total project size, and the size of the loan disbursed by the IFC client to the project developer. Data is available broken out by the fiscal year based on the date the project was created and the fiscal year based on the commitment date (i.e., when the bank funded the project). The former metric may be several years after the project was funded because the bank reports it to the IFC ex-post, thus it is used for year breakdowns.

Government policy data are calculated using information from the IEA, which tracks government green building policies in two different databases.

TABLE 3.1

IEA PAMS Database, 'Buildings' Policy Categories

Residential	• Detached house
	• Attached house
	• Apartment in low-rise building
	• Apartment in high-rise building
Services	• Public administration
	• Education
	• Information & communication
	• Data center
	• Warehousing and support for transportation activities
	• Health and social activities
	• Accommodation and food services
	• Restaurants
	• Administration and offices
	• Wholesale and retail
	• Food retail
	• Public assembly
	• Water supply
	• Sewerage, waste and remediation
	• Repair, industrial and other service activities
New buildings	
Existing buildings and retrofits	

The IEA PAMS database covers government policies issued since 1975 to reduce greenhouse gas emissions, improve energy efficiency, and increase development of renewables. However, there is no budget information per policy, thus all analysis is based on frequencies. Figures look specifically at the PAMS 'buildings' sector, which includes the below categories. Most of these policies relate to building energy codes, energy labels, and building-related incentive programs.

The database includes categorizations for 'policy type' (i.e., regulation, codes/standards, grants, etc.), however policy types are not mutually exclusive, and most policies are categorized as multiple policy types. World Bank region and income classification data were appended to produce regional and income breakouts. However, many policies are issued by the EU, which does not have a specific income classification, and thus the EU is not included in any income breakout figures.

IEA PAMS data limitations also include the fact that coverage of emerging and developing economies' energy policies is less detailed compared to OECD member countries – due mostly to resource and translation issues. IEA has also caveated that there are disparities across time, thus making historical comparisons less reliable.

The IEA has also published a Sustainable Recovery Tracker. This tracker shows policy-level data, including the total amount committed, not spent, via government policies including total fiscal support in response to COVID-19, economic recovery spending, government spending on sustainable recovery as highlighted in the IEA Sustainable Recovery Plan, and total mobilized sustainable recovery. Detailed definitions of categories can be found here. This database includes an 'energy-efficient buildings and industry' category, which includes 224 policies with budget volume. However, there are 81 policies from relevant subsector categories that are used in the final figures, including 'efficient new builds,' 'energy efficient retrofits,' 'heat pumps,' and 'appliances.' All 81 policies were issued by high-income countries. Like the PAMS database, policies in the Sustainability Recovery Tracker may be classified under multiple 'policy types'.

Carbon Trading – Compliance Markets

The UNFCC Clean Development Mechanism (CDM) database contains project-level data on CDM-authorized carbon issuances. The database includes information on the year of the first issuance for each project, and total credits are allotted to the project over its lifetime. To note, many projects have missing information under the 'total CERs issued' variable. Thus, figures only represent totals among projects with complete information at this variable.

Project type and sub-project type information was leveraged to narrow down relevant green buildings and building materials projects. Credits issued by projects listed as 'air conditioning,' 'appliances,' 'district heating,' 'EE new buildings,' 'EE public buildings,' 'geothermal heating,' 'lighting,' 'lighting & insulation & solar,' 'solar lamps,' and 'solar water heating' were including in the 'green building' figures. Credits issued by projects listed under the project type 'building materials' and 'building materials heat' were included in 'building materials' figures. Credits issued by projects listed as 'clinker replacement,' 'cement heat,' and 'cement' were included in the 'cement' figures, while projects listed under 'iron & steel heat' or 'iron & steel' were included in 'iron & steel' figures. Finally, projects classified under the subtype 'glass' or 'glass heat' were included in 'glass' figures. Note that projects were not manually analyzed to isolate solely those producing materials specifically for buildings. Similarly, 'iron & steel' projects were not analyzed to isolate only steel projects.

Carbon Trading – Voluntary Markets

The Berkeley Carbon Credit Data Base contains all carbon offset projects listed by the four major project registries (CAR, ACR, VCS, Gold Standard). These four registries represent most of the total voluntary market (and to note, are also eligible to be used under the Quebec and California cap and trade compliance programs). The Berkley database contains project level data, each with total CER issued and information on the first year of the project. Firm sector information was leveraged to narrow down relevant green buildings projects. Credits issued in 'advanced refrigerants,' 'lighting,' 'solar lighting,' 'solar water heaters,' as well as manually identified green buildings projects within the 'energy efficiency' category and manually identified steel, cement, and glass decarbonization in the 'waste heat recovery' category, are included in figures. To note, cookstoves and solar cookstoves have not been included in this analysis. Total credits are allotted to the year recorded under the 'first year of project' variable.

References

Acemoglu, D., Aghion, P., Bursztyn L., and Hemous, D.. 2012. "The Environment and Directed Technical Change." American Economic Review, 102 (1): 131-66. DOI: 10.1257/aer.102.1.131.

Ali H. 2022. "Global cement industry's GHG emission." Global Efficiency Intelligence. Available at: https://www.globalefficiencyintel.com/new-blog/2021/global-cement-industry-ghg-emissions [Accessed November 16, 2022].

Allman, E. and Won, J. 2021. "Can ESG disclosure improve investment efficiency?" [online] blogs.worldbank.org. Available at: https://blogs.worldbank.org/allaboutfinance/can-esg-disclosure-improve-investment-efficiency#:~:text=Taken%20together%2C%20these%20results%20suggest [Accessed November 28, 2022].

American Concrete Institute (ACI). 2022. "Technical Questions. ACI committees, membership, and staff have answered common questions on a variety of concrete related topics." Available at: https://www.concrete.org/tools/frequentlyaskedquestions.aspx?faqid=697#:~:text=Q.-,What%20is%20a%20natural%20pozzolan%3F,its%20composition%20or%20physical%20state [Accessed November 28, 2022].

ArcelorMittal. 2020. "ArcelorMittal sets 2050 group carbon emissions target of net zero." ArcelorMittal. Available at: https://corporate.arcelormittal.com/media/press-releases/arcelormittal-sets-2050-group-carbon-emissions-target-of-net-zero [Accessed November 16, 2022].

Bastos, P. and Castro, L. Mimeo. Diffusion of Green Technologies. Evidence from Construction Value Chains. World Bank Group. Washington DC. Mimeo.

BEIS, U.K. 2020. "Industrial Heat Recovery Support (IHRS) Programme." Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894592/1_Programme_Guidance_Note_PV8_June2020.pdf\ [Accessed November 16, 2022].

Berkley Public Policy. 2022. "Voluntary Registry Offsets Database." Available at: https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database [Accessed July 2022].

BHP. 2020. "Pathways to decarbonization episode two: steelmaking technology." Available at: https://www.bhp.com/news/prospects/2020/11/pathways-to-decarbonisation-episode-two-steelmaking-technology [Accessed November, 16 2022].

Böhringer, C., Peterson, S., Rutherford, T.,Schneider, J.,Winkler. M. 2021. "Climate policies after Paris: Pledge, Trade and Recycle: Insights from the 36th Energy Modeling Forum Study (EMF36)." Energy Economics, Volume 103,105471,ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2021.105471. (https://www.sciencedirect.com/science/article/pii/S0140988321003571).

BP. 2023. "BP Energy Outlook 2023." Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2023.pdf [Accessed July, 25 2023].

Branger, F., Quiron, P., and Chevallier, J. 2017. "Carbon Leakage and Competitiveness of Cement and Steel Industries under the EU ETS: Much Ado about Nothing." The Energy Journal 37 (3): 109–35.

Business Wire. 2022. "Kimco Realty Publishes Second Green Bond Report." www.businesswire.com.Available at: https://www.businesswire.com/news/home/20220815005071/en/Kimco-Realty%C2%AE-Publishes-Second-Green-Bond-Report [Accessed November 8, 2022].

C40 Cities. 2019. "Building and Infrastructure Consumption Emissions." New York: C40 Cities. Available at: https://www.c40.org/wp-content/uploads/2021/11/C40-2019-Annual-Report.pdf [Accessed November 29, 2022].

Cao, Y. 2021. “How Financial Market Development Can Encourage Innovation Activity.” Research and Policy Brief; No. 52. World Bank, Malaysia.

Caramichael, J. and Rapp, A. 2022. “The Green Corporate Bond Issuance Premium.” International Finance Discussion Paper, (1346), pp.1–46. doi:10.17016/ifdp.2022.1346.

Castro, L., Chepeliev, M. and Michelena, G. Mimeo. Climate Mitigation Policies and Greening of the Construction Value Chains. IFC-GTAP.

Cavallo, E. A., & Noy, I. (2009). The economics of natural disasters: a survey. IDB Working Paper Series No. IDB-WP-124

CEMEX. 2021. “Vertua® Low Carbon Concrete and UK’s first CarbonNeutral® concrete solution.” Available at: https://www.cemex.co.uk/vertua-low-carbon-concrete [Accessed November 16, 2022].

CEMEX. 2022. “Green Financing Framework.” Available at: https://www.cemex.com/documents/20143/53544776/cemex-green-financing-framework.pdf/2412d811-1541-08cd-d1c3-7258c10fd5f4?t=1656297024704.

Centre for Public Impact, a BCG Foundation. 2017. “The Solar Home Systems initiative in Bangladesh.” Available at: https://www.centreforpublicimpact.org/case-study/solar-home-systems-bangladesh#:~:text=The%20Solar%20Home%20Systems%20(SHS,of%20Bangladesh%22.%5B3%5D.

Chatterton, I. and De Vautibault, M. 2021. “Making greenfield projects bankable.” (blogs.worldbank.org.) Available at: https://blogs.worldbank.org/ppps/making-greenfield-projects-bankable [Accessed November 8, 2022].

Chen J., Li S., Li X., and Li A.Y. 2021. “Pursuing zero-carbon steel in China: A critical pillar to reach carbon neutrality.” RMI. Available at: https://rmi.org/insight/pursuing-zero-carbon-steel-in-china/ [Accessed November 16, 2022].

Chepeliev, M., Aguiar, A., Farole, T., Liverani, A. and van der Mensbrugghe, D., 2022. “EU Green Deal and Circular Economy Transition: Impacts and Interactions.” Global Trade Analysis Project (GTAP).

China Baowu Group. 2020. “China Baowu corporate social responsibility report.” Available at: https://res.baowugroup.com/attach/2021/10/29/1a2ad022172a46f6b2f31b5377a07ea5.pdf [Accessed November 16, 2022].

Chinyama, M. P. 2011. “Alternative Fuels in Cement Manufacturing.” In (Ed.), Alternative Fuel. IntechOpen. https://doi.org/10.5772/22319.

Climate Policy Initiative. 2022. “Financing Net Zero Carbon Buildings: A Building and Scoping Paper.” Available at: https://www.climatepolicyinitiative.org/id/publication/financing-net-zero-carbon-buildings/ [Accessed November 16, 2022].

CW Construction World. 2021. “LC3 cement can reduce carbon emissions by 40%.” Available at: https://www.constructionworld.in/gold/cement-news/lc3-cement-can-reduce-carbon-emission-by-40-/26622 [Accessed November 16, 2022].

Delmonico, D., Jabbour, C.J.C., Pereira, S.C.F., de Sousa Jabbour, A.B.L., Renwick, D.W.S. and Thomé, A.M.T. 2018. “Unveiling barriers to sustainable public procurement in emerging economies: Evidence from a leading sustainable supply chain initiative in Latin America.” Resources, Conservation and Recycling, [online] 134, pp.70–79. doi:10.1016/j.resconrec.2018.02.033.

Dodge Data & Analytics. 2021. “World Green Building Trends 2021.” At: https://www.construction.com/toolkit/reports/World-Green-Building-trends-2021 [Accessed November 13, 2022].

EDGE. 2017. “From Romania to costa Rica – The Persuasive Power of Green Mortgages”. Available at: https://edgebuildings.com/from-romania-to-costa-rica-the-persuasive-power-of-green-mortgages/ [Accessed November 8, 2022].

Energy Transition Commission. 2022. "Toward Net Zero: Decarbonization Roadmap for China's Cement Industry". https://www.energy-transitions.org/publications/decarbonization-roadmap-for-chinas-cement-industry-2/

Envirotech online. 2019. “Concrete is responsible for 8 percent of CO_2 emissions.” Available at: https://www.envirotech-online.com/news/air-monitoring/6/breaking-news/concrete-is-responsible-for-8-percent-of-co2-emissions/48038 [Accessed November 16, 2022].

European Cement Association. 2020. "Cementing the European Green Deal: Reaching climate neutrality along the cement and concrete value chain by 2050." Available at: https://cembureau.eu/media/kuxd32gi/cembureau-2050-roadmap_final-version_web.pdf [Accessed November 16, 2022].

European Commission. 2019. "A European Green Deal." [online] European Commission. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en [Accessed November 10, 2022].

European Commission. 2022. "Innovation Fund: EU invests 1.8 billion euros in clean tech projects." Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4402.

EU (European Union). 2021. "Circular economy: definition, importance, and benefits." News | European Parliament (europa.eu) [Updated March 3, 2021; Accessed October 27, 2021].

EU (European Union). 2022. "A European Green Deal. Striving to be the first climate-neutral continent." Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en [Accessed November 16, 2022].

Fennell, P., Florin, N., Hills, T., and Leeson, D. 2016. "Carbon Capture in the Cement Industry: Technologies, Progress, and Retrofitting." Environmental Science and Technology 50 (1): 368–77. https://doi.org/10.1021/acs.est.5b03508

Financial Times. 2021. "Quest for 'green' cement draws big name investors to $200bn industry." Available at: https://www.ft.com/content/24d610a0-fb65-45bb-b747-e015e1f10c1a.

Frank, C. 2014. "Pricing Carbon: A Carbon Tax or Cap-And-Trade?" Brookings. Planet Policy Blog. https://www.brookings.edu/blog/planetpolicy/2014/08/12/pricing-carbon-a-carbon-tax-or-cap-and-trade/ [Accessed November 10, 2022].

GCCA (Global Cement and Concrete Association). 2021. "Global cement and concrete industry announces roadmap to achieve groundbreaking "net zero" CO_2 emissions by 2050." Available at: https://gccassociation.org/news/global-cement-and-concrete-industry-announces-roadmap-to-achieve-groundbreaking-net-zero-co2-emissions-by-2050/ [Accessed November 16, 2022].

GFDRR (Global Facility for Disaster Reduction and Recovery). 2017. "Commonwealth of Dominica / Post-Disaster Needs Assessment / Hurricane Maria." September 18, 2017, Available at: https://www.gfdrr.org/en/publication/dominica-post-disaster-needs-assessment-following-hurricane-maria

Ghoneim, R., Mete, G., and Hobley, A. 2022. "Steel and cement can drive the decade of action on climate change. This is how." UNIDO. Available at: https://iap.unido.org/articles/steel-and-cement-can-drive-decade-action-climate-change-how [Accessed November 16, 2022].

Global CCS Institute. 2019. "Dalmia Cement (Bharat) Limited and Carbon Clean Solutions Team up to Build Cement Industry's Largest Carbon Capture Plant." https://www.globalccsinstitute.com/news-media/latest-news/dalmia-cement-bharat-limited-and-carbon-clean-solutions-team-up-to-build-cement-industrys-largest-carbon-capture-plant/.

Green Finance Institute. 2021. "The way ahead for the UK's green mortgage market." Green Finance Institute.

Greenovate Europe.2019. "Commission announces €10bn Innovation Fund for low carbon technologies." [online] Greenovate Europe. Available at: https://greenovate-europe.eu/commission-announces-e10bn-innovation-fund-for-low-carbon-technologies/ [Accessed November 10, 2022].

Groh, A.P. and Wallmeroth, J. 2016. "Determinants of venture capital investments in emerging markets." Emerging Markets Review, 29, pp.104–132. doi:10.1016/j.ememar.2016.08.020.

Hasanbeigi, Ali. 2021. "Global Cement Industry's GHG Emissions." Global Efficiency Intelligence (blog), May 17. Retrieved from https://www.globalefficiencyintel.com/new-blog/2021/global-cement-industry-ghg-emissions

HeidelbertMaterials. 2021. "HeidelbergCement produces cement with climate-neutral fuel mix using hydrogen technology." Available at: https://www.heidelbergmaterials.com/en/pr-01-10-2021.

Hertwich, E.G., Ali, S., Ciacci, L., Fishman, T., Heeren, N., Masanet, E., Asghari, F.N., Olivetti, E., Pauliuk, S., Tu, Q. and Wolfram, P., 2019. "Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review." Environmental Research Letters, 14(4), p.043004.

Hills, T., Duncan L., Nicholas, F., and Paul, F. 2016. "Carbon Capture in the Cement Industry: Technologies, Progress, and Retrofitting." Environmental Science and Technology 50 (1): 368–77. https://doi.org/10.1021/acs.est.5b03508.

Hino, M. and Burke, M. 2021. "The effect of information about climate risk on property values." Proceedings of the National Academy of Sciences, 118(17), p.e2003374118. doi:10.1073/pnas.2003374118.

Hong, H., Li, F.W. and Xu, J. 2019. "Climate risks and market efficiency." Journal of Econometrics, 208(1), pp.265–281. doi:10.1016/j.jeconom.2018.09.015.

Hsu, P.-H., Tian, X. and Xu, Y. 2014. "Financial development and innovation: Cross-country evidence." Journal of Financial Economics, 112(1), pp.116–135. doi:10.1016/j.jfineco.2013.12.002.

Huang, Y. and Wu, J. 2021. "Bottom-up analysis of energy efficiency improvement and CO_2 emission reduction potentials in the cement industry for energy transition: an application of extended marginal abatement cost curves." Journal of Cleaner Production. Volume 296. Available at: https://doi.org/10.1016/j.jclepro.2021.126619.

IDMC (Internal Displacement Monitoring Center). 2019. "Disaster Displacement - A Global Review." Norwegian Refugee Council. Available at: https://www.internal-displacement.org/sites/default/files/publications/documents/201905-disaster-displacement-global-review-2008-2018.pdf.

IEA (International Energy Agency). 2018. "Technology Roadmap Low-Carbon Transition in the Cement Industry." Available at: https://iea.blob.core.windows.net/assets/cbaa3da1-fd61-4c2a-8719-31538f59b54f/TechnologyRoadmapLowCarbonTransitionintheCementIndustry.pdf, [Accessed November 19, 2022].

IEA (International Energy Agency). 2021. "A call to action on efficient and smart appliances." IEA, Paris. https://www.iea.org/articles/a-call-to-action-on-efficient-and-smart-appliances License: CC BY 4.0.

IEA (International Energy Agency). 2022a. "Buildings." IEA, Paris. https://www.iea.org/reports/buildings, License: CC BY 4.0.

IEA (International Energy Agency). 2022b. "Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030." IEA, Paris. https://www.iea.org/reports/technology-and-innovation-pathways-for-zero-carbon-ready-buildings-by-2030, License: CC BY 4.0.

IEA. 2020c. "Direct CO_2 Emissions in the Iron and Steel Sector by Scenario, 2019–2050." https://www.iea.org/data-and-statistics/charts/direct-co2-emissions-in-the-iron-and-steel-sector-by-scenario-2019-2050.

IEA. 2023. "Scaling Up Private Finance for Clean Energy in Emerging and Developing Economies", IEA, Paris https://www.iea.org/reports/scaling-up-private-finance-for-clean-energy-in-emerging-and-developing-economies, License: CC BY 4.0

IFC (International Finance Corporation). 2014. "Waste Heat Recovery for the Cement Sector: Market and Supplier Analysis." Available at: https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/report_waste_heat_recovery_for_the_cement_sector_market_and_supplier_analysis [Accessed November 29, 2022].

IFC (International Finance Corporation), World Bank, African Development Bank, European Bank, European Investment Bank, IDB, KFW, FMO, NIB and Asian Development Bank. 2015. "Green Bonds: Working Towards a Harmonized Framework for Impact Reporting."

IFC (International Finance Corporation). 2017a. "EDGE Guidance Document for Refrigerant Selection to Reduce Climate Impact based on the Montreal Protocol." Available at: https://www.edgebuildings.com[Accessed November 13, 2022].

IFC (International Finance Corporation). 2017b. "Increasing the use of alternative fuels at cement plants: international best practices." Available at: https://www.ifc.org/wps/wcm/connect/33180042-b8c1-4797-ac82-cd5167689d39/Alternative_Fuels_08+04.pdf?MOD=AJPERES&CVID=lT3Bm3Z [Accessed November 16, 2022].

IFC (International Finance Corporation). 2019a. "Green Buildings: A Financial and Policy Blueprint for Emerging Markets." International Finance Corporation, Washington, D.C.

IFC (International Finance Corporation). 2019b. "Greening Construction: The Role of Carbon Pricing." International Finance Corporation, Washington, DC.

IFC (International Finance Corporation), and Amundi. 2020. "Emerging Market Green Bonds Report 2019: Momentum Builds as Nascent Markets Grow." Amundi Asset Management and International Finance Corporation.

IFC (International Finance Corporation). 2021. “Ctrl Alt Del. A Green Reboot For Emerging Markets Key Sectors For Post-Covid Sustainable Growth.” Available at: https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/climate+business/resources/a+green+reboot+for+emerging+markets [Accessed November 16, 2022).

IFC (International Finance Corporation). 2022a. “Effect of white paint and tinted glass on energy consumption.” Mimeo.

IFC (International Finance Corporation). 2022b. “IFC provides US$60 million loan to BBVA Perú to finance green buildings and fight climate change.” International Finance Corporation, Washington D.C.

IFC (International Finance Corporation). 2023a. “Capturing the Value of Green Steel.” International Finance Corporation, Washington D.C.

IFC (International Finance Corporation). 2023b. “Accelerating Coal Transition in Private Sector”. International Finance Corporation, Washington D.C.

IIP (Institute for Industrial Productivity). 2022. “Dry Kilns with Multistage Pre-heaters and Pre-calcination.” Available at: http://www.iipinetwork.org/wp-content/Ietd/content/dry-kilns-multistage-pre-heaters-and-pre-calcination.html [Accessed November 22, 2022].

IMF (International Monetary Fund). 2021. “Investment Funds: Fostering the Transition to a Green Economy.” In: Global Financial Stability Report. Washington D.C.: International Monetary Fund.

IMF (International Monetary Fund). 2022. “World Economic Outlook: Countering the Cost-of-Living Crisis.” Washington, DC. October.

IPCC (Intergovernmental Panel on Climate Change). 2022. “ Climate Change 2022: Impacts, Adaptation, and Vulnerability.” Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, U.K. and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

IRENA (International Renewable Energy Agency). 2020. “Making Green Hydrogen a Cost-Competitive Climate Solution.” Available at: https://www.irena.org/news/pressreleases/2020/Dec/Making-Green-Hydrogen-a-Cost-Competitive-Climate-Solution [Accessed November 22, 2022].

Ji Chen, Shuyi Li, Xiangyi Li, Ye (Agnes) Li. 2021.”Pursuing Zero-Carbon Steel in China: A Critical Pillar to Reach Carbon Neutrality.” RMI. http://www.rmi.org/insight/pursuing-zerocarbon-steel-in-china.

Johnson, S. 2021. “Invesco launches first ‘green building’ ETF.” Financial Times. [online] 22 Apr. Available at: https://www.ft.com/content/88db6314-45e1-45c9-898f-d98e2ff60967 [Accessed November 8, 2022].

Karlsson, I., Rootzén, J. and Toktarova, A. . 2020. “Roadmap for Decarbonization of the Building and Construction Industry - A Supply Chain Analysis Including Primary Production of Steel and Cement Energies.” 13(16) http://dx.doi.org/10.3390/en13164136.

Kaya, Y. 1990. “Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios.” Paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris.

Keppel.2022. "Introduction to Keppel". [PowerPoint slides]. Presentation prepared for IFC. October, 2022.

Larsen, G., Brandon, C. and Carter, R. 2022. “Adaptation Finance: 11 Key Questions, Answered.” [online] World Resources Institute. World Resources Institute. Available at: https://www.wri.org/insights/adaptation-finance-explained [Accessed November 22, 2022].

Liekefett, K., Berg, B., Zaba, D., Gregory, H., Grapsas, R. and Wood, L. 2021. “Shareholder Activism and ESG: What Comes Next, and How to Prepare.” Sidley Austin LLP. Available at: https://www.lexology.com/library/detail.aspx?g=8a079167-4773-48ad-9aa9-052efa75d250.

Loukoianova, E., Prasad, A., Oman, W. and Xiaochen Feng, A. 2022. “Mobilizing Private Climate Financing in Emerging Market and Developing Economies.” IMF Staff Climate Notes, 2022(007), p.1. doi:10.5089/9798400216428.066.

Lorea, C.,Sanchez, F and Torres, Mrales, E. 2022. Green Cement Technology Tracker, Version 11/2022, Stockholm, Dataset, https://www.industrytransition.org/green-cement-technology-tracker.

Markandya, A., Sampedro, J., Smith, S. J., Van Dingenen, R., Pizarro-Irizar, C., Arto, I., & González-Eguino, M. (2018). Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. The Lancet Planetary Health, 2(3), e126-e133.

Material Economics. 2018. The Circular Economy—A Powerful Force for Climate Mitigation. Stockholm, Sweden: Material Economics.

McKinsey & Company. 2017. "Reinventing Construction through a Productivity Revolution." https://katerra.com/2017/02/01/reinventing-construction-through-a-productivity-revolution.

McKinsey & Company. 2019. "How should steelmakers adapt at the dawn of the EAF mini-mill era in China?" Available at: https://www.mckinsey.com/~/media/mckinsey/industries/metals%20and%20mining/our%20insights/how%20should%20steelmakers%20adapt%20at%20the%20dawn%20of%20the%20eaf%20mini%20mill%20era%20in%20china/how-should-steelmakers-adapt-at-the-dawn-of-the-eaf-mini-mill-era-in-china.pdf [Accessed November 16, 2022].

McKinsey & Company. 2020. "Decarbonization challenge for steel." McKinsey & Company. Available at: https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel [Accessed November 16, 2022].

McKinsey & Company. 2021. "Tackling the challenge of decarbonizing steelmaking." McKinsey & Company. Available at: https://www.mckinsey.com/industries/metals-and-mining/our-insights/tackling-the-challenge-of-decarbonizing-steelmaking [Accessed November 16, 2022].

McKinsey & Company. 2022. "The path to net zero: Investing in carbon markets." [online] www.mckinsey.com. McKinsey & Company. Available at: https://www.mckinsey.com/featured-insights/future-of-asia/the-path-to-net-zero-investing-in-carbon-markets [Accessed November 9, 2022].

MPA (Mineral Product Association). 2021. "World first UK hydrogen trials demonstrate pathway to net zero cement." Available at: https://mineralproducts.org/News-CEO-Blog/2021/release31.aspx, [Accessed November 16, 2022].

Naqvi, B., Mirza, N., Rizvi, S.K.A., Porada-Rochoń, M. and Itani, R. 2021. "Is there a green fund premium? Evidence from twenty-seven emerging markets." Global Finance Journal, 50, p.100656. doi:10.1016/j.gfj.2021.100656.

Narayanaswamy, M., Blitzer, C. and Carvajal, A. 2017. "The Importance of Local Capital Markets for Financing Development." EMCompass, no. 28; International Finance Corporation, Washington, D.C.

OECD (Organization for Economic Co-operation and Development). 2016. "The Role of Public Procurement in Low-carbon Innovation." OECD Headquarters, Paris: OECD.

Oslo Kommune. 2020. "Zero-Emission Construction Sites." https://sustainable-procurement.org/fileadmin/user_upload/layout/homepage/NGO_Network/2.4_-_BestPractice_-_Omsorgsbygg_Oslo.pdf.

Patel, G. 2017. "India's first district cooling system at GIFT City," Air Conditioning and Refrigeration Journal, December 2017.

Reuters. 2023. "Germany backs Norwegian plan to capture carbon from cement." Available at: https://www.reuters.com/business/environment/germany-backs-norwegian-plan-capture-carbon-cement-2023-01-06/

Revelli, C. and Viviani, J.-L. 2014. "Financial performance of socially responsible investing (SRI): what have we learned? A meta-analysis." Business Ethics: A European Review, 24(2), pp.158–185. doi:10.1111/beer.12076.

SCCS (Scottish Carbon Capture & Storage). Available at: https://www.sccs.org.uk/expertise/global-ccs-map, 'Al Reyadah: Project Details', available at: https://www.geos.ed.ac.uk/sccs/project-info/622 [Accessed 2023].

Schorcht F., Kourti I., Scalet B.M, Roudier S., and Sancho L.D. 2013. "JRC Reference Report. Best Available Technique (BAT) Reference Document for the Production of Cement, Lime and Magnesium Oxide." European Commission JRC, Seville. Available at: https://core.ac.uk/download/pdf/38626619.pdf [Accessed November 16, 2022]

Sherratt, A.. 2013. "Encyclopedia of Corporate Social Responsibility." ISBN : 978-3-642-28035-1.

Steuer, S. and H Tröger, T. 2022. "The Role of Disclosure in Green Finance." Journal of Financial Regulation, 8(1). doi:10.1093/jfr/fjac001.

The World Counts. 2022. "Tons of steel recycled." Available at: https://www.theworldcounts.com/challenges/planet-earth/mining/advantages-of-recycling-steel [Accessed November 16, 2022].

Ul Haq, I. and Doumbia, D. 2022. "Structural Loopholes in Sustainability-Linked Bonds." Policy Research Working Paper Series, 10200. World Bank., Washington, D.C. Available at: https://ideas.repec.org/p/wbk/wbrwps/10200.html [Accessed November 9, 2022].

UNEP (UN Environment Program), and Global Alliance for Building and Construction. 2021. "Global Status Report for Buildings and Construction." At: https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction [Accessed November 13, 2022].

UNEP Copenhagen Climate Centre. 2022. "SMARTER-Green Homes for a better and healthier future." [online] Copenhagen Centre on Energy Efficiency. Available at: https://c2e2.unepccc.org/smarter/ [Accessed November 9, 2022].

UNFCC. 2022. "CDM Adjusts to COVID-19 Challenges." Unfccc.int. [online] 16 Jun. Available at: https://unfccc.int/news/cdm-adjusts-to-covid-19-challenges [Accessed November 8, 2022].

UN Environment and IEA. 2018. Global Status Report 2017—Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector. https://wedocs.unep.org/handle/20.500.11822/27140.

Vogl, V., Ahman, M., and Nilsson, L.J. 2018. "Assessment of hydrogen direct reduction for fossil-free steelmaking." Journal of Cleaner Production. Volume 203, Pages 736-745, Available at: https://doi.org/10.1016/j.jclepro.2018.08.279.

WBCSD/ARUP. 2021. "Net-zero buildings Where do we stand?" https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/Net-zero-buildings-Where-do-we-stand [Accessed November 11, 2022].

World Bank. 2020. "Capital Markets Development: A Primer for Policymakers." World Bank, Washington, D.C. Available at: https://openknowledge.worldbank.org/handle/10986/36058.

World Bank. 2021a. "Green Public Procurement: An Overview of Green Reforms in Country Procurement Systems." Climate Governance Papers;. World Bank, Washington, D.C.

World Bank. 2021b. "State and Trends of Carbon Pricing 2021." World Bank, Washington, D.C. Available at: https://openknowledge.worldbank.org/handle/10986/35620.

World Bank. 2022. "Carbon Pricing Dashboard." [online] carbon pricing dashboard.worldbank.org. Available at: https://carbonpricingdashboard.worldbank.org/ [Accessed November 10, 2022].

World Bank. Mimeo. "Decarbonizing Industry Through Innovation: A Scoping Study of Opportunities in Developing Countries." World Bank Group. Washington DC.

World Bank-IBRD. Mimeo. "Decarbonizing Industry Through Innovation: A Scoping Study of Opportunities in Developing Countries".

World Economic Forum. 2021. "Carbon retirement portfolio: a faster and fairer way to retire carbon-emitting assets." World Economic Forum. [online] 1 Sep. Available at: https://www.weforum.org/agenda/2021/09/a-better-way-to-retire-carbon-emitting-assets/ [Accessed November 9, 2022].

World Economic Forum. 2022a. "'Massive shortfall' in green financing for region's emerging markets: Asean chair." [online] 25 Apr. Available at: https://intelligence.weforum.org/monitor/latest-knowledge/38ccd243518e4a4ca5dad28bb708a3b3 [Accessed November 9, 2022].

World Economic Forum. 2022b. "Green Public Procurement: Catalysing the Net-Zero Economy." [online] World Economic Forum. Available at: https://www.weforum.org/whitepapers/green-public-procurement-catalysing-the-net-zero-economy/.

World Green Building Council. 2022. "What are green mortgages & how will they revolutionize home energy efficiency?" [online] World Green Building Council. Available at: https://www.worldgbc.org/news-media/what-are-green-mortgages-how-will-they-revolutionise-home-energy-efficiency [Accessed November 8, 2022].

World Steel Association. 2021. "Climate change and the production of iron and steel. Available at: https://worldsteel.org/wp-content/uploads/Climate-change-and-the-production-of-iron-and-steel.pdf [Accessed November 16, 2022].

World Steel Association. 2022. "World Steel in Figures 2022." Available at: https://worldsteel.org/wp-content/uploads/2020_2021-top-steel-producers_tonnage.pdf [Accessed November 16, 2022].

2121 Pennsylvania Avenue, N.W.
Washington, D.C. 20433
Internet: www.ifc.org

International Finance Corporation
WORLD BANK GROUP