

2022 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION

Towards a zero-emissions, efficient and resilient buildings
and construction sector



2022

GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION

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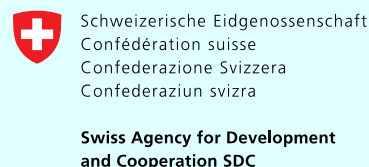




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Photo credit: UNEP

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Under-Secretary-General of the **United Nations** and
Executive Director of the **UN Environment Programme**

FOREWORD

The warnings issued by the Intergovernmental Panel on Climate Change (IPCC) about the consequences of climate change are no longer warnings. They are reality. In 2022, we saw heatwaves across the globe. We saw wildfires that destroyed forests, homes, and lives. We saw droughts that are threatening the food security of millions of people. If we do not rapidly cut emissions in line with the Paris Agreement, we will be in deeper trouble.

Decarbonizing the buildings sector by 2050 is critical to delivering these emission cuts – and to addressing the wider triple planetary crisis of climate change, nature and biodiversity loss, and pollution and waste. However, as the 2022 Buildings Global Status Report shows, the sector is not making the deep systemic changes needed to get on the path to this goal.

After the pandemic slowdown, the sector's operational emissions in 2021 rebounded to two per cent more than the all-time high set in 2019. One positive sign is that investment in building energy efficiency grew around 16 per cent in 2021, but this growth is tentative in the face of a cost-of-living crisis in 2022 and must be sustained to achieve building sector decarbonisation. Building sector energy intensity did not improve in 2021 and renewable energy growth in buildings remains modest, although green building certification are improving.

Yet, as the report shows, the sector can change. For example, rising fossil fuel costs make continued investment in energy efficiency more attractive – although the erosion of purchasing power might slow investment. The solution may lie in governments directing relief towards low and zero-carbon building

investment activities through financial and non-financial incentives, particularly for those who are most vulnerable to energy price shocks.

There are also opportunities in rethinking construction materials. Raw resource use is predicted to double by 2060 – with construction materials such as concrete and steel already major contributors to greenhouse gas emissions. However, the sector can reduce its impact by, for example, looking at alternative materials and decarbonizing cement. The use of alternative materials is particularly relevant for the African continent, a special focus of the report. Much of the new housing stock over the coming decades will be built in Africa. To avoid increasing emissions and create buildings that are resilient to the impacts of climate change, African countries should look at sustainable construction materials and techniques, in which the continent is rich.

Yes, we are running out of time to get on top of the triple planetary crisis. Yes, the buildings sector is not doing enough to change. However, by following the recommendations in this report, the sector can catch up and create buildings that are zero-carbon, resource-efficient and resilient.

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Note: Reference to emissions in this report refers to direct or indirect CO₂ emissions from buildings operations, or the CO₂ from energy used in materials production, or the CO₂ equivalent for materials process emissions, such as from concrete and steel.

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ABBREVIATIONS

°C	degrees Celsius
ASEAN	Association of Southeast Asian Nations
BPIE	Buildings Performance Institute Europe
CBECS	Commercial Buildings Energy Consumption Survey
CO₂	carbon dioxide
EJ	exajoule
EU	European Union
GBCT	Global Buildings Climate Tracker
GDP	gross domestic product
GlobalABC	Global Alliance for Buildings and Construction
Gt	gigaton
IEA	International Energy Agency
IECC	International Energy Conservation Code
IFC	International Finance Corporation
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
kWh	kilowatt-hour
LEED	Leadership in Energy and Environmental Design
m²	square metres
MEPS	minimum energy performance standard
NDC	Nationally Determined Contribution
NZE	net zero emissions
OECD	Organisation for Economic Co-operation and Development
PEEB	Programme for Energy Efficiency in Buildings
PV	photovoltaic
SDG	Sustainable Development Goal
t	ton
TWh	terawatt-hour
SEforAll	Sustainable Energy for All
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
W	watt

STATEMENTS OF SUPPORT FROM GLOBALABC MEMBERS



María Fernanda AGUIRRE
Executive Director of Chile Green Building Council
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World Green Building Council

Chile Green Building Council
Chile

Although many countries have made progress in generating initiatives aligned with carbon neutrality goals for the built environment, information provided by referring organizations such as GlobalABC through valuable resources such as the Global Status Report for Buildings and Construction, has made the urgency of accelerating the transformation of the construction sector towards one that not only reduces its emissions but is also resilient and regenerative evident.

Our prosperity and the planet's future depend on how we treat our built-environment. It is a great concern that the greenhouse effect and climate changes will threaten our cities, neighborhoods and buildings for generations to come.

No tracker exists like the Global Status Report for buildings and construction referencing trends, key data and actions taken by leading global champions to decarbonize the sector activities from reporting, monitoring to certifications.

Faisal ALFADL
Chief Representative
to the United Nations
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The Global Status Report for Buildings and Construction tracks progress in the transition towards a sustainable and resilient building sector. And the report's insights help Autodesk as we work to empower our customers to create solutions, connect data, and accelerate more sustainable outcomes such as net-zero buildings, resilient infrastructure, and waste reduction. As members, we are honored to contribute to the important work led by GlobalABC.

We are so glad that the 2022 edition of GlobalABC's flagship Global Status Report for Buildings and Construction (GlobalABC) will be launched soon on November and would be available for all of us to use the benefits, discuss and learn from its example.

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Ministry of Communications and Work
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International Living
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The global buildings industry has an enormous responsibility to transform towards a regenerative and decarbonized future. The Global Status Report for Buildings and Construction is a critical resource that helps our movement understand how we are doing, where we need to focus, and what's next. It is an invaluable source of data that we use at the International Living Future Institute to inform our work and membership, and we commend the GlobalABC for its continued support and collaboration.

Current circumstances require new structures and management methods to ensure climate and environmental governance. Reports such as the Buildings-GSR represent a key element to drive innovation through associative models, build alliances and launch platforms that enable the emergence of the required new structures to face actual challenges with greater dynamism and flexibility, drawing the attention of stakeholders to engage in this collective commitment.

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As Chairman of the Sustainable Construction Committee for Civil Buildings, I confirm my support for actions to achieve low carbon and sustainability in buildings. This includes: First working to update regulation texts and technical specifications to introduce ecological materials and procedures, second increase the renewable energy use and improve buildings' energy efficiency. Finally manage the waste construction site and develop a life cycle system for construction materials.



Aref BOUALWAN
Chief Initiatives and Startups Officer

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Contractors Company
Greece



The CCC journey towards a zero-emission, efficient, and resilient construction sector would never be possible without GlobalABC active membership. With GlobalABC, we can work closely with private and public sector members for the benefit of the industry, stakeholders and definitely the environment.

Dr. Toshiya CHIKADA
Chairperson of the Environmental Subcommittee

Sekisui House, Ltd.
Japan

Congratulations for publishing the Buildings-GSR 2022. I hope that this report, which provides basic data and advanced case studies from a global perspective, will be widely read and used as a basis for understanding the need to achieve decarbonization in the building and construction sector and for formulating policies to support it. As one of the construction companies, Sekisui House understands the climate crisis the planet faces, and is committed to leading the way in decarbonization.



Congratulations to GlobalABC on the 2022 Buildings-GSR, especially for advancing discourse on the Africa Region and Building Materials. As growth accelerates in Africa, India, and elsewhere in the "Global South", regionally appropriate solutions are essential. Embodied emissions from the vast construction industry are as crucial as operational emissions and, in many ways, more challenging to arrest. The 2022 Buildings-GSR opens long-overdue international discourse on these important topics.

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Egypt's 2021-NDC focuses on decarbonising energy-intensive industries. The buildings sector is one of its largest GHG emitters at 15 per cent, and represents 23 per cent of the energy GHG emissions. Actions for demand side mitigation of building materials is critical. It should include overcoming overbuilding practices with low-cost materials, alternative materials use, circular economy technology, efficient designs, incentives and policies setting to reach the global 40 per cent embodied carbon reduction threshold by 2030.



With almost 40 per cent of global energy-related emissions coming from the built environment, governments everywhere must prioritise it as a way of scaling economic, social and climate resilience and keeping a 1.5 degree future within reach. As a supporter of the collaborative efforts of GlobalABC, WorldGBC welcomes the Global Status Report for Buildings and Construction 2022 as a resource for describing the state of play and opportunities to deliver a more sustainable built environment.

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Commonwealth
Association of Architects
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The findings of the Buildings-GSR's highlight the shortfall in the global built environment sector's decarbonisation progress to date, urging actions to be implemented by all actors, with utmost priority. The lack of mandatory building codes in nearly 60 per cent of the countries worldwide, places greater emphasis, now more than ever before, on rapid upskilling and capacity building which will rely on radical collaborations across the industry and academia to advance the sector's decarbonisation consistently and at scale.



The Buildings-GSR provides every year an updated and credible source of information to all built environment stakeholders. Importantly, this helps forge common understanding and action in a very fragmented economic system.

Roland HUNZIKER
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Executive Director

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Though rapidly industrializing, Africa contributes only 4 per cent of greenhouse gas (GHG) emissions. Yet, it is the most vulnerable to climate change. Alongside pressuring finance and support for mitigation and adaptation, Africa must leapfrog since 50 per cent of potential 2050 GHG-emitting industries are yet to be built. As an advocate of innovative approaches for a climate-smart construction sector, BIM Africa supports the policy guidance by the 2022 Buildings-GSR, particularly the regional focus on Africa.

The intersecting of the economic, energy, security and climate crises is challenging the progress needed to decarbonise the global buildings sector. Greater political and organizational leadership are required to further prioritize and implement actions supporting the decarbonisation and sustainability transition of the built environment. The Buildings-GSR 2022 describes also the essential investment and financing for sustainable buildings required in order to achieve the Paris Agreement goals.

**Dr. Arch. Silke
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LAMBERTS**

**Federal University
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Efficiency in Buildings**
Brazil

The Global Status Report for Buildings and Construction is a very important report that monitors CO₂ emissions by the building sector worldwide. It is written by top authors in the field and is a must read for people concerned with building decarbonization and resilience. This year it has included a very important topical deep dive on building materials that leads us to a whole lifecycle approach.

This report is totally important for creating transparency about where we stand in different countries around the world. It thus forms a resilient common basis for our international and national activities.

Dr. Christine LEMAITRE

CEO

**German Sustainable Building
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Germany



**Vincent
MARTINEZ**
President and COO

Architecture 2030
United States

Congratulations to GlobalABC on the annual Global Status Report for Buildings and Construction, which charts progress on the transition to a carbon positive, energy-efficient, resilient built environment. It's great to see the focus on carbon impacts of materials, as well as the focus on sustainable development examples in the global south. Now is the time to accelerate and expand our efforts, looking beyond buildings to opportunities for emission reductions in planning, infrastructure, and landscape design and construction.

This new report highlights and recalls the unique role of buildings in the transformative patterns toward the decarbonization of our economies. The sleeping giant remains insufficiently considered and has to be pushed upfront of political agendas to deliver concrete, immediate and measurable co-benefits both on mitigation, adaptation and resilience while considering the just transition. Solutions are there and most of them are affordable or make economic and social sense.

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CEO

ENERGIES 2050
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**Birgit
SCHWENK**
Director General for
Climate Action

Federal Ministry for
Economic Affairs and
Climate Action
Germany

The buildings sector is essential for climate mitigation, resilience, and well-being. Germany is therefore committed to supporting the GlobalABC and its Global Status Report for Buildings and Construction.

This 2022 edition highlights that the carbon footprint of building materials needs to be drastically reduced to achieve our climate goals. We are convinced that the reports' findings and policy recommendations will be key to inform stakeholders on the necessary steps to decarbonise the international buildings sector.

As a social enterprise investing in green and affordable homes in Africa and Asia, Reall welcomes the call of the Global Status Report for Buildings and Construction for an urgent reset in the way we plan, design and fund our built environments. The focus on Africa is particularly timely, given the significant opportunities which still exist to support and invest in innovative and creative solutions. We join the call to collectively scale up ambition, strengthen partnerships and unlock the investment needed.

Ian SHAPIRO
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**Dominic
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International Code
Council
United States

Each year the International Code Council anticipates the release of the Buildings-GSR as a tool to assess progress and identify work to do to decarbonize and increase the resilience of the building sector. We applaud this year's focus on building materials, particularly as we launch development of a new standard for measurement and verification of whole life carbon in buildings. We look forward to continued collaboration with GlobalABC to create adaptation and mitigation tools that assist the sector.

At the U.S. Green Building Council, we are transforming buildings and communities through our LEED program, improving health and resilience while reducing carbon. Better buildings must be a core solution to the climate crisis. The Global Status Report for Buildings and Construction underscores the urgency of momentum in investment and policy to drastically reduce building emissions. The Report is an important resource for all in the buildings and construction sector, adding critical accountability to our collective effort.

**Peter
TEMPLETON**
CEO and President

U.S. Green Building
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**Max
VIESSMANN**
Group CEO

Viessmann Group
Germany

The report highlights that despite record investments into energy efficiency and 15 per cent heat pump growth globally, buildings are still dramatically off track to reach the Paris goals. The report's message must be heard loud and clear: We cannot afford to slow down investment into sustainable buildings especially in times of crisis. Building decarbonisation must remain a priority not only for our climate but also for energy resilience and better living conditions all over the world.

EXECUTIVE SUMMARY

In 2021, construction activities rebounded back to pre-pandemic levels in most major economies, alongside more energy-intensive use of buildings as workplaces reopened but hybrid working remained.

In addition, more emerging economies increased their use of fossil fuel gases in buildings.

As a result, buildings energy demand increased by around 4 per cent from 2020 to 135 EJ – the largest increase in the last 10 years.

CO₂ emissions from buildings operations have reached an all-time high of around 10 GtCO₂, around a 5 per cent increase from 2020 and 2 per cent higher than the previous peak in 2019.



DISRUPTIVE TRENDS IMPACTING BUILDING DECARBONIZATION

The COVID-19 pandemic resulted in an unprecedented change across the world in the buildings and construction sector in 2020. This included a major drop in demand for construction across major economies, workplace shutdowns due to lockdown, labour and material shortages, changing work patterns, and energy affordability challenges, which all still persist today. The result was the single largest drop in CO₂ emissions in the last decade, as documented in the last Global Status Report for Buildings and Construction.

In 2021, construction activities rebounded back to pre-pandemic levels in most major economies (section 4.1), alongside more energy-intensive use of buildings as workplaces reopened but hybrid working remained (section 4.2). In addition, more emerging economies increased their use of fossil fuel gases in buildings. As a result, buildings energy demand increased by around 4 per cent from 2020 to 135 EJ – the largest increase in the last 10 years (International Energy Agency [IEA] 2022). The impact of this is that CO₂ emissions from buildings operations have reached an all-time high of around 10 GtCO₂, around a 5 per cent increase from 2020 and 2 per cent higher than the previous peak in 2019. When including estimated CO₂ emissions from producing buildings materials of around 3.6 GtCO₂ (i.e. concrete, steel, aluminium, glass, and bricks), buildings represented around 37 per cent of global CO₂ emissions in 2021.

Also in 2021, the goals of the Paris Agreement were reaffirmed at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP26). The Glasgow Climate Pact agreed at COP26 emphasizes accelerating and rapidly scaling up energy efficiency measures (United Nations

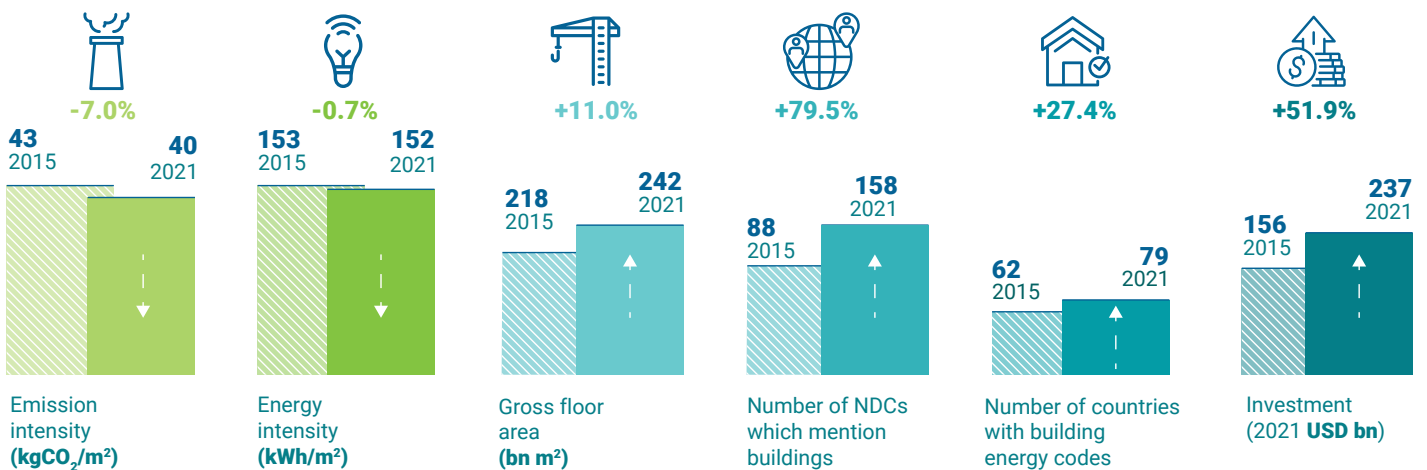
Framework Convention on Climate Change [UNFCCC] 2022a). In addition, COP26 saw more than 120 events focused on the built environment and the [launch of a number of important buildings initiatives](#).

Nevertheless, the rebound in CO₂ emissions shows that few structural changes have yet occurred within the buildings sector to reduce energy demand or cut emissions, and that 2020 was merely a pandemic-related outlier in building emissions trends. Overall, the key trends for the Global Status Report for Buildings and Construction highlight that since 2015, some progress has been made on the policy level and with an increase in investments, but there must be greater effort to reduce emissions overall and improve building energy performance alongside the continuing trend of increasing floor area (see figure 1). The 2022 update of the Global Buildings Climate Tracker confirms this observation and shows a growing gap between the actual climate performance of the sector and the necessary decarbonization pathway. This is despite 2021 having seen a growing number of countries committing to energy efficiency and offering extensive details for decarbonization of buildings within their nationally determined contributions (NDCs) (section 5.1), and an approximate 16 per cent increase in global investment in energy efficiency to over USD 230 billion (section 6).

As we move forward through 2022, there are significant risks to the decarbonization trajectory due to the Russian invasion of Ukraine and the ensuing energy crisis in Europe. Further risks are posed by global energy price volatility, along with the cost-of-living crisis facing economies and the implications of interest rate rises on investment in building decarbonization from governments, households and businesses.

The latest assessment report from the Intergovernmental Panel on Climate Change (IPCC) for the mitigation

Figure 1. Global buildings and construction key trends 2015 and 2021¹



¹ Values included for the baselines have been updated from previous versions of the Buildings-GSR due to both historic input data updates for emissions and floorspace, and also deflation factors for USD. The proportional changes between previous years remains similar.

working group (AR6 WGIII) sent a clear message that the buildings and construction industry offer significant global mitigation potential for reaching the Paris Agreement. Opportunities include improving existing buildings efficiency and use, high-performance new buildings, efficient lighting appliances and equipment in buildings, integrating renewables in buildings, and decarbonizing production of building materials. The consensus of the IPCC report is that buildings' operational emissions will need to drop by more than 95 per cent compared to current levels, and that these reductions are cost-effective and beneficial to building occupants and energy security (see section 2.3).

The growing and intersecting economic, energy, security and climate crises both challenge and highlight the progress needed to decarbonize and to improve the resilience of the global buildings sector. Greater political and organizational leadership is needed to further prioritize and implement actions that support the decarbonization and sustainability transition of the built environment and transformation of construction materials production.

In 2021, many governments continued to act with a clear interest to address climate change and buildings sustainability. The European Union's REPowerEU initiative

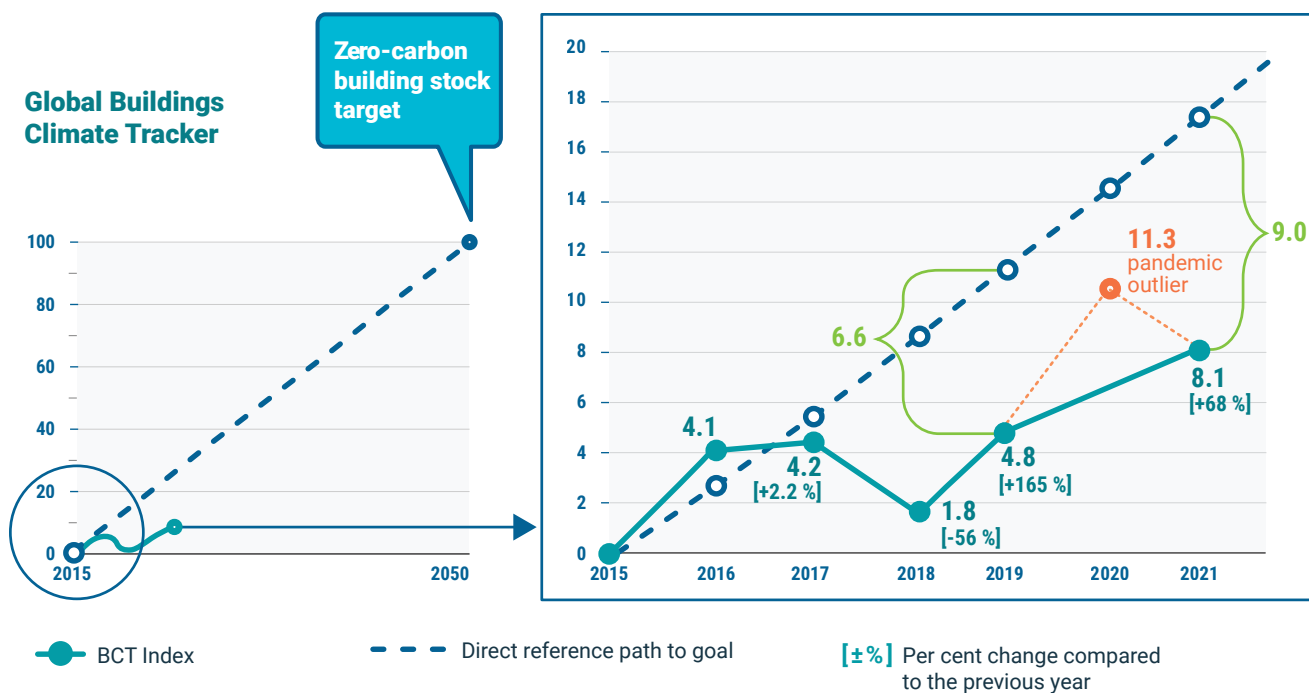
has sought to improve the energy performance of buildings by boosting the take-up of efficiency retrofits, renewables and heat pumps, and the use of fiscal measures for energy efficiency products for buildings. Similarly, the US Inflation Reduction Act has also made specific reference to supporting energy efficiency and renewable energy in buildings. Multiplying such policy commitments and a focus on sustaining and increasing investment will be critical to bending the emissions trajectory downward in the coming years.

GLOBAL BUILDINGS CLIMATE TRACKER

The Global Buildings Climate Tracker (section 3) indicates that the buildings and construction sector remains off track to achieve decarbonization by 2050. The Global Buildings Climate Tracker monitors the progress of the buildings and construction sector towards achieving the Paris Agreement.

In 2021, the decarbonization level decreased to 8.1 points, from a high point of 11.3 in 2020². The tracker shows that since the pandemic, building decarbonization activities have reverted to their previous speed of change.

Figure 2. Direct reference path to a zero-carbon building stock target in 2050 (left); zoom into the period between 2015 and 2021, comparing the observed Global Buildings Climate Tracker to the reference path (right)



Source: Adapted by the Buildings Performance Institute Europe.

²2021 Global Status Report for Buildings and Construction showed 17.3 points for 2020. The 2022 report uses updated historic data and indicators, which explains the discrepancies between the numbers in the two reports. For details, see Annex.

Current observations show a negative rebound since 2020 in the decarbonization of the buildings sector, with increased energy intensity and higher emissions. This leads to a growing gap between the observed performance and the desired pathway, as shown in the lower part of figure 2. The gap grew from 6.6 points in 2019 to 9.0 points in 2021.

GLOBAL BUILDINGS AND CONSTRUCTION STATUS

Operational energy demand in buildings (such as space heating and cooling, water heating, lighting and cooking) has grown to around 135 EJ, which is an increase of around 4 per cent from 2020 and exceeds the previous peak in 2019 by over 3 per cent (IEA 2022f). Related to energy demand, the global buildings sector CO₂ operational emissions have also rebounded from 2020 by about 5 per cent to a level of around 10 GtCO₂. This increase in emissions exceeds the pre-pandemic all-time high in 2019 by 2 per cent (IEA 2022f) (see Figure 3).

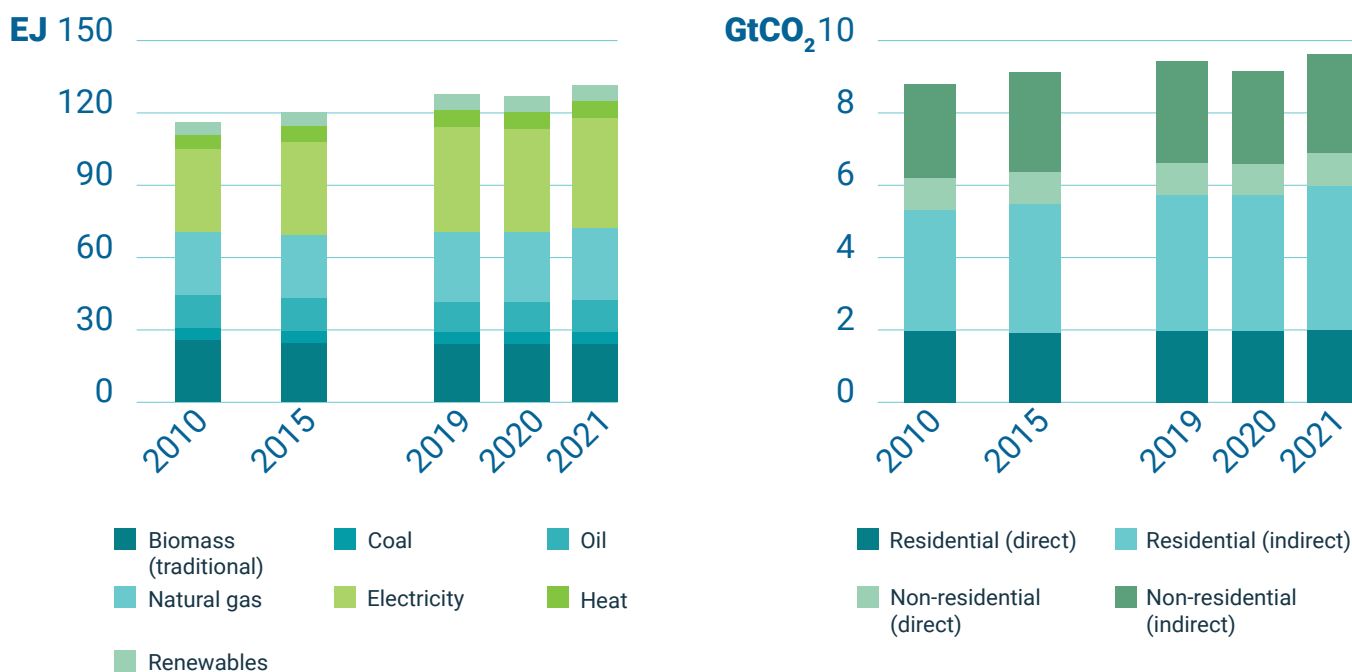
The increase reflects the reopening of the global economy as workplaces began to use more energy, alongside households continuing to work in hybrid mode, and a growth in economies using gas for heating.

The energy intensity of buildings, representing the total final energy consumption per square metre, has remained unchanged over the last three years at around 150 kWh/m². To achieve the needed pathway toward net zero carbon, the International Energy Agency estimates that intensity needs to drop by around 35 per cent of its current level to around 95 kWh/m² (IEA 2022f). Unfortunately, energy intensity has largely been unchanged since 2019 and must improve at a rate of 5 per cent per year by 2030 to achieve these targets. To do so, alongside decarbonization of the grid, the building renovation rate must increase to 2.5 per cent per year (or 10 million dwellings per year) by 2030 in developed economies (IEA 2021b).

SUSTAINABLE BUILDINGS AND CONSTRUCTION POLICIES

Buildings and construction policies saw progress in 2021, with 23 countries revising and updating their NDCs with a greater level of commitment to building efficiency and adaptation, and a greater level of detail. 80 per cent of countries now refer to buildings as part of their NDC action plans, compared to around 69 per cent in 2020 (see Figure 4). This is a positive sign as more governments recognize and make commitments to the role buildings play in their decarbonization actions (see section 5.1).

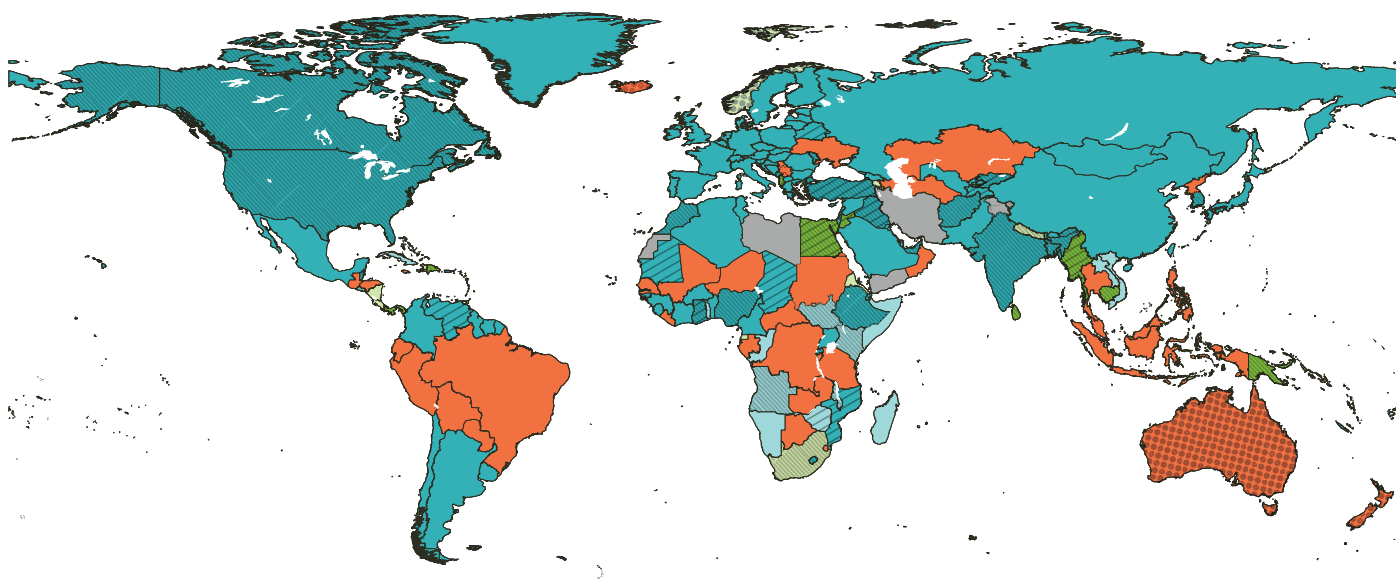
Figure 3. Energy consumption in buildings by fuel, 2010-2021 (left) and CO₂ emissions in buildings 2010-2021 (right)



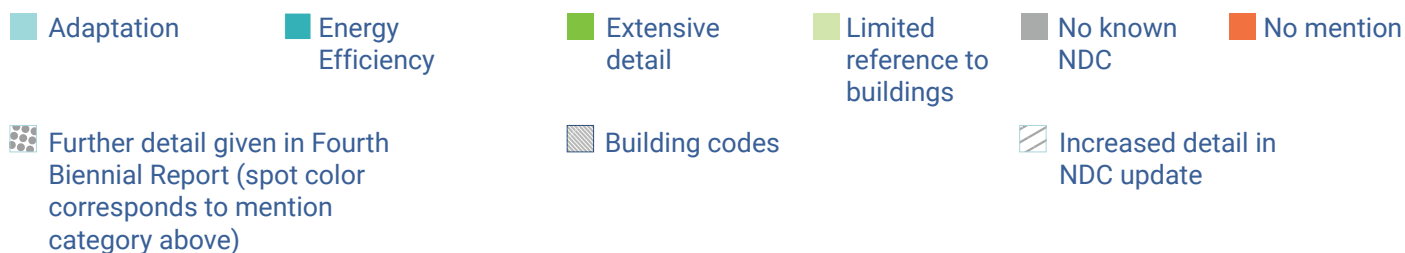
Source: International Energy Agency (2022). *Tracking Clean Energy Progress*. Paris.

Figure 4. Mentions of buildings across all countries' latest NDCs

This map is without prejudice to the status of or the sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city, or area.



NDC mentions of buildings



Source: United Nations Framework Convention on Climate Change [UNFCCC].

Notes: Adaptation can refer to any measures to improve resilience to the impacts of climate change, such as improved flood resilience for housing. Regions with fine left-hatching have specific reference to building codes. Regions with dotted hatching have reported actions through the Biennial Report.

Building codes are vital to addressing buildings sector emissions and providing clear guidelines on their features. They can be a main driver for improvements in energy performance. As of September 2022, 40 per cent of countries have mandatory or voluntary regulations or codes for building energy performance (see section 5.2) – this marks an increase of only one country from last year's Buildings Global Status Report, due to Georgia now formally applying the EU directive 2010/31/EU (European Parliament 2010). When looking at countries with mandatory codes or regulations for both residential and non-residential buildings, the proportion falls to 26 per cent. In 2021, seven US states adopted more stringent building codes for enforcement, including Washington and New York states, which have focused on promoting electrification and use of heat

pumps, and geothermal heating and cooling systems, while Denmark and France implemented lifetime CO₂ levels for new buildings (see section 5.2 and 5.3).

As a priority, more jurisdictions need to align their building codes to meeting the Paris Agreement. In 2021, several organisations and jurisdictions undertook efforts to align their new building energy codes towards being zero carbon. For example, the new voluntary appendix to the 2021 International Energy Conservation Code (IECC) works towards providing a standard for achieving zero-carbon buildings (IECC 2021), and Washington DC's 2020 energy code includes a net-zero energy appendix for new buildings (Government of the District of Columbia 2017).

As a further tool for promoting building sustainability, green building certification offers a way to adopt and recognize higher standards of building energy performance and broader metrics of building sustainability. Since 2020, there has been a 19 per cent increase in certifications across the world among the tracked systems (section 5.4).

Energy used for equipment and appliances represented around 18 per cent of building energy use in 2021 (IEA 2022f). To further address building emissions reductions, more countries have introduced minimum energy performance standards for equipment and appliances. These cover more than 80 per cent of refrigerators, 75 per cent of lighting and 82 per cent of air conditioners globally by final energy use, and are supported by a growing use of labels to indicate performance levels (IEA 2022f).



Photo credit: Kevin Grieve

INVESTMENT AND FINANCING FOR SUSTAINABLE BUILDINGS

In 2021, global buildings sector investment in energy efficiency increased by around 16 per cent from 2020 to a total of approximately USD 237 billion (IEA 2022g). This increase occurred primarily among European countries with existing programmes of public investment in efficiency, including Germany, UK and Italy, and sustained investment in USA, Canada and Japan (see section 6).

The growth in construction activities also increased the investment in more efficient new buildings and buildings covered under sustainability or “green” certifications, with an estimated 19 per cent growth in certified buildings compared to 2020.

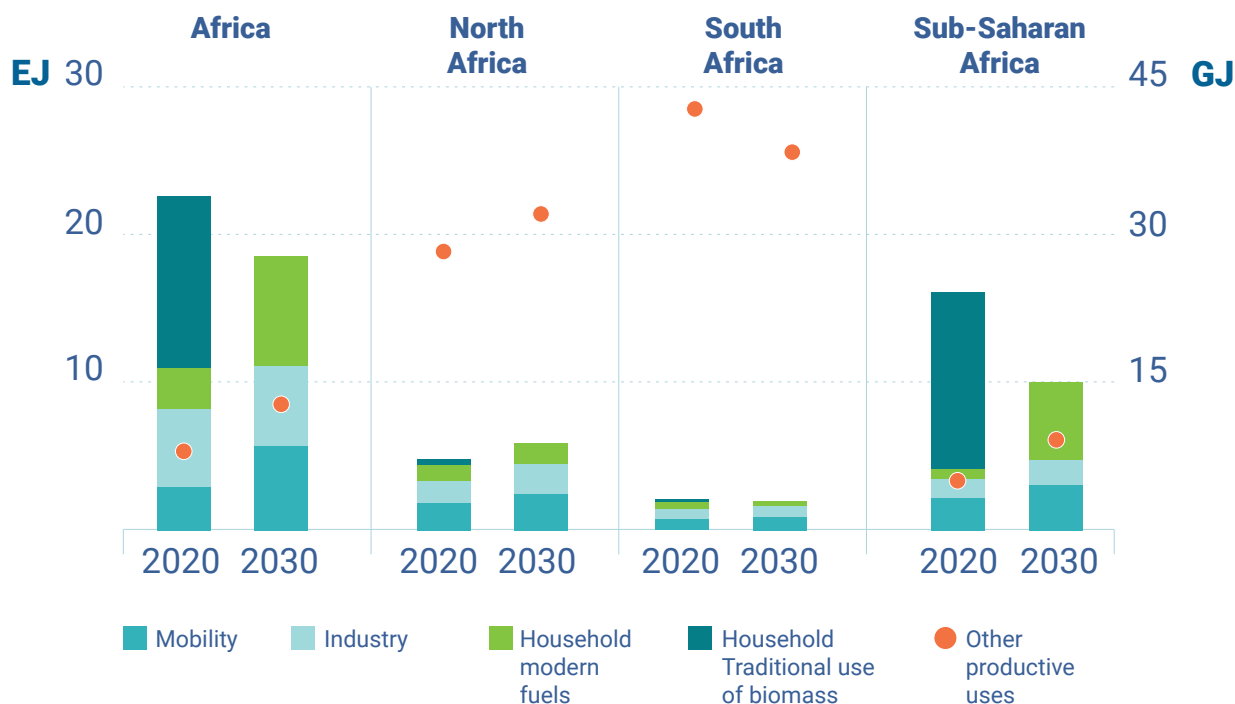
Investment in improving the energy performance of existing buildings and ensuring existing systems are operating as designed is critical to both reducing energy demand and avoiding related CO₂ emissions. Investing in fuel switching to clean fuels, such as through electrification and adoption of heat pumps for space heating and cooling, will play a major role in this transition, with the global heat pump market estimated to have grown by around 15 per cent in 2021 (IEA 2022g).

This increase in investment is welcome news but also highlights the challenge of needing to continue to increase investments in efficiency during a period of inflation that will cause increasing pressure on borrowing costs. Yet in the face of rising energy prices, investing in efficiency is a way to avoid future energy price volatility as well as reducing emissions.

A PATHWAY TOWARDS SUSTAINABILITY FOR AFRICA'S BUILDINGS AND CONSTRUCTION SECTOR

Around 56 per cent of the African population lives in informal housing (UN Habitat 2016). The population across Africa is expected to reach 2.4 billion people by 2050 and 80 per cent of this growth will occur in cities (African Development Bank [ADB] 2019). The need to provide housing now and in the future is a major driver of growth for buildings across the African continent. There are enormous opportunities for these buildings and urban environments to be built to a high-quality and sustainable standard, to be zero carbon (or zero carbon ready) and to be capable of adapting to a changing climate.

Figure 5. Africa's final energy consumption by sector 2020-2030



Source: IEA Africa Energy Outlook 2022 (IEA 2022b).

Notes: TUOB = traditional use of biomass. Other productive uses include services and agriculture. Household modern fuels include fossil fuels, electricity and renewables, such as the use of biomass in modern stoves.

Africa accounts for around 6 per cent of global energy demand and contributed to less than 3 per cent of global greenhouse gas emissions in 2021 (IEA 2022b). Households in Africa accounted for 56 per cent of total final energy consumption in 2021, but only 43 per cent of the continent's population had access to electricity. The IEA estimates that household energy demand by 2030 for cooling and appliances will more than double, though the energy intensity of lighting in the residential sector will decrease due to the movement towards energy-efficient lamps (IEA 2022b). Further, Sustainable Energy for All highlights that of the 54 high-impact and high-temperature risk countries, 24 are on the African continent (Sustainable Energy for All [SEforALL] 2022). This means that the need for cooling is a major future challenge for residential energy demand, with ownership of fans standing at 0.6 units per household and current cooling device ownership standing at only 0.06 units per household (IEA 2022b).

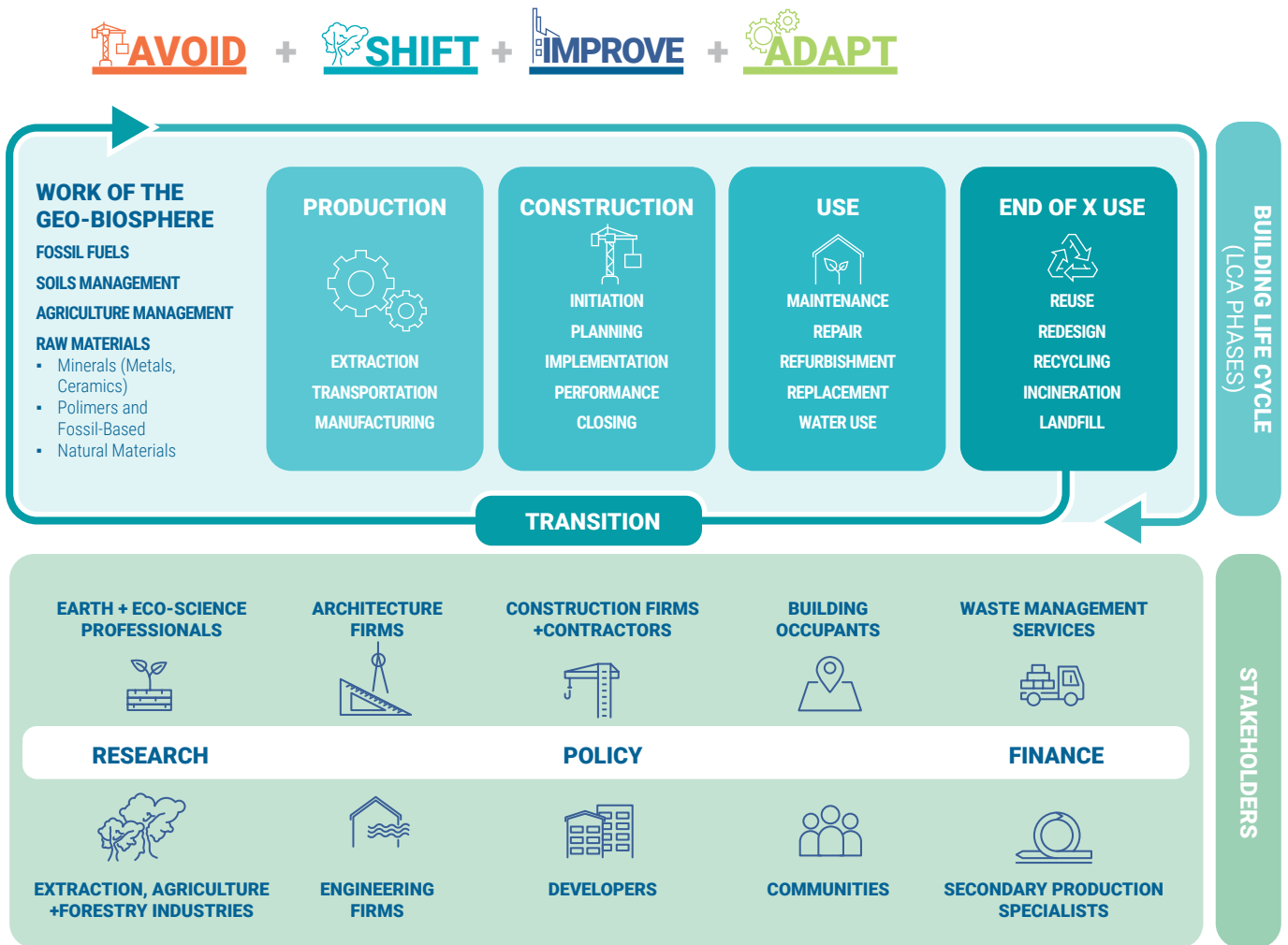
Since the 2021 Buildings-GSR, ten African countries provided further detail within their NDC update regarding commitments to decarbonizing the building stock (see section 5.2 and section 7.2). However, only five African countries (9 per cent) have a mandatory building code (section 5.2). As a priority, it will be critical for those nations that do not yet have mandatory codes to develop both the codes and their regulatory framework and the

skills and capacity to implement energy efficient and sustainable building codes that make use of local best practices and traditions. As part of this effort, energy efficient traditional and sustainable construction and building practices, which are a cornerstone of African cultural heritage, should be promoted and formalized in building codes so that housing is constructed within the local context and acts to preserve African culture while being of a high quality and affordable.

CONSTRUCTION WITH WHOLE LIFE CYCLE APPROACHES TO BUILDING MATERIALS

The global consumption of raw materials will almost double by 2060 as the world economy grows and living standards rise, exacerbating the environmental overloading we are experiencing today (Organisation for Economic Co-operation and Development [OECD] 2019). The International Resource Panel has underlined the massive greenhouse gas emissions reduction potential from material efficiency strategies applied across the building stock (Hertwich et al. 2020). In G7 countries alone, material efficiency strategies, including the use of recycled materials, could reduce greenhouse gas emissions in the material cycle of residential buildings by over 80 per cent in 2050.

Figure 6. From data to actionable knowledge: How to get the right information to stakeholders at the right phase of the built environment process life cycle in order to facilitate maximum decarbonization through systems-thinking



Transitioning to a future of low-carbon buildings requires the design of multi-beneficial material strategies that take a whole building life cycle and systems-thinking approach. The longevity of buildings infrastructure needs to be incentivized financially and legislatively to encourage low-carbon adaptation and refurbishment that extends building lifespans without locking in operational energy inefficiencies.

Despite its massive contribution to global greenhouse gas emissions, embodied carbon has previously been under addressed in strategies to reduce building emissions. A (whole) life cycle analysis approach is increasingly being adopted by industry leaders to guide strategies to simultaneously address embodied and operational carbon. These can be clustered in three strategies – “avoid”, “shift” and “improve” – all of which lead to “adaptability”. Measures range from building less,

requiring less material and using low-carbon materials, to circular approaches and improved designs that have a longer lifetime and lower operational emissions during building use.

To decarbonize the building materials sector, all stakeholders need to take greater responsibility to understand the environmental impact of their decisions regarding material selections across the life cycle. Doing so requires getting the right data to the right stakeholders at consequential stages of decision-making (see Figure 6).

Built environment carbon rating systems need to include better rewards for avoiding new construction where possible, for shifting to low-carbon biobased solutions, and for improving production methods for conventional materials. Avoiding carbon emissions by

building better-designed, resource-efficient buildings is key to reducing raw material consumption and related emissions. However, the most urgent priority must be to increase the longevity of existing and new building stock and reuse existing components whenever possible.

CHARTING THE PATHWAY TO SUSTAINABLE, ZERO-CARBON, EFFICIENT AND RESILIENT BUILDINGS THROUGH BUILDING AND CONSTRUCTION ROADMAPS

To support countries and regions in developing a clear set of actions towards enabling a sustainable, zero-carbon and resilient buildings and construction sector, the roadmap development process provides a way to build targets, strategies and partnerships through a collaborative approach.

A growing number of countries and regions are using the roadmap process for charting the path to a sustainable buildings and construction sector. Roadmaps already published include the GlobalABC and IEA's jointly published global, Asia, Africa and Latin America roadmaps along with country and regional roadmaps, including for the ASEAN region, Indonesia and Colombia (see section 9).

In addition, roadmaps are being developed for more than 30 countries and regions, highlighting the importance of national governments and regional cooperation and partnerships in efforts to decarbonize the building sector. Planned roadmaps include Türkiye, Sri Lanka, Burkina Faso, Senegal, Ghana, India, Bangladesh, 22 countries and territories in the Arab League, China's Greater Bay Area (Guangdong–Hong Kong–Macau), Cambodia and Viet Nam.

The GlobalABC provides support through the Roadmap Coordination Hub, which is a group of country and non-state stakeholders working together to “build synergies between the different initiatives [...] ensuring that the lifespan of the roadmaps extends well beyond the projects, through local engagement and implementation.”



Photo credit: Pedro Miranda

KEY RECOMMENDATIONS FOR POLICY AND DECISION MAKERS

The structural changes needed in the buildings and construction sector are not yet showing, as is clearly documented in the series of Global Status Reports for Buildings and Construction. While the increase in investment in energy efficiency among existing buildings and a greater number of new buildings being constructed to higher energy performance standards are welcome trends, the impact on energy use and energy intensity is not yet showing, nor is there any sign of emissions from the buildings sector being decoupled from energy or construction.

Policymakers and decision makers must urgently implement definitive near-term actions that deliver the needed emissions reductions while achieving the objectives of a sustainable and resilient buildings and construction sector. The buildings sector will continue to grow to meet citizens' needs for safe housing and workplaces, but its growth must be in alignment with the Paris Agreement.

The following recommendations are designed to respond to these challenges:

- 1.** Coalitions of national stakeholders should be developed to **set targets and strategy towards a zero-emission, efficient and resilient buildings and construction sector** through building decarbonization and resilience roadmaps and in line with the Marrakech Partnership Global Climate Action Human Settlements Pathway.
- 2.** National and sub-national governments must put in place mandatory building energy codes and **set out a pathway for their new building codes and standards to be performance based and to achieve zero carbon across a building's life cycle as quickly as possible**. For jurisdictions without building energy codes, these need to be formulated and adopted. Codes should consider the [Guidelines for Energy Efficiency Standards in Buildings](#) (United Nations Economic Commission for Europe [UNECE] 2020).
- 3.** Governments and non-state actors **must increase their investment in energy efficiency**. This investment needs to target all businesses and households. Governments will need to use financial and non-financial incentives to encourage investment and provide support for vulnerable households.
- 4.** The construction and real estate industries must **develop and implement zero-carbon strategies for new and existing buildings** in all jurisdictions, in order to effectively support government policies.
- 5.** The building materials and construction industries must commit to **reducing their CO₂ emissions throughout their value chain in line with the Paris Agreement**, supporting government policies towards a carbon neutral building stock.
- 6.** Increased funding is urgently required for public-private research partnerships to **accelerate the development, demonstration and commercialization of innovations to reduce embodied carbon** in building materials.
- 7.** For governments aiming to achieve a net-zero-carbon built environment, regulations and assessment of emissions need to **take a life cycle approach** that considers both materials' embodied carbon emissions and operational emissions.
- 8.** Governments, especially cities, need to **implement policies that promote the shift to circular economies** that replace linear, non-renewable, toxic material processes with sustainable renewable materials that can sequester carbon and be managed sustainably over their life cycles. In parallel, for materials that cannot (yet) be replaced, their use and their carbon footprint should be reduced as much as possible.
- 9.** Fast-growing countries and economies, including in Africa and Southeast Asia, need investment to **build capacity, resources and supply chains** to promote energy-efficient designs and low-carbon and sustainable construction.

1. DISRUPTIVE TRENDS IMPACTING BUILDING AND CONSTRUCTION DECARBONIZATION IN 2021 AND 2022

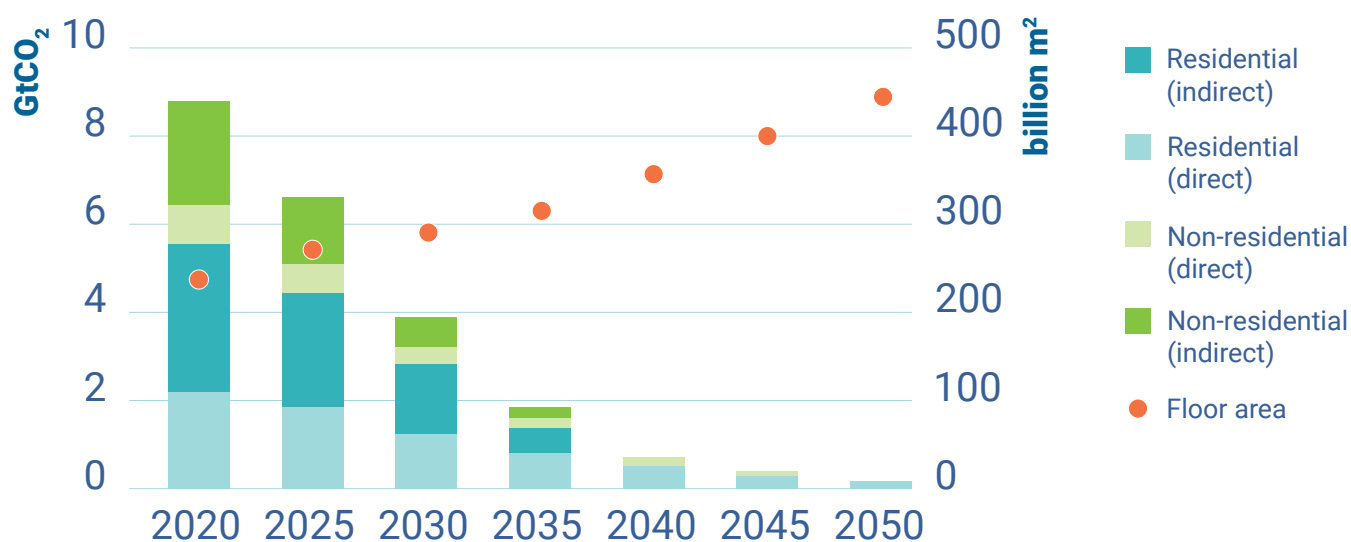
The decarbonization and sustainability transition of the built environment remains “not on track”. Building operational emissions are at an all-time high, exceeding the 2019 peak. The “perfect storm” of the concurrent economic, energy, security and climate crises is challenging the necessary progress to decarbonize and improve the resilience of the global buildings and construction sector, but presents an opportunity as well. Political and organizational leadership must prioritize actions that support the decarbonization and sustainability transition of the built environment.



The global buildings sector consumes an estimated 30 per cent of global energy (135 EJ), in the form of electricity and gaseous, liquid and solid fuels and district energy for building energy uses (e.g. heating, cooling, cooking, lighting and equipment), and is responsible for around 27 per cent of global operational related CO₂ emissions (10 GtCO₂) (IEA 2022f). The production of concrete, steel and aluminium, important materials used in the construction of buildings, added a further 4 per cent of global energy use and 6 per cent

of global emissions in 2021 (IEA 2022f). The production of glass and bricks could amount to a further 2-4 per cent of global emissions. Combined, CO₂ emissions from buildings operations and the materials used in the construction of buildings are estimated to account for around 37 per cent of global energy and process-related emissions. To be aligned with reaching net zero carbon emissions by 2050, emissions would need to fall by over 98 per cent from 2020 levels (see figure 10).

Figure 7. Global buildings energy demand and floor area growth under the IEA Net Zero Emissions by 2050 Scenario



Source: IEA 2021. All rights reserved. Adapted from "Tracking Clean Energy Progress" (IEA 2021c).

Decarbonizing the global buildings sector is therefore critical to preventing catastrophic climate change. To achieve the Paris Agreement, the global buildings and construction sector must become net zero-carbon by 2050, and all new buildings must be net-zero carbon from 2030 (United Nations Environment Programme [UNEP] 2021; United Nations Framework Convention on Climate Change [UNFCCC] et al. 2021). The [Marrakech Partnership for Global Climate Action Human Settlements Pathway](#), which is co-led by GlobalABC, has explicitly called for the following targets:

- 1) By 2030, the built environment should halve its emissions whereby 100 per cent of new buildings must be net-zero carbon in operation;
- 2) By 2050, all new and existing assets must be net zero across the whole life cycle, including operational and embodied emissions ([Marrakech Partnership for Global Climate Action \[MPGCA\] 2021](#)).

Most countries recognize this challenge and around

sixty per cent of countries that have submitted NDCs (196) have cited improving building energy performance as a way to tackle emissions (UNFCCC 2021). Non-state organizations continue to make commitments to address their emissions through partnership initiatives, such as [Science-Based Targets](#).

Yet efforts to address buildings sector energy performance and CO₂ emissions have not kept pace with the Paris Agreement targets, with the IEA describing the sector as "not on track" in 2022 (IEA 2022f). Investment in energy efficiency remains low, buildings sector energy intensity is only slightly improving, and growth in integrating renewable energy into buildings and cities is modest, though green building certification and NDCs are improving (United Nations Environment Programme 2021). Most challenging is that only 35 per cent of countries have mandatory building energy regulations or codes for some or all building types that regulate how energy efficient a building needs to be when constructed; this drops to 26 per cent for those with mandatory codes for both residential and non-residential buildings. When combined with countries with available performance standards, this amounts

to 40 per cent of countries (see section 5.2). It is estimated that 82 per cent of the population to be added by 2030 will be living in countries without any building energy codes or only voluntary codes (United Nations Environment Programme 2021). Building codes need to be designed to ensure buildings are fit for purpose, energy efficient, and resilient to future change in climate and should take into account existing best practices for energy efficiency standards in buildings (see Box 7). Further, the overwhelming majority of current building codes fail to consider embodied carbon in building construction, which is critical to achieving the sector- and energy-system wide targets and adopting whole-life-cycle thinking (see section 7).

There are significant challenges to addressing these ambition gaps. These include the political capital needed to address regulatory barriers and financing for building energy efficiency and decarbonization; promoting behaviour changes to reduce unnecessary energy demand; improving skills around designing new buildings and refurbishing existing ones; and the technological requirements of recommissioning and replacing heating and cooling systems and refurbishing hundreds of millions of buildings around the world. Finally, there is a need to ensure climate actions in the built environment support equity and justice as part of the transition to a sustainable buildings stock that is net zero carbon by 2050.

1.1. EMERGENT CHALLENGES FOR DECARBONIZING THE BUILDING STOCK

The Russian invasion of Ukraine and the impact on energy supply and prices, alongside an existing cost of living crisis and the continued pressures of the COVID-19 pandemic on supply chains, present major political challenges but also opportunities for the transition of the global building stock. European countries are having to make difficult choices about how to continue to provide security of supply for households and businesses, while energy prices and materials and equipment costs for investing in energy efficiency rise. The circumstances arising from these converging crises show the fragility of a volatile, fossil-fuel-based energy system and its limited resilience to shocks. Yet they also highlight the opportunity and urgency of investing in buildings sector energy efficiency to both reduce current emissions and improve energy security and resilience to climate change.

Since the start of 2022, the cost of fossil-based energy has accelerated at rates not seen since the onset of the global financial crisis in 2008 (Trading Economics

2022b; Trading Economics 2022a). Between February and August 2022, fossil (natural) gas prices doubled in the US and increased by 2.5 times in Europe (Trading Economics 2022b). These steep rises in fossil-fuel-based energy costs have been a shock to households and businesses around the world, with increasing monthly energy expenditure adding to the impact of inflation eroding purchasing power (Trading Economics 2022c). Across OECD countries, for the first two quarters of 2022, the annual growth rate for consumer prices index³ was up to 10 per cent and 36 per cent for energy (OECD 2022). Europe's energy cost increases are even higher than the OECD average at 50 per cent (or 70 per cent in the Netherlands) (OECD 2022) due to their energy market's close connection to Russia, with the European Union receiving 40 per cent of its energy from Russia in 2021 (IEA 2022a). Much of this energy price inflation was due to fossil gas and gasoline price increases that affect both direct consumer fuel prices and gas used for electricity generation. With greater adoption of renewables, building energy use would be less impacted by fossil fuel price volatility.

Adding to these cost pressures, the effects of the COVID-19 pandemic through 2021 continued to constrain supply chains. Increased transport costs (shipping costs surged by over 500 per cent by May 2019 (Freightos 2022), limited production and shortages of manufactured goods, and work stoppages or slowdowns due to pandemic restrictions (International Labour Organization [ILO] 2021) have all made getting materials and goods to markets more costly. The pandemic has also shown the vulnerabilities and divides that exist among urban and rural households, who have very different costs and levels of access to services that can address energy insecurity and vulnerability (Memmott et al. 2021). To calm inflation, central banks across the OECD have taken action to start raising interest rates, which increases the cost of borrowing and has a dampening effect on business and household expenditure and investment.

These converging energy and living cost crises have significant implications for decarbonizing the global building stock. Although high energy costs are an incentive to invest in energy efficiency, the erosion of purchasing power due to inflation and the impact of labour and materials, alongside the sustained high price of goods due to logistical pressures, will all add pressure to slow investment, especially in the face of higher borrowing costs. Recommissioning existing buildings systems is one important action that does not rely on substantial upfront investment and can maintain system performance as designed, though ultimately considerable refurbishment will be needed to meet decarbonization goals.

³ OECD define Inflation measured as Consumer Price Index (CPI) as: "the change in the prices of a basket of goods and services that are typically purchased by specific groups of households. Inflation is measured in terms of the annual growth rate and in index, 2015 base year with a breakdown for food, energy and total excluding food and energy. Inflation measures the erosion of living standards." (OECD 2022)

The political solutions may lie in the ability of governments to direct support towards a broad range of low- and zero-carbon building investment activities, standards and delivery systems – through education, partnerships, financial and non-financial incentives for households and businesses, and their own leadership through policies and international commitments. Governments have a duty to be efficient with public expenditures, so supporting private households and businesses to make choices to reduce energy demand and to make their own investments in energy efficiency and low-carbon technologies and materials should be a priority.

1.2. EMISSIONS REBOUND FROM COVID AND EFFORTS FOR ECONOMIC RECOVERY

The global pandemic precipitated the largest annual reduction in global CO₂ emissions, falling 6 per cent from their 2019 peak of 35 GtCO₂ to 33.3 GtCO₂ (Davis et al. 2022). However, as economies have reopened, work and production patterns (such as hybrid working and increased product demand following delays) have adapted. Estimates for 2021 show that overall global emissions have rebounded to less than 1 per cent below their 2019 all-time high to 34.9 GtCO₂, and residential and industrial emissions rebounded to their 2019 levels, while power sector emissions from China and India increased (Davis et al. 2022).

For the buildings sector, emissions have rebounded: suppressed demand for new buildings re-emerged as countries began to reopen their economies, and simultaneously households and businesses began to make use of their buildings more intensively than during the height of the pandemic. Estimates for the buildings sector operational CO₂ emissions showed a 3 per cent drop in 2020 from 2019 levels, followed by around 5 per cent increase in CO₂ emissions in 2021 (IEA 2022f). The latest estimates for mid-2022 suggest a levelling of residential emissions (Carbon Monitor 2022). This appears to be related to cost-of-living and inflation effects, which have a tendency to reduce energy demand in new and existing buildings.

The slow nature of structural changes in the buildings sector means that actions that support dramatic emissions reductions, such as behaviour change, energy efficiency refurbishment, and widespread fuel switching to zero-carbon-ready heating and cooling systems, have not been realized during this period of health, economic and energy crises.

1.3. SOLUTIONS FOR GOVERNMENTS AND DECISION MAKERS

Incremental improvements in the energy efficiency of the existing building stock may – even at an accelerated rate – take a decade to substantially reduce carbon emissions across the buildings sector. Actions for new buildings will avoid unnecessary future emissions but will have limited impact on emissions being generated from the buildings sector today.

Creating benchmarks and performance standards for existing buildings, such as those used in Europe under the Energy Performance of Buildings Directive, and developing building codes for existing buildings are an important step towards the necessary structural changes needed. Developing codes and standards that account for operational *and* embodied carbon when constructing new buildings and refurbishing existing buildings will ensure whole-life-cycle thinking is addressed. With open and transparent information on a building's energy performance, building owners and managers will be able to better understand the options available to them to reduce energy demand through investment and improving existing building control systems.

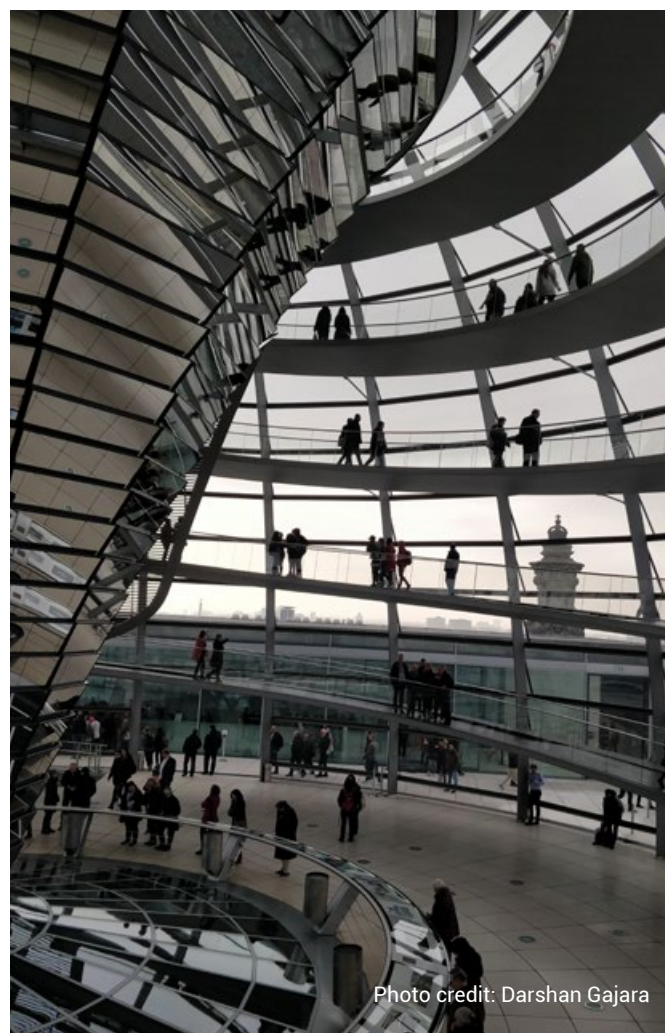


Photo credit: Darshan Gajara



Photo credit: Gary Butterfield

Building performance and embodied carbon information can also provide the necessary evidence for consumers, lenders and investors to direct funds to improve building energy performance through recommissioning and refurbishment. Additionally, integrating sustainability, low-energy design and understanding of embodied carbon into training programmes will normalize the concepts of sustainable and zero-carbon buildings.

Commitments from governments and heads of state affirm the importance of built environment sustainability in supporting their mandates to protect citizens, increase energy system resilience and security, and address climate change. For example, the European Commission, working with European governments, has launched REPowerEU, which aims to reduce EU dependence on Russian fossil fuels and tackle the climate crises through energy savings, diversification of energy supplies and accelerated roll-out of renewable energy (see Box 1) (European Commission 2022d). The US Inflation Reduction Act 2022 has also set out clear support for buildings decarbonization through energy efficiency

and renewable energy adoption (United States of America, The White House 2022b). Additionally, the recent Declaration on Sustainable Urbanization from the leaders of Commonwealth governments acknowledged the relationship between a sustainable built environment and citizen safety and well-being, and looked to support and encourage cities to work together to address climate risks and reduce their emissions (see Box 2) (The Commonwealth 2022). National-level actions continue to play a critical part in addressing the buildings sector and regulations. Laws that support NDCs must now be implemented to chart a pathway to a decarbonized and resilient buildings and construction sector. For example, Colombia's Law 2169 2021 sets out targets to achieve its NDC and includes the construction sector, with guidance for building certifications, local appliance labels and certificates (El Congreso de Colombia 2021). A further example is the Saudi Green Initiative, which is promoting green buildings concepts, methodologies, applications and technologies through more than 1,000 projects in buildings, neighbourhoods and cities (Kingdom of Saudi Arabia 2021).

Box 1. European response to the energy crisis

The Russian invasion of Ukraine, which has caused devastating impacts and loss of human life in Ukraine, has also precipitated an energy crisis in Europe. Energy prices in most of Europe have increased dramatically, causing rising costs for electricity, natural gas and fuel oil in the building sector.

In February 2022, approximately 43 per cent of imported natural gas in Europe came from Russia; by the end of June, Russian imports had been halved with gas increasingly coming from other sources (Simson 2022). However, to further reduce imported Russian energy and continue to secure energy supplies for the coming winter period, demand reductions are critical.

The buildings sector represents 40 per cent of Europe's energy demand; 80 per cent of this is generated by fossil fuels. This makes the sector an area for immediate action, investment and policies to promote short- and long-term energy security.

The IEA produced a 10-point plan setting out how Europe could manage and reduce Russian gas from the energy mix (IEA 2022a). It highlighted actions that included speeding up the replacement of gas boilers with heat pumps; accelerating energy efficiency improvements in the buildings sector, increasing renovation rate from 1 per cent to 1.7 per cent; and demand-side management to reduce indoor temperatures when safe to do so.

More specific to the buildings sector, a report by the Building Performance Institute Europe focused on four cluster areas for change and a set of supporting actions (Building Performance Institute Europe [BPIE] 2022):

1. Showing leadership with innovative organizational machinery

- a. Create a task force for building renovation in the European Commission
- b. Set up a "Renovation Compact" uniting business and social representatives in the construction value chain

2. Telling the story, promoting the new vision

- a. Run an all-media communication campaign
- b. Promote all new and existing renovation and decarbonization programmes
- c. Enhance the mapping of the building stock, especially at regional and local levels

3. Making financing easily available

- a. Reallocate EU and national funding
- b. Reduce VAT on renovation products and works
- c. Mobilize private sector financial solutions

4. Preparing the supply chain to deliver

- a. Boost upskilling activities to have a workforce ready to renovate and install quickly
- b. Create a special initiative for energy-saving coaches
- c. Set up a special funding line called the Industrial Renovation Alliance, managed by the European Investment Bank, to boost investments in these types of renovations and scale them up quickly
- d. Roll out one-stop-shops throughout Europe

Box 2. Declaration on Sustainable Urbanization

Declaration on Sustainable Urbanization 25 June 2022 (The Commonwealth 2022)

We, the Commonwealth Heads of Government:

- Acknowledge the need for integrated strategies for safe and sustainable urban development that enhance community wellbeing and security;
- Support cities, municipalities, and other urban authorities to mobilise resources to develop comprehensive, scalable programmes to address key challenges of sustainable urbanization and build climate resilience to reduce risk and vulnerability;
- Encourage cities to create an enabling environment that support local economic development, job creation, and attract investment; and
- Encourage sharing of knowledge and experience including through Commonwealth dialogue; twinning of cities, and increased opportunities for professional training in urban development, including town planning.



Photo credit: Nerea Marti Sesarino

2. GLOBAL BUILDINGS CLIMATE TRACKER

After the improvement of decarbonization progress reported in the 2020 Global Status Report for Buildings and Construction – an effect of the COVID-19 pandemic – the Global Buildings Climate Tracker finds that the buildings sector remains off track to achieve decarbonization by 2050. While decarbonization efforts have marginally improved since 2019, the observed emissions and energy consumption continued to increase in 2021 even beyond pre-pandemic levels. The decarbonization of the building stock is “not on track” to reach the goals of the Paris Agreement. In 2021, the buildings decarbonization index is only at 8.1 points out of 100 while it should be at over 17.1 points out of 100. This shows that the sector is achieving about half of the necessary decarbonization. The gap between the actual decarbonization performance and the desired pathway has been widening since 2018. The significant rebound in building sector emissions confirms that the boost in decarbonization during the pandemic was temporary. No structural, systemic improvement was achieved in the buildings sector, leaving it vulnerable to external factors, such as fluctuating consumer prices, inflation and temperature changes.

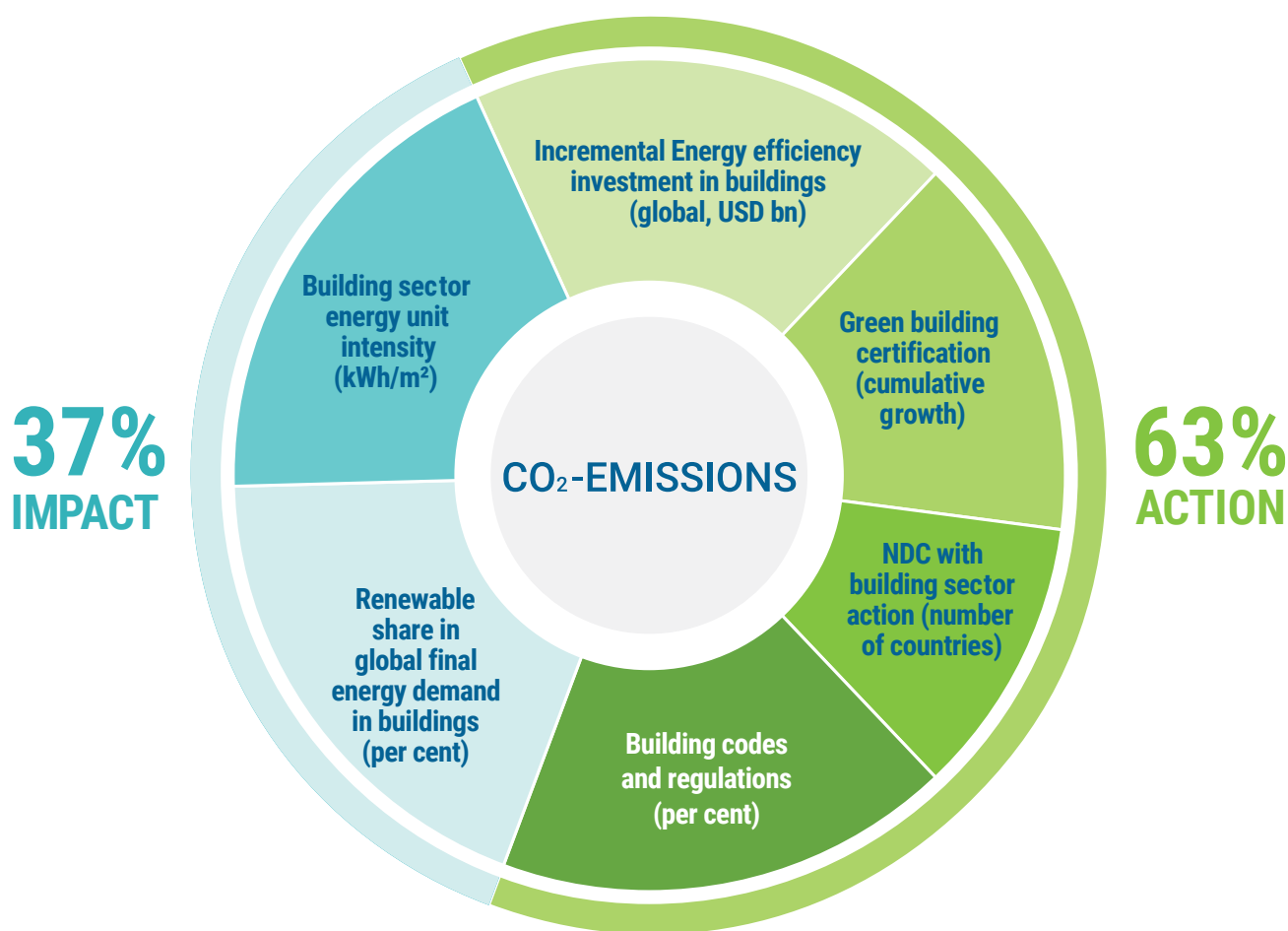


The Global Buildings Climate Tracker (GBCT), first published in 2020, aims to monitor progress towards decarbonizing the construction and operation of buildings. It provides a snapshot of the status of building stock emissions as compared to a scenario for the future (2050). To do this, the GBCT uses a set of indicators – covering emissions, energy intensity, investments and policy – to identify global trends in decarbonization action and impacts.

2.1. DESCRIPTION OF THE TRACKER

The Global Buildings Climate Tracker is a seven-part composite index created to track the progress towards decarbonization of buildings. It includes three indicators – CO₂ emissions⁴, energy intensity⁵ and renewable energy share⁶ – that together show the impact of decarbonization efforts. In addition, it includes four indicators that measure the actions taken towards decarbonization: building regulations, energy efficiency investments, green building certifications and building

Figure 8. Composition of the Global Buildings Climate Tracker showing its elements and their weight



Source: Adapted by the Buildings Performance Institute Europe (BPIE) 2022.

Note: The weighting of individual indicators in the decarbonization index, and their data sources, are as follows: energy intensity 19 per cent (IEA 2022f); renewable share 19 per cent (IEA 2022f); building regulations 18 per cent (author analysis); energy efficiency investments 19 per cent (IEA 2022f); green building certifications 15 per cent (author analysis); building measures in NDCs 11 per cent (author analysis⁷). Instead of a weighted share, CO₂ emissions are used as a factor because they are the main measurement for decarbonization (IEA 2022f). For more information, see the Annex.

⁴ Global buildings sector (residential and non-residential) energy-related emissions (direct and indirect)

⁵ Final energy used in buildings globally per unit of floor area

⁶ Share of renewables in the final energy use of the buildings sector globally

⁷ Percentages shown are rounded

measures in NDCs. These indicators are normalized and aggregated according to their weight (see Figure 8) to construct the decarbonization index. For more information, see the annex. The GBCT is updated with the latest data from 2021 and adjustments in historic data for 2019 and 2020 (from updated and new statistics that became available in 2021). New indicators were not included in the index; however, a major building certification scheme (BREEAM) was added to the green building certifications indicator and a sub-element (quality control in construction⁹) in the building codes and regulations indicator was excluded as its source was discontinued. The data on emissions related to global building materials is not sufficiently comprehensive, so these emissions are currently not reflected in the GBCT. Chapter 8 provides detailed insights on this topic.

2.2. STATUS IN 2021: ASSESSING PROGRESS TOWARDS THE 2050 DECARBONIZATION GOAL

As shown in last year's Global Status Report for Buildings and Construction, the decarbonization level in 2020 was calculated at 11.3 points⁹ (the highest since 2015). In 2021, the decarbonization level decreased to 8.1 points, which indicates a lower progress compared to 2019 (see Figure 9 in box 3), driven mainly by the return of the sector to its pre-pandemic operation levels.

This year's analysis confirms that the progress recorded in 2021 was an outlier due to the impact of COVID-19, with no lasting effect as it was disconnected from true improvement in buildings' energy efficiency. A strong rebound in the global buildings sector is visible, especially in the operation of non-residential buildings and associated greenhouse gas emissions.

2.3. POST-PANDEMIC REBOUND AND ECONOMIC RECOVERY

Due to periods of economic slowdown during 2020, a strong decline in global emissions was observed in the Global Status Report for Buildings and Construction 2021¹⁰. However, in 2021 construction projects restarted and supply chains were revived, with higher inflation and consumer prices discouraging energy efficiency measures in buildings. The economic recovery and the

Box 3. Explaining the Global Buildings Climate Tracker

The GBCT tracks decarbonization progress in the buildings sector from 2015. The decarbonization status is therefore set at 0 for 2015, which was defined as the base year. The target value in the year 2050 is set at 100 to reflect the maximum decarbonization needed in the sector*. A linear pathway for decarbonization was defined between 2015 and 2050.

The house image below represents the 2050 goal, and its green portion represents the achieved progress in decarbonization. The bar on the scale to the right mark the progress achieved towards that goal. In 2021, 8.1 points were reached.

Figure 9. Decarbonization of buildings using the Global Buildings Climate Tracker 2021



Source: Adapted by the Buildings Performance Institute Europe.

*Note: Each indicator has an individual goal, which is assigned a certain value. Indicators together agglomerate to the maximum decarbonization levels. Details on the methodology can be found in BPIE (2020).

⁸ For more on the methodology, see the Annex and a detailed description in BPIE (2020).

⁹ The Buildings Global Status Report 2021 showed 17.3 points for 2020. The 2022 report uses updated historic data and indicators, which explains the discrepancies between the numbers in the two reports. For details, see Annex.

¹⁰ The emissions reported for 2020 have since been corrected, showing that the pandemic did not cause the emission reductions initially assessed. As a result, this year's Global BCT shows that even during the pandemic the net-zero pathway was not reached.

connected rebound in energy use in buildings caused an increase in CO₂ emissions¹¹ and moved the index further away from the reference path than during the pandemic, showing the lack of lasting progress in the sector in 2020 and 2021. Emissions went beyond a simple rebound to exceed the pre-pandemic levels, showing that policy and investment measures are not materializing fast enough to counteract increases in energy use and emissions.

2.4. DECARBONIZATION PROGRESS SINCE THE PARIS AGREEMENT

The yearly index has improved from 4.8 in 2019 to 8.1 in 2021 but the overall operational emissions from buildings have increased by about 5 per cent compared to 2020 and 2 per cent compared to 2019¹², showing no real progress towards the 2050 goal.

To put these results into context, Figure 10 shows the direct path to the goal of the Paris Agreement on the left. The blue dot illustrates the target of a zero-carbon building stock by 2050 as defined by the GBCT. The direct path to goal connects the starting point 0 in the base year 2015 with the target point 100 in 2050.

In 2021, the tracker is at 8.1 points while it should be at over 17.1 points. The sector is achieving about half of the necessary decarbonization. The gap between the actual decarbonization performance and the desired pathway has been widening since 2018. This requires bolder actions by policymakers and the private sector.

Figure 10 zooms into the period from 2015 to 2021. The dotted dark blue line serves as a benchmark. To be on track, the lighter blue line must be on or above the dotted blue line. In 2020, the GBCT index moved closer to the reference path, as indicated by the grey dashed line that approaches the blue line. This is due to the exceptional slowdown of large parts of the economy, including the construction sector, and the limited use of non-residential buildings such as offices during the COVID-19 pandemic. As this would give a false positive message of decarbonization moving towards being “on track”, the 2020 observation is treated as an outlier.

In fact, buildings' decarbonization progress is slowing down and the decarbonization gap is increasing. Despite the 68 per cent improvement shown in the GBCT index between 2019 and 2021, the index has fallen further away from the path to a zero-carbon

building stock: the distance between the orange and the blue line has increased from 6.6 in 2019 to 9.0 in 2021. This observation represents the rebound in CO₂ emissions described in section 4.3. The numbers confirm the slowing down of decarbonization and provide evidence that the reduction of emissions in 2020 was temporary and no lasting progress was achieved.

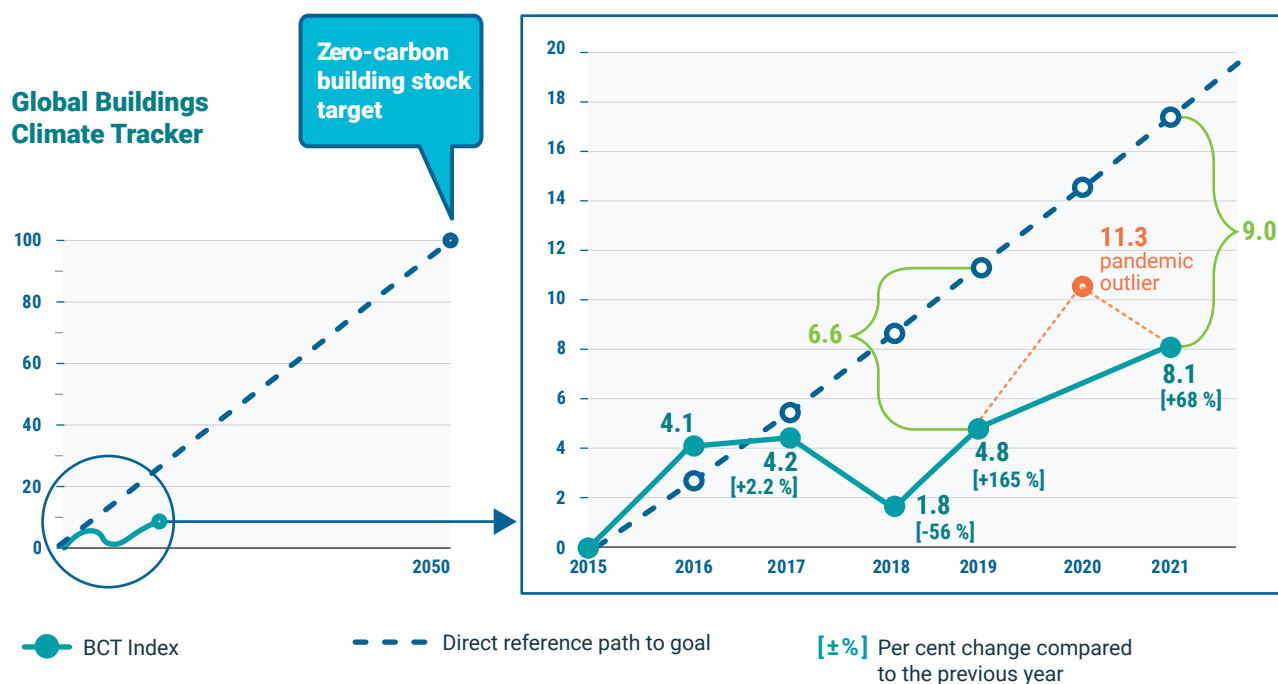


Photo credit: Jose Llamas

¹¹ Find more details on the energy consumption development in section 4.2

¹² Find more details on the emissions development in section 4.3

Figure 10. Direct reference path to a zero-carbon building stock target in 2050 (left); zoom into the period between 2015 and 2021, comparing the observed Global Buildings Climate Tracker to the reference path (right)



Source: Adapted by the Buildings Performance Institute Europe 2022.

2.5. SUMMARY OF THE RESULTS

Some positive developments can be highlighted in the buildings decarbonization index in 2021. For example, a 19 per cent cumulative growth (compared to 2020) is observed in green building certifications indicating significant progress in energy-efficient buildings, even if this is only reflected in schemes that made their data transparent and available¹³. In addition, energy efficiency investments went up by around 16 per cent¹⁴ (compared to 2020), one country has put in place a law that regulates energy performance of buildings, and two have published new draft building codes that are not yet in force¹⁵; a growing number of countries are aligning their existing codes towards being net-zero; and 23 more countries have mentioned or expanded their focus on buildings in their NDCs¹⁶.

The pandemic also accelerated awareness of the influence of buildings on health and well-being and deepened the consideration of occupants' comfort along with energy efficiency (Awada et al. 2021). Decarbonization measures will need to take these aspects into account.

However, after the temporary improvement in decarbonization levels estimated in the Global Status Report for Buildings and Construction 2021, the observed emissions and energy consumption have continued to increase in 2021 even beyond pre-pandemic levels, indicating the decarbonization of the building stock is "not on track" to reach the goals of the Paris Agreement.

The significant rebound in buildings sector emissions confirms that the boost in decarbonization during the pandemic was temporary. No structural, systemic improvement was achieved in the buildings sector, leaving it vulnerable to external factors such as fluctuating consumer prices, inflation and temperature changes.

An increase in investments and progress of national policies is essential to reduce future emissions, given that they have an impact over the long term. However, investment and policy improvements are not yet triggering the necessary impacts to comply with the Paris Agreement pathway.

¹³ Schemes that made their certification data available were: LEED (USA), BREEAM (UK), MINERGIE (Switzerland), WELL (USA), Passive House (Germany), EDGE (UK), DGNB (Germany), IGBC (India), GREEN STAR (Australia), CASBEE (Japan), SGBC (Sweden), SGBF (Saudi Arabia), GRIHA (India) and BEAM Plus (Hong Kong).

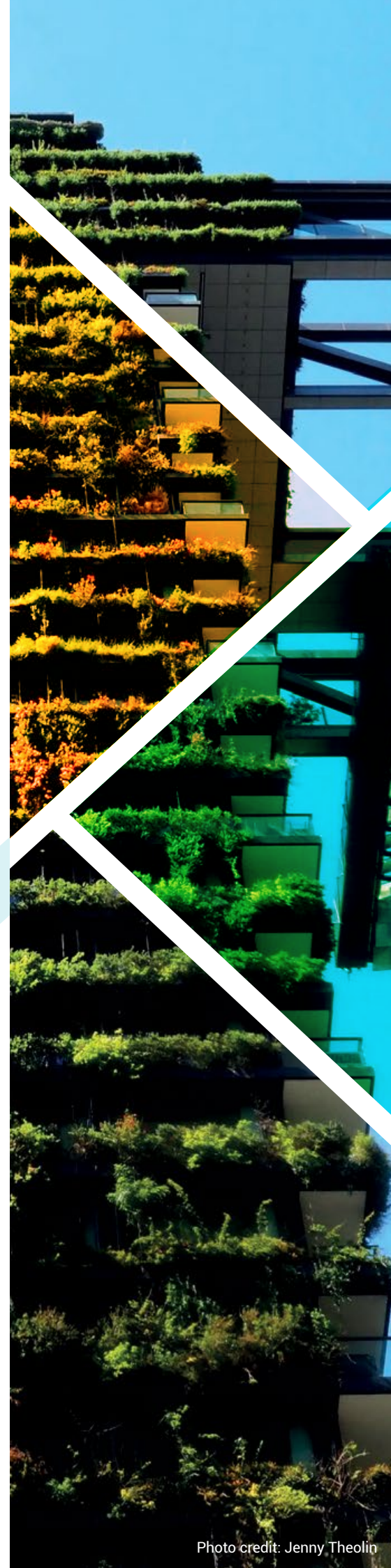
¹⁴ Find more details on investment in section 6.

¹⁵ Find more details on building energy codes in section 5.2.

¹⁶ This progress is linked to the NDC update for the COP26, the first update including buildings since 2017 (refer section 5.1).

3. GLOBAL BUILDINGS AND CONSTRUCTION STATUS

The global buildings sector's operational energy use grew by around 4 per cent from 2020 levels, and CO₂ operational emissions increased by around 5 per cent, reaching approximately 10 GtCO₂ – an increase that exceeds the pre-pandemic 2019 peak by 2 per cent. This reflects both the reopening of the global economy and the lack of structural changes to support buildings sector decarbonization during the period of the pandemic. The buildings and construction industry represents an estimated 37 per cent of global operational energy and process-related CO₂ emissions.



3.1. CONSTRUCTION ACTIVITIES GLOBAL AND REGIONAL

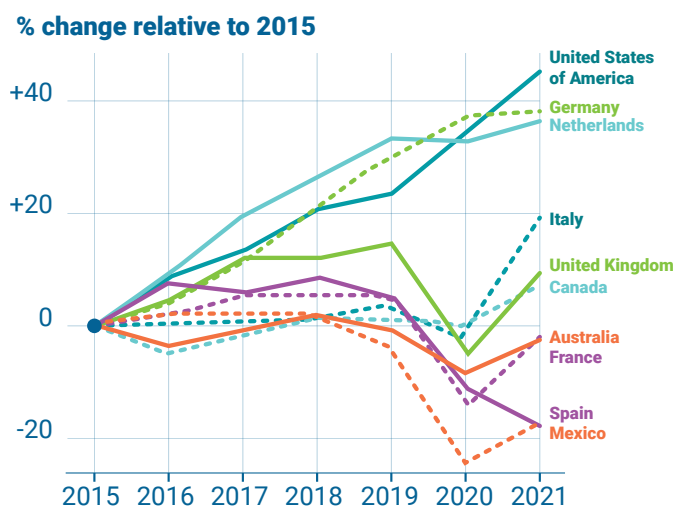
Building construction activities have rebounded from their pandemic lows and have been a driver behind both the growing investment in more efficient buildings (see section 5) and the increased global energy demand and related emissions (see section 3.2 and 3.3). The IEA estimates that building floor space grew by around 1 per cent from 2021 to just over 242 billion m² of constructed buildings¹⁷.

Proportionally more construction occurred among high-income countries, which reflected strong investment through 2021. Across Europe, construction sector expenditure, which drives the increase in floorspace, has varied due to their differences in pandemic economic recovery. For example, the increase in construction sector activities compared to 2020 for Italy was 23 per cent, the UK 12 per cent, Hungary 11 per cent and France 10 per cent (see Figure 11). Others have seen more modest increases, such as Australia (5 per cent), Canada (6 per cent), South Africa (8 per cent) and the United States of America (8 per cent). Some economies continued to struggle with construction and show no growth (Germany and Switzerland at <1 per cent or Poland at 0 per cent) or even continued decline as in Spain (-6 per cent), Brazil (-1 per cent) or Morocco (-4 per cent). It is expected, however, that the majority of future buildings construction growth overall will be in Sub-Saharan Africa (see section 6) and Asia.

Yet despite this rebound in growth in buildings construction activities in 2021, a different situation is unfolding through 2022. The increased level of inflation could put downward pressure on construction through increased labour and material costs alongside increased borrowing costs for building purchasers and construction companies, though such effects may be temporary for construction trends overall (Royal Institution of Chartered Surveyors [RICS] 2022). Housing unaffordability across a range of countries has risen by more than 10 per cent compared to Q1 of 2021 – though has slowed from previous growth peaks across 2021 (Knight Frank 2022). This adds to what is already a housing affordability crisis and the challenge of addressing housing informality and land insecurity, which the COVID-19 pandemic exacerbated by making living conditions more precarious due to reduced incomes among poor households across the globe (Cities Alliance 2021).

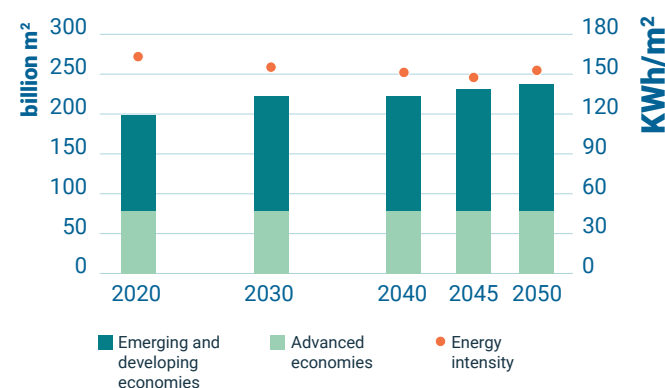
A key challenge that must be addressed is how this anticipated growth in construction activities will deliver net-zero-carbon buildings both now and in the future and what these concepts mean in different locations around the world. The IEA has suggested a definition of working towards whole-life zero-carbon buildings (see box 4).

Figure 11. Change in construction activities in selected G20 countries, 2015-2021 (relative to 2015)



Source: OECD 2022.

Figure 12. Global floor area and buildings energy intensity, 2010-2021



Source: IEA 2021. All rights reserved. Adapted from "Tracking Clean Energy Progress" (IEA 2021c).

¹⁷ As a result of data and model updates, the floorspace value for 2021 and previous year's baseline data has changed for this report.

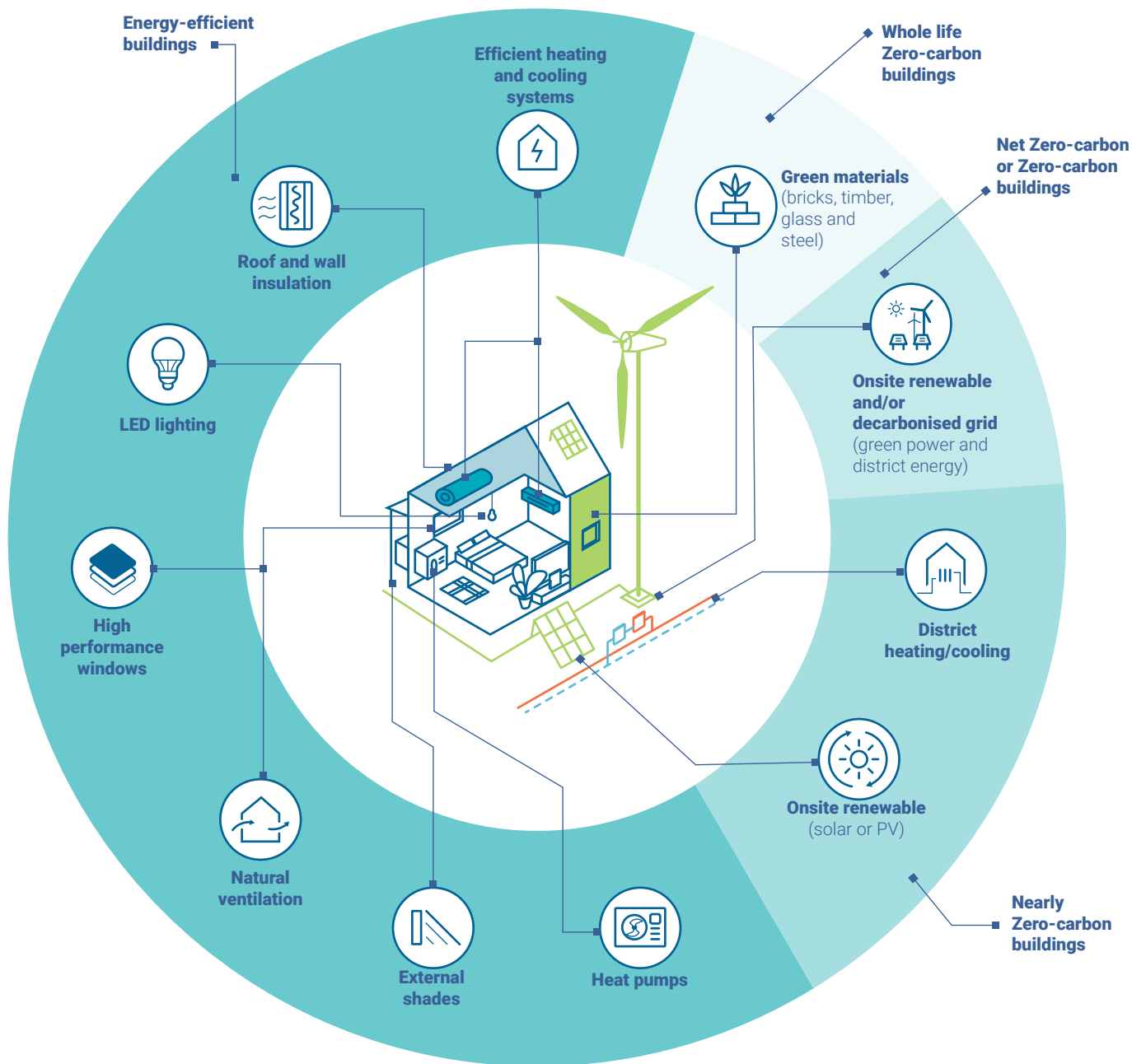
Box 4. Defining net-zero-carbon buildings

There are a number of terms that describe the CO₂ emissions of buildings and construction. In the recently published Roadmap for Energy-Efficient Buildings and Construction in the Association of Southeast Asian Nations (IEA 2022e), these different terms, which can apply to different scopes and site boundaries, are provided as examples. The definitions are drawn from the Net Zero by 2050 report (IEA 2021b) and Zero Energy Building Definitions and Policy Activity – an International Review (Organisation for Economic Co-operation and Development [OECD] and International Partnership for Energy Efficiency Cooperation [IPEEC] 2018).

The progress to net-zero-carbon buildings can cover:

- **Energy-efficient:** a building with a high degree of energy efficiency in its fabric and building services that consume energy, e.g. heating, cooling, cooking, lighting, ventilation, hot water and appliances.
- **Low-carbon:** a building that is energy efficient (low energy) and is supplied by low-carbon energy. Some building services equipment may not be capable of decarbonizing without being replaced (e.g. fossil gas boilers).
- **Nearly zero-carbon:** a building that is energy-efficient and may have some available zero-emission energy supply (onsite or offsite), but that does not offset 100 per cent of the building's energy demand.
- **Net zero-carbon:** a building that is energy efficient and relies on zero-emission energy sources that meet the energy demand over the course of a year (or another established timeline, e.g. a month).
- **Zero-carbon:** a building that is energy efficient and has its energy demand completely met through zero-emission energy generated either onsite or offsite.
- **Carbon-negative:** an energy-efficient building that generates renewable energy onsite that not only fully covers the building's own energy demand, but also produces excess renewable energy which is fed back into a grid and can be used for other offsite purposes.
- **Whole life cycle, net zero-carbon:** A zero-carbon building with the additional requirement that the embodied emissions associated with the materials used for construction are themselves net zero, either through decarbonization or offsetting (IEA 2022e).

Figure 13. Different levels of zero-carbon buildings



Source: IEA 2021. All rights reserved. Adapted from 'Roadmap for Energy-Efficient Buildings and Construction in the Association of Southeast Asian Nations. (IEA 2022e).

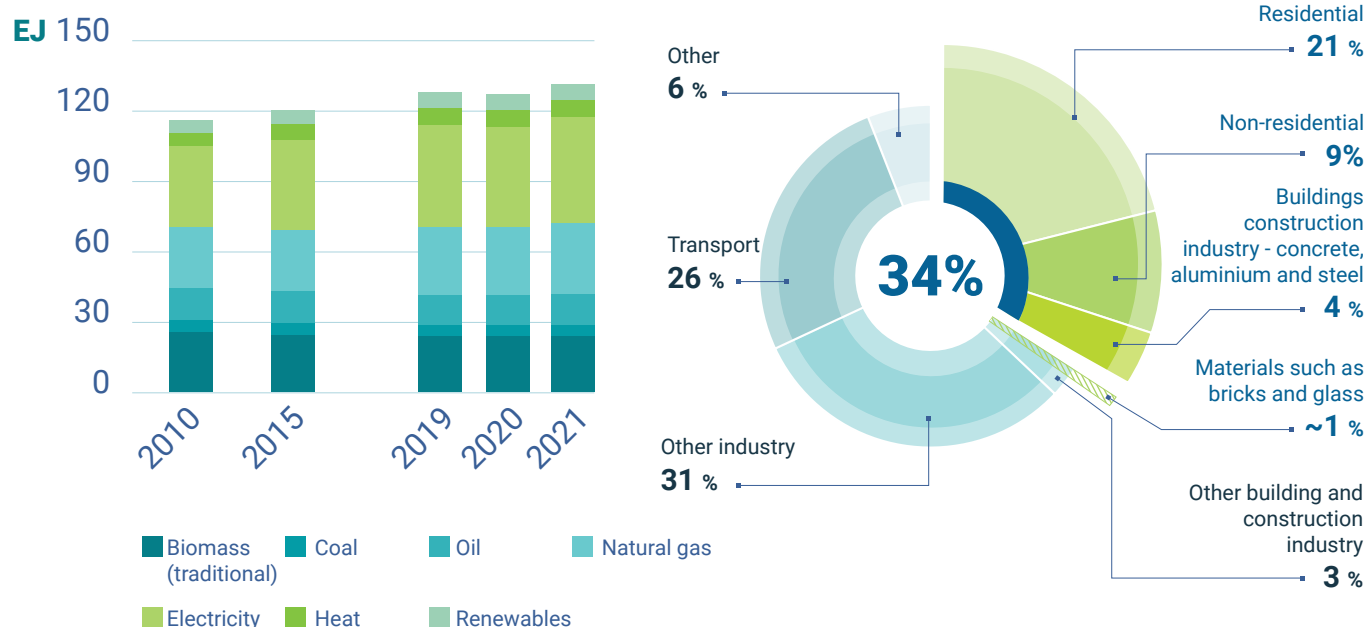
3.2. ENERGY IN THE BUILDINGS AND CONSTRUCTION SECTOR

Operational energy demand in buildings (for space heating and cooling, water heating, lighting, cooking and other uses) accounts for around 30 per cent of final demand and has grown to 135 EJ, which is an increase of around 4 per cent from 2020 and exceeds the previous peak in 2019 by 3 per cent (IEA 2022f). The change in energy demand in buildings in 2021 reflects a complex picture. On the one hand, buildings are being operated more intensively than during the pandemic as workplaces reopen and businesses resume more “normal” operations. Equally many workplaces are choosing to maintain hybrid working policies (Microsoft 2022), so a distribution of energy demand in both workplaces and homes remains. Energy used for buildings to produce concrete, steel, and aluminium accounts for a further 4 per cent of final energy demand (IEA 2022f). Together with operational energy demand this brings buildings energy demand to 34 per cent. Other materials used in the construction of buildings, such as bricks and glass, also contribute to global energy use and together with concrete, steel and aluminium could account to around 5 per cent of global energy demand (UNEP 2021).

Similarly, in low- and middle-income countries, access to modern fuels was disrupted due to the pandemic, with the most recent SDG 7 progress report showing that 733 million people lack access to electricity and around 2.4 billion people are using fuels for cooking that emit pollution impacting their health (IEA et al. 2022). The countries with the largest number of people without access to electricity were within Central and Western Africa, with 442 million (or 60 per cent) being within the African continent (see chapter 7). These levels of energy access have improved from 2010 but are off track to meeting the commitments of the Sustainable Development Goals by 2030.

Between 2010 and 2020, for example, energy efficiency measured as the ratio of primary energy over purchasing power parity has fallen from 5.6 MJ/USD to 4.7 MJ/USD but the annual rate of improvement in energy intensity would need to more than double the current rate to 3.2 per cent to reach the 2030 SDG 7 goal. In 2021, the increase in energy demand saw an energy intensity improvement of 1.9 per cent compared to 2020, returning to an average of the previous decade (IEA et al. 2022).

Figure 14. Energy consumption in buildings by fuel, 2010-2021 (left), and share of buildings in total final energy consumptions in 2021 (right)



Notes: Buildings construction industry and other building construction industry refers to concrete, steel and aluminium for buildings and infrastructure construction respectively. Buildings construction industry related energy use not shown in left panel. The numbers in the pie chart are rounded values and should not be summed up to calculate total values.

Source: IEA 2022. All rights reserved. Adapted from "Tracking Clean Energy Progress" (IEA 2022f).

3.3. EMISSIONS IN THE BUILDINGS SECTOR

Operational energy-related CO₂ emissions from buildings grew by around 5 per cent in 2021 compared to 2020 to around 10 GtCO₂, exceeding the previous 2019 peak of 9.6 GtCO₂ by 2 per cent (see Figure 15). This increase follows the unprecedented reduction in CO₂ emissions in 2020 of around 10 per cent from 2019 levels to due to the COVID-19 pandemic. The rise in buildings sector CO₂ emissions shows there has been little structural change in the overall energy efficiency of existing building (see Figure 12). Buildings account for around 27 per cent of operational energy related CO₂ emissions¹⁸, which excludes materials (IEA 2022f).

The IEA estimates that, in 2021, around 8 per cent of operational energy and process-related CO₂ emissions were from the direct use of fossil fuels in buildings (i.e. direct emissions) and a further 19 per cent were due to electricity use (i.e. indirect emissions). The IEA ascribes the increase in direct CO₂ emissions to increased use of fossil fuels in both advanced and emerging economies, particularly fossil fuel gas in emerging economies.

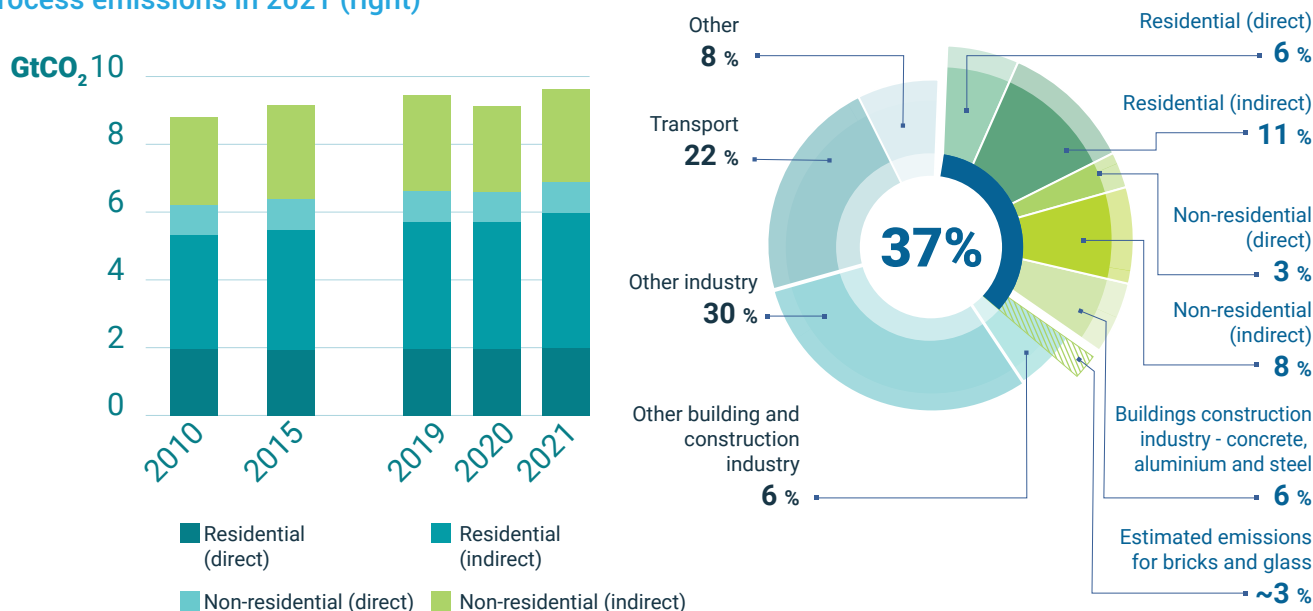
The emissions from the manufacturing of concrete, steel and aluminium used in the construction of buildings are

estimated to represent a further 6 per cent (around 2.3 GtCO₂) of global emissions (IEA 2022f). Other materials used in the construction of buildings, such as bricks and glass, are estimated to account for around 2-4 per cent (~1.2 GtCO₂) of global emissions (see Box 5). Added together, these would represent around 9 per cent of global operational energy and process-related emissions, meaning the buildings and construction industry represent around 37 per cent of global operational energy and process-related CO₂ emissions.

Advancing techniques that reduce the emissions from concrete and steel would lead to a fall in embodied emissions for newly constructed buildings (see Box 6), though there is also a strong need to reduce the demand for materials and reuse construction materials more effectively. For more information on buildings materials see chapter 8.

The rebound in global emissions is unfortunate and shows that the investment in emission reductions through pandemic stimulus programmes has to date made limited impact. To achieve a pathway of net zero CO₂ emissions by 2050, the IEA estimates that overall buildings sector CO₂ emissions should fall to around 5 GtCO₂ in 2030, or by 0.6 GtCO₂ per year. This would imply an annual rate of emissions reduction equal to -8.3 per cent per year over the eight-year period – equivalent to sustaining the reduction in emissions related to the pandemic each year until 2030.

Figure 15. CO₂ emissions in buildings 2010-2021 (left) and share of buildings in global energy and process emissions in 2021 (right)



Notes: Buildings construction industry and other construction industry refers to concrete, steel and aluminium for buildings and infrastructure construction respectively. The boundaries of the emissions (energy and process) account for construction materials include from raw materials preparation and processing and the different steps to produce the materials. For example, for cement this includes the entire manufacturing processes, from obtaining raw materials and preparing the fuel through to grinding and milling. The numbers in the pie chart are rounded values and therefore do not necessarily sum to the total value for a given sector.

Source: IEA 2022. All rights reserved. Adapted from "Tracking Clean Energy Progress" (IEA 2022f).

¹⁸Total direct and indirect building operations emissions sum to 27% but due to rounding Figure 15 shows a total of 28%.

Box 5. Global CO₂ emissions from brick, aluminium and glass production

Tracking the global use of subsidiary construction materials and their associated carbon emissions is challenging (see also section 8 on materials). There are few openly accessible repositories of materials production data from which to derive emissions estimates. There is some degree of consensus that annual brick production globally is around 1.5 trillion, or 1.9 trillion including concrete blocks (Global Industry Analysts, Inc 2021); however, these estimates are not backed up by rigorous, openly available data. As such, the carbon emissions associated with brick production are highly uncertain.

An estimate by Zhang (Zhang 1997) found that China produced 800 billion bricks in 1994, and that the CO₂ emissions varied between 48 and 113 tonnes of CO₂ per million bricks depending on the production process, resulting in 43 million tonnes of CO₂ and 1.9 million tonnes of SO₂. Estimates by the International Centre for Integrated Mountain Development (ICIMOD) suggest that Indian brick production was 260 billion bricks in 2017 (emitting 60–65 million tonnes of CO₂) (International Centre for Integrated Mountain Development [ICIMOD] 2019a), with 82.5 billion bricks produced in Pakistan (ICIMOD 2019c) and 5.14 billion bricks produced in Nepal (ICIMOD 2019b) in 2018. In 2014, carbon dioxide emissions from the manufacture of 330 billion bricks across South Asia were estimated at 127 million tonnes per year, or 0.16 kg of CO₂ per kg of bricks (Rajarathnam et al. 2014). In other nations, brick production quantities are lower: according to official figures, the UK produced 1.9 billion bricks in 2021 (United Kingdom, Department for Business, Energy & Industrial Strategy [BEIS] (2022b).

A study being carried out by EPFL estimates the total global production of fired clay bricks to around 2.2 billion tonnes. The average global emissions intensity of the production process is around 0.48 kg CO₂eq/kg. This gives an estimate of around 1.1 Gt CO₂eq emissions from the fired clay brick industry (Scrivener and Hafez 2022).

The glass industry is believed to contribute only around 0.1 Gt CO₂eq/year, despite the energy-intensive production process resulting in an emissions intensity of 0.69 kg CO₂ eq/kg (IEA 2020a).

Box 6. Trends in production of low-carbon cement

In 2020, the IEA estimates 4.2 Gt of cement was manufactured worldwide, 55 per cent of which was manufactured in China (IEA 2022f). Cement production leads to around 600 kg of CO₂ per tonne of product (Nature 2021), so substantial changes to reduce its associated emissions are required if the goals of the Paris Agreement are to be met.

Recently it has become technically and economically feasible to reduce the Portland clinker content in cement to as low as 50 per cent while achieving similar performance to existing cements, significantly reducing CO₂ emissions. One option is limestone calcined clay cement (LC3) where limestone and calcined clay are added to substitute up to half the Portland clinker content. As a result, CO₂ emission reductions of up to 40 per cent can be achieved overall compared to ordinary Portland cement (Limestone Calcined Clay Cement [LC3] 2022).

National cement standards and regulations can sometimes be an obstacle to the production and market introduction of cement with a lower clinker content than the usual Portland cement. Nevertheless, more and more countries are adapting their regulations in order to clear the way for greener cement alternatives. The first such adaptation took place in Europe where the EN 197 standard was amended to EN 197-5 in May 2021 (European Standards 2021). In most of Latin America, the use of LC3 is also already possible. Several additional countries are also in the process of adapting their own standards to this new clinker factor, including India, Senegal and Egypt. Several LC3 production plants have been either built (e.g. Colombia, Cuba and Ivory Coast) or are currently under construction (e.g. France, Ghana, Cameroon). By 2025, the global capacity to produce LC3 is expected to reach 90 million tonnes annually, which equates to CO₂ savings of at least 20 million tonnes per year compared to ordinary Portland Cement (LC3 2022).

Several other avenues also exist for the reduction of cement emissions. In May 2022, researchers at Cambridge University announced a “zero emissions” cement innovation (Cambridge Department of Engineering 2022). The IEA points to the necessity of carbon capture technologies reaching commercialization by 2030 (IEA 2021a). It remains unclear whether such new innovations can be scaled to meet global demand.

3.4. IPCC AR6 FINDINGS FOR BUILDINGS

The Intergovernmental Panel on Climate Change (IPCC) sixth assessment report for the mitigation working group (AR6 WGIII) has sought to provide a definitive update on the scientific, technological, environmental, economic and social aspects of mitigation of climate change since its last report in 2015.

The 2022 AR6 WGIII report sent a clear message to the buildings sector on the opportunity for rapid but achievable change, with comprehensive policy packages integrating technology and policy actions tailored to national circumstances (Cabeza et al. 2022). Examples assessed with a high degree of confidence of being able to achieve these changes included emissions reductions from buildings through a mix of efficiency targets, building codes, appliance performance standards, information provision, carbon pricing, finance and technical assistance, and industrial greenhouse gas emissions reductions through innovation support, market creation and capacity building.

The AR6 WGIII identified critical actions for the buildings sector to achieve the targets of the Paris Agreement. These included implementing ambitious measures, including:

- Mandatory building energy codes for new construction alongside a compliance framework
- Energy efficiency refurbishment for existing buildings supported through an integrated policy framework
- Building labels and energy performance benchmark certificates for new and existing buildings
- Mandatory labels for plug-load appliances (e.g., washers, dryers, stoves) and installer-based equipment (e.g., air conditioning units, hot water systems)
- Energy audits of buildings and systems to ensure operational energy performance, which are mandatory for large buildings or energy users
- Minimum energy performance standards for building equipment and systems to limit inefficient products on the market
- Adopting low-carbon materials and nature-based materials to reduce the long-term embodied carbon of buildings.

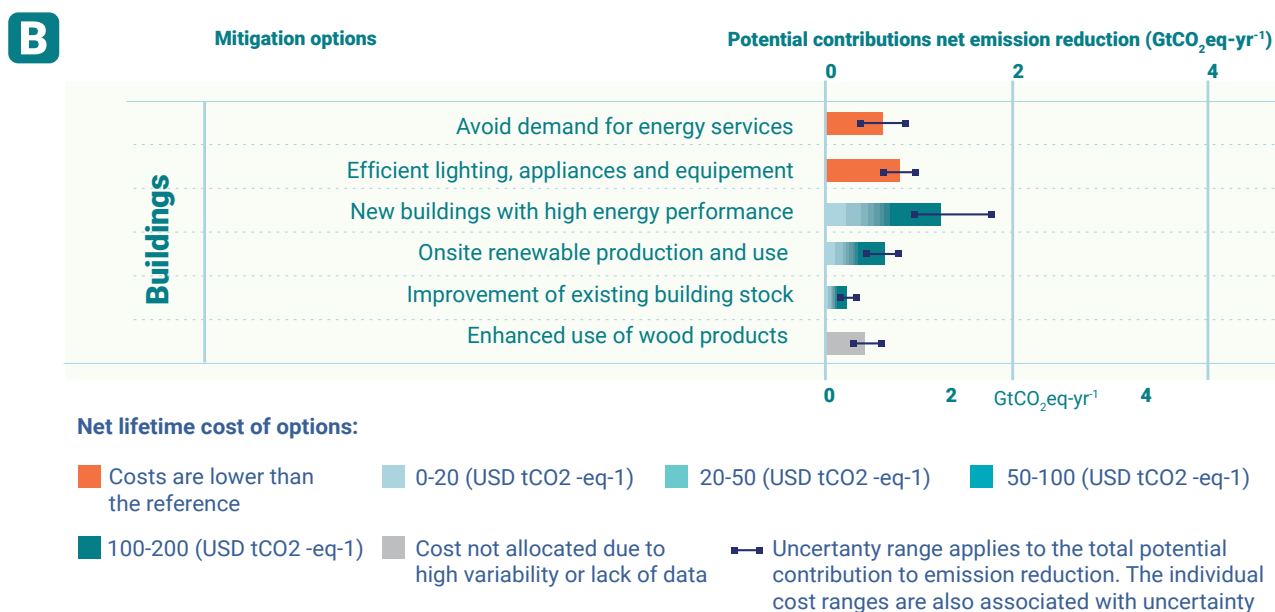
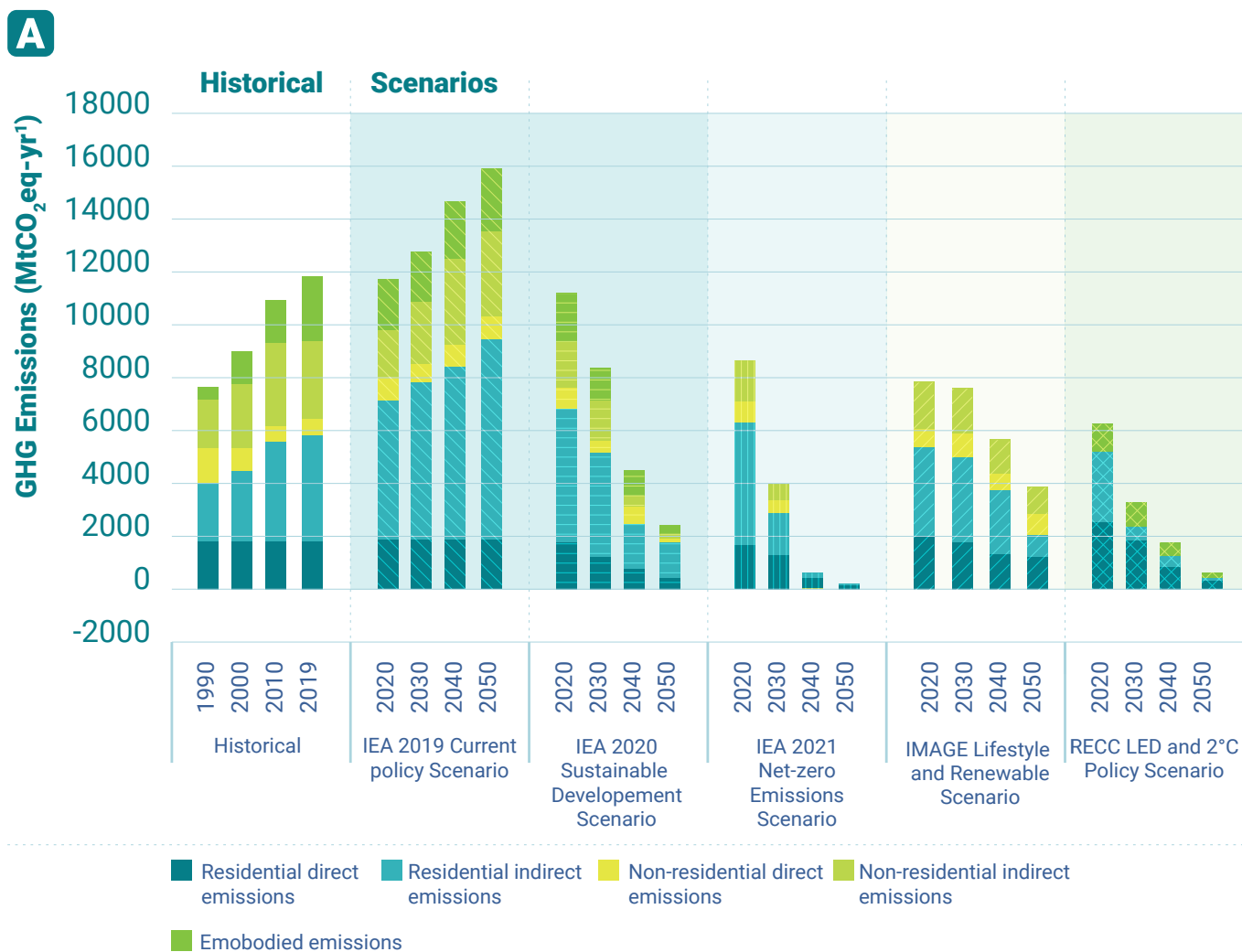
Actions to remove barriers to decarbonization include:

- Providing information on practices and technologies that can reduce energy demand and increase energy efficiency
- Increasing investment in technological solutions (e.g., insulation, efficient equipment and building integrated renewable energy)
- Changing practices and behaviours to reduce energy waste and make more efficient use of delivered energy services (e.g., heating, cooling, lighting, cooking).

The mitigation potential of the buildings sector is considerable. Most scenarios reviewed in AR6 WGIII show substantial reductions from the buildings sector by 2050 (see Figure 16). The IEA's net-zero emissions scenario sees emissions from the buildings sector falling to 29 MtCO₂/year by 2050 (or over 95 per cent of current levels) (IEA 2021b). Many of these mitigation options for buildings are largely cost-effective in their emissions abatement, with costs ranging from overall cost savings (through avoided demand and efficient equipment), to actions ranging to mostly <USD 100/tCO₂eq) (see Figure 16).

Yet there are serious risks to delivering this net-zero-carbon future if zero-carbon-ready construction and renovation of buildings continue at such slow rates. The report identifies risks related to the long lifespan of buildings. While this is clearly beneficial from an embodied carbon point of view (i.e. spreading emissions over the lifetime of the building), it risks locking in higher emissions for a long period if buildings are not designed and constructed with energy performance in mind.

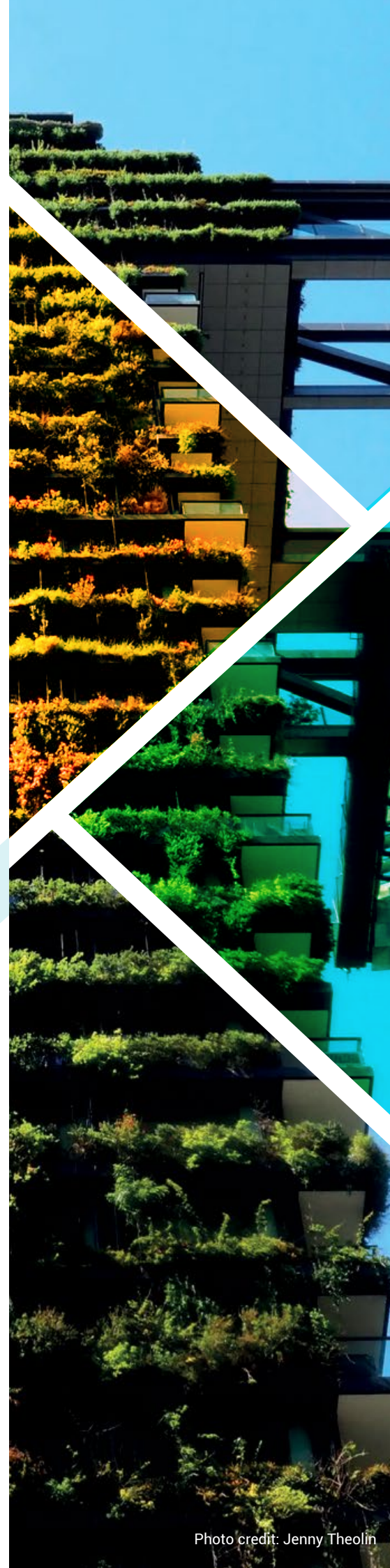
Figure 16. IPCC AR6 WGIII - Overview of A) Global building emission reduction scenarios and B) Mitigation options and their estimated ranges of costs and potentials in 2030



Source: Adapted from IPCC AR6 Working Group III – Mitigation, Chapter 9: Buildings, Figure 9.3, page 168 and SPM.7, page 63 (IPCC 2022).

4. SUSTAINABLE BUILDINGS AND CONSTRUCTION POLICIES

Progress on buildings and construction polices remains slow in the face of the pandemic and the lack of action has meant emissions are not being reduced. To date, 158 out of 196 countries (80 per cent) reference buildings as part of their NDC action plans and 79 out of 196 (40 per cent) have building energy codes, though only 26 per cent of countries have mandatory codes for all buildings.



Decarbonizing the global building stock is a key step towards fulfilling the commitments of the Paris Agreement. The UNFCCC's nationally determined contributions (NDCs) play a central role in outlining countries' sectoral commitments and strategies. Alongside this, regional, national and local building energy codes, green certification programmes and minimum energy performance standards can drive up efficiency and reduce building energy use.

4.1. INTERNATIONAL POLICY AND NATIONALLY DETERMINED CONTRIBUTIONS

According to the UNFCCC NDC repository (UNFCCC 2022b), 193 countries plus the EU have submitted an NDC. Only, Libya, Iran and Yemen have yet to submit an NDC in any form. This is despite a request at COP26 for all nations to submit revised NDCs in time for COP27. Since the Global Status Report for Buildings and Construction 2021, a further 68 NDCs have been published: Iraq and

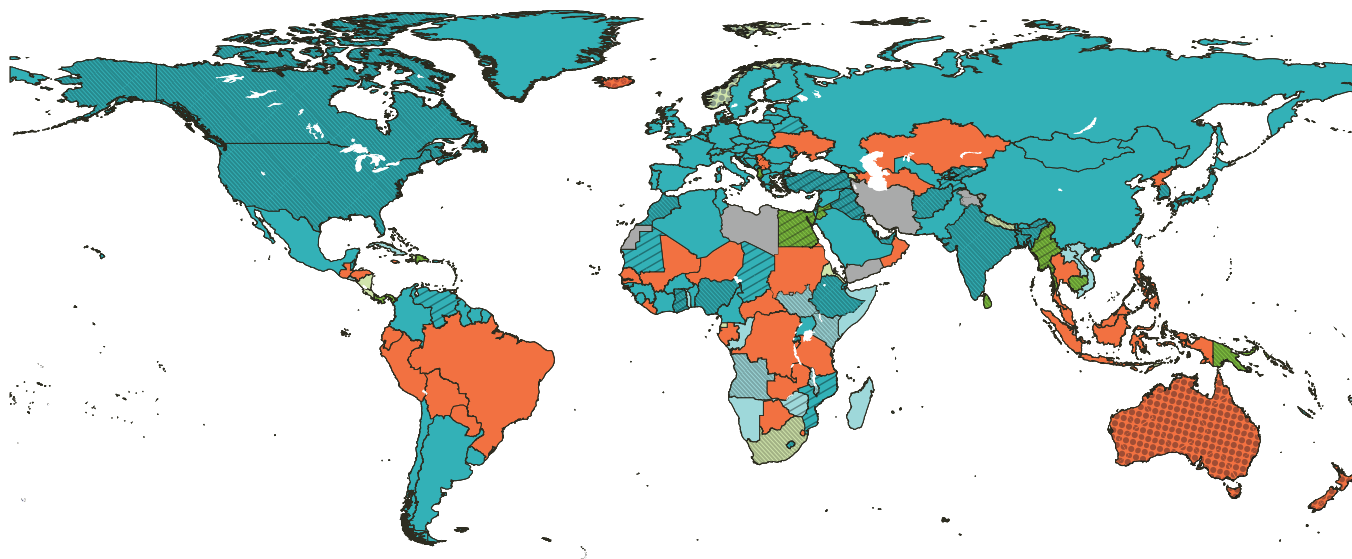
Türkiye submitted an NDC for the first time. Figure 17 provides details of the mentions of buildings within these new NDCs, as well as previously submitted versions. There has been an increase of 23 countries mentioning buildings in their NDCs, but just under 20 per cent of the world's population lives in countries whose NDC has no or limited references to buildings.

Several countries now provide extensive details of their plans to respond to climate change in the buildings sector with the mention of adaptation, mitigation and buildings codes in their NDC – Myanmar and Sri Lanka's latest NDCs are particularly detailed. However, Indonesia, Brazil and the Philippines are notable populous countries which lack a description of plans for buildings in their NDC.

This year's Global Status Report for Buildings and Construction also incorporates mentions of buildings in the fourth round of biennial reports, which are submitted by the group of Annex 1 industrialized countries. New Zealand is a notable example; even though buildings are not mentioned in the NDC, the country has committed to an extensive building decarbonization programme (New Zealand, Ministry of Business, Innovation and Employment 2021).

Figure 17. NDC mentions of buildings

This map is without prejudice to the status of or the sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city, or area.



NDC mentions of buildings

- Adaptation
- Energy Efficiency
- Extensive detail
- Limited reference to buildings
- No known NDC
- No mention
- Building codes
- Increased detail in NDC update
- Further detail given in Fourth Biennial Report (spot color corresponds to mention category above)

Table 1. Buildings-related statements in NDCs

Year	2021	2022
Adaptation	17	20
Energy efficiency	94	103
Extensive detail	10	15
Limited reference to buildings	14	16
No known NDC	5	3
No mention	56	35
Further detail in 4th biennial report	–	4
Total mentioning buildings	135	158
Total	196	196

As of 4 August 2022. 68 NDCs updated since last Buildings-GSR:

Detail: less (6), same (39), more (23) (highlighted in map)

The following table provides selected country highlights from the latest updates and newly published NDCs that reflect actions being undertaken on building decarbonization and adaptation and resilience.

Table 2. Selected countries' first, first updated, and second NDCs with building-focused actions, submitted since September 2021

Country	Date	Description of measures relevant to buildings	Type
Sri Lanka	30/07/2021	Introduce mandatory building energy efficiency code in 2021-2022. Establish sectoral databases for eco-certification system, minimum performance and energy efficiency labelling programmes, green buildings, and building management systems.	First updated NDC
Türkiye	11/10/2021	New buildings constructed in accordance with energy performance regulations. Tax incentives for low-energy building materials.	First NDC
Jordan	12/10/2021	Adopt green building codes. Retrofit for energy efficiency in public buildings. Improve resilience of buildings through better insulation. Promote energy-efficient devices.	First updated NDC
Iraq	15/10/2021	LED lighting in all government and commercial buildings. Energy efficiency labelling. Green building codes. Smart meter roll-out. Integrated solar PV in buildings.	First NDC
Mozambique	27/12/2021	Reformulate buildings code to develop resilience. Micro-generation of energy on commercial and residential buildings. Increase energy efficiency. Promote energy-efficient appliances.	First updated NDC
Egypt	07/07/2022	COP27 host country. Promotion of renewables and energy efficiency in new and existing buildings. Expand energy efficiency labelling programme. Voluntary green building guidelines.	First updated NDC

4.2. BUILDING ENERGY CODES

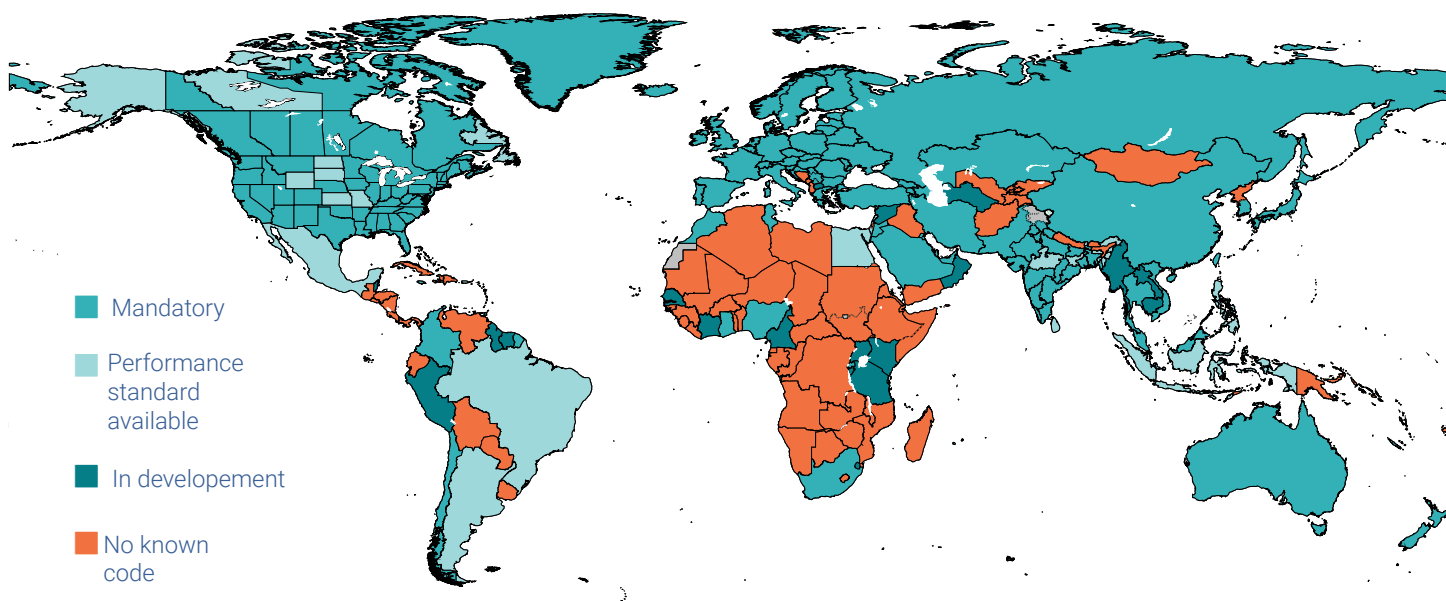
Building energy codes have a central role to play in improving buildings' energy efficiency and reducing carbon emissions. They allow governments to mandate standards for the construction and maintenance of buildings which, when properly enforced, ensure the building's fabric meets criteria for preventing heat flow, ventilation rates are maintained, and the building's operational equipment meets energy use standards. Building energy codes must be designed with local environmental conditions and building use at their heart. They are important not just at the construction stage of new buildings, but also for the maintenance and retrofit of existing buildings. The IEA's Net-Zero 2050 Roadmap requires 50 per cent of existing buildings to be retrofitted to zero-carbon-ready status by 2040 (IEA 2021b). To achieve this aim, a dramatic increase in the presence of building energy codes worldwide is required.

This year's Global Status Report for Buildings and Construction updates the method by which global building codes are tracked. As of September 2022, 79 out of 196 countries (40 per cent) have building energy codes which are either mandatory for at least part of the building stock or have a voluntary component.¹⁹ Yet only 35 per cent per cent of countries have mandatory codes or regulations for some or all building types that regulate how energy efficient a building needs to be

when constructed, which drops to 26 per cent per cent for those with mandatory codes for both residential and non-residential buildings. The legislative landscape that regulates energy in buildings is complicated by differences in the geographic scope of buildings energy codes. In some cases, especially in federated countries, individual states will determine the stringency or scope of a building code. In other countries, a single building code might apply to the whole country. Cities or municipalities may also have local building energy codes, but these are not tracked here. Further complication occurs with regards to buildings standards, which may be mandatory or merely available to local authorities as a means of indicating compliance. Mexico, for example, has a mandatory building energy standard, which is not strictly speaking a building energy code even though it may function in a similar manner, though it must be adopted by state governments to become mandatory. There are also differences regarding the scope of codes, whether they cover all buildings or just a subset, for example new buildings above a particular threshold footprint. These complexities are summarized in Figure 18 and Table 3, with the inclusion of a new "performance standard available" category, referring to the existence of a national building energy standard. Finally, the extent to which buildings energy codes are enforced or complied with is not tracked but will influence, alongside a host of other factors, the final energy demand of the building stock.

Figure 18. Global status of building energy codes in 2021

This map is without prejudice to the status of or the sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city, or area.



¹⁹In total, 51 out of 196 countries tracked by the Buildings Global Status Report have mandatory building energy codes which cover both residential and non-residential buildings. This number is higher than last year's total, but the methodological changes this year means these numbers should not be directly compared.

In the past year there has been little progress on national building energy codes in countries which are yet to adopt them. An exception to this is the new law in Georgia on energy efficiency of buildings (Zourabichvili 2020), which came into force in mid-2021, which applies EU directive 2010/31/EU (European Parliament 2010) to buildings in the country. Alongside this, draft energy efficiency building codes have been published for Kenya (Kenya, State Department for Public Works 2022) and Trinidad and Tobago (Trinidad and Tobago, Bureau of Standards 2022), but not yet brought into force. In June 2022, the US government announced a programme to accelerate the adoption of modern national building codes (United States of America, the White House 2022a).

Progress is clearer at the state, city and local level. The states of India which had yet to implement a building energy code have now ratified India's 2017 Energy Conservation Building Code, which mandates energy efficiency for large commercial buildings and provides voluntary codes for other buildings (Kwatra et al. 2021). The past year has seen the scope and stringency of mandatory and voluntary building energy codes in the United States of America increased in California (California Energy Commission 2021), Massachusetts (Wasser 2022), Wisconsin (Hoffmann 2022), Hawaii (HI Public Works 2021) and Oregon (Oregon Home Builders Association 2021). The strongest commercial

building energy code is set to come into force in July 2023 in Washington state (Sierra Club 2022), where electrification will be mandated for space and water heating (S&P Global 2022). Similarly, New York state is planning on prohibiting the use of fossil fuels for heating and cooling by 2030 (New York State 2022), with new legislation designed to promote the construction of geothermal networks for heating (Geothermal Rising 2022).

Canada published the 2020 update of the national energy codes for buildings in March 2022. These model codes include four or five levels of energy efficiency for buildings, depending on size, with increasing ambition, towards the requirement that new buildings meet an energy performance approximating net zero energy ready (Beer 2022). In France, the new Code RE2020 came into force on 1 January 2022 and includes improved mandatory thresholds for energy demand and consumption and for the first time adds mandatory thresholds for greenhouse gas emissions (one for emissions from energy and the second for emissions related to construction, including embodied emissions in materials). This new code will enable the removal of fossil fuels in new buildings, promote the use of low-carbon materials, and address adaptation through a limit on the number of hours of thermal discomfort in case of heatwaves (France, Ministry of Ecological Transition 2022).

Table 3. Building energy codes status in 2022

Mandatory	68
Performance standard available	11
In development	32
No known code	85
Grand total	196

To align towards meeting decarbonization targets, new buildings must be built to higher performance standards and codes. An example of this is the BC Energy Step Code (Energy Step Code Council 2018), which provides a first step towards net-zero-carbon-ready buildings by 2032 and fully zero-carbon as the utility grid decarbonizes. For existing buildings, the focus is to upgrade buildings – through either an incremental approach (e.g., adopting retrofits when renovating a building or upgrading to a high-performance system at its end-of-life) or targeted deep renovations that upgrade a building through a multi-system upgrade to achieve a high performance standard. However, the Step Code does not yet meet the characteristics identified by the IPCC as necessary to meet the goals of the Paris Agreement. Europe's Renovation Wave aims to at least double the annual energy renovation rate of buildings by 2030 and focus on deep energy renovations with a goal of renovating more than 35 million buildings – or 13 per cent of the total – by 2030 (European Commission 2020).

The technological solutions for the transition of the global building stock are clear and include the use of high-performance and low-cost insulation materials, glazing units with solar control films and gases, high efficiency heating and cooling systems, high performance appliances and equipment, and smart and digital control systems (GlobalABC et al. 2020). In a recent analysis, the IEA estimated that to achieve the target of net zero emissions by 2050, the buildings sector would need to realize an annual average energy intensity improvement of 4-5 per cent per year between now and 2050. Existing buildings would need to be net zero ready (i.e. efficient and able to operate at zero emissions as grids decarbonize). More than 1.8 billion heat pumps and 1.2 billion solar thermal systems would need to be installed, along with around 7,500 TWh of building-integrated PV generation, while the energy efficiency of household appliances would need to improve by 40 per cent compared to today (IEA 2021b).

4.3. ZERO-EMISSION/ENERGY CODES AND THE PARIS AGREEMENT

In recent years there has been an increased interest in developing building energy codes that deliver net zero energy use on-site, usually by combining stringent energy efficiency standards with renewable energy generation. A new voluntary appendix to the International Energy Conservation Code (IECC) 2021 works towards providing such a standard (IECC 2021). For residential buildings, the supplementary energy

can be generated through local projects, such as on-site solar PV arrays. For commercial buildings, the IECC makes use of the Architecture 2030 ZERO Code, which also incorporates requirements for highly efficient building envelopes, passive heating and cooling, and either on-site renewables or carbon-free energy purchases from the grid (Architecture 2030 2018). However, a major challenge exists in ensuring that the "net zero" codes described in this section achieve the goals set out by the IPCC (Schlegel 2022) and the UN Framework Guidelines for Energy Efficiency Standards in Buildings (see Box 7).

The Getting to Zero Forum tracks the development of new, stringent energy codes in the United States of America (Getting to Zero Forum 2022). California has a number of reach codes which are adopted by local county and city jurisdictions (Steele 2021), alongside a proposed California ZERO code for commercial buildings (Zero-Code 2022). In New York state, a stretch code is available to provide an additional 10 per cent of energy savings in buildings over the current state energy conservation code (New York State 2019). The building code of Delaware requires programmes to be established which promote zero-energy homes (Delaware Government 2010), and Washington DC's 2020 energy code includes a net-zero energy appendix for new buildings (Government of the District of Columbia 2017).

In China, a technical standard for nearly zero-energy buildings was issued in 2019 (and come into force in 2022). However, challenges still remain in ensuring that whole life-cycle emissions are considered, not just operational energy-related emissions (Yang and Li 2021). In the European Union, a new proposal from the EU Commission would require all new buildings to be zero energy by 2030 (European Commission 2021b). The World Green Building Council's EU Policy Whole Life Carbon Roadmap sets out in detail the necessary policy initiatives and targets at a national level for achieving net zero whole-life carbon emissions from the EU building stock by 2050 (Nugent et al. 2022).

One of the primary drivers behind these efforts to promote zero-energy codes is compliance with the Paris Agreement. In the United States of America, an initiative run by the New Buildings Institute aims to promote climate-aligned codes through the Codes for Climate programme (New Buildings Institute and RMI 2021). Such explicit alignment of building energy codes to the goals of the Paris Agreement is not currently common elsewhere, although an increasing number of countries mention building codes in their NDCs. Ensuring that any code which is described as "Paris-aligned" actually achieves the emissions savings required presents a considerable challenge.

A Climate Bonds Initiative report (Climate Bonds Initiative 2022) into the role that financing must play in achieving the Paris Agreement underscored the importance of in-use buildings energy data, which building codes alone often do not provide. A report by BPIE examined whole-life-cycle emissions from buildings in Europe (Broer et al. 2022), and echoed these findings, emphasizing the need for transparent emissions data and independent certification schemes to provide the market signals necessary to drive down emissions. In a presentation delivered at COP26, the World Business Council for Sustainable Development defined the primary market levers for achieving net zero whole-life-cycle emissions in the built

environment, including integrating the cost of whole-life carbon emissions into built environment services and products (World Business Council for Sustainable Development 2021).

The above codes are critical to the improvement of new buildings and the majority focus on operational carbon. However, to be zero carbon aligned, it will be necessary for these codes to expand to cover embodied carbon so that the choice of materials, in addition to performance targets, is managed. Such an approach might benefit from an embodied carbon performance-based method, which would allow construction to achieve targets through the most appropriate routes.

Box 7. Updated Framework Guidelines for Energy Efficiency Standards in Buildings

In September 2020, the Joint Task Force on Energy Efficiency Standards in Buildings of the UN Economic and Social Council developed [Updated Framework Guidelines for Energy Efficiency Standards in Buildings ECE/ENERGY/GE.6/2020/4](#) (UNECE 2020). This update built on previous work of the Joint Task Force, following its establishment in 2015. The goal of the work is to reduce the energy use of buildings, while transforming buildings to provide the high standards of sustainability, comfort and health.

The result of the task force's efforts was to establish a three-part framework of principles, falling into three categories. First, the strategic element outlines, among other principles, that buildings must be science-based, properly valued, cost-effective and performance oriented using low-carbon, low-energy technologies, with the health impacts of buildings considered. Second, the design and construction principles emphasize affordable, sustainable and code-driven conception and delivery of buildings, using validated energy performance models that reliably predict real-world performance. Third, the management principles recognise that buildings must be maintained over their whole life cycle. Here, the importance of buildings system commissioning is emphasized, with a need for monitoring and benchmarking alongside energy performance certification. Finally, the framework guidelines emphasize that education and research are central to the transformative change of buildings, alongside engagement, dissemination to and participation from broader civil society.

4.4. GREEN BUILDING CERTIFICATION

There is a continued recognition of green building certification systems across the world. Building energy and sustainability rating systems are continuously evolving to address net zero emissions and have established criteria for the assessment of sustainable actions in the building sector related to energy, water, waste, transport, materials and resource consumption, pollution, land use and health. These certifications provide growing evidence of the progress being made by the buildings sector towards sustainable and eco-friendly practices in building and construction.

As of 2021, there are 74 green building certification systems²⁰ across the world, with the majority administered by members of the World Green Building Council (WorldGBC). At least 184 countries have buildings that are certified under these certification systems. Table 4 below shows the green building certification systems across the world. However, based on the transparent and available data, only 14 certification systems are used in the Global Buildings Climate Tracker (section 3). The number of certificates issued under these 14 certification systems grew with an average cumulative growth of 19 per cent in 2021 compared to 18 per cent in 2020 and 24 per cent in 2019.

²⁰ More certification systems/rating tools exist but are not administered by members of WorldGBC.

Green building certifications act to increase local knowledge, creating awareness and training opportunities. They can also play an important role as a standard for sustainable investment and financing as a form of quality mark. For example, the European Bank for Reconstruction and Development has a requirement for all buildings construction investments to use a green certification

such as EDGE, BREEAM or LEED – though the limited recognition of local labels can reduce locally recognized approaches to sustainability. Ultimately, presenting a clear pathway around the uses of certifications will help designers, investors, manufacturers, government and non-governmental organizations across the whole value chain to accelerate decarbonization.

Table 4. Global building certification programmes²¹

REGION	COUNTRY	RATING
Africa	Egypt	Green Pyramid Rating System
	Kenya	Green Mark
	South Africa	Green Star SA, Net Zero/ Net Positive
	Tunisia	EcoBat
	Uganda	Green Star Uganda
Americas	Brazil	GBC Brasil CASA, GBC Brasil Condomini, GBC Zero Energy
	Colombia	Casa (Colombia), ICONTEC
	Guatemala	Casa Guatemala
	United States of America	LEED, ILFI Zero Energy and Zero Carbon, Parksmart, PEER, RELi, SITES, TRUE, WELL
Asia	China	Assessment Standard for Green Building of China
	Hong Kong	BEAM Plus
	India	IGBC, GRIHA
	Indonesia	GreenShip
	Japan	CASBEE
	Lebanon	ARZ rating system
	Malaysia	Green Building Index
	Pakistan	Pakistan Green Building Guideline (PGBG) BD+C
	Philippines	BERDE, Advancing Net Zero (ANZ/PH), PHILGBC Health and Well-being Tool for Buildings
	Saudi Arabia	saaf (Saudi Green Building Forum)
	Singapore	Green Mark, Singapore Green Building Product/Services Certification
	South Korea	Korea Green Building Certification
	Sri Lanka	GreenSL
	Turkey	B.E.S.T – Residential and Commercial Buildings Certificate
	United Arab Emirates	PEARL (Abu Dhabi), TARSHEED
Vietnam	LOTUS	

²¹ The list is not comprehensive and includes some certification systems/rating tools which are not administered by members of WorldGBC.

REGION	COUNTRY	RATING
Europe	Austria	DGNB Austria
	Croatia	DGNB Croatia
	Denmark	DGNB Denmark
	France	HQE
	Germany	DGNB
	Ireland	Home Performance Index
	Italy	GBC Home, Historic Building, Quartieri, Condomini
	Latvia	BREEAM-LV
	Netherlands	BREEAM-NL, DGBC Woonmerk
	Norway	BREEAM-NOR
	Russia	OMIR
	Spain	DGNB Spain, VERDE
	Sweden	BREEAM-SE, Miljöbyggnad, Miljöbyggnad iDrift, CEEQUAL, NollCO ₂
	Switzerland	Minergie, SNBS, DGNB Switzerland
United Kingdom	BREEAM, EDGE	
Oceania	Australia	Green Star
	New Zealand	Homestar, NABERSNZ, Carbon zero

Source: Adapted by authors from WorldGBC 2022.

4.5. MINIMUM ENERGY PERFORMANCE STANDARDS AND LABELS

Minimum energy performance standards provide an important mechanism in improving the energy performance of buildings through ensuring that equipment and appliances used in buildings achieve a minimum level of energy performance. The IEA estimates that minimum energy performance standards now cover over 80 per cent of final energy use for residential refrigerators and air conditioners and over 75 per cent for lamps/lighting (see Figure 19), although selecting appropriate standards which are compatible with contemporary use practices remains important.

More than 100 countries have minimum energy performance standards in place for at least one of the key appliance and equipment related end uses (e.g. cooling, lighting and refrigerators), and another 20 are currently developing policies.

Using minimum energy performance standards to set product energy performance requirements that cover all major appliances and systems is an effective way to reduce demand in current and new buildings as new appliances are replaced or added. When minimum energy performance standards are developed in collaboration across regions for cross-border applicability they can be especially effective to enable stronger local manufacturing and increased trade. For example, the ASEAN SHINE initiative (ASEAN 2016) has been working to support Southeast Asian countries on improving their appliance and equipment standards for the last 10 years with a focus on air conditioners, lighting, motors and transformers.

When implementing minimum energy performance standards, regulators should use both voluntary and mandatory energy ratings and labelling programmes so that consumers understand the products they are purchasing. Product labels ensure that consumers have a visual reference for comparison when selecting which products to purchase. These labels are especially

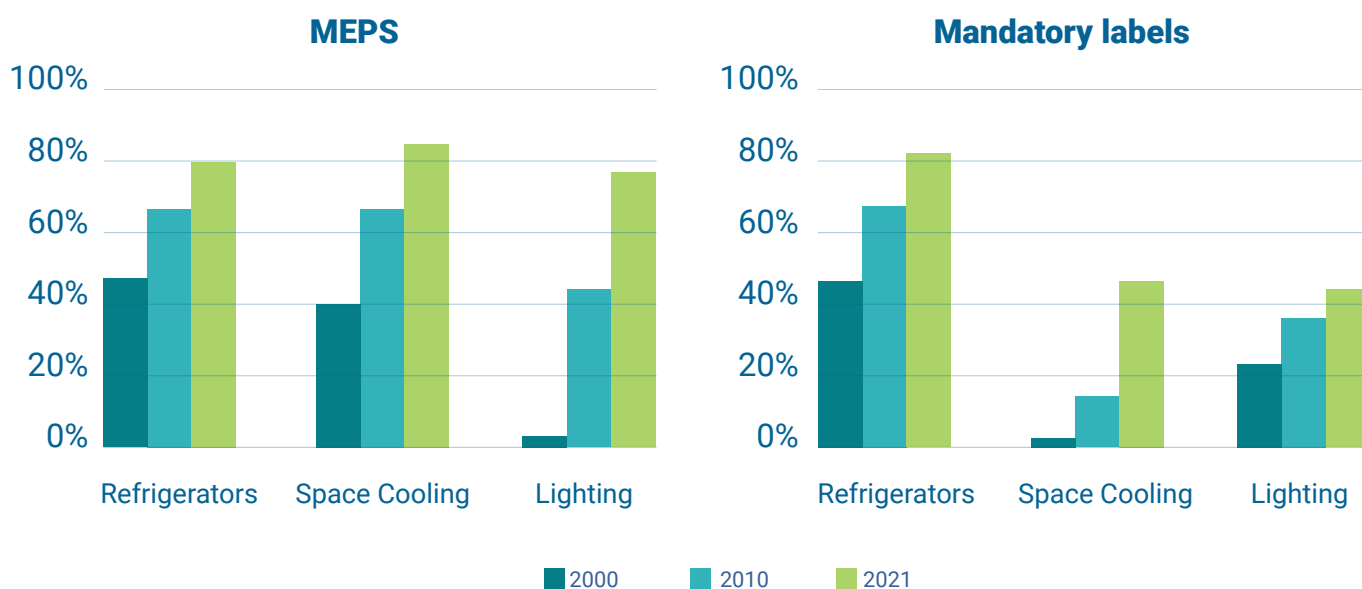
powerful when showing the average annual costs of operations, which can be dramatically different among similar appliances due to technologies used. For example, direct current (DC) ceiling fans can use 70 per cent less energy than more common alternating current (AC) fans, which offers significant savings to bill payers – especially those reliant on fans for cooling.

However, as technologies improve through the enforcement of these standards, it is important to reset the baseline so that consumers can identify the most efficient products. The European Union rescaled its minimum energy performance standards for most appliances in 2021 (European Commission 2021c). Additionally, regulators should consider the implications of embodied carbon in their minimum energy performance standards to support component-based approaches to upgrading appliance performance. A recent standard in California requires all hot water

tanks to include smart hot water heating management components to be available for installation and upgrading (California Energy Commission 2020).

Since the 2021 Global Status Report for Buildings and Construction there have been a limited number of new developments in minimum energy performance standards. In Australia, regulations came into force in April 2022 which limit energy consumption of air conditioning units larger than 65kw (IEA 2022d) – this legislation extends existing minimum energy performance standards for units below 65kw. In the United States, new minimum energy performance standards will come into force regulating air conditioning units and heat pumps manufactured after January 2023 (IEA 2020b). Next year will also see the enforcement of minimum energy performance standards on lighting in Singapore, which will require all bulbs to be at least as energy efficient as LED lighting (IEA 2017).

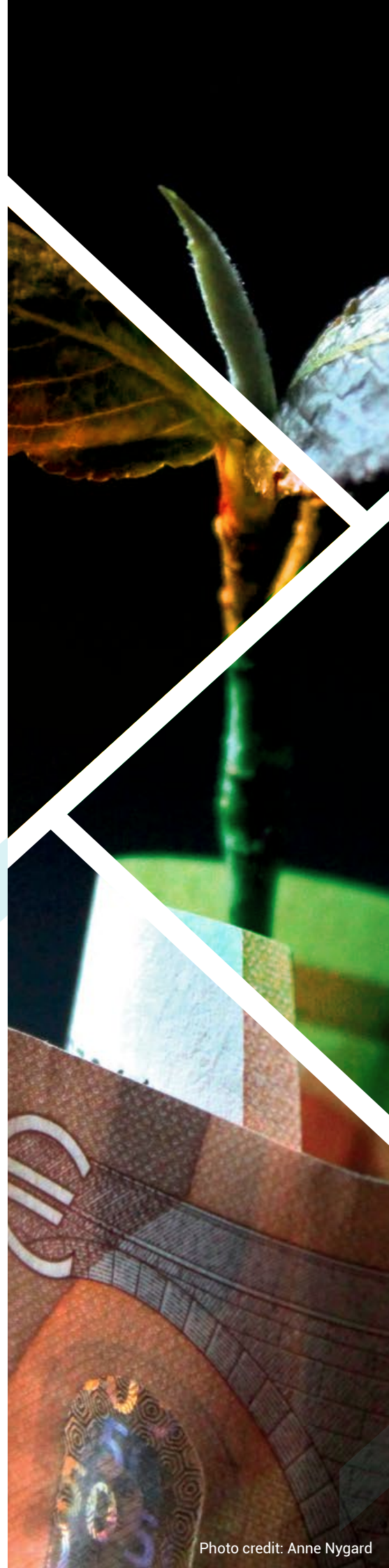
Figure 19. Share of energy consumption for selected end-uses covered by minimum energy performance standards (MEPS) or mandatory comparative labels, 2000-2021



Source: IEA 2022. All rights reserved. Adapted from "Tracking Buildings" (IEA 2022f).

5. INVESTMENT AND FINANCING FOR SUSTAINABLE BUILDINGS

Investment in energy efficiency within the global buildings sector grew to over USD 237 billion in 2021, marking a growth of around 16 per cent from 2020 levels and reflecting both major government investment in efficiency and greater numbers of new, efficient buildings.



There was an increase in building energy efficiency investment in 2021 of around 16 per cent compared to 2020, the single largest increase in the last 10 years of tracking by the IEA (IEA 2022g). The increase reflects both the rebound in buildings construction activities within the United States of America and Canada, along with France, Italy and the United Kingdom, and the sustained low-level growth in Germany, Japan and China. The IEA estimates the global buildings construction sector value increased by 5 per cent to more than USD 6.3 trillion in 2021 (IEA 2022g).

In high income countries, building energy efficiency upgrades have benefited from large public programme investments. The German state-owned bank KfW invested nearly €37 billion in 2021 in improving energy performance of existing and new buildings. In 2022, the German investment programmes were paused due to funds being depleted but were resumed under a smaller budget and focused on retrofits and more ambitious efficiency standards for new builds. Germany plans to unleash significant spending through to 2024, announcing €177.5 billion on climate actions (Germany, Federal Ministry for Economic Affairs and Climate Action 2022) and around €17 billion to invest in energy-efficient buildings (Fokuhl 2022). In Japan, zero-energy housing accounted for over 16 per cent of the private housing market in 2021, up from around 3 per cent in 2014, showing a considerable increase in sustainable building construction activities in a short period.

Analysis shows pandemic recovery stimulus packages have made a major contribution to energy efficiency investment in Western Europe. Large public sector programmes such as those in the United Kingdom and France prioritized expenditure towards decarbonising buildings. The United Kingdom's Public Sector Decarbonisation Scheme has seen £1 billion spending between 2020 and 2022 on buildings carbon emissions reductions (United Kingdom, Department for Business, Energy and Industrial Strategy 2022b). In France, the France Relance provided up to €4 billion in loans for

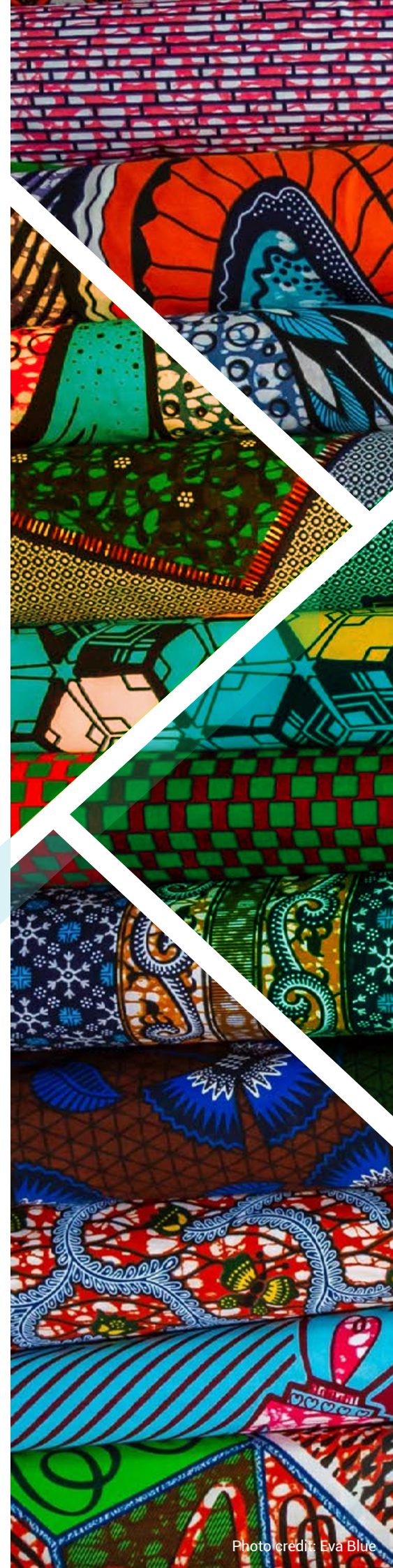
renovations of schools, hospitals and local and state buildings (European Commission 2021a). However, despite the focus on buildings as part of the economic recovery from the pandemic, some countries have shown only modest increases in efficiency spending. The United States of America spent USD 377 million in 2021 on energy efficiency investment through the federal government Weatherization programmes, which was the same as 2020 due to budget requisition process to maintain federal spending (United States of America, Office of the Chief Financial Officer 2020). Canada's Greener Homes grant offers CAD 5,000 to support household investment to improve building energy performance through a total budget of CAD 2.6 billion over the coming seven years (Canada, Natural Resources Canada 2022).

Many emerging economies showed a continued decline in new building construction activities, including in South Asia, Southeast Asia and Africa (for more details on sustainable construction trends in Africa see chapter 7). Developing economies in Asia have struggled with the continued impact of the pandemic and have experienced continued disruption in buildings construction activities and limited public programmes of investment. The impact has been a significant slowdown in energy efficiency investment in 2021 from an already low level, and investment in these countries remains below 2019 levels.

Pandemic stimulus programmes are being tapered through 2022 as governments focus on addressing inflation, which has affected the construction sector due to both substantial increases in demand and supply constraints. As supply chains continue to return to a more normal level of operation, materials and labour supply will meet growing buildings construction demand across the globe, but consumer interest in housing investment may wane without continued directed programme support. Based on these early trends, the IEA has estimated that global investment in energy efficiency will increase by a modest 2 per cent in 2022.

6. REGIONAL FOCUS: AFRICA

An estimated 70 per cent of the African building stock in 2040 still has to be built, with much of this growth happening in cities. The current resilience of buildings against the growing impacts of climate change is low, in particular as more than half of African citizens are living in informal housing. Traditional sustainable construction and building practices are a cornerstone of African cultural heritage. Promoting, preserving and further developing these construction techniques is key to enabling more affordable housing that is adaptable to climate conditions.



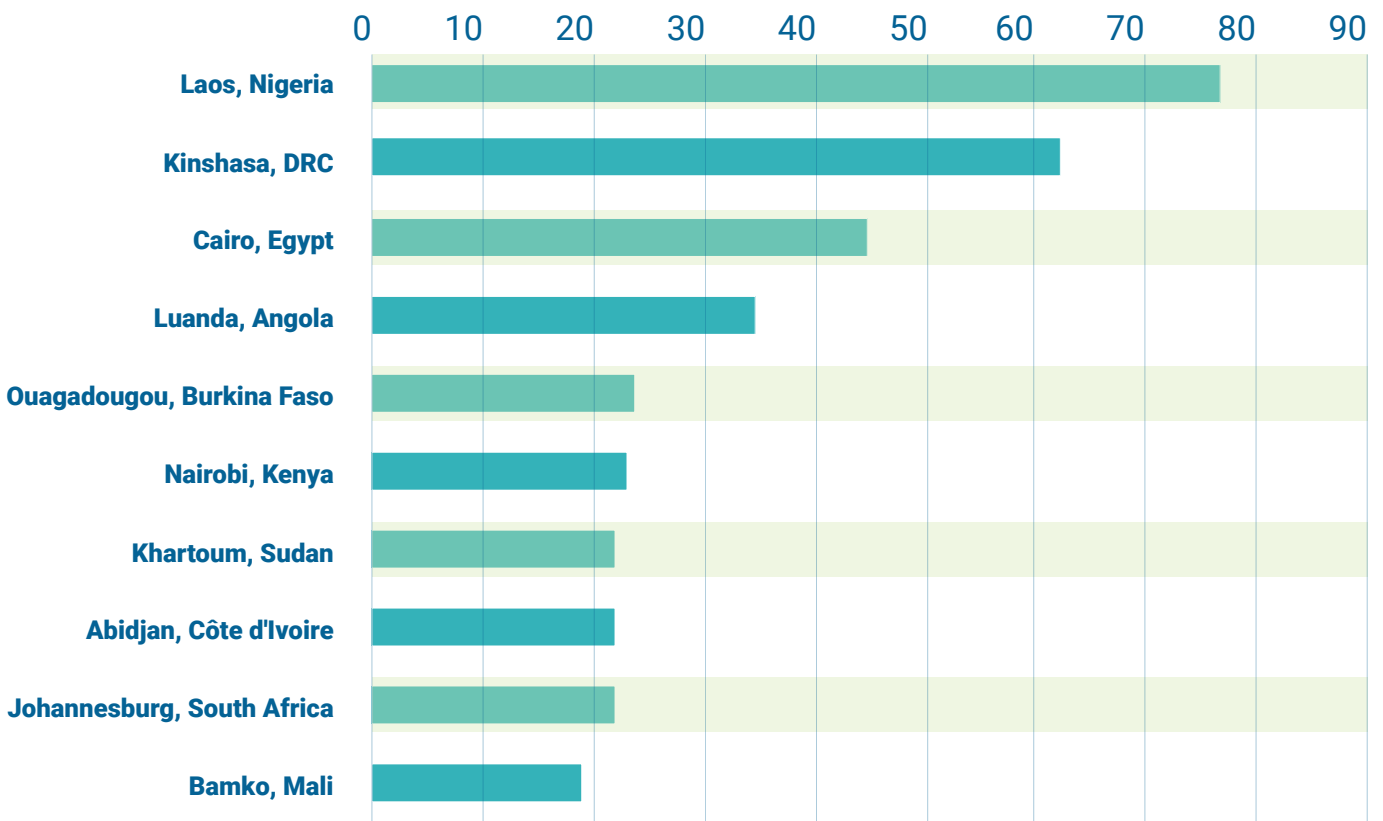
6.1. INTRODUCTION

Africa is a dynamic continent with diverse cultures and a youthful population. The continent's population is projected to double by 2050, reaching approximately 2.4 billion (ADB 2019). Seventy per cent of the African building stock expected for 2040 has yet to be built (IEA 2019) and more than 80 per cent of that growth will occur in cities, especially slums (Myers 2016). This generates new prospects for economic growth and will influence the urban landscape of the continent. By 2025, Africa will have three megacities: Lagos (Nigeria), Cairo (Egypt) and Kinshasa (Democratic Republic of the Congo) (see figure 19). Additionally, hundreds of smaller African cities have doubled in size every 20 years (Vidal 2018).

But this context of fast expansion presents challenges, as it is expected to strain infrastructure and energy resources while exacerbating existing social and environmental imbalances. Africa is one of the regions most vulnerable to the effects of climate change: UN-Habitat estimates that around 56 per cent of the population lives in informal housing (UN-Habitat 2016) (see Figure 21), while the frequency of natural disasters has tripled in the last 30 years (United

Nations Children's Fund [UNICEF] 2021). Figure 22 depicts Africa's vulnerability to climate change index. Despite being endowed with renewable energy sources, the majority of the African population suffers from low energy accessibility and affordability. Only 43 per cent had access to electricity in 2021 (IEA 2022b), while the number without access to clean cooking was 970 million (IEA 2022b). In terms of energy and emissions, the continent accounts for around 6 per cent of global energy demand and contributes less than 3 per cent of greenhouse gas emissions (IEA 2022b). In 2018, buildings contributed 61 per cent of Africa's final energy consumption and 32 per cent of carbon dioxide emissions (IEA 2019). Households in Africa accounted for 56 per cent (Figure 23) of total final energy consumption in 2020. The IEA projects that, by 2030, African household energy demand for cooling will increase the most and energy demand for appliances will quadruple, whereas energy demand for lighting in the residential sector will decrease due to the movement towards energy-efficient lamps (IEA 2022b). This indicates that the need for cooling is the major future challenge for residential energy demand, with ownership of fans standing at 0.6 units per household and current cooling device ownership standing at only 0.06 units per household (IEA 2022b).

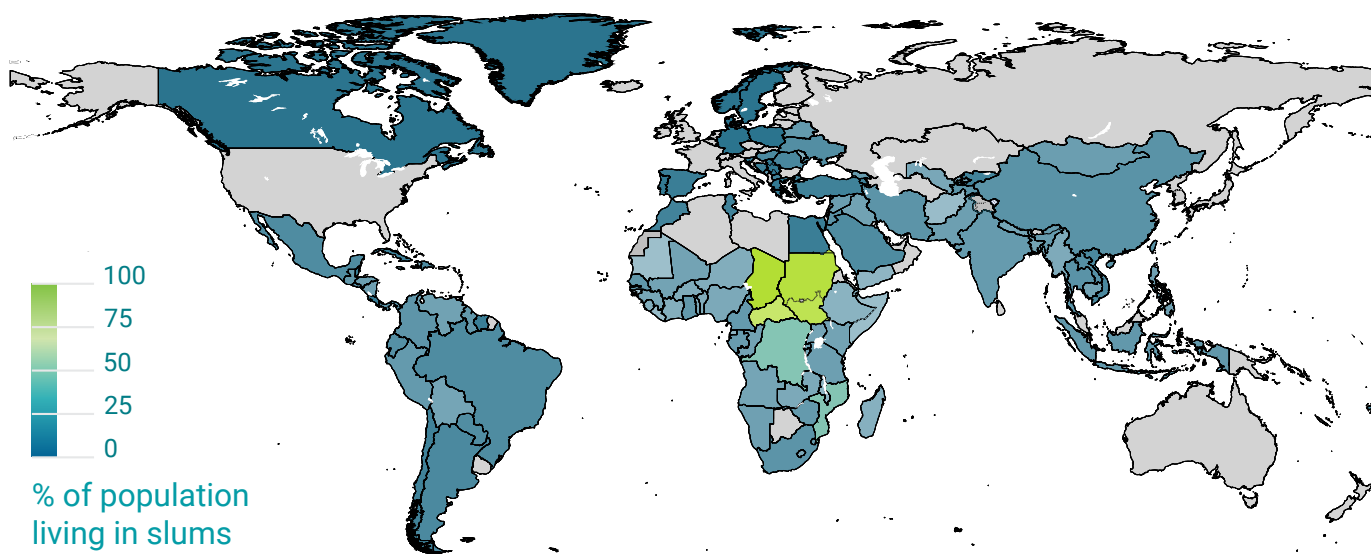
Figure 20. Population growth per hour in African cities



Source: UN World Urbanization Prospects 2014 (Myers 2016).

Figure 21. Global population living in slums 2018 (per cent of population)

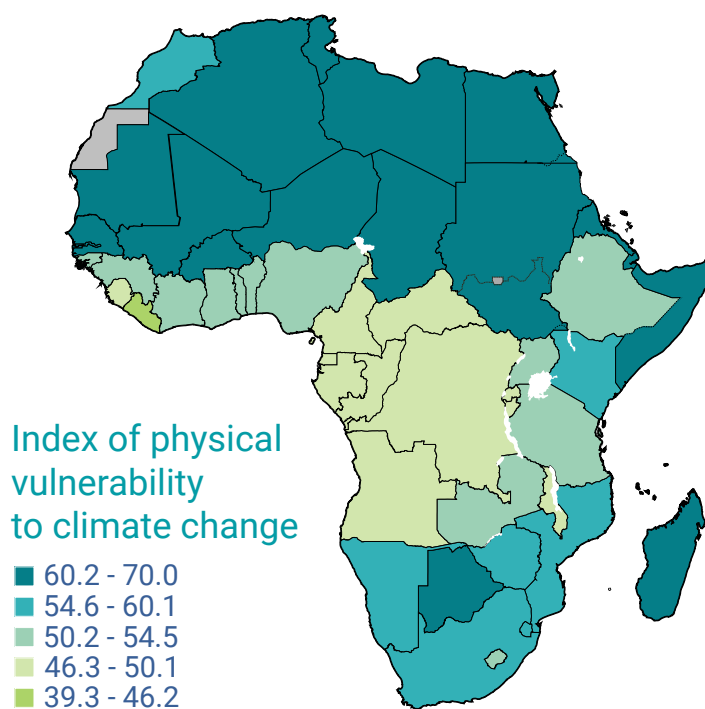
This map is without prejudice to the status of or the sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city, or area.



Source: World Bank 2018. Adapted from "Population living in slums (% of urban population) - Sub-Saharan Africa". (World Bank 2018).

Figure 22. Vulnerability to climate change. The lowest level of vulnerability is given a score of 0, the highest 100

This map is without prejudice to the status of or the sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city, or area.

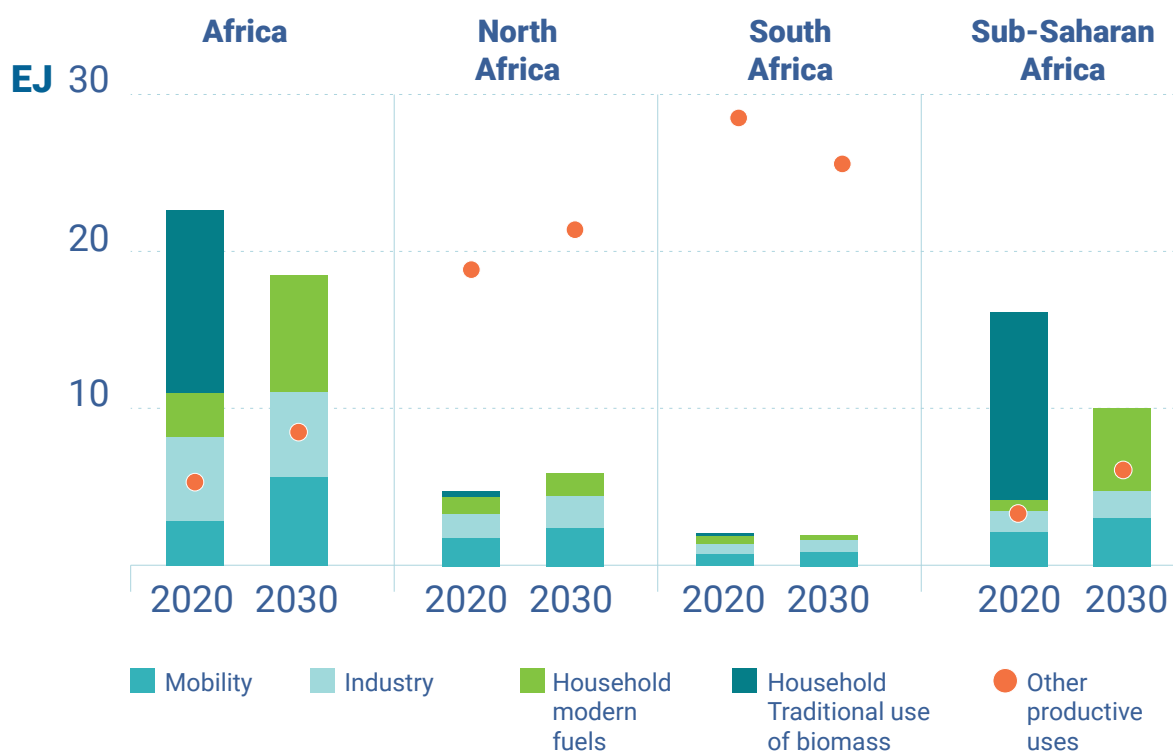


Source: Feindouno et al (2020). Adapted from "The Physical Vulnerability to Climate Change Index: An Index to Be Used for International Policy". (Feindouno et al 2020).

Given that increased use of materials is strongly associated with urban growth, a rise in greenhouse gas emissions is also predicted as the steel and cement industries account for 38 per cent of African emissions (Nwamarah et al. 2018b) (see also chapter 8 case study on Sub-Saharan Africa). This highlights the need to promote the use of sustainable construction materials and adopt low-carbon development (Nwamarah et al. 2018b), particularly when Africa is rich in local

construction techniques and materials. Local materials include adobe, laterite, termite mound soil (Legese et al. 2021), timber, stone, bamboo, sand and a variety of dry vegetation, while traditional construction techniques include rammed earth, sun-dried bricks, compressed earth blocks, wattle and daub, cob, timber-framed construction, sandbag construction and thatched roofs (Dosumu and Aigbavboa 2019).

Figure 23. Africa's final energy consumption by sector 2020-2030



Source: IEA 2022. All rights reserved. Adapted from "Africa Energy Outlook 2022" (IEA 2022b).

Notes: Other productive uses include services and agriculture. Household modern fuels include fossil fuels, electricity and renewables, such as the use of biomass in modern stoves.

The buildings and construction sector in Africa is worth USD 5.4 billion and is expected to grow at a compound annual rate of 6.4 per cent by 2024 (Cheong et al. 2021). Across Africa, large-scale construction activities decreased by approximately 15 per cent between 2019 and 2020, with 50 per cent of total construction by value occurring in Egypt, Nigeria and South Africa and only 2 per cent in Central African countries (Cheong et al. 2021). The climate finance flows into Africa have increased by 3 percentage points, from 23 per cent (between 2010-2015) to 26 per cent (2016-2019) to a total investment value of USD 73 billion (ADB 2022). Moreover, the economy is anticipated to expand 2.8 per cent in 2022 and 2.7 per cent in 2023, powered by the construction and services industries (Nwamarah et al. 2018a).

There is no one-size-fits-all answer when addressing the future building demands in Africa. Despite common patterns and issues, meeting Africa's construction needs will necessitate creative thinking and scalable solutions considering the specificities of each context. In an effort to be proactive, table 5 below sums up the main challenges and opportunities facing the African buildings sector. The African buildings sector should be contextualized within the broader framework of sustainable cities. Integrating environmental sustainability should extend to include urban food systems, infrastructure, waste, water and sanitation, and energy efficiency to pave the way for overall sustainability on the city level.

Box 8. Examples of low-carbon and traditional construction approaches in Africa

The 10x10 sandbag houses in Freedom Park on the outskirts of Cape Town, South Africa are a case of local materials and techniques being used to build affordable housing units (MMA Architects 2008). The budget was USD 4,300–8,600 in 2007 (Fairs 2008). The sand used in the bags was locally sourced from dunes near the site and most of the labour was carried out by the locals and future residents (South Africa Today 2019).



Photo credit: Freedom Park sandbag houses, Cape Town (South Africa Today 2019). Sandbag homes in Mitchells Plain, Cape Town (Doppler and Mpahlwa 2021).

Another project that demonstrates the fusion between local construction materials and adaptability to the local climate is the Tayebat Workers Village in El Baharya Oasis, Egypt, built in 2015. The village is designed to provide housing for 350 workers and is constructed from local materials including sandstone (Cooke 2016). Vaults and domes are used for roof construction and PV solar panels are integrated within the design to generate energy but also to provide solar protection for the roofs (Cooke 2016).

Despite financial and land access challenges, cooperatives can also play an effective role in the dissemination of local construction materials. Evidence of this can be seen in the Regional Union of Construction and Housing Cooperatives in Thiès, Senegal, which launched a framework by which locals can construct affordable housing units (USD 125-140/m²) in 2015-2016 (Programme for Energy Efficiency in Buildings 2021). The union facilitated and oversaw the complete project process – from building permissions and design to completion of construction – through the provision of 25 design options and trained local craftspeople and site supervisors. The union's two-storey headquarter was built as a prototype using reinforced concrete for the structure, compressed earth blocks made from locally sourced materials for the walls and fully powered by solar energy (Programme for Energy Efficiency in Buildings 2021).



Photo credit: The Regional Union of Construction and Housing Cooperatives Headquarters in Thiès, Senegal.

Table 5. Challenges and opportunities for Africa's buildings sector

Challenges

- Lack of access to energy sources.
- Extreme vulnerability of the built environment to natural disasters.
- Expected expansion in the informal building sector.
- Increase in future cooling demand, specifically in the residential sector.
- Lack of enforced building energy codes (see section 4.2).
- Limited mortgage finance and high interest rates on mortgages when available, which range from 3 per cent to 32 per cent (Centre for Affordable Housing Finance in Africa 2021).
- Difficulty of mobilizing funds towards green buildings and construction.

Opportunities

- 70 per cent of the African building stock expected for 2040 has yet to be built (IEA 2019).
- Africa's young population and diversifying economy.
- Africa is rich in renewable energy sources, with nearly half (44.8 per cent) of the total renewable energy technological potential (Ulbrich and van Oostrom 2021).
- Overall energy demand in the residential sector can be reduced by one-quarter by implementing energy efficiency measures (building energy efficiency codes and higher minimum energy performance standards for appliances and cooling systems) and displacing biomass in cooking. This would decrease the residential sector's share to approximately 33 per cent of total energy consumption in 2040, assuming accelerated industrialization (IEA 2021d).
- Capitalizing and developing Africa's local construction materials and techniques can contribute to creating jobs, stimulating economic growth, reducing negative impacts on ecosystems, fostering cultural heritage and improving housing conditions (IEA 2019).
- Passive design measures are an effective strategy in Africa as allowing for natural ventilation and reducing solar heat gains can reduce the air conditioning cooling demand by 65-70 per cent in climates similar to coastal Senegal (IEA 2019).
- Integrating renewable energy into building design can solve problems associated with energy accessibility and biomass use without requiring costly infrastructure investments (Centre for Affordable Housing Finance in Africa 2021).
- Investment in African infrastructure is a global public good in the context of the worldwide significance of Africa's demographic evolution and its necessary productive transformation.

6.2. DECARBONIZING THE AFRICAN BUILDINGS AND CONSTRUCTION SECTOR

On the policy level, many African countries have joined the global effort to reduce greenhouse gas emissions through NDCs. All African countries except Libya have submitted their first NDCs, and 38 countries out of 54 have submitted their updated NDCs. Many of these address the buildings sector in a variety of topics, including building codes, energy-efficient appliances and lighting, integration of renewable energy, and the use of local and traditional construction materials and techniques. This is a step in the right direction for the continent's green transition. Table 3 identifies NDC measures relating to buildings in key African countries.

In addition to the NDC commitments, building energy codes are an effective measure to promote energy efficiency. Worldwide, Sub-Saharan Africa and South and Central America have the fewest mandatory codes (section 4.2, figure 10). Countries that have implemented a mandatory building code include South Africa, Ghana,

Nigeria, Tunisia and Morocco, while Egypt has a voluntary code. At least seven other African countries are in the process of developing building codes (see section 4.2).

Building labelling schemes are complementary to policies and are an effective tool to inform actors in the construction sector, buyers and tenants about the energy performance of buildings and promote energy efficiency improvements (IEA 2021d). Actors in the African buildings and construction sector have sought accreditation from non-African building energy labels. According to the US Green Building Council's LEED rating system inventory for 2022, the number of LEED-certified buildings in Africa stands at approximately 80 (with a total of 286 buildings certified or registered for certification); Egypt ranks highest with 22 buildings followed by South Africa with 18 (Verdinez 2022). Although voluntary certification might have its advantages, it can seldom be a scalable approach where it is not context sensitive or reflective of national policies such as national energy codes or land-use policies.

Table 6. Selection of African NDCs related to buildings

Region	Country	NDC draft	Issue	Area of focus of NDC
North Africa	Egypt	2		Promoting the use of renewable energy and energy efficiency in new and existing buildings e.g. using rooftop PV, solar water heaters, and expanding the use of LED lighting in residential sector by 2030.
				Expanding on specifications and energy efficiency labels for appliances.
				Activating the energy efficiency codes for new and existing buildings, embracing voluntary green buildings guidelines, promoting community participation on achieving sustainable standards, and allocating incentives to encourage the use of sustainable technologies with the aim of achieving 16,960 green standard residential units by 2030.
	Tunisia	2		Determining the most appropriate and practical energy technologies for the buildings sector, which consumed 37 per cent of the total energy demand and contributed 55 per cent of total greenhouse gas emissions in Tunisia.
				Including renewable energy in buildings and making use of available carbon market mechanisms to promote energy efficiency in the sector.
	Morocco	2		Reducing energy consumption in buildings, industry and transport sector by 5 per cent in 2020 and by 20 per cent in 2030.
			Encouraging the use of green roofs and walls.	

Region	Country	NDC draft	Issue	Area of focus of NDC
West Africa	Cape Verde	2		Promoting energy-efficient appliances and developing loans for companies active in the energy efficiency/renewable energy field (e.g. insulation materials, solar water heaters, energy-efficient appliances).
				Integrating low-carbon specifications in building codes e.g. passive design techniques (natural ventilation, orientation, vegetation) and local construction/ vernacular techniques and materials.
	Guinea-Bissau	2		Implementing energy efficiency measures in public and commercial buildings.
				Increasing the distribution rate of prepaid meters to allow households to monitor and optimize electricity consumption.
Senegal	1		Promoting energy efficiency through the use of energy-efficient lamps and appliances.	
Southern Africa	South Africa	2		Including climate-change-conscious measures in urban planning and building design and incorporating climate risks in building standards/ codes.
East Africa	Ethiopia	2		Promoting improvements in the energy efficiency of appliances and buildings.
	Mozambique	2		Promoting the use of energy-efficient household appliances.
	Seychelles	2		Increasing energy efficiency measures in public lighting, appliances and buildings.
				Adopting context-sensitive low-carbon specifications and criteria into building codes, e.g. passive, low-tech and vernacular construction methods.
	Malawi	2		Reducing consumption of charcoal through promotion of efficient charcoal stoves.
				Increasing dependence on sustainable local materials and developing local construction materials market.
			Promoting the use of earth stabilized blocks in place of cement stabilized blocks in governmental and residential buildings. Encouraging low-carbon cement production processes.	
			Updating existing building standards with climate change considerations.	
Central Africa	Cameroon	2		Promoting energy efficiency in buildings through the use of energy-efficient lamps.

Legend:

- Addressing renewable energy and energy efficiency technologies in buildings
- Addressing energy efficiency in household appliances
- Addressing building codes and standards
- Addressing building materials and construction techniques

Source: UNFCCC, Nationally Determined Contributions Registry (UNFCCC 2022b).

As for African labelling schemes, the Egyptian Housing and Building National Research Centre (HBRC) introduced the Green Pyramid rating system in 2009 (Moussa 2019), and the Green Mark rating system was introduced in Kenya in 2018, both of which are voluntary. On the other hand, Tunisia's building energy labelling system is a best practice example of integration, as it was developed in 2004 alongside the national building energy code (IEA 2013). Both became mandatory for office buildings larger than 500 m² in 2008, extended to include residential buildings (excluding single-family dwellings) in 2009 (IEA 2013). South Africa's Green Star rating system has also achieved significant success. After being established in 2007, it reached 200 certifications in 2016 (Eproperty News 2016) and 140 buildings were certified in 2021 (Magoum 2021). One hundred buildings with Green Star accreditation can save 170 million kilolitres of water and 130 million kilowatt hours of electricity (Green Building Council South Africa [GBCSA] 2017). Green Star has also extended to certify buildings in other African countries: Botswana, Ghana, Kenya, Mauritius, Morocco, Namibia, Rwanda, Tanzania, Uganda (GBCSA 2017). As for household appliances, South Africa's standards are voluntary, while Ghana has achieved a compliance rate of 97 per cent for refrigerators and air conditioning units (REN21 2022). Regarding renewable energy and energy efficiency, many regional and national efforts have been launched in Africa (International Renewable Energy Agency [IRENA] and African Development Bank [AfDB] 2022). On the building level, the government of Ghana

provides a subsidy for solar water heater installations and Senegal passed legislation in 2015 requiring all new buildings to be outfitted with solar panels (IRENA and AfDB 2022). Solar photovoltaic panels have also been installed on municipal buildings in Cape Town, South Africa: by 2020, 42 megawatts of rooftop PV cells had been approved, with plans to expand into residential and commercial buildings (IRENA and AfDB 2022).

6.3. THE ROUTE TO NET ZERO THROUGH NATIONAL INITIATIVES

The construction and buildings sectors have a critical role to play on the road to decarbonization. In South Africa, the government has mandated that all new buildings be designed and constructed to be net zero energy by 2030, similarly in Kenya by 2035 and Nigeria by 2050 (IRENA and AfDB 2022). Several African countries have committed to achieving net zero carbon emissions by 2050. This includes reducing their emissions as much as possible and offsetting any remaining emissions through activities such as investing in renewable energy. The list of African countries committed to achieving net zero carbon emissions by 2050 includes Algeria, Egypt, Ethiopia, Kenya, Morocco, Nigeria, South Africa, Sudan and Tunisia (IRENA and AfDB 2022).

Figure 24. Green certification projects across Africa (blue labels) and initiatives relating to construction materials (orange labels)



Source: The map identifies projects registered or accredited under non-African and African energy labels. Find out more here: padlet.com.

Among the African countries that have or are planning roadmaps towards decarbonization are Senegal, Ghana and South Africa (African Development Bank 2018). Senegal has promoted energy efficiency in the buildings sector through optimized thermal insulation, LED lighting, an energy audit of existing public and commercial buildings and energy demand studies for the newly constructed. Ghana has taken measures to create climate-resilient infrastructure to adapt to climate change (Adshead et al. 2022). South Africa has set measures to upgrade existing infrastructure and reduce the environmental impact of the residential building stock by enhancing the buildings' energy performance, encouraging the use of solar thermal or heat pumps for domestic hot water, and facilitating clean cooking methods.

The United Arab Emirates Ministry of Energy and Infrastructure, in coordination with Guidehouse and the Regional Center for Renewable Energy and Energy Efficiency (RCREEE), is leading the development of building decarbonization roadmaps for the 22 countries and territories in the Arab League. Based on an assessment of general socio-economic indicators, high-level sustainability indicators and efficient buildings indicators, these 22 countries/territories have been classified into three groups (early, medium and advanced). A sub-roadmap is developed for each group, allowing each country/territory to build its own national roadmap. These roadmaps, which follow the GlobalABC roadmap model, will be launched at COP27 (see section 9.7.1). The forthcoming roadmap for buildings and construction for the countries and territories in the Arab League will be highly focused on actions to support building decarbonization across the region (see section 9.6.3).

Box 9 showcases efforts towards net-zero construction in Africa. The examples represent different urban scales and uses, and include existing and newly constructed buildings.



Photo credit: Adriaan Venner Scheepers

Box 9. Net-zero construction methods in Africa

Assie Gaye solar PV array

Photo credit: habiter-autrement.org



Assie Gaye is an energy-positive refurbishment of a 264 m² residential area in Dakar, Senegal carried out between 2009 and 2010 (Couture 2016). The project was carried out by local craftspeople and used compressed earth blocks, energy-efficient LED lighting, a 160-litre solar water heater and renewable energy, which included 10 solar panels (capacity: 1,300 W) and a small 200 W wind turbine. The house achieves an energy saving of approximately 2,000 kWh and an 80 per cent reduction in CO₂ emissions when compared with similar houses.

The Faculty of Science at the University of Kisangani is a 2,700 m² low-carbon building dedicated to housing and education uses in the Democratic Republic of the Congo. The building is constructed using earthen bricks (see Image 5) and applies passive design techniques of natural ventilation and solar shading to reduce its carbon footprint (Gonzalez 2018). The project team took the time to train unskilled local workers to carry out the construction process efficiently (Gonzalez 2018).

The Faculty of Science at the University of Kisangani

Photo credit: CIFOR Photo/Axel Fassio.



Sustainable Energy Africa's office building in Cape Town is a 700 m² net-zero-energy building constructed in 2004. The building was constructed using local stone, reconstituted bricks and recycled metal and timber. It achieves an energy consumption of 30-50 kWh/m²/year. To achieve net zero carbon, the building uses on-site renewable energy generation. It was initially constructed with a 2 kW solar PV system, which was upgraded to 14 kW by 2018 as the price of the system became cheaper (World Economic Forum 2022).

Solar PV system on the roof of Sustainable Energy Africa office building

Photo credit: Sustainable Energy Africa 2018.



One Airport Square in Accra, Ghana is a large multi-use building constructed between 2010 and 2015. It includes retail use on the ground floor, office space distributed throughout the upper floors and two basement levels for parking (Yemeli 2021). The building's concrete structure and floor overhangs provide overshadowing to the glazed levels (see above image). Additionally, an internal atrium was introduced to enhance ventilation and increase natural lighting levels. The building was granted a 4-star rating by the Green Star rating system of the South Africa Green Building Council (Yemeli 2021).

A low-carbon transition in the African construction sector faces several challenges, which include the provision of finance, promoting low-carbon transition policies, developing labour skills, and supporting research,

development and demonstration (Hogarth et al. 2015). Box 10 provides several case studies of entrepreneurs attempting to produce green and low-carbon materials based on local materials and techniques.

Box 10. Advanced construction practices and sustainable and zero-carbon materials

ISOCALM uses Napier grass (*Pennisetum purpureum* species, also known as elephant grass) to create thermal insulation boards which are hand-manufactured in Gambia. The process is CO₂ neutral from growth to transport, and reduces air pollution by avoiding burning of the grass (Kelsch 2018). Similarly in Rwanda, Strawtec uses straw and recycled paper to manufacture compressed boards for partitioning with low embodied energy and carbon emissions.

Interlocking compressed earth blocks in construction

Photo credit: DSF Africa (Clean tech Malawi 2022)



The Burkinabe Agency for Standardization, Metrology and Quality has developed eight codes to standardize the technical specification and manufacturing process of compressed earth blocks (Cheong et al. 2021). EcoKiln in Malawi is reducing emissions through energy-efficient kilns that use industrial waste and achieve savings of 30-50 per cent on fuel costs.

Earth Enable in Rwanda is advocating for a healthier indoor environment by replacing dirt floors with waterproof compressed earth floors made from locally sourced laterite, fine earth mix and sealed by a layer of oil (Easy Housing 2022).

Easy Housing sustainably sourced timber construction

Photo credit: Easy Housing 2022



Finally, Easy Housing in Uganda is supporting carbon-negative construction materials through its affordable housing prototype (see Figure 26) built in Arua from sustainably sourced timber (Easy Housing 2022).

Manufacturing process for straw panels

Photo credit: Strawtec Building Solutions.



7. TOPIC FOCUS: BUILDING MATERIALS

Globally, approximately 100 billion tonnes of waste is caused by construction, renovation and demolition, with about 35 per cent sent to landfills. In fast-growing developing economies, construction materials are set to dominate resource consumption, with associated greenhouse gas emissions expected to double by 2060. Embodied carbon in buildings – all emissions associated with materials and construction processes – need to be tackled soon to avoid undermining the carbon reductions achieved from energy-saving measures.



Materials used in the construction of buildings represent an estimated 9 per cent of overall energy-related CO₂ emissions (see section 5). Material efficiency strategies could significantly reduce greenhouse gas emissions in the construction material cycle. However, there are still considerable challenges in comparing the environmental impacts of materials and systems, though measurement and quality of data on the environmental impacts of construction materials continue to improve. As a key solution, the longevity of buildings infrastructure needs to be incentivized by financial and legislative means. Measures should encourage low-carbon adaptation and refurbishment that extends building lifespans without locking in operational energy inefficiencies. Built environment carbon rating systems need to include better rewards for the avoidance of new construction where possible, for the shift to low-carbon biobased solutions, and for the improvement of production methods for conventional materials.

we are experiencing today (OECD 2019). The report estimates that the biggest increase in resource consumption by 2060 will be in minerals, including construction materials and metals, particularly in fast-growing, developing economies (OECD 2019).

Many current construction materials rely on energy-intensive, mineral-based extractive processes which cause deleterious environmental impacts across the material life cycle, such as biodiversity loss and water scarcity as well as contributing to both embodied and operational carbon emissions. Additionally, at the end-of-use phase of building systems and infrastructure, materials are often wasted, exacerbating the environmental impacts associated with current 'take-make-waste' linear material production practices. Globally, approximately 100 billion tonnes of construction, renovation and demolition waste is generated annually. About 35 per cent of that waste is sent to landfills (Chen et al. 2022) whereas it could be recovered and upcycled.

7.1. BUILDING MATERIALS AND THE CLIMATE: STATUS AND SOLUTIONS

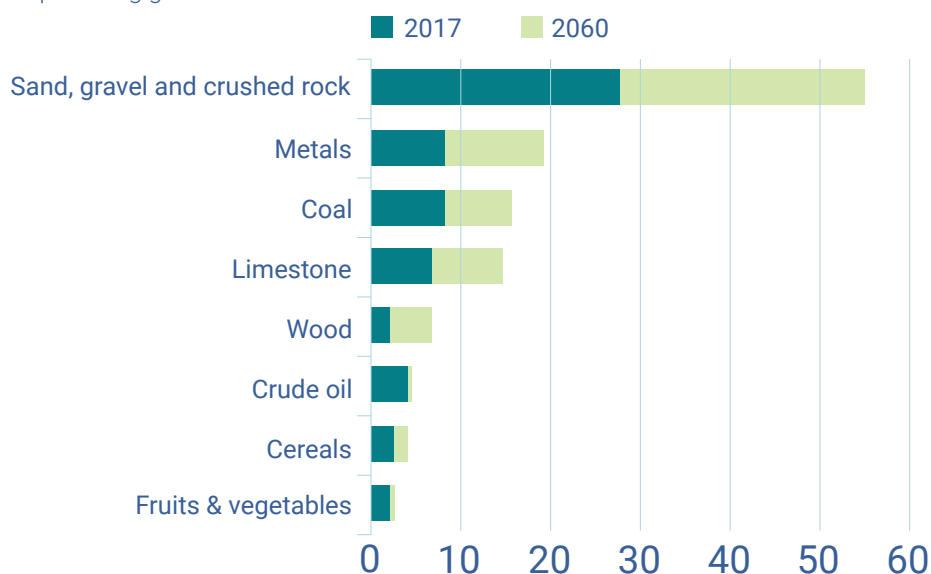
According to a 2019 OECD report, the global consumption of raw materials will almost double by 2060 as the world economy grows and living standards rise, exacerbating the environmental overloading

Transitioning to a future of low-carbon built environments requires the design of multi-beneficial material strategies that take a whole building life cycle and systems-thinking approach. The [International Resource Panel](#) underlined the massive greenhouse gas emissions reduction potential from material efficiency strategies applied in residential buildings (Hertwich et al. 2020).

Figure 25. Construction materials are set to dominate resource consumption in fast-growing developing economies, with building material-related emissions projected to increase by 3.5 to 4.6 Gt CO₂eq/year by 2060

Construction materials dominate resource consumption

Consumption in gigatonnes



Source: OECD 2019. Adapted from 'Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences' (OECD 2019).

In G7 countries, material efficiency strategies, including the use of recycled materials, could reduce greenhouse gas emissions in the material cycle of residential buildings by 80–100 per cent in 2050. Potential reductions could amount to 80–100 per cent in China and 50–70 per cent in India by 2050. However, there is a growing gap between the available supply and demand for recycled materials, especially for high-carbon metals such as steel, which is already being recycled in certain markets at over 90 per cent.

Cumulative measures must therefore be taken across the sector, with a whole-life and systems-thinking approach to enable multi-stakeholder engagement and cross-industry collaboration. The siloed approach that currently predominates across the built environment process hampers the necessary collective action to decarbonize the sector. The built environment process involves energy, material and information flows at each of its phases from initial extraction of material to final dismantling and deconstruction.

Figure 26. Whole-life and systems-thinking approach to enable multiple stakeholders at each decision point



Source: Adapted from Programme for Energy Efficiency in Buildings 2022.

7.2. TOWARDS THE ADOPTION OF A WHOLE-LIFE-CYCLE AND SYSTEMS-THINKING APPROACH

Despite its substantial contribution to global greenhouse gas emissions, embodied carbon has previously been under-addressed in strategies to reduce buildings emissions. Most building codes and regulations address operational carbon, that is, from the energy required to heat, light or cool the indoor environment, but do not typically require an accounting of embodied carbon, which refers to emissions from the extraction, manufacturing, construction, maintenance and disposal of materials. As municipal grids move towards electrification and building operations become ever more efficient, the relative contribution of embodied carbon in materials is set to dramatically increase (Architecture 2030 2018).

Embodied emissions in buildings need to be tackled soon, and related actions and targets should be introduced

in NDCs to avoid undermining the carbon reductions achieved from energy-saving measures. Global industry leaders are emerging with pledges, internal benchmarks and novel methods to reduce carbon impacts of construction materials and methods. On the materials procurement side, 60 of the globe's largest architecture, engineering and construction firms and organizations signed the 1.5°C COP26 Communiqué, an open letter to world governments demonstrating their commitment to reach the Paris Agreement climate goals. On the supply side, one example is the Global Cement and Concrete Association (GCCA) which declared its commitment to cut carbon emissions by 25 per cent by 2030 and reach carbon neutrality by 2050. The GCCA, made up of 80 per cent of cement and concrete manufacturers outside China, with some Chinese manufacturers, has unveiled plans for meeting the goals, including alternatives to clinker, using more renewable energy, and further developing methods for at-plant carbon capture and sequestration. Major companies are increasingly committing to net zero for scope 1 and 2 emissions by 2030 (e.g. AIA2030), and others are pledging net zero embodied carbon goals by 2050 (e.g. SE2050 challenge).

Earlier the WorldGBC launched its Net Zero Carbon Buildings Commitment, while the Science Based Targets Initiative is developing a sectoral decarbonization approach for the buildings sector, including GHG both operational and embedded CO₂ emissions. However, firmer commitments and associated regulation need to be made across the global industry and policy needs to move towards more pertinent standards and metrics for actually decarbonizing building materials.

Strategies to simultaneously address embodied and operational carbon can be clustered in three categories – “avoid”, “shift” and “improve” – all of which lead to “adaptability”. “Avoid” strategies range from building less, to circular approaches, requiring less material or using low-carbon materials, to improved designs that have a longer lifetime and lower operational emissions during building use. For the selection and implementation of new building materials, innovators in the field are working on two major fronts to (i) reduce the emissions of conventional building materials, such as steel-reinforced concrete, aluminium, plastic and glass (the “improve” strategy), and (ii) increase the market share of alternative building materials, such as local low-carbon solutions and hybrid and biobased materials (the “shift” strategy). In the below figure (27), assuming a medium-sized office building, the majority of embodied carbon is released upfront during the product and construction stages, but selection of materials and systems is also critical towards creating a high-performance building with low operational carbon over time. For example, when designing materials for both new and retrofit construction sites, swapping a concrete-based exterior wall system with a biobased structure (such as timber or bamboo) could greatly reduce the upfront embodied carbon, as well as the ongoing emissions from maintaining cooling systems in a tropical climate.

7.3. CHALLENGE: PROCUREMENT AND IMPLEMENTATION OF MATERIALS – FROM DATA TO ACTIONABLE KNOWLEDGE

To decarbonize the building materials sector, stakeholders from across the built environment process must take responsibility to understand the environmental impact of their decisions regarding material selections across the life cycle. Due to the complexity of supply chains for building materials and systems, emerging computational tools and data visualization frameworks are key to enabling decision makers to compare the pros and cons of different materials in terms of their embodied, operational and end-of-life climate impact.

Data management and visualization tools are critically important in engaging multiple stakeholders in the decision-making process and offering “at-a-glance” scenarios to support decision-making in real time. Although the transparent measurement and quality of data on the environmental impacts of construction materials continues to improve, there are still considerable challenges in comparing the environmental impacts of materials and systems through the use of third-party certifications, such as Environmental Product Declarations. These have been developed as verifiable life cycle assessment-based reporting mechanisms, but are hampered as tools for making procurement decisions due to issues of variability in data quality, methods, functional equivalencies and product category rules.



Photo credit: Avel Chuklanov

Figure 27. Materials selection and implementation affects the carbon footprint of a building over its life cycle

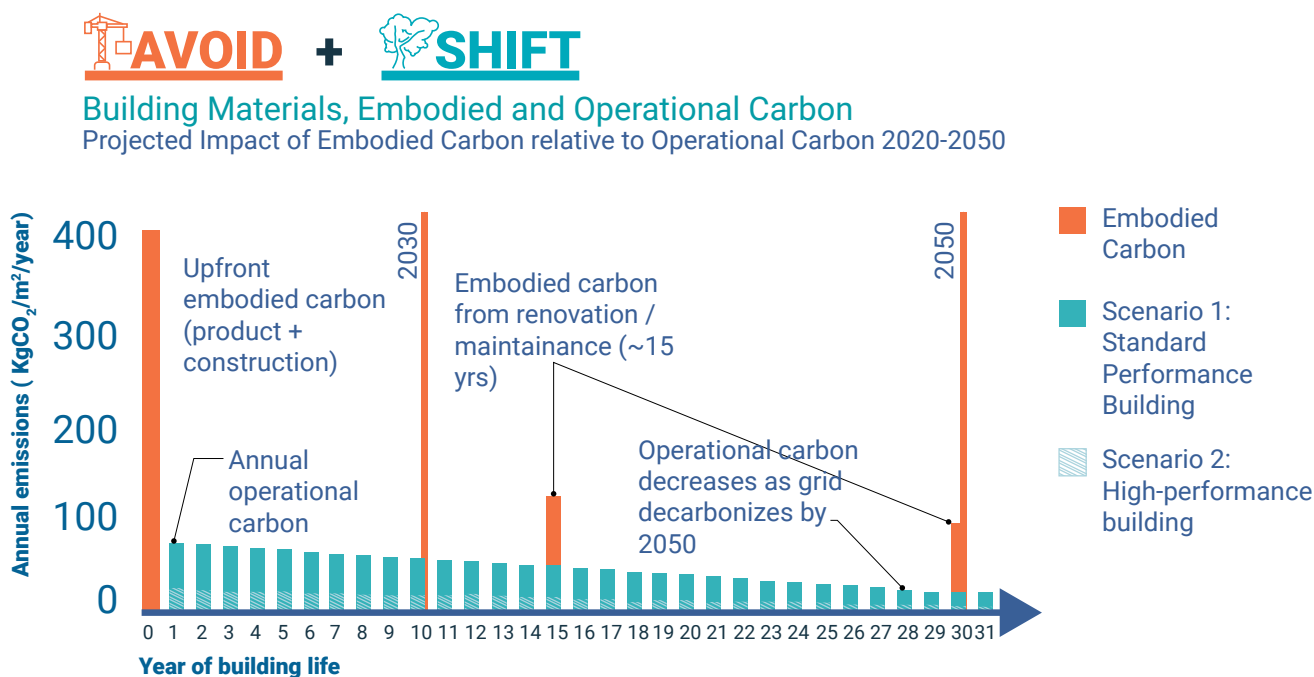


Fig : Adapted from Carbon Leadership Forum
Sources: Embodied Carbon Benchmark Study and CBECS

Source: Adapted by authors from Carbon Leadership Forum (2022) and data from Embodied Carbon Benchmark Study and Commercial Buildings Energy Consumption Survey (CBECS 2022).

The challenge across all global sectors, from informal to formal construction, is to get the right data to the right stakeholders at the consequential stages of decision-making (see Figure 28). Only limited information flows from one life-cycle stage to the next or only a part of the information generated throughout the building life cycle is available to stakeholders on the demand side (building owners, tenants, investors, financing institutions, buyers or operators). None of the above represents entirely new insights. The issue of data collection and management has been at the centre of discussion within the construction and real estate market for years. The issue of harmonization and standardization is and remains one of the major tasks for the sector and related policymaking in the future. Potential practical solutions to improve data access and information flow across the life cycle, such as building logbooks and material passports, will also need to be rolled out consistently across the globe.

7.4. AVOIDING CARBON EMISSIONS BY BUILDING BETTER, AND (WITH) LESS

Increasing the longevity of existing and new building stock and reusing existing components whenever possible are urgent priorities. Yet the lifespan of buildings and infrastructure is not solely determined

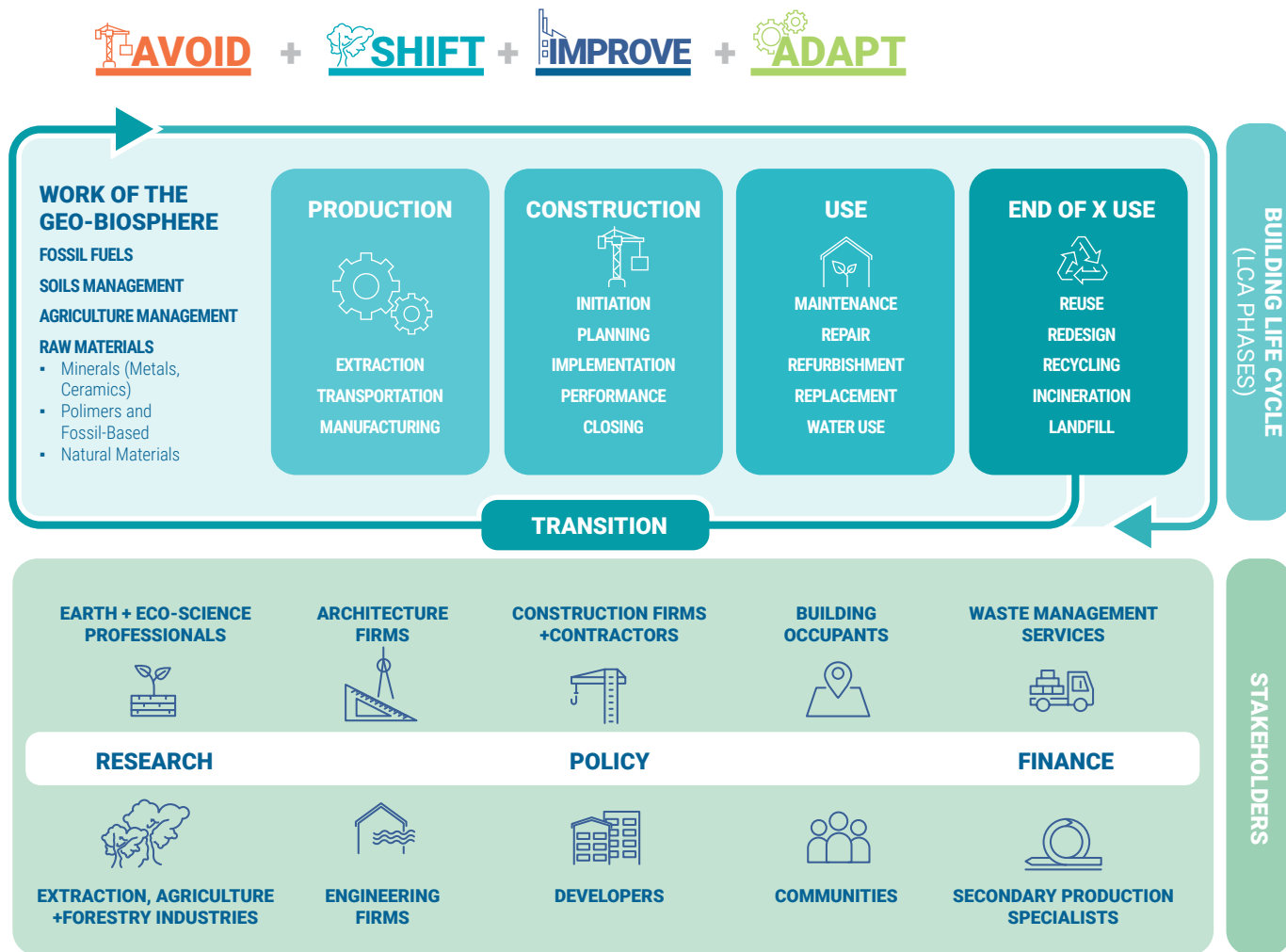
by physical durability, but also by social, cultural and economic factors (Cao et al. 2021). Materials are fundamental in establishing the perception of durable value over time, and the impact that materials have on occupants' emotional and cultural connection to a place transcends mere functional use. This is a critical aspect of sustainability that is typically underacknowledged. Currently, the average lifetime of buildings of all types is approximately 78 years in the United States of America (Müller et al. 2006; Kapur et al. 2008), 32 years in China (Hong et al. 2016) and 31 years in India (Liu et al. 2013; Pauliuk et al. 2013; Cao et al. 2021). However, even with the current methods in high-carbon materials such as reinforced concrete, these numbers could be significantly extended (Cao et al. 2021).

On a technical level, one of the most promising approaches towards extending material lifespan is the circular economy, which provides significant opportunities to reduce the greenhouse gas emissions associated with construction materials. A circular economy envisions a future where material waste is designed out of the built environment by keeping construction materials in use and extending the life of a building for as long as possible (Haas et al. 2015). In other words, the longer a building and its elements last, through maintenance and upkeep, the less embodied carbon is expended over the life of the building (Historic

England 2019). Material reuse and recovery offers one path towards circular production and consumption of building materials, while at the same time improving

the operational performance of buildings (such as the environmental impact of maintaining heating, cooling, lighting, plug loads, etc.).

Figure 28. From data to actionable knowledge: How to get the right information to stakeholders at the right phase of the built environment process



Credits: Naomi Keena, Daniel Rondinel, Alejandra Acevedo, Seth Embry, Anna Dyson

The choice of construction materials affects every aspect of a building's carbon footprint. The iron and steel industry alone accounts for 7.2 per cent of global greenhouse gas emissions, of which 55 per cent goes into the built environment sector, with 33 per cent into buildings and 22 per cent into infrastructure. Historically, the concrete and cement sectors have grown tenfold over the past 65 years, in comparison with a threefold increase in steel production and nearly stagnant growth in low-carbon timber production per capita (Monteiro et al. 2017). Additionally, design for "circular" material recycling and reuse of concrete and cement materials has lagged behind other sectors, while these materials have disproportionate impacts on operational carbon across many climates.

Reducing the use of high-volume, carbon-intensive materials such as concrete, steel and plastics, and replacing them with low-carbon and circular alternatives, should be the main approach. But although facilitating a shift towards low-carbon and biobased materials is critical, the rapid increase in urban densification and infrastructure within the global south means that high-carbon sectors such as cement, concrete and steel will continue to soar. It is therefore essential that incentives support far more ambitious pathways for multiple stakeholders to mitigate CO₂ production across the life cycle of high-carbon sectors, with different priority levers in various markets, particularly among the major producers such as India, China and the United States of America.

Increased funding is urgently required for public–private research partnerships to accelerate development, demonstration and commercialization to prioritize improvements in the following pathways:

1. Chemical carbon reduction of concrete and cement production techniques;
2. Carbon capture and sequestration at plant manufacturing;
3. CO₂ mineralization techniques;
4. Design-for-disassembly and reuse of components;
5. Novel (biobased) concrete mixtures to reduce binder requirements;
6. Computer-assisted and additive manufacturing to reduce carbon from transport and on-site construction waste.

7.5. ADAPT AND SHIFT BY USING BIOBASED PROCESSES TO REDUCE CARBON EMISSIONS

Using local, low-embodied-carbon materials like wood, bamboo, clay, stone and farm waste such as straw can have a huge impact on reducing the embodied carbon emissions of construction. Local sourcing is important, because otherwise carbon emissions from transportation can significantly drive up the embodied emissions. Biomaterials derived from plants, including wood and agricultural by-products, also sequester carbon over the course of their lifetime, as the carbon

that the living plants absorbed from the atmosphere continues to be stored in the building, until the materials biodegrade or are burned at end-of-life.

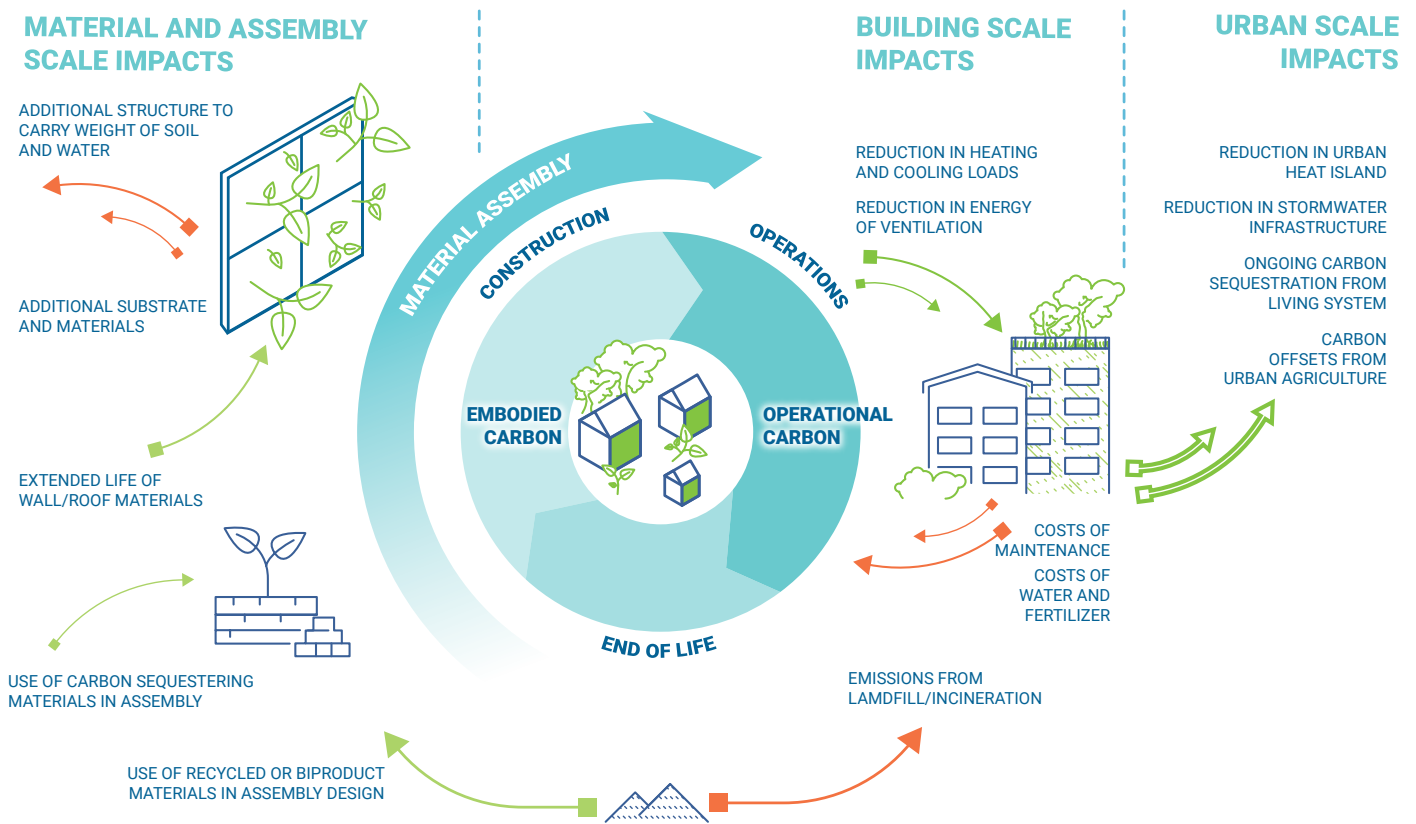
7.6. REDUCING THE CARBON EMISSIONS AND URBAN HEAT ISLAND EFFECT OF CONCRETE SURFACES THROUGH BIOMATERIALS (GREEN ROOFS, FACADES AND WALLS)

Global cities are under increasing pressure to reduce their disproportionate impact on global greenhouse gas emissions. There are abundant opportunities to transform the negative effects of concrete surfaces and transition urban areas from net carbon emitters into carbon sinks that absorb greenhouse gas emissions. The multiple potential benefits of biomaterial systems (green roofs, living facades, indoor living walls, etc.) have been recognized by numerous municipalities (Liberalesso et al. 2020). The benefits are both public and private, including energy savings from heating, cooling and ventilation requirements; improvements in air and water quality; reductions in urban heat island effects; and storm water reduction (Kosareo and Ries 2007; Shafique et al. 2018; Koroxenidis and Theodosiou 2021; Manso et al. 2021). One study estimated the carbon sequestration potential of covering all exposed concrete roof areas within the city of Detroit, USA with inexpensive lightweight green roofs as being equivalent to the removal of 10,000 SUVs from the road (Getter et al. 2009).



Photo credit: Markus Winkle

Figure 29. Green infrastructure and biomaterial systems



Source: Ciardullo and Dyson, Yale Center for Ecosystems and Architecture 2022.

The figure above shows an assessment of biomass material systems (green roofs, living facades and indoor living walls). The potential for added upfront embodied carbon costs of additional assemblies and structures must be weighed against the potential opportunities for operational carbon savings from reduced building cooling and/or heating loads, reduced urban heat island effects, improved air quality and biodiversity at both the building and the urban scale.

However, to further quantify and qualify these benefits towards enabling widespread adoption, holistic assessments of the carbon impacts of living materials across the life cycle are needed. While highly dependent on climate type, system design and comparative building insulation requirements (Susca 2019; Bevilacqua 2021), living wall systems have been shown to reduce energy for cooling by as much as 58.9 per cent compared to exposed concrete wall systems, particularly in areas of high solar irradiance (Coma et al. 2017). The type

of system and the diversity of plant species also significantly affect carbon sequestration potential; some systems pay back the embodied carbon within only three years after which they become a carbon sink. (Whittinghill et al. 2014).

Building-integrated green infrastructure may require additional structures, so there are potential trade-offs with the embodied energy these contain. However, the added biomaterials show potential to offset the operational carbon emissions from increased building cooling loads and urban heat island effects caused by exposed concrete materials, with added benefits for human health and well-being and biodiversity. Although the energy and cost payback periods are relatively modest for most climate types, far more policy support and encouragement is needed in the form of incentives and municipal building codes to overcome the added initial costs and concerns regarding ongoing maintenance costs.

7.7. SUMMARY OF INDUSTRY TRENDS AND IMPEDIMENTS TO GLOBAL DECARBONIZATION OF BUILDING MATERIALS

- 1. Embodied carbon labelling:** There is increasing support for the establishment of an international standards committee for embodied carbon labelling of building materials to address the wide discrepancies in methods and quality. However, for certification to support a transition to low-carbon materials, more development is required for methods that address the “carbon loophole”, so that the consumers and specifiers of materials in countries with strict pollution controls share accountability with producers from regions with lax controls. Examples include Environmental Product Declarations and Product Environmental Footprint.
- 2. CO₂ footprint assessments can be divided into two categories:** (i) expert assessments, which may include sophisticated simulations, and which tend to be time-consuming and expensive, and (ii) assessments conducted with easy-to-use tools that provide useful feedback for typical developments. Both are needed. Expert assessments continue to add to the body knowledge on the complexities of materials impacts on greenhouse gas emissions, ecosystems and energy flows. Expert assessments also facilitate the development of easy-to-use tools. Easy-to-use tools, on the other hand, can provide the opportunity for multiple stakeholders across the spectrum to apply and track greenhouse gas assessments of materials choices. Easily accessible tools have the potential to transform the industry, but they are in their infancy, and should only be expected to provide rough frameworks, not high-fidelity analyses. Accounting tools are being developed to better represent the potential whole-life-cycle carbon impacts of both traditional construction materials and prefabricated assemblies. These are critical comparisons, in which companies can capture the benefits of digitized production methods, from efficiencies in materials and structures, to reductions in on-site emissions and the improved ability within factories to design for disassembly and circular reuse. However, anticipating the impact of materials on a building's operational performance is
- 3. Shift from prescriptive to performance-based building codes:** Emerging economies without mandatory or voluntary building energy codes have a tremendous opportunity to leapfrog prescriptive building codes. The first wave of environmental building standards were largely based on best practice case studies. However, with the emergence of low-cost tracking and access to use-side metrics such as energy and water consumption, performance-based building codes have a greater chance to connect to a range of stakeholders, from global companies to owner-builders in informal settings. Example tools include EnergyPlus, Zero Tool, Building Energy Modelling, PV Calculator, DSIRE Efficiency/Energy Incentives Database²²
- 4. Low-carbon public procurement practices:** Policy and aggressive targets from municipal and national governments are establishing leading industry precedents for integrated decarbonization across multiple scales of infrastructure and buildings. Public procurement expenditure, or the purchase of materials, products and services by governments, comprises up to 13 per cent of GDP in OECD countries, with an even higher share among emerging and developing economies (Baron 2016). The impact of public procurement in generating more sustainable growth is outlined in the Sustainable Development Goals (SDG 12.7). However, policy goals for decarbonization must be formally linked to the purchasing of materials, with additional budgets in the planning phases for rigorous whole life-cycle assessments for public projects in order to improve the quality and quantity of data on the impact of material choices. Requirements for whole life-cycle assessments can also spur the development of effective solutions across specific local climate types and building traditions where the vast majority of builders and property owners have neither the means nor the inclination to conduct such analyses.

²²OCDE (2019), Global Material Resources Outlook to 2060 : Economic Drivers and Environmental Consequences, OCDE Editions, Paris.

- 5. Designing for circularity is gaining traction across education and practice.** However, far more investment is required for research and development and equipment to recover and process construction, renovation and demolition waste, particularly for cement-based materials. For example, design-for-disassembly and modular construction can enhance longevity, while enabling dismantling at the end of life to retain the building elements' value and potential for reuse (Keena and Dyson 2017). Coupled with this, digitalization in the construction process enables more prefabrication and modular construction, which has been shown to reduce material waste by 23-100 per cent (Jaillon et al. 2009; Lu and Yuan 2013; Chen et al. 2022). Additionally, even in industries with very high reuse of secondary materials, avoidance should be the primary strategy: in the iron and steel sector, for example, where material reuse is over 90 per cent, there is a growing gap between increasing demand and the scarcity of secondary (scrap steel) supplies.
- 6. Coordination across the construction, forestry and agriculture sectors:** Models are emerging for enhanced cooperation around land use through the development of supply chains and building products from earth-based materials, forestry and agricultural by-products (see Ghana and Senegal case studies). This can dramatically reduce carbon emissions from forest fires and crop burning.
- 7. Decarbonization of the cement sector and other major emitters** is being enhanced through replacing traditional methods with hybrid biomaterials and other low-carbon alternatives. However, these emerging methods are not yet cost competitive, and there are widespread biases that protect entrenched methods. Substantial research and development investment alongside incentives and/or enforceable building codes are needed to scale up these approaches.
- 8. Economics of carbon offsets:** Demand for carbon offsets will increase as net-zero deadlines approach. There is a risk that an escalating carbon offset economy may hamper the actual decarbonization of building materials and their production processes, as industries market "net-zero" products based on carbon offsets of varying quality. This trend requires more serious regulation in the certification of decarbonization of the actual processes of material production.

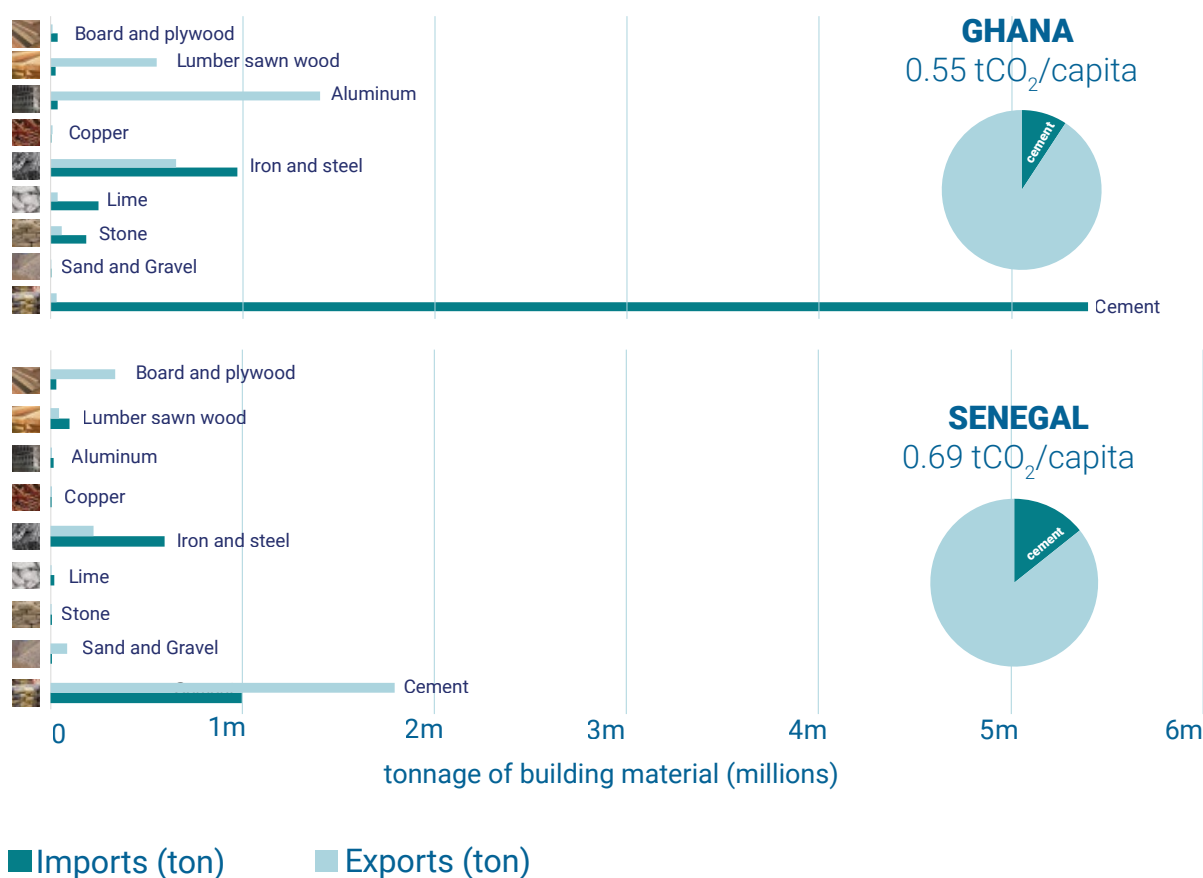
7.8. CASE STUDY: SHIFT – LOW-CARBON BUILDING ALTERNATIVES IN WEST AFRICA

There is recognition in the Sub-Saharan African region that using locally sourced, low-carbon materials in the private sector has an essential role in scaling building decarbonization efforts. However, in national building codes and green certification programmes, the narrow focus on energy efficiency does not directly address the need to reduce dependency on imported, high-carbon building materials.

The building materials sector in West Africa is currently following an entrenched high-carbon development pathway. There is a high dependence on imported materials (80 per cent in Ghana) and an increasing dependence on fossil-fuel-based electricity for production, at roughly 86 per cent in Senegal and 66 per cent in Ghana (Ritchie et al. 2020).

In 2019, cement alone contributed to 10 per cent of Ghana's and 17 per cent of Senegal's total carbon dioxide emissions (Andrew and Peters 2021; Friedlingstein et al. 2022). The use of cement in external envelope construction has risen from 39 per cent to 64 per cent in Ghana (Ghana Statistical Service 2021) and close to 70 per cent in Senegal (ARSO 2018). The uptake of cement has been even more rapid in urban contexts, reaching 82 per cent in urban Ghana and 86 per cent in urban Senegal.

Figure 30. Annual building materials trade for Ghana (2020) and Senegal (2019) and corresponding CO₂ emissions from cement building material production, based on data from Chatham House (2021) and Global Carbon Atlas 2019



Source: Lokko, Willow Technologies 2022.

Recent policies addressing decarbonization through local building codes have largely concentrated on improved energy efficiencies of mechanical systems and appliances, paying less attention to the performance of locally sourced, low-carbon building materials. Building on longstanding traditions of earth construction across Africa, a key opportunity for decarbonization in national and regional building sectors is through the scale-up of compressed stabilized earth blocks made from predominantly local materials. In 2018, the African Standard for compressed stabilized earth blocks was ratified to address the quality, production and performance of earth-based blocks for general building construction (ARSO 2018).

There is growing interest from private commercial and residential developers to achieve green certification in African cities. Since 2017, a small portfolio of buildings in Ghana has achieved EDGE (Excellence in Design for Greater Efficiencies) certification. An initiative of the International Finance Corporation (IFC), the EDGE programme is geared towards carbon footprint reduction through reducing embodied energy in materials alongside energy and water efficiency (Ampratwum et al. 2021; Edge Buildings 2022). In 2021, Reall and the Afreh Group received EDGE certification for a development of 100 affordable housing units in northern Ghana, demonstrating a 50 per cent reduction in embodied energy from the use of compressed earth blocks (Agboklu 2022). Larger-scale projects in the region have been critical for supporting biobased material commercialization. In Diamniadio, the Senegal Ministry of the Environment completed a technology-transfer demonstration “ecopavilion” in 2019, showcasing the use of adobe and natural fibre products made from typha, a local aquatic weed (Dieye et al. 2017; Niang et al. 2017).

Architectural approaches using locally adapted materials and designs that further sustainability, valorise traditional approaches and support local supply chains and communities’ are receiving increased recognition, with e.g. Architect [Francis Kere](#) from Burkina Faso receiving the 2022 Pritzker Prize as the first Architect from the African continent.

7.9. CASE STUDY: ADAPT – CARBON FOOTPRINT OF BUILDING MATERIALS AND HOUSING TYPOLOGIES IN RAPIDLY DEVELOPING URBAN INDIA

Transitioning to a low-carbon housing sector in India requires a comprehensive analysis of the impact of material choices on both embodied and operational carbon within different informal and formal housing types.

India has pledged to reduce its emissions intensity relative to GDP to 33-35 per cent below 2005 levels by 2030 (Rahiman et al. 2019). While various goals have been defined for the power sector, other sectors such as the built environment lack detailed plans to reduce emissions. Against the background of burgeoning demand, the residential sector is emerging as a promising place to target emissions reductions with a transition towards sustainable material choices. The urban population is expected to rise to well above 55 per cent in 2030, and India’s urban centres are on a path to becoming significantly more energy intensive. With plans to build “smart” cities in the future to accommodate this growing urban population, coordinated material and energy practices are urgently needed (Rahiman et al. 2019). Although the construction phase currently accounts for 20-30 per cent of the total life cycle energy of a typical building in India, it is arguably the most influential phase, as decisions made in the early stages of a project impact all the subsequent phases and their energy demand.

In the global south, most countries have high cooling needs, and India is one of the most vulnerable to global warming, with the transition from traditional to modern materials exacerbating this vulnerability (Mastrucci et al. 2019).

Ecopavilion 2019, Diamniadio. Ministry of the Environment of Senegal by CraTerre, Elementerre and Worofila



Photo credit: Worofila.

Photo credit: Ayer, Aishwarya V. 2022



The impact of material choices on both embodied carbon and cooling requirements is a key ingredient to reduce the carbon footprint of India. It is necessary to assess the range of vernacular and emerging technical materials, while considering the range of housing typologies. Use-phase energy has been well researched with specific focus on cooling (Rathore et al. 2022). However, these studies primarily focus on urban formal housing, with little consideration of other typologies that rely on the passive performance of materials and layouts. Currently, operational cooling forms only a small part (~3–10 per cent) of the total residential energy consumption in India (Chunekar et al. 2016) due to the low penetration rates of air conditioning in India. However, the market pressures for mechanical cooling devices is projected to grow dramatically (IEA 2017), stressing the need for good material choices and design (Mastrucci et al. 2019). Thus far, efforts have been hampered by a lack of data (Verma et al. 2012). A mapping of the building stock will help to create future projections for energy expenditures and understand the future flow of materials into the residential building sector.

7.10. CASE STUDY: SHIFT NEIGHBOURHOOD-LEVEL LIFE-CYCLE CARBON FOOTPRINT IN FINLAND

Future development of low-carbon buildings and cities will require data visualization tools that give decision makers an “at-a-glance” holistic understanding of all the environmental impacts of materials and systems choices for both new construction and renovation of buildings and infrastructure.

While building-level carbon footprint assessments are becoming increasingly available in many parts of the EU, neighbourhood-level assessments are still rare – even though this is a critical scale for municipalities and countries to plan and implement the low-carbon cities of the future. A Finnish project has created and continues to develop a tool that aims to bring neighbourhood-level assessments to the mainstream. This could substantially bolster efforts to lay out low-carbon infrastructure that optimizes resource efficiency (avoid), alternative materials (shift) and the use of conventional materials (improve) across the life cycle.

Although the quantity, quality and accessibility of data relating to the life cycle of the built environment process is extremely variable across regions, Finland will require mandatory life-cycle carbon footprint assessments for new buildings and major renovations by 2025. The city of Helsinki is testing new tools to assess the life-cycle impacts of urban development. These will include emissions related to site preparation (e.g. earth moving and soil stabilization), infrastructure construction and maintenance, traffic, and soil and vegetation carbon sinks. This will enable information which is often completely ignored to be included in routine calculations of a holistic carbon footprint assessment.

This development tackles the main barriers for assessing neighbourhood-level plans, which include a lack of coordination, expertise and time. The neighbourhood-level carbon footprint assessment tool in use in Helsinki is currently being developed into an assessment method suitable for all parts of Finland and can eventually be adopted around the world in different climates.

8. ROADMAPS FOR BUILDINGS AND CONSTRUCTION

A growing number of countries and regions are using the GlobalABC building decarbonization roadmaps process or categories for charting the path to a sustainable buildings and construction sector. At least eight roadmaps have already been published and there are plans for many more. These include the GlobalABC and IEA's jointly published Global, Asia, Africa and Latin America roadmaps, along with published roadmaps for the ASEAN region and emerging roadmaps for more than 30 countries.



8.1. GLOBALABC SUPPORT AND COORDINATION ON ROADMAPS

The GlobalABC provides support through the [Roadmap Coordination Hub](#), which is a group of country and non-state stakeholders working together to build synergies between initiatives and extend the lifespan of the roadmaps well beyond the projects through local engagement and implementation. Through expertise sharing and the pooling of data, these organizations are working together to lay the foundations for 2050 sectoral visions and to bridge roadmaps to higher-level political processes like NDCs and the [Marrakech Partnership for Global Climate Action Pathways](#).

8.2. ASEAN ROADMAP FOR ENERGY-EFFICIENT BUILDINGS AND CONSTRUCTION

In the Association of Southeast Asian Nations (ASEAN), buildings account for close to a quarter of total final energy consumption and energy-related CO₂ emissions. With continued economic development, urbanization and population growth across the region, IEA analysis shows that both final energy consumption and CO₂ emissions in buildings will continue to grow without ambitious policy actions. Improving the energy efficiency of building envelopes and systems, increasing renewable energy utilization, phasing out the use of traditional biomass and switching to clean cooking and electricity, while enhancing energy access for vulnerable households across the region, can result in more than a 60 per cent reduction in CO₂ emissions from buildings by 2040 in relation to 2020, and provide many other benefits to households, society and governments.

The Roadmap for Energy-Efficient Buildings and Construction in the Association of Southeast Asian Nations (ASEAN) (IEA 2022e) focuses on the policy tools available for ASEAN Member States to drive energy efficiency improvements in the buildings sector to help meet growing needs for residential and non-residential floor space and energy services, while limiting the growth in energy demand and related emissions. It identifies key energy-efficient and low-carbon actions and activities that governments could consider for implementation by 2025, 2030 and beyond, moving towards net zero-carbon buildings.

8.3. DANISH NATIONAL STRATEGY FOR SUSTAINABLE CONSTRUCTION

In 2019 the Danish government and most of the political parties decided an ambitious plan to reduce CO₂ emissions by 70 per cent by 2030, equal to 28.7 megatonnes of CO₂/year. At the same time the government asked 14 sectors to set up climate partnerships to identify how their sector could contribute to the reductions. The climate partnership for the buildings and constructions sector identified more than 60 areas with potential reductions and suggested solutions that could reduce CO₂ emissions by 5.6 megatonnes per year in 2030 or close to 20 per cent of the overall ambition in Denmark (Denmark, Ministry of Interior and Housing 2021).

A key element of the strategy is to use life-cycle assessments requirement with a view to introducing these into the national building code as a requirement for all buildings by 1 January 2023.

In addition, the strategy introduces a threshold of 12 kg CO₂/m²/year for new buildings of more than 1,000 m² by 1 January 2023 – effectively setting a maximum limit for CO₂ emissions from new buildings. Such requirements help to reduce the climate footprint of construction and support the industry and developers in their aim to build more sustainably and promote climate-friendly construction solutions. The industry supports the implementation.

The level for maximum CO₂ emissions in the building regulation will decrease gradually. In 2025 a threshold of 10.5 kg CO₂/m²/year will be introduced for all new construction, no matter the size. The level will be followed by further strengthening in 2027 and 2029, bringing the level down to 7 kg CO₂/m²/year by 2029.

The phasing in of life-cycle assessment requirements and thresholds is expected to motivate the construction sector to reduce CO₂ emissions from construction dramatically and to create huge innovation during the decade.

8.4. COLOMBIA NET ZERO CARBON BUILDING ROADMAP

Colombia's National Roadmap for Net Zero Carbon Building (Colombia, Ministry of Environment and Sustainable Development et al. 2022) establishes a reference framework by the national government, through the Ministry of Environment and Sustainable Development, to support the buildings sector's contribution to achieving the target of carbon neutrality by 2050. The roadmap establishes short-, medium- and long-term actions across the construction sector, including urban planning, materials, transport and

distribution, design and labelling, and their inclusion in the circular economy. The roadmap complements Colombia's NDC, which sets a goal of 51 per cent reduction in greenhouse gas emissions by 2030 and which includes different measures aimed at sustainable construction.

The roadmap sets out a gradual implementation for new and existing buildings. By 2030, new buildings and large building renovations are to achieve a 40 per cent reduction in operational carbon and 30 per cent reduction in embedded carbon. By 2040, 80 per cent of new buildings and major renovations in urban areas are to be net zero operational carbon and achieve a 70 per cent reduction in embedded carbon. And by 2050 100 per cent of new buildings and major renovations are to be net zero at the operational and embedded carbon level. For existing buildings, the roadmap sets out targets for a minimum reduction of 30 per cent of operational carbon by 2030, 70 per cent by 2040 and 100 per cent by 2050.

The roadmap defines a net zero carbon building as a building that is energy efficient and includes renewable energy, and which takes into account the interaction of the building with the environment and thus generates well-being for people. It must include the parameters of its life cycle and its materials to ensure low impacts in its construction as well as its operation. A monitoring process is incorporated to evaluate how the emissions reduction is being achieved.

The roadmap also plans to raise awareness, education and capacity for its implementation, not only in the construction sector but throughout all the components and institutions in the value chain.

8.5. ROADMAP FOR AN ENERGY EFFICIENT, LOW-CARBON BUILDINGS AND CONSTRUCTION SECTOR IN INDONESIA

The [Roadmap for an Energy Efficient, Low-Carbon Buildings and Construction Sector in Indonesia](#) (Svendsen 2022) was developed by the Danish Energy Agency in close cooperation with the Indonesian Ministry of Energy and Mineral Resources and the report authors from both Denmark and Indonesia.

The Indonesia buildings roadmap "provides orientation and guidance to public and private key stakeholders in the Indonesian buildings and construction sector

as well as non-governmental organizations and civil society to lead the transition toward strategic implementation of low greenhouse gas emission, energy efficient and environmentally friendly buildings and construction in Indonesia."

The roadmap cover eight themes: planning, new buildings, building retrofits, building operations, building systems, materials, building resilience and renewable energy. It sets targets for achieving net zero energy by 2050, and by that date for all new buildings to be constructed to a nearly zero-energy building standard and existing buildings to achieve a nearly zero-energy building operational standard.

8.6. EU POLICY WHOLE LIFE CARBON ROADMAP FOR BUILDINGS

In May 2022, the World Green Building Council launched the EU Policy Whole Life Carbon Roadmap for buildings (Nugent et al. 2022). The roadmap aims to catalyse transformation in the buildings sector in the EU in three areas: well-being and health, climate change, and resources and circularity. It sets out a timeline of recommendations, with the greatest number of actions to occur before 2030. Four main thematic areas are focused on: building regulations, waste and circularity, sustainable procurement, and sustainable finance. Further actions are given in these thematic areas up to 2050.

The timeline seeks to establish a clear vision of how the EU can achieve net zero whole-life carbon by 2050. Between 2022 and 2024, among other actions, it recommends the harmonization and updating of EU energy performance certificates to improve their reliability and make use of measured building performance. It also suggests that EU Member States develop open-source databases which cover measured and modelled energy performance and greenhouse gas emissions of their building stock (Nugent et al. 2022).

8.7. EMERGING ROADMAP ACTIVITIES

An emerging set of countries and regions are developing roadmaps, highlighting the importance of national governments and regional cooperation and partnerships in efforts to decarbonize the building sector.

8.7.1. UN AGENCIES WORKING TOGETHER ON BUILDINGS AND CONSTRUCTION ROADMAPS

UN-Habitat, UNEP and United Nations Office for Project Services (UNOPS) joined forces for the development of national buildings and construction roadmaps starting with Burkina Faso and Sri Lanka in collaboration with the Burkina Faso Ministry of Urban Planning, Land Affairs and Housing and the Sri Lanka Ministry of Urban Development and Housing. These roadmaps are being developed under the programme “SDG 12 Resource Efficient Housing” of the One Planet Multi-partner Trust Fund on SDG 12, and will be finalized by the end of 2022. In 2023, the three agencies will continue their collaboration for the development of additional national buildings and construction roadmaps for Bangladesh, Senegal and Ghana in the framework of the UNEP-led, BMZ-funded project “Transforming the Built Environment through Sustainable Materials”, as well as a state-level roadmap in India in collaboration with Development Alternatives. As part of these efforts, the three agencies are working on a process guide and tool to support the elaboration of buildings and construction roadmaps. This builds on the UNOPS Capacity Assessment Tool for Infrastructure (CAT-I) and the learnings from experience to date in cascading the GlobalABC roadmaps to national and subnational levels.

8.7.2. BUILDINGS ROADMAPS FOR 22 COUNTRIES AND TERRITORIES IN THE ARAB LEAGUE

The UAE Ministry of Energy and Infrastructure, in coordination with Guidehouse and RCREEE, is leading the development of building decarbonization roadmaps for the 22 countries and territories in the Arab League (Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Gaza and West Bank, Oman, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, UAE, Yemen.)

Based on an assessment of their current situation in terms of general socio-economic indicators, high-level sustainability indicators and efficient buildings indicators, these 22 countries and territories have been classified into three groups (early, medium and advanced). A sub-roadmap is being developed for each group, allowing each country/territory to build its own national roadmap. These roadmaps, which follow the GlobalABC roadmap model, will be launched at COP27.

8.7.3. NDC ROADMAP FOR LOW-CARBON, CLIMATE-RESILIENT BUILDINGS AND CONSTRUCTION 2050 IN CAMBODIA

The construction industry in Cambodia has experienced strong growth and its building stock continues to increase in all market segments. Buildings are responsible for 45 per cent of the country's primary energy demand and are a major source of greenhouse gas emissions. The NDC Roadmap aims to help the government of Cambodia and its stakeholders to transform the industry towards zero-emission, efficient and resilient buildings and construction in order to support the country's commitments under the Paris Agreement.

The NDC Roadmap suggests a number of actions in key areas, with targets for 2030, 2040 and 2050 based on a comprehensive sector analysis and multi-stakeholder consultations conducted in early 2021.

8.7.4. CHINA'S GREATER BAY AREA (GUANGDONG–HONG KONG–MACAU)

The German Energy Agency (dena), together with the China Academy of Building Research and the ICLEI East Asia Secretariat, is developing a Regional Roadmap for Buildings and Construction for China's Guangdong – Hong Kong – Macau Greater Bay Area, in support of the region's decarbonization efforts. Despite accounting for less than 1 per cent of China's overall territory, this vibrant megalopolis generates nearly 12 per cent of the country's GDP. The roadmap strategy includes regional workshops and the launch of a living document in 2023.

8.7.5. NDC ROADMAP FOR A LOW-CARBON, CLIMATE-RESILIENT BUILDING SECTOR IN VIET NAM

The NDC Roadmap for a low-carbon, climate-resilient buildings and construction sector in Viet Nam was developed based on the methodology of the Regional Roadmaps for Buildings and Construction 2020–2050 for Asia and the Pacific by the GlobalABC and IEA in 2018. Developed by the Programme for Energy Efficiency in Buildings in cooperation with the Ministry of Construction, this NDC Roadmap shows the pathway for the short-, medium- and long-term contribution of the buildings and construction sector to the achievement of the NDC targets of Viet Nam and beyond. It provides a tool for formulating sector/subsector transition policies toward sustainable development. It identifies common goals, targets and timelines for key actions across eight activities, and provides orientation and guidance to stakeholders in the buildings and construction sector and authorities in urban management, non-residential and residential building subsectors.

9. KEY RECOMMENDATIONS FOR POLICY AND DECISION MAKERS

The buildings sector will continue to grow to meet citizens' needs for safe housing and workplaces, but its growth must be in alignment with the Paris Agreement. Policymakers on all governance levels must therefore implement effective policy instruments and tools which deliver the needed emission reductions while achieving the objectives of a sustainable and resilient buildings and construction sector. Decisionmakers in industry and the finance sector must embrace the transformation of their sector and invest in innovation, products and services which accelerate decarbonisation. Civil society participation will be crucial to support the necessary change.





The impact of the global COVID-19 pandemic on the buildings and construction sector saw energy use reduce as workplaces were shuttered, homeworking increased, and vulnerable households fell into fuel poverty. This precipitated the largest emissions drop experienced in the buildings sector in the last decade. But this drop in emissions was short-lived as economies reopened and a rebound in the use of buildings occurred alongside an increased demand for energy among workplaces and households.

During this period, more countries have placed buildings within their commitments for action to reduce emissions. This is a welcome update given that the use of buildings is responsible for around 27 per cent of global building operations energy-related emissions. During this period investments in energy efficiency in buildings increased by around 16 per cent, the largest increase in investment in the last 10 years.

What is clear from these past two years is that the structural changes needed in the buildings and construction sector are not yet happening. While the increase in investment in energy efficiency in existing buildings and a greater number of new buildings being

constructed to higher energy performance standards are welcome trends, the impact on energy use and energy intensity is not yet showing, nor is there any sign of emissions from the buildings sector being decoupled from energy use or construction activities. The war in Ukraine and the ensuing energy crisis being felt in some regions underline the urgency of such a structural change.

To achieve the emissions targets needed for all buildings to be aligned to the Paris Agreement goal of the global economy being net zero CO₂ emissions by 2050, emissions from the buildings sector will need to halve by 2030 (from 10 GtCO₂ to 5 GtCO₂). This will require an annual emission reduction rate of -8 per cent per year, equivalent to the impact of the pandemic each year.

Policymakers and decision makers must urgently put in place concrete near-term actions that can begin to deliver the needed emissions reductions, while achieving the objectives of a sustainable and resilient buildings and construction sector that will continue to grow and meets citizens' need for safe, healthy and affordable housing and workplaces.

The following recommendations are designed to respond to these challenges:

1. Coalitions of national stakeholders should be developed to **set targets and strategy towards a zero-emission, efficient and resilient buildings and construction sector** through building decarbonization and resilience roadmaps and in line with the [Marrakech Partnership for Global Climate Action Human Settlements Pathway](#).
2. National and sub-national governments must put in place mandatory building energy codes and **set out a pathway for their new building codes and standards to be performance based and to achieve zero carbon across a building's life cycle as quickly as possible**. For jurisdictions without building energy codes, these need to be formulated and adopted. Codes should consider the Guidelines for Energy Efficiency Standards in Buildings ([UNECE 2020](#)).
3. Governments and non-state actors must **increase their investment in energy efficiency**. This investment needs to target all businesses and households. Governments will need to use financial and non-financial incentives to encourage investment and provide support for vulnerable households.
4. The construction and real estate industries must **develop and implement zero-carbon strategies for new and existing buildings** in all jurisdictions, in order to effectively support government policies.
5. The building materials and construction industries must commit to **reducing their CO₂ emissions throughout their value chain in line with the Paris Agreement**, supporting government policies towards a carbon neutral building stock.
6. Increased funding is urgently required for public-private research partnerships to **accelerate the development, demonstration and commercialization of innovations to reduce embodied carbon** in building materials.
7. For governments aiming to achieve a net-zero-carbon built environment, regulations and assessment of emissions need to **take a life cycle approach** that considers both materials' embodied carbon emissions and operational emissions.
8. Governments, especially cities, need to **implement policies that promote the shift to circular economies** that replace linear, non-renewable, toxic material processes with sustainable renewable materials that can sequester carbon and be managed sustainably over their life cycles. In parallel, for materials that cannot (yet) be replaced, their use and their carbon footprint should be reduced as much as possible.
9. Fast-growing countries and economies, including in Africa and Southeast Asia, need investment to **build capacity, resources and supply chains** to promote energy-efficient designs and low-carbon and sustainable construction.

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ANNEX: GLOBAL BUILDINGS CLIMATE TRACKER

The objective of the Global Buildings Climate Tracker (GBCT) is to show the worldwide decarbonization progress of buildings. The tracker is designed as a composite indicator based on the OECD approach (OECD and Joint Research Commission 2008) and is therefore referred to as a “decarbonization index” for buildings and construction. The GBCT’s development is based on extensive data research using global data sets that are critically evaluated to ensure their quality (for details, see BPIE 2020a). The identified data sources are checked for measurability, source of data, geographic coverage and, since 2021, sensitivity to change and data continuity.

The decarbonization index is composed of seven indicators:

1. Global buildings sector energy-related emissions (GtCO₂/year)
2. Global buildings sector energy intensity (kWh/m²/year)
3. Renewable energy share in final energy in buildings, globally (per cent)
4. Building codes and regulations (cumulative growth)
5. Incremental energy efficiency investments in buildings, globally (billion dollars/year)
6. NDCs with buildings sector action (number of countries)
7. Green building certifications (cumulative growth).

These indicators measure the “impacts” and “actions” of decarbonization efforts. Decarbonization impact is defined as an outcome of the efforts that influence CO₂ emissions, final energy demand or the share of renewable energy sources used in buildings. Decarbonization action is defined as those efforts that aim to contribute to or enable the reduction of CO₂ emissions such as policy and industry actions.

To form the decarbonization index, all indicators are aggregated. A weighting for each indicator is factored into the index composition and represents the relative importance of each indicator in the index. The indicators are also normalized using the definition of the base-

year (2015) values and the target (2050) values that represent full decarbonization. For a full description and discussion of the GBCT approach and methods, see the separate methodology paper in BPIE (2020a).

Updated indicators in the decarbonization index in the 2022 Global Status Report for Buildings and Construction:

GREEN BUILDING CERTIFICATION

In addition to certification schemes previously used in the indicator composition, several new ones have been added to improve global representation.

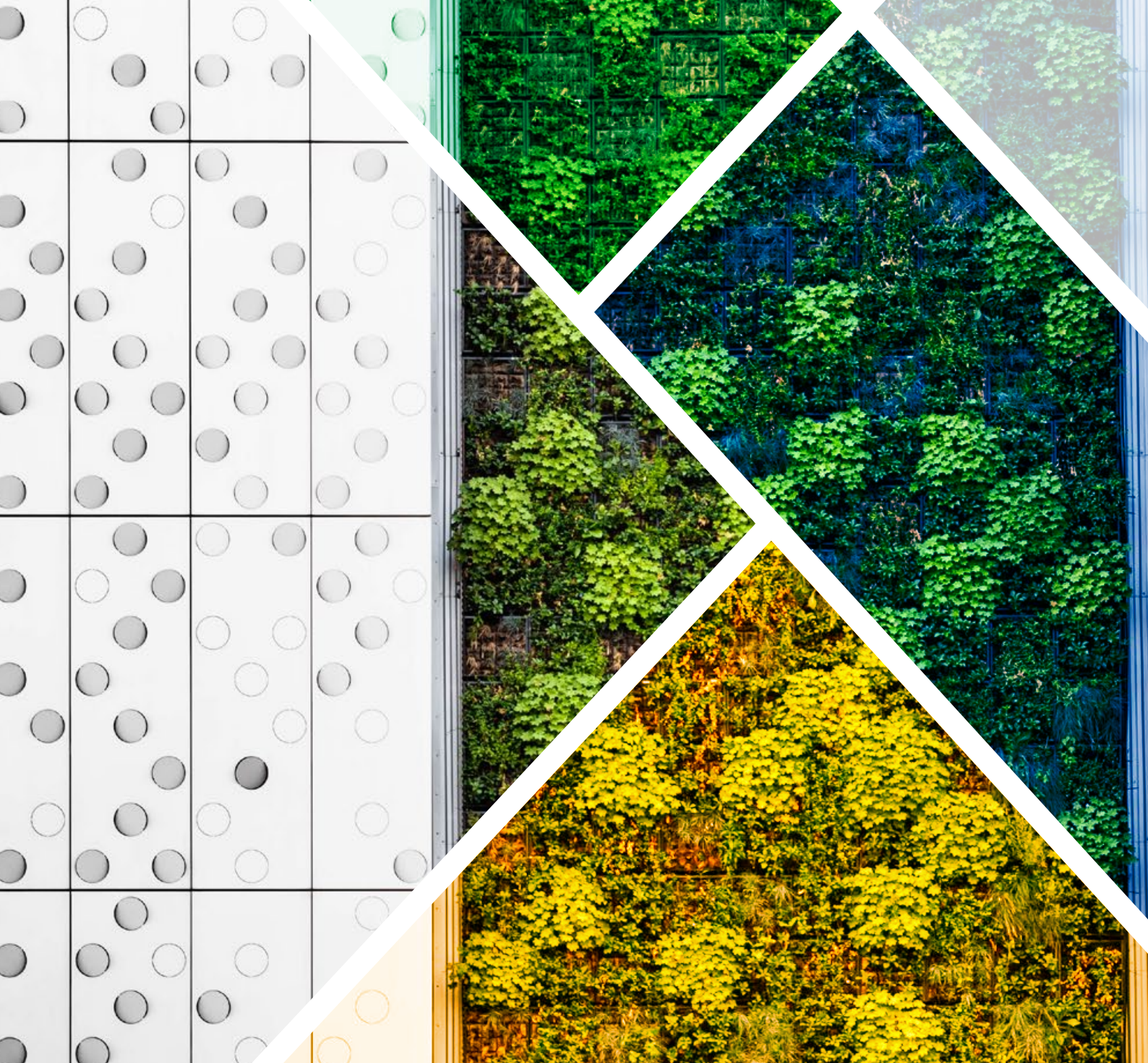
The rising trend of green building certification in the buildings sector would be better captured if data were available and transparent from most of the largest schemes worldwide. However, this is not the case. Despite individual research, the annual number of new certifications was not available for a number of schemes.

The indicator currently includes a total of 14 data sets. These include the six global frontrunners – [LEED](#), [BREEAM](#), [DGNB](#), [Passive House](#), [WELL](#) and [EDGE](#) – as well as six relatively developed national schemes: [MINERGIE](#) (Switzerland), [IGBC](#) (India), [Miljöbyggnad](#) (Sweden), [BEAM Plus](#) (Hong Kong), [GREEN STAR](#) (Australia) and [CASBEE](#) (Japan). They also include two more locally adopted schemes: [SGBF](#) (Saudi Arabia) and [GRIHA](#) (India).

To account for this diversity, the indicator was calculated considering both the schemes’ geographic coverage, and their number of certifications.

BUILDING CODES AND REGULATIONS

This year’s version of the indicator “Building energy codes and standards” considers only the number of countries with building energy codes and standards in place. This count provides an approximate assessment of the buildings sector efforts towards decarbonization. Last year an additional element, “Quality control before, after and during construction”, was added to track regulatory measures in place in a country that ensure quality management in construction. However, as announced last year, the data on this element was discontinued by its source indefinitely, so it has been excluded from the indicator calculations this year.



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