2021 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION

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

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2021 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION

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FOREWORD

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As highlighted by the Intergovernmental Panel on Climate Change (IPCC) last month, humanity's continued dependence on fossil fuels is warming the world. The consequences – such as droughts, wildfires and floods – are already affecting everyone and will only intensify without urgent action to reduce emissions. The buildings and construction sector is ripe for such action, as the Buildings Global Status Report shows.

According to the report, the sector accounted for 36 per cent of global final energy consumption and 37 per cent of energy related CO2 emissions. While we saw a drop in emissions, largely due to the COVID-19 crisis, the worry is that construction demand will push emissions higher. In Asia and Africa, building stock is expected to double by 2050. Global material use is expected to more than double by 2060, with a third of this rise attributable to materials used in the building and construction sector.

There have been improvements. Since 2015, coverage of buildings in Nationally Determined Contributions (NDCs) has increased from 90 to 136 countries. Today, 80 countries have developed building codes, an increase from 62 in 2015

Investment in building energy efficiency has increased by 40 per cent since 2015. This year alone, and despite the COVID-19 pandemic, we see that global investment in energy efficiency in the buildings sector rose by over 11% to ca. USD 184 billion in 2020. The fact that for the first time since 2015, the annual rate of growth in energy efficiency investment has exceeded 3% is a signal of hope.

Yet, overall, actions are too few to drive the kind of structural transformation we need for our homes and workspaces. Two thirds of countries where we see most of the growth in building stock still lack mandatory buildings codes. Most of the energy efficiency spending increase came from a small number of European countries. And there is a lack of ambitious decarbonization targets in NDCs.

We can do a lot more, particularly in areas such as space cooling, which is expected to double its energy consumption by 2040. Building and urban design solutions such as cool roofs, self-shaded building designs or urban ventilation corridors can reduce cooling demand.. We need to build differently, and use local, bio-based and recycled materials to create local jobs. We need to move towards circularity, where we have seen companies making ambitious commitments.

The next five years will be about widely adopting transformational approaches. It will be about collaborating through platforms such as the Global Alliance for Buildings and Construction. It will be about putting in place incentives and regulations that can take those solutions to the scale needed. With all stakeholders fully engaged we can create a built environment that is not only zero-carbon and resilient but provides inspiring places to live and work.

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ABBREVIATIONS

°C	degrees Celsius
ASEAN	Association of Southeast Asian Nations
BPIE	Buildings Performance Institute Europe
CO_2	carbon dioxide
EDGE	Excellence in Design for Greater Efficiencies
EJ	exajoule
EPD	environmental product declaration
EU	European Union
GBCT	Global Buildings Climate Tracker
GDP	gross domestic product
GlobalABC	Global Alliance for Buildings and Construction
Gt	gigaton
HFC	hydrofluorocarbon
IEA	International Energy Agency
ICC	International Code Council
IECC	International Energy Conservation Code
IFC	International Finance Corporation
IgCC	International Green Construction Code
kWh	kilowatt-hour
LEED	Leadership in Energy and Environmental Design
m^2	square metres
MEPS	minimum energy performance standard
NCAP	National Cooling Action Plan
NDC	Nationally Determined Contribution
NRRP	National Recovery and Resilience Plan
OECD	Organisation for Economic Co-operation and Development
PEEB	Programme for Energy Efficiency in Buildings
PV	photovoltaic
RRF	Recovery and Resilience Facility
SBT	Science-Based Target
SDG	Sustainable Development Goal
t	ton
TWh	terawatt-hour
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
W	watt
WBCSD	World Business Council for Sustainable Development

TRENDS OF 2020

FIVE YEARS IN REVIEW

Since the signing of the Paris Agreement in 2015, CO_2 emissions from the buildings and construction sector have peaked in recent years and subsequently fallen to 2007 levels in 2020. This current decline is due mostly to the COVID-19 pandemic, whereas transformative, long-term progress in sector decarbonizing remains limited. However, since 2015, some emission reduction in the power sector is visible and more countries have adopted policies and codes that may have a future impact on the emissions and energy efficiency of buildings.

In 2015, the construction and operation of buildings was responsible for 38 per cent (13.1 gigatons) of global energy-related carbon dioxide (CO_2) emissions. By 2020, CO_2 emissions in the sector had fallen an estimated 10 per cent to 11.7 gigatons, a level not seen since 2007. This decline was driven largely by reduced energy demand due to the COVID-19 pandemic, but also by continued efforts to decarbonize the power sector. In 2015, energy use for the construction and operation of buildings totalled 144 exajoules (EJ), or 38 per cent of global demand. By 2020, energy consumption was 149 EJ or 36 per cent of global demand, slowed from a peak of 150 EJ in 2019. This reduction reflects the impact of pandemic related lockdowns and the precarious ability of many households and businesses to maintain and afford energy access.

In 2015, 90 countries included actions for addressing buildings-related emissions or improving energy efficiency in their Nationally Determined Contributions (NDCs) under the Paris Agreement. In 2020, 136 countries mentioned building emission reductions in their NDCs, although these vary in their ambition. Additionally, around 62 countries had adopted building energy codes as of 2015, while today more than 80 countries have developed such codes, alongside similar efforts by local governments and cities.

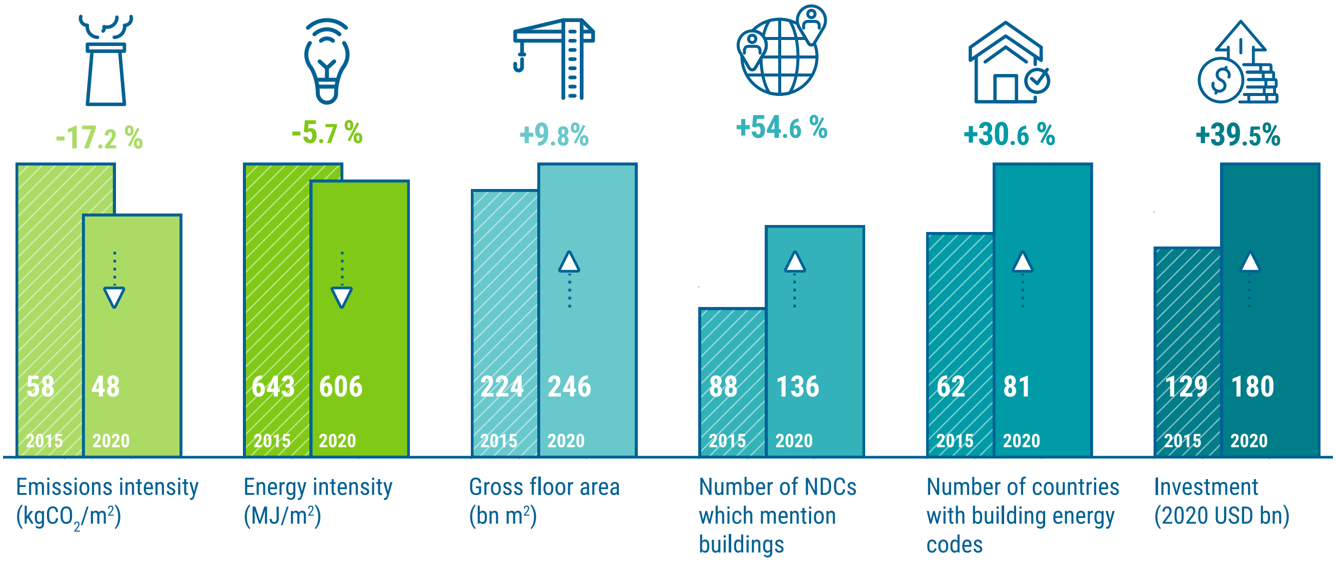
Investment in the energy efficiency of buildings continues to climb and reached more than US$180 billion in 2020, up from $129 billion (in 2020 dollars) in 2015. However, most of this increase came from a small number of European countries. Without broader investment, this level is unlikely to be sufficient to tackle efficiency improvements among the existing global building stock.

Looking ahead, the challenges to reaching a net zero, energy-efficient and resilient buildings and construction sector are considerable, with 82 per cent of the population that is to be added by 2030 living in countries without any building energy codes or only voluntary codes. Yet more than 65 per cent will be living in countries that have NDCs that mention building energy efficiency and/or building codes to improve energy performance, which offers a positive sign.

In addition, the recent reduction in energy-related emissions from buildings and construction is likely to be short-lived and is expected to rebound in 2021 as economies emerge from the pandemic. Therefore, immediately and significantly reducing greenhouse gas emissions from the buildings sector, on the global level, is critical for reaching the Paris Agreement goals.

As a global tool for tracking progress, the *Global Status Report for Buildings and Construction* has continued to evolve over the past five years, bringing forward insights and pointing to information to help understand efforts that support the transition to a zero emission, energy-efficient and resilient buildings and construction sector.

Figure 1 - Key changes in buildings sector between 2015 and 2020



Sources: UNFCCC 2021; Buildings-GSR 2021; IEA 2021a. All rights reserved.

Notes: Emissions intensity is total buildings construction and operations emissions over total floor area, energy intensity is total building operational energy over

GLOBAL BUILDINGS CLIMATE TRACKER

The Global Buildings Climate Tracker appears to indicate that the buildings and construction sector is on track to achieve complete decarbonization by 2050. However, this is a temporary result, reflecting the unprecedented changes in building use during the pandemic. While there is some progress in energy investment and power decarbonization, a negative rebound in overall progress should be expected unless building sector decarbonization efforts significantly increase.

The Global Buildings Climate Tracker monitors the progress of the buildings and construction sector towards achieving the Paris Agreement. It is designed as an index comprising a range of indicators that are used to measure progress in NDCs, certifications, building codes, the share of renewable energy in buildings, finance for energy efficiency in buildings, CO_2 emissions and energy intensity. Although this year's index shows a significant improvement compared to the previous level, on a closer look, the 2021 results indicate that the sector is not on track to reach the Paris Agreement goals.

An analysis concluded that the observed progress in 2020 is largely the result of a decrease in economic activity due to the COVID-19 pandemic. Nevertheless, some indicators used in the composite index show improvement from 2019. Energy efficiency investment in buildings increased 11 per cent, while green building certification increased 13.9 per cent, and 10 more countries adopted building energy codes. However, if the effect of the pandemic is excluded, the decarbonization level in 2020 was only at 40 per cent of the 2050 reference path to achieve the Paris Agreement goals.

EFFECTS OF THE COVID-19 PANDEMIC

The COVID-19 pandemic had a major impact on the global buildings and construction sector in 2020. The effects were wide-ranging, from construction sites being left empty for months during lockdowns, to disruptions in the financing of construction, to how supply chains for materials reacted to sudden drops and surges in demand. In addition, the way buildings were occupied and used changed dramatically, from a status quo of workplace-based employment for most sectors, to a quick transition to remote working arrangements, the abandonment of commercial and retail premises, increased demand on warehousing and logistics and delivery, and the shutdown of public services and buildings.

In 2020, the average annual growth rate in buildings and construction across the world fell an estimated 4 per cent from 2019 levels. The main reason for this decline in market growth was the profound impact of the global pandemic on construction activities through the effects of lockdowns on the labour supply, limited demand for new buildings, the slowdown in public and private procurements, and disruptions in the supply chain.

ENERGY AND EMISSIONS

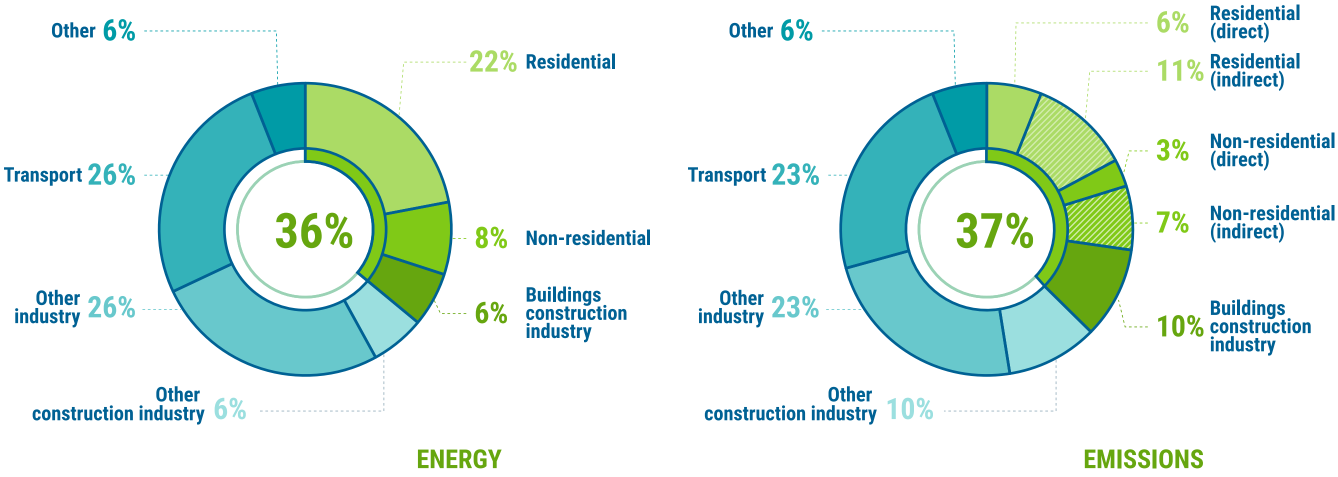
Global CO_2 emissions from buildings operations fell 10 per cent, although this decline appears to be temporary as emissions pick up again with increasing economic activity. Overall, buildings accounted for 36 per cent of global energy demand and 37 per cent of energy-related CO_2 emissions in 2020.

Global energy demand in buildings fell 1 per cent in 2020 to around 127 EJ, although the sector's share of overall energy demand stands at 36 per cent, compared to 35 per cent in 2019. This is due to a shift in sectoral demand. The decline in energy use for buildings and construction was largely driven by the change in the way existing buildings were used as a result of the pandemic, alongside the overall drop in production and demand for construction materials due to the economic slowdown. Energy demand shifted from the commercial and retail sectors to the residential sector, while many public buildings also closed for significant periods

CO_2 emissions from building operations fell 10 per cent in 2020 to around 8.7 gigatons, down from around 9.6 gigatons in 2019, as a result of the shift in building-related energy use patterns. With the historic drop in new buildings and construction, construction-related energy emissions - mostly from the manufacturing of buildings construction materials - fell from 3.6 gigatons of CO_2 in 2019 to 3.2 gigatons of CO_2 in 2020.

Despite these reductions, the global share of energy-related CO_2 emissions from buildings and construction compared to other sectors stands at 37 per cent in 2020, compared to 38 per cent in 2019, due to sectoral shifts (see figure 2).

Figure 2. Buildings and construction's share of global final energy and energy-related CO_2 emissions, 2020



Note: "Buildings construction industry" is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.

Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

To achieve the Paris Agreement, the global buildings and construction sector must almost completely decarbonize by 2050. Collectively, stakeholders in the sector must seize the opportunity that the COVID-19 economic recovery period offers to foster transformation for decarbonizing the sector. The sector must simultaneously meet a projected near-doubling of global demand for energy services in buildings and at least a doubling of floor space as developing economies continue to respond to the growing demand for building floor space, access to energy services and economic activities.

Building emissions will need to be reduced along their lifecycle through a triple strategy, namely a combination of reducing energy demand (behaviour change and energy efficiency), decarbonizing the power supply (e.g., electrification through renewable sources and increased use of other zero-carbon heating technologies) and addressing embodied carbon stored in building materials. Through the first two measures, it could be possible to nearly eliminate carbon emissions from building operations by 2050.

Additionally, emissions from materials and construction processes must be urgently addressed, to ensure that the buildings being built today are optimized for low-carbon solutions across the full life cycle. This involves maximizing the refurbishment of existing buildings, evaluating each design choice using a whole life-cycle approach and seeking to minimize upfront carbon impacts (e.g., lean construction, low-carbon materials and construction processes, etc.), as well as taking steps to avoid future embodied carbon during and at the end of life (e.g., maximize the potential for renovation, future adaptation, circularity, etc.).

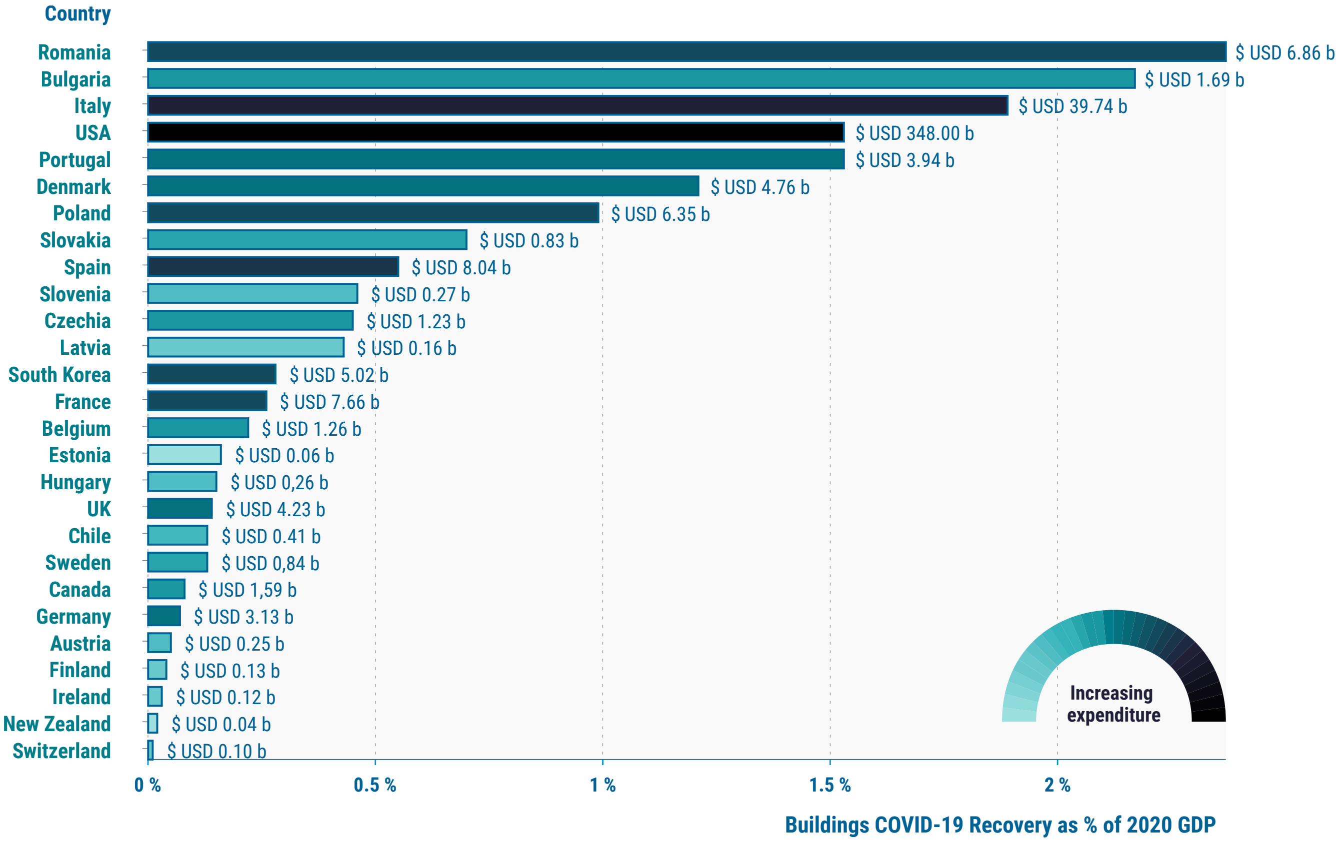
COVID-19 STIMULUS

The buildings and construction sector plays a critical role in pandemic recovery plans.

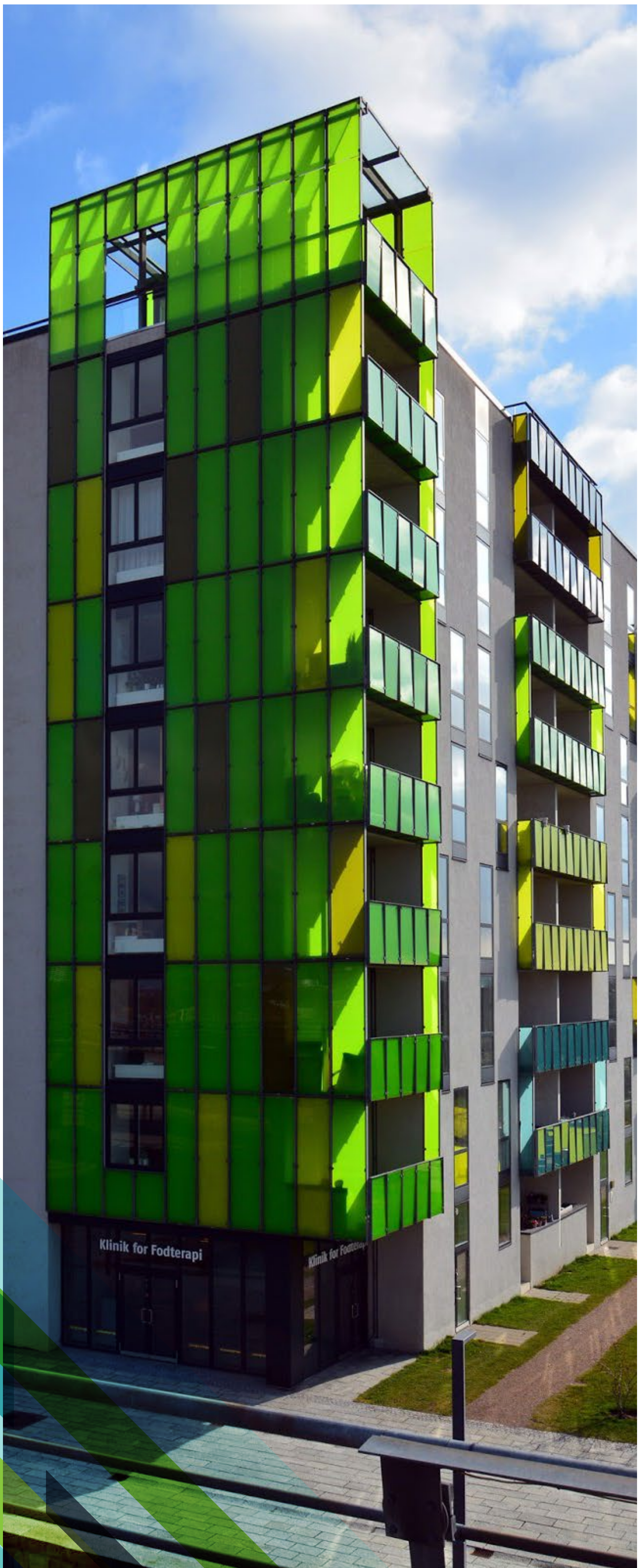
The COVID-19 pandemic has prompted a focusing of investment on supporting critical industries, such as buildings and construction, which represents around 4-7 per cent of most major economies' added value, according to the Organisation for Economic Co-operation and Development (OECD).

Many countries have provided investment to support the buildings and construction industry through economic stimulus packages and policies and as a reaction to the global pandemic (see figure 3). Yet the effect of support for decarbonizing the sector has been limited. A survey of major global economies has shown that many countries have dedicated pandemic funding to buildings, and that elements of these initiatives will have a beneficial impact on decarbonizing the sector; however, more effort is needed to direct stimulus and future economic investment towards aligning to the Paris Agreement.

Figure 3. COVID-19 recovery funding relating to buildings as per cent of 2020 GDP, with total buildings commitment figures in billion US dollars



Source: Latest available data based on Carbon Brief (Evans and Gabbatiss 2020) and Green Recovery Tracker (2021a), with data for Switzerland from the Global Recovery Observatory (Smith School of Enterprise and the Environment 2021). Figures are liable to change as new policies are announced and programmes are cancelled.



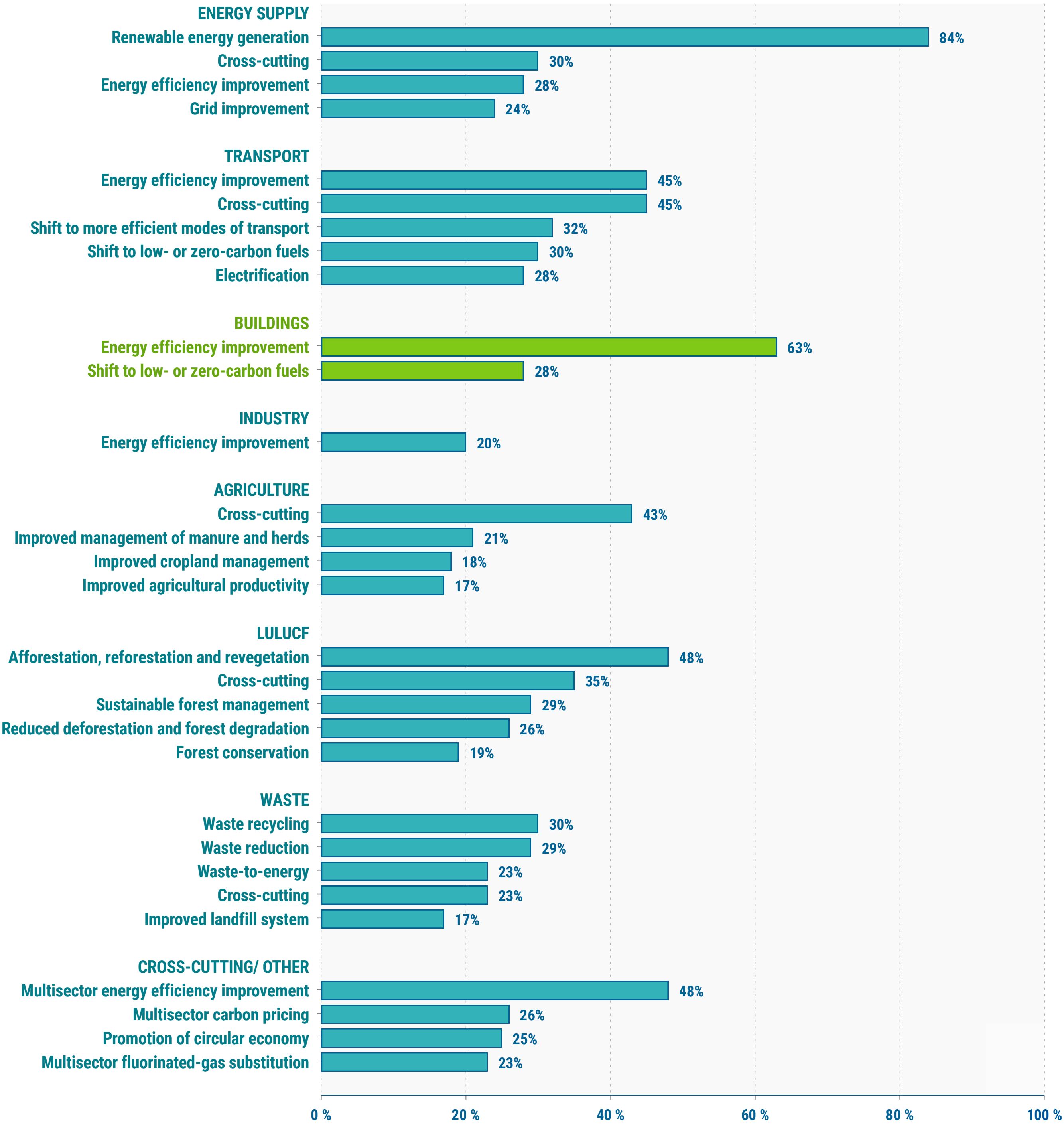
The construction sector is essential for an economic recovery from the COVID-19 crisis and offers a pathway forward to building a more sustainable future aligned with the goals of the Paris Agreement. It is therefore essential that we build back better, literally. The International Energy Agency's *Sustainable Recovery* report pointed out that stimulus programmes for the buildings and construction sector are a proven response to economic crises and will typically align to the needs that countries face for housing, economic activities and the renovation of existing buildings.

NATIONALLY DETERMINED CONTRIBUTIONS

Energy efficiency and energy codes in buildings are the second most frequently cited actions within all Nationally Determined Contributions.

As of October 2021, a total of 192 countries had submitted a first NDC and 11 had submitted a second NDC outlining their national contributions towards reducing emissions under the Paris Agreement. Across the NDCs communicated, improvement in the energy efficiency of buildings is the second most frequently referred to policy after the use of renewable energy in the power sector (see figure 4). While actions related to building energy efficiency codes are dominant, other actions targeted by countries include incentives and market instruments as well as resilience, renovation and retrofitting measures. For example, the NDCs from Colombia, the European Union, Lebanon, Maldives, Montenegro, Panama and Vanuatu mention efforts to either improve energy efficiency in buildings or reduce building-related emissions.

Figure 4. Share of Parties referring to the frequency indicated mitigation options in Nationally Determined Contributions



Note. If a Party communicated more than one measure for one of the frequently indicated mitigation options, it was counted as one Party communicating measures for that option.

Source: UNFCCC 2021

Despite these promising examples, when considering the needed triple strategy of reducing energy demand, decarbonizing the power supply, and addressing the footprint of construction materials, it is noticeable that building materials are under-addressed in countries' NDCs. Going forward, governments need to strengthen key areas such as sustainable urban development, new construction, rehabilitation and materials through the relevant implementing ministries and agencies, as was done in Viet Nam's NDC Roadmap for a low-carbon, climate-resilient buildings and construction sector.

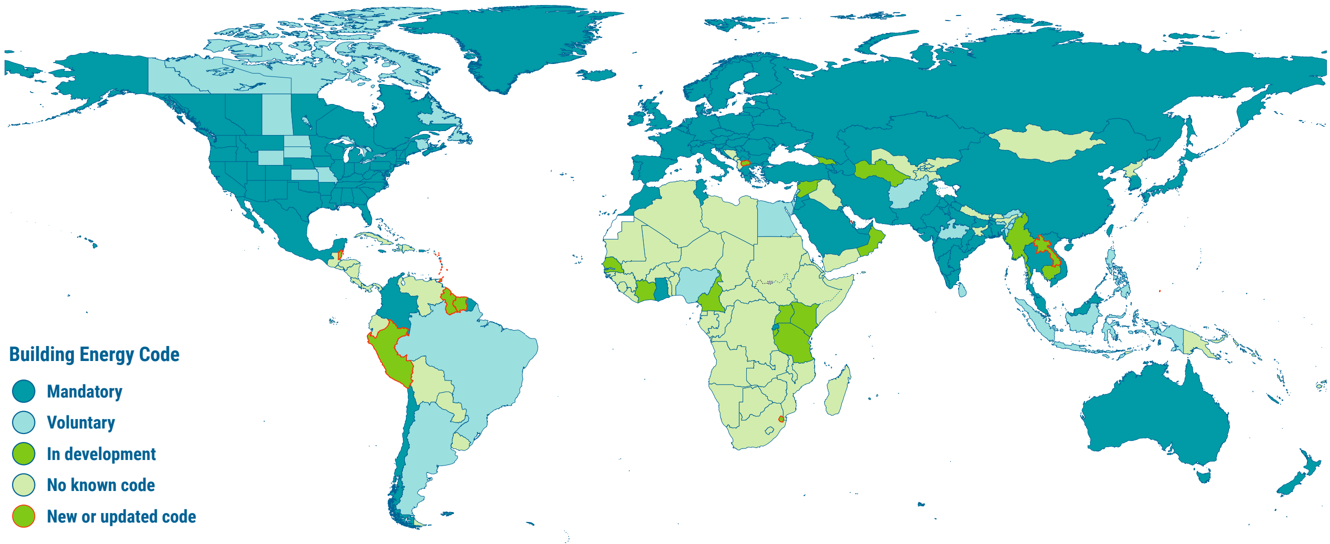
BUILDING CODES

Countries increasingly recognize that building energy codes are essential, yet their application remains low in Sub-Saharan Africa and in South and Central America.

Building energy codes are a key tool for governments to mandate the construction and maintenance of low-energy buildings. However, current coverage of building energy codes is far from universal, and where they are implemented, the codes are typically not aligned with meeting a net zero goal by 2050. To support countries in their NDCs and implementation of codes, the Global Alliance for Buildings and Construction (GlobalABC) has produced 10 key messages for the buildings and construction sector, covering ambitious energy codes, integrated design, energy efficiency financing and the carbon footprints of materials, among others (GlobalABC 2021a).

As of September 2021, 80 countries had mandatory or voluntary building energy codes on the national or sub-national level, out of which 43 countries had mandatory codes on the national level for both residential and non-residential buildings (see figure 5). Eighteen of the countries have adopted their codes since 2015. The current extent of national and sub-national building energy codes worldwide shows that Sub-Saharan Africa and South and Central America have the least coverage of mandatory codes.

Figure 5. Building energy codes by country/state



Note: 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. Recent updates are highlighted with a red border. Building energy codes relating to specific cities only are not shown.

Source: IEA 2021e. All rights reserved.

However, there are some signs of change, notably through the 2018 CARICOM Regional Energy Efficiency Building Code (CREEBC), which is currently being implemented throughout the Caribbean. Morocco and Tunisia have mandatory building codes that cover the entire buildings sector. Ghana and Nigeria have codes that cover part of the sector, while Egypt and South Africa have voluntary codes. Several additional countries are in the process of developing building code standards, including Botswana, Burundi, Cameroon, Côte d'Ivoire, Ghana, the Gambia, Kenya, Senegal, Tanzania and Uganda.

ENERGY EFFICIENCY INVESTMENT IN BUILDINGS

Global investment in the energy efficiency of buildings increased an unprecedented 11 per cent, dominated by EU investments. The flow of finance to this area continues to accelerate.

In the face of the COVID-19 pandemic, global investment in energy efficiency in the buildings sector rose an unprecedented 11.4 per cent in 2020 to around $184 billion, up from $165 billion in 2019, primarily through targeted government support in Europe (separate from any stimulus packages). For the first time since 2015, the annual rate of growth in energy efficiency investment in the sector has exceeded 3 per cent.

Despite the negative impact of the pandemic on the value of the global buildings and construction sector, which the IEA estimate declined by an estimated 2 per cent to $6 trillion in 2020, the increased investments in Europe supported the acceleration in global investments in buildings efficiency.

However, this relative increase occurred as most economies slowed and the buildings and construction sector faced unprecedented challenges in demand, delivery and supplies. The need to meet the global lack of housing alongside the need to decarbonize the sector means that more investment in improving the energy efficiency of existing buildings and in constructing buildings that are net zero emission is needed from all actors within the finance and investment sector.

BUILDINGS DATA MAPPING

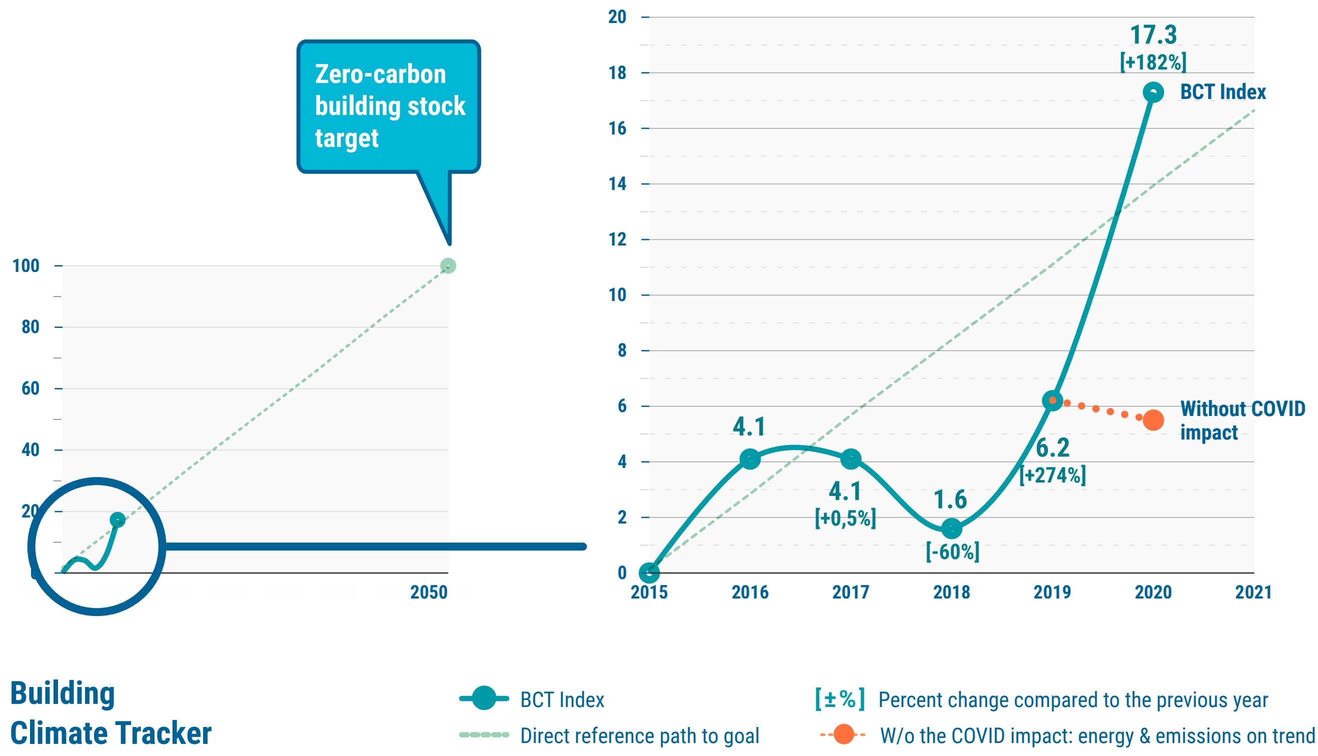
The availability of data describing the global building stock is limited and lacks sufficiently high resolution to present a clear picture of the trends and changes experienced across regions and parts of the sector.

A data mapping activity was undertaken through an in-depth search and review of databases and datasets that provided insights in describing the trends and drivers affecting energy performance and carbon performance within the building stock.

The findings of the review of over 40 key indicators and more than 300 sources of data shows that some very basic information on buildings at the country level is largely lacking or incomplete. Building stock characteristics at a national level are mostly unavailable, which makes it very challenging to track the changes in the composition and amount of building stock area constructed.

No global source of data yet exists to describe buildings in a comprehensive way, and the knock-on implications are that activities related to economic activities, energy and CO_2 emissions, and materials are all open to a degree of uncertainty.

Figure 6. Direct reference path to a zero-carbon building stock target in 2050 (left); zooming into the period between 2015 and 2020, comparing the observed Global Buildings Climate Tracker to the reference path (right)



Source: Adapted by the Buildings Performance Institute Europe

ADDRESSING THE CLIMATE IMPACT OF BUILDINGS AND CONSTRUCTION ACROSS THE WHOLE LIFE CYCLE

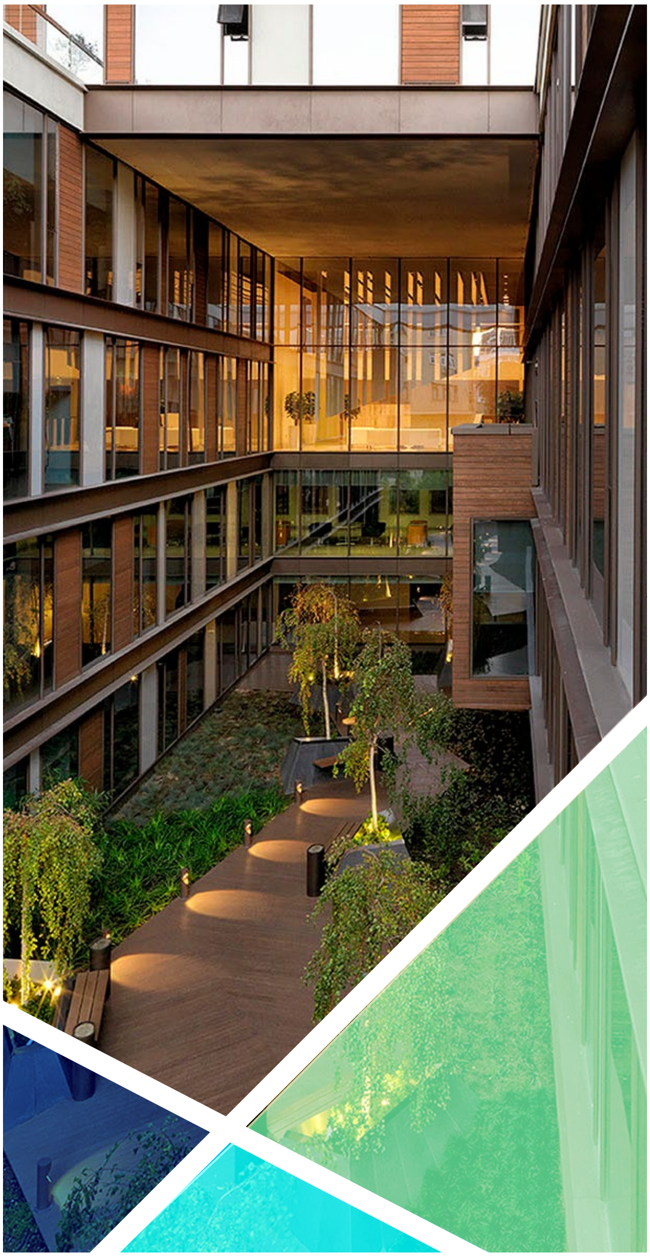
Some European countries have introduced policies to reduce whole-life carbon emissions from buildings and construction. Further national and EU-level initiatives can be expected in the near future.

A whole-life carbon perspective includes carbon emissions arising from the built environment during both the use of buildings (operational emissions) and their construction (embodied emissions). The *2021 Global Status Report for Buildings and Construction* puts a spotlight on recent developments in Europe and provides a high-level summary of the latest policy and data development. The importance of embodied emissions is set to increase dramatically as more buildings are constructed and renovated to higher energy efficiency standards.

Until recently, embodied carbon in buildings has been addressed at the EU level only with voluntary measures. Various provisions have been put in place across Europe by cities, regions and countries in the form of certification systems, regulations, standards and guidelines.

However, the European policy landscape is set to change. In the Renovation Wave strategy, the European Commission has adopted the principle of "life cycle thinking and circularity" to make buildings "less carbon-intensive over their full life cycle" (European Commission 2020a). The ongoing review of key policy and legislative files – such as the Energy Performance of Buildings Directive, the Energy Efficiency Directive and the Construction Products Regulation – is likely to start integrating whole-life carbon in the policy framework.

While a common EU policy on whole-life carbon is still in the making, Denmark, the Netherlands and France have introduced CO_2 limits for a large share of new buildings, while Finland and Sweden have plans to do so. Germany, as well as non-EU members the United Kingdom and Switzerland, have life-cycle assessment requirements for certain public buildings; Belgium is planning similar requirements.



OUTLOOK FOR 2021–2026

BUILDING BACK BETTER

In the effort to recover from the global pandemic and simultaneously address climate change through making substantial and lasting reductions in global emissions, the buildings and construction sector offers a route forward for all countries to build back better, literally.

Although 2020 was an exceptional year in terms of the pandemic's impact on reducing energy use and emissions related to buildings and construction, there is still much that needs to be achieved. In the coming five-year cycle, countries will need to make substantial improvements in the ambitions of their NDCs and must build on their commitments, for which buildings efficiency is a notable focus. Countries also need to address building materials in their NDCs in order to increase awareness and drive the availability and specification of low-carbon materials.

The ambitions for the sector should be extended by committing to and instituting policies that increase the scope and coverage of building energy codes for all building types, to increase the performance standards for building envelopes, heating, cooling, ventilation systems and appliances, and to ensure that decarbonization is integrated from the outset in urban planning. But even where buildings are not explicitly mentioned, countries need to harness the sector's transformative potential for achieving the energy transition, increasing the resilience of regions and unlocking green finance.

Building certifications play a key role, especially in regions where mandatory building energy codes are not (yet) in place. While uptake of green building certification increased 13.9 per cent in 2020 compared to 2019, countries should consider using certification systematically for all building types (residential and public) to drive improvements in design and delivery and to support unlocking investment for decarbonizing buildings.

While the recent increase in global investment on energy efficiency was welcome, it occurred among a handful of countries that already have well-established programmes and markets for improving building energy performance. In the coming five years, investment in efficiency will need to double its rate of growth to more than 3 per cent annually, and will need to expand beyond direct government investment, to private investors. Regulatory efforts in Europe and strengthened partnerships between global investors and financial institutions within fast-growing economies will ensure that greater access to capital is available to ever more building and user types.

Energy demand in the buildings and construction sector is likely to rebound as economic recovery efforts take hold and as pent-up demand continues to unfold. However, this increased demand must occur carefully and quickly, without a corresponding rise in emissions. Governments will need to use this moment to commit to further decarbonizing the power supply as well as the heating and cooling supply and put forward efforts to increase access to and use of clean and renewable energy.

ADAPTATION AND MITIGATION NEED TO BE PURSUED SIMULTANEOUSLY

The growing impacts of the changing climate are visible around the world and have serious consequences for buildings and their occupants. Over time, changing climates and extreme weather events will substantially impact the performance of buildings and the energy consumption of the sector. A typical building constructed today will still be in use in 2070 and beyond, but the climate that it encounters will have changed significantly. Thus, there is a clear need to implement effective, low-carbon policies and to enable cost-effective investments in a net zero building stock to decarbonize buildings along their life cycle while addressing resilience.

So far, few countries are reviewing their building or energy codes to embed adaptation and resilience links. New buildings should be specified accordingly, while the necessary interventions to reduce the climate impact of existing buildings should be combined with investing in adaptation and resilience measures. Overall, efforts to increase the resilience of buildings to extreme weather events such as sea-level rise, heatwaves, droughts and cyclones will have to be increased, so that buildings provide safe, reliable and healthy shelters during extreme events of any nature and the sector avoids "locking" emissions in inefficient and unsafe built environments.

HEADING TO 2030 AND 2050

To achieve the Paris Agreement goals, the United Nations Framework Convention on Climate Change's Marrakech Partnership for Global Climate Action Human Settlements Pathway, co-led by GlobalABC and also adopted by the #BuildingToCOP26 Coalition, has set the following goal: *"By 2030, the built environment should halve its emissions, whereby 100 per cent of new buildings must be net-zero[1] carbon in operation, with widespread energy efficiency retrofit of existing assets well underway, and embodied carbon must be reduced by at least 40 per cent, with leading projects achieving at least 50 per cent reductions in embodied carbon. By 2050, at the latest, all new and existing assets must be net zero across the whole life cycle, including operational and embodied emissions."*

1 *The terms "net-zero energy" and "net-zero carbon" emissions buildings do not have widely recognised standard definitions, and they can be applied to different scopes and site boundaries. However, the following definitions exist, based on those described in "Zero energy building definitions and policy activity: An international review" (OECD/IPEEC, 2018): Net-zero operational energy buildings are buildings whose energy consumption over the course of the year is offset by renewable energy generation. Depending on the definition boundary, the renewable energy generated can be on-site or off-site; Net-zero operational carbon buildings are buildings whose carbon emissions resulting from electricity consumption and any other fuels consumed on-site are offset through renewable energy generation or other forms of carbon offsetting. Again, the offset may occur on- or off-site; whole-life net-zero carbon emissions buildings are buildings whose carbon emissions from the materials used in their construction, or embodied carbon, are offset, as well as their operational carbon emissions; note: These definitions of net-zero imply a strong effort to increase efficiency first. In the event that renewable energy is not available or feasible, the term "near-zero" or "net-zero" can also be used to reflect the fact that the building itself has done what it can to get as close to zero energy demand; These definitions can be applied to the building level as well as to the neighbourhood, district or city level, i.e., achieving net-zero carbon neighbourhoods, districts or cities*

By 2030, to be on track to achieving a goal of net zero operational emissions by 2050, the International Energy Agency suggests that direct CO_2 emissions from buildings would need to decrease by 50 per cent and indirect emissions from the sector would need to decline through a 60 per cent reduction in power generation emissions by 2030. In doing so, building sector emissions would fall by around 6 per cent annually from 2020 to 2030. Energy efficiency needs to support decarbonization, and renovation rates must increase. The energy demand of buildings per square metre needs to drop 45 per cent by 2030, which is five times faster on an annual basis than what it did over the past years. GlobalABC's *Global Buildings and Construction Roadmap* and regional roadmaps for Asia, Africa and Latin America have set out the pathway to implement the policies and technologies supporting the 2030 goal, including a materials pathway, addressing embodied carbon.

Stakeholders including donors and recipients increasingly recognize the potential of forging such pathways. These regional pathways are now being cascaded to the national and local level, working with ministries and cities to develop decarbonization and resilience strategies for buildings along their whole life cycle, while considering the urban planning context. More than 20 such national decarbonization roadmap processes are under way or about to be launched. Such efforts – especially where they address building energy codes, NDCs, renewable energy and certification – also mean a better outlook for the Global Buildings Climate Tracker to be on track.

With careful planning and focused effort, the buildings sector can achieve these ambitions. This *Global Status Report for Buildings and Construction* presents an overview of the status and tracks the efforts as the world moves beyond recovery towards a path for securing prosperity.

1. FIVE YEARS IN REVIEW

Since the signing of the Paris Agreement in 2015, greenhouse gas emissions from the buildings and construction sector have peaked (in 2019) and subsequently fallen to 2007 levels. This current decline is due mostly to the COVID-19 pandemic, whereas transformative, long-term progress in sector decarbonizing remains limited. However, since 2015, next to some emission reduction in the power sector, more countries have adopted policies and codes that may have a future impact on the emissions and energy efficiency of buildings.

The signing of the Paris Agreement in 2015 was a landmark moment in global efforts to address climate change. The Agreement's goals of limiting global warming to well below 2 degrees Celsius (°C) and for carbon dioxide (CO_2) emissions to peak as quickly as possible in the coming decades are critical to ensuring our future (United Nations Framework Convention on Climate Change [UNFCCC] 2015). The Agreement was signed by almost all countries in the world, which are to pursue these efforts while enhancing adaptive capacity, strengthening resilience and contributing to sustainable development. The buildings sector is key to achieving these goals.

The built environment must be decarbonized throughout its life cycle, while increasing the resilience of buildings. This requires a triple strategy: reducing energy demand and increasing energy efficiency, decarbonizing our energy system, and addressing embodied carbon stored in building materials[2]. Such an approach also means buildings play a key role in enabling the energy transition through improving access to clean fuels, decreasing energy intensity and increasing renewable energy. This will help us get closer to achieving the UN Sustainable Development Goals (SDGs) – especially SDG 11 on sustainable cities and communities and SDG 13 on climate action – by providing housing for all, having cleaner and resilient cities, protecting and enhancing health, and supporting economic prosperity.

In 2015, the construction and operation of buildings worldwide was responsible for 13.1 gigatons of energy-related CO_2 emissions, or 38 per cent of the global total. By 2019, emissions from the buildings and construction sector had risen to a peak of 13.4 gigatons of CO_2, and they were continuing to grow until the COVID-19 pandemic impacted the global economy. In 2020, buildings' CO_2 emissions fell an estimated 10 per cent to about 12 gigatons, a level not seen since 2007; this was largely driven by a reduction in energy demand, but also by continued efforts to decarbonize the power sector (International Energy Agency [IEA] 2020b).

Total final energy consumption in the buildings and construction sector increased 4 per cent between 2015 and 2019, from 144 exajoules (EJ) to more than 150 EJ, with the sector representing 38 per cent of total global final energy demand (IEA 2021a). In 2020, global building energy consumption slowed to 149 EJ, or 36 per cent of total energy use reflecting the impact of pandemic-related lockdowns, the dependence of services sector energy demand to commercial activities, but also the precarious ability of many households and businesses to maintain and afford access to energy.

The reduction in energy-related emissions from buildings and construction is likely to be short-lived, and energy demand was expected to rebound in 2021 as economies emerge from the pandemic (IEA 2020a). It therefore remains critical to immediately and significantly reduce greenhouse gas emissions from the buildings sector, on the global level, to reach the Paris Agreement goals. Global partnerships such as the Global Alliance for Buildings and Construction (GlobalABC) are focused on providing information and creating partnerships to accelerate mitigation and adaptation within the sector.

2 *Embodied carbon is the CO_2 emissions associated with materials and construction processes throughout the whole lifecycle of a building and includes CO_2 emitted during the manufacturing of building materials, their transport for distribution and job site, and construction activities.*

The GlobalABC was founded and launched at the 21st Conference of the Parties to the UNFCCC in Paris in 2015 by a group of businesses, non-profit organizations and governments under the auspices of the French government. In the years since its launch, the GlobalABC has advocated for, developed, and implemented policies, business strategies and initiatives for reducing climate impacts across the buildings and construction sector. It works with the private sector, non-governmental organizations and governments to promote policies, initiatives and pathways that support the transition to a net zero carbon, energy-efficient and resilient buildings and construction sector. As of mid-2021, the GlobalABC had 192 members that were actively engaged in supporting this transition.

Enabling policy transformation and supporting countries based on their situation, the GlobalABC has sought to influence the global trajectory through the development of global, regional and national roadmaps; it currently counts more than 20 regional or national roadmap processes completed or under way[3]. These roadmaps are developed in collaboration with government and regional organizations and with many hundreds of stakeholders around the globe, aiming to build a bottom-up coalition of active stakeholders to support the transition to a zero-emission, efficient, and resilient buildings and construction sector. The GlobalABC also catalysed programmes, such as the Programme for Energy Efficiency in Buildings to assist developing countries and emerging economies (PEEB 2020a) and the Africa-Europe for BioClimatic Buildings project (ABC 21).

As of 2015, 90 countries included actions for addressing buildings emissions or improving energy efficiency in their Nationally Determined Contributions (NDCs) under the Paris Agreement (GlobalABC, IEA and United Nations Environment Programme [UNEP] 2016). NDCs are national non-binding plans of how a country is to achieve emission reductions to contribute to achieving the global climate goals, and are important references to national commitments. By 2020, the number of countries mentioning emission reductions in buildings in their NDCs had grown to 136; however, this content varies greatly in ambition and includes efforts for energy efficiency, emission reductions, and adaptive resilience, whereas embodied carbon is often missing (see section 5.1).

The number of countries adopting building energy codes has increased from around 62 countries in 2015 (GlobalABC, IEA and UNEP 2016) to 80 countries in 2021; half of these codes are mandatory, while others exist at a local government level and help to drive forward overall performance improvements (REN21 2020). Some jurisdictions have even set goals for full decarbonization of the buildings sector. For example, the European Union requires its Member States to develop strategies to achieve a highly energy-efficient and fully decarbonized building stock by 2050 (European Parliament n.d.). China, in its 14th Five-Year Plan (2021-2025), has advanced plans to build low-carbon cities and mandates for green buildings and green building materials, building on the 13th Five-Year Plan's requirements for energy conservation in buildings and green building targets (Vaughan 2021).

Since 2015, a growing number of regulations, codes and certifications have been developed to shift the buildings and construction sector towards net zero carbon. Governments have also sought to tackle emissions in the buildings sector through phasing out fossil fuels for home heating – examples include California's adoption of electric heat pumps (California Energy Commission 2021), France's ban on new gas-fired boilers from 2022 (Ministère de la transition écologique 2020) and more than 50 city governments phasing out or banning fossil fuels (REN21 2020).

Several commitments and pledges that include buildings and construction have been launched. More than 200 companies from the sector have committed to the Science Based Targets initiative (SBTi) to reduce their emissions in line with climate science. This makes the construction sector one of the larger sectors committed to the SBTi. The Race to Zero, a global campaign to rally leadership and support from businesses, cities, regions and investors for a healthy, resilient, zero-carbon recovery so far counts more than 695 companies (66 from the construction sector). The Clean Energy Ministerial (CEM) Global Call, the Zero Carbon Buildings for All, and GlobalABC's currently active Buildings as Critical Climate Solutions (BCCS) call to-date count eleven countries committing to actions to decarbonize buildings. The World Green Building Council's Net Zero Carbon Buildings Commitment now has more than 140 signatories from industry, regions, cities and building councils and reflects a growing concern to take swift action across the sector towards zero carbon buildings (WGBC n.d.).

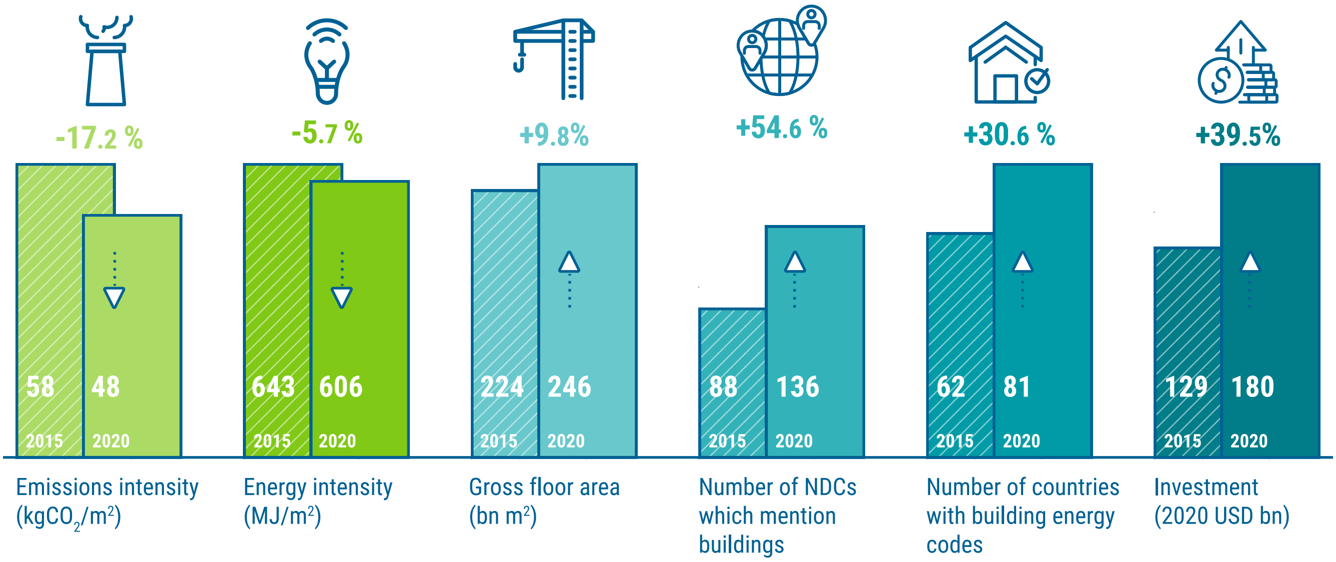
Investment in the energy efficiency of buildings in 2015 totalled around $129 billion ($118 billion in 2015 dollars), or 8 per cent of total spending on building construction. Nearly three-quarters (73 per cent) of this investment was realized in Germany, China, the United States and France (IEA 2021b). By 2020, investment in building energy efficiency had increased nearly 40 per cent, to an estimated $180 billion, although most of this increase came from a small number of European countries. Without broader investment, this amount is unlikely to adequately tackle efficiency improvements in the existing global building stock.

3 In 2020, the Global Roadmap for Buildings and Construction was released, alongside three regional roadmaps for Latin America, Sub-Saharan Africa and Southeast Asia (GlobalABC, IEA and UNEP 2020a-d). In addition, multiple roadmaps are under way, including: ASEAN, Colombia, Turkey, Cambodia, India and Viet Nam; ten whole-life carbon roadmaps in Europe; and 2 additional processes starting in Burkina Faso and Sri Lanka.

Looking ahead, the challenges to reaching a net zero, energy-efficient and resilient buildings and construction sector are considerable. Globally, there is a growing demand for more buildings and floor area, with the floor area of the global buildings sector projected to double by 2060, adding more than 230 billion square metres (GlobalABC, IEA and UNEP 2018). Much of this demand is expected to occur in Asia and Africa and to be driven by a growing standard of living, and it will also need to adapt to a changing climate.

Driven by these trends, global material use is expected to more than double by 2060, with a third of this rise attributable to materials used in the buildings and construction sector among rapidly growing populations and economically developing countries (Organisation for Economic Co-operation and Development [OECD] 2019). Over time, changing climates and extreme weather events will substantially impact the performance of buildings and the energy consumption of the sector. A typical building constructed today will still be in use in 2070 and beyond, but the climate it encounters will have changed significantly. The demand for cooling, followed by appliances, is the fastest growing energy demand and is concentrated in hot regions with growing populations and economic purchasing power (IEA 2018). Thus, there is a clear need to implement effective, low-carbon policies and to enable cost-effective investments in a net zero building stock to decarbonize buildings along their life cycle while addressing resilience.

Figure 7 - Key changes in buildings sector between 2015 and 2020



Sources: UNFCCC, 2021; Buildings-GSR, 2021; IEA, 2020. All rights reserved.

Notes: Emissions intensity is total buildings construction and operations emissions over total floor area, energy intensity is total building operational energy over

To achieve the Paris Agreement goals, the UNFCCC's Marrakech Partnership for Global Climate Action Human Settlements Pathway, co-led by GlobalABC and also adopted by the #BuildingToCOP26 Coalition, has set the following goal: *By 2030, the built environment should halve its emissions, whereby 100 per cent of new buildings must be net zero carbon*[1] *in operation, with widespread energy efficiency retrofit of existing assets well underway, and embodied carbon must be reduced by at least 40 per cent, with leading projects achieving at least 50 per cent reductions in embodied carbon. By 2050, at the latest, all new and existing assets must be net zero across the whole life cycle, including operational and embodied emissions. In addition, that by 2050, all buildings must be net zero, both operationally and in embodied emissions"* (UNFCCC n.d.a).

This transition to an efficient and resilient buildings and construction sector with zero carbon emissions across the life cycle of the built environment calls for a sector-wide transformation. The IEA's report on achieving a net zero global energy sector by 2050 (IEA 2021c) shows the implications for the buildings sector in achieving this target – including through the adoption of efficient designs, low-carbon heating and cooling, and efficient operation (see section 3.6).

As set out in the GlobalABC's global and regional roadmaps, as well as in the '10 Key Measures for Decarbonizing Buildings' Tool,, achieving these goals will necessitate a series of actions across the buildings and construction sector, including: integrated low-carbon urban planning policies, enforcement of mandatory progressive building codes in all buildings, improving the energy performance of existing buildings, adoption of high-performance and low-cost systems and appliances, improved resilience in construction, adoption of decarbonized construction materials and low-pollution supply chains; and adoption of building-integrated clean and renewable energy (GlobalABC, IEA and UNEP 2020a). Reflecting the close links between adaptation and mitigation, GlobalABC released a call to action on Buildings and Climate Change Adaptation, which finds that few countries are reviewing their building or energy codes for such links (GlobalABC 2021b). Submersion and heatwaves stand out as the two biggest risks to combat for buildings. Against these hazards, two main recommendations are put forward: limiting urbanization in risk-prone areas and anticipating the increasing needs for cooling, and choosing more resistant foundations, structures, and materials. Overall, efforts to increase the resilience of buildings to extreme weather events such as sea level rise, heat waves, droughts, and cyclones will have to be increased and all actors along the built environment value chain need to undertake action towards adaptation, so that buildings provide safe, reliable and healthy shelters during extreme events of any nature and the sector avoids 'locking' emissions in inefficient and unsafe built environments

Within this *2021 Global Status Report for Buildings and Construction (Buildings-GSR)*, the GlobalABC sets out to monitor and track the progress being made, or the lack thereof, in global efforts to decarbonize and increase the sustainability of the global building stock. As with previous reports, the aim is to clearly articulate the state of the built environment in terms of energy, emissions and initiatives that reflect the status of sectoral decarbonization over the relevant coverage period.

Since its launch in 2016, the *Buildings-GSR* has continued to evolve, bringing forward insights and pointing to information to help understand efforts that support the transition to a net zero carbon, energy-efficient and resilient buildings and construction sector. Over the coming five years, the report will renew its mandate to be the leading voice in tracking these efforts and will draw from the growing coalition and strength of the GlobalABC membership to inform and report on the global progress towards reaching a net zero carbon buildings and construction sector.

1 *The terms "net-zero energy" and "net-zero carbon" emissions buildings do not have widely recognised standard definitions, and they can be applied to different scopes and site boundaries. However, the following definitions exist, based on those described in "Zero energy building definitions and policy activity: An international review" (OECD/IPEEC, 2018): Net-zero operational energy buildings are buildings whose energy consumption over the course of the year is offset by renewable energy generation. Depending on the definition boundary, the renewable energy generated can be on-site or off-site; Net-zero operational carbon buildings are buildings whose carbon emissions resulting from electricity consumption and any other fuels consumed on-site are offset through renewable energy generation or other forms of carbon offsetting. Again, the offset may occur on- or off-site; whole-life net-zero carbon emissions buildings are buildings whose carbon emissions from the materials used in their construction, or embodied carbon, are offset, as well as their operational carbon emissions; note: These definitions of net-zero imply a strong effort to increase efficiency first. In the event that renewable energy is not available or feasible, the term "near-zero" or "net-zero" can also be used to reflect the fact that the building itself has done what it can to get as close to zero energy demand; These definitions can be applied to the building level as well as to the neighbourhood, district or city level, i.e., achieving net-zero carbon neighbourhoods, districts or cities*

2. GLOBAL BUILDINGS CLIMATE TRACKER: DECARBONIZATION OF THE BUILDING STOCK IS NOT ON TRACK

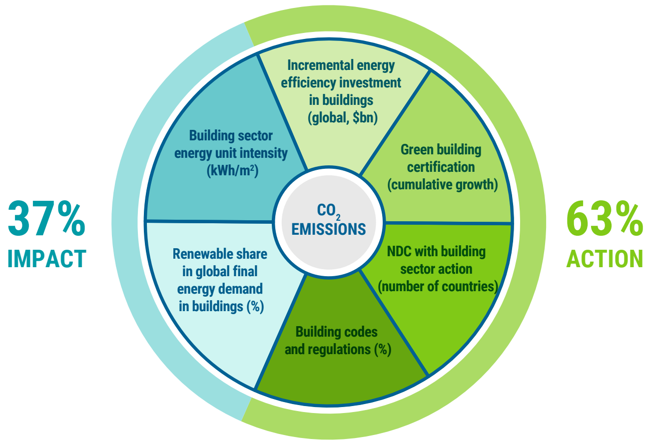
The Global Buildings Climate Tracker appears to indicate that the buildings and construction sector is on track to achieve complete decarbonization by 2050. However, this is a temporary result, reflecting the unprecedented changes in building use during the pandemic. While there is some progress in energy efficiency investment and power decarbonization, a negative rebound in overall progress should be expected unless building sector decarbonization efforts significantly increase.

The Global Building Climate Tracker (GBCT), first published in 2020, aims to monitor progress in decarbonizing the construction and operations of buildings. It provides a snapshot of the current status, as compared to a scenario for the future. 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 decarbonization of buildings and the building construction sector. It includes three indicators – 1) CO_2 emissions, 2) energy intensity and 3) renewable energy share – that together show the *impact* of decarbonization efforts. In addition, it includes four indicators that measure the *actions* taken towards decarbonization: 4) building regulations, 5) energy efficiency investments, 6) green building certifications and 7) building measures in NDCs. These indicators are normalized and aggregated according to their weight (see figure 5) to form the decarbonization index.

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



Note: The weighting of individual indicators in the decarbonization index, and their data sources, are as follows: energy intensity 19% (IEA 2021a); renewable share 19% (IEA 2021a); building regulations 18% (author analysis; World Bank, 2019); energy efficiency investments 19% (IEA 2021a); green building certifications 15% (author analysis); building measures in NDCs 11% (author analysis). Instead of a weighted share, CO_2 emissions are used as a factor because they are the main measure for decarbonization (IEA 2021a). For more information, see the Annex.

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

This year's GBCT is improved compared to the previous version, as more accurate data have become available. To make it more robust, new indicators were included in the index: additional building certification schemes and new elements on quality control in construction[4]. Therefore, the GBCT development projection differs in this year's report compared to the previous report.

2.2 STATUS IN 2020: ASSESSING PROGRESS TOWARDS THE 2050 DECARBONIZATION GOAL

As shown in last year's *Global Status Report for Buildings and Construction*, the decarbonization level in 2019 was calculated as 6.2 points[5]. For 2020, the GBCT shows a significant increase to 17.3 points, which appears to indicate a much deeper annual decarbonization level than in 2019 (see figure 9 in box 1). However, a large part of this progress stems from the effects of the COVID-19 crisis. When non-residential buildings were temporarily closed during 2020, this resulted in a reduction in energy consumption, including for heating and lighting, as well as associated greenhouse gas emissions[6]. Therefore, the 2019-2020 progress of 11.1 points can be interpreted as a "false positive".

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

5 *The Buildings Global Status Report 2020 showed 2.5 points for 2019. The 2021 report uses updated data and new indicators, which explains the discrepancies between the numbers in the two reports. For details, see Annex.*

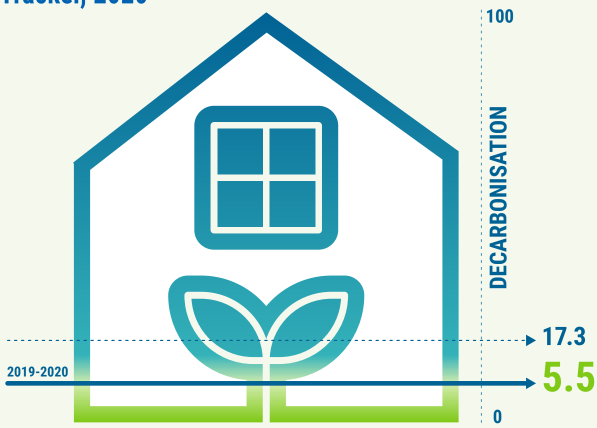
6 *Measures taken included, for example, mandatory closures of schools, universities, public buildings, religious or cultural buildings, restaurants, bars and other non-essential businesses. CO_2 emissions from public buildings and commerce fell an estimated 21 per cent (Le Quéré et al. 2020, p. 650).*

Box 1. Explaining the Global Buildings Climate Tracker (GBCT)

The GBCT started tracking decarbonization in the buildings sector in 2015. Therefore, the decarbonization status is set at "0" for 2015, the starting point of the measurements. The year 2050, meanwhile, is set at "100" to reflect the maximum decarbonization needed in the sector*. The goal is to progress towards and get to 100 points by 2050.

In figure 9, the house image represents the 2050 goal, and its green portion represents the achieved decarbonization. Bars on the scale to the right mark the progress achieved towards that goal. In 2020, 17.3 points were reached. However, much of this achievement is a temporary effect of the reduced economic activity due to the COVID-19 crisis. It reflects a change in the use of buildings rather than actual efficiency improvements or decarbonization efforts. If the impact of the pandemic is excluded, and assuming that energy use and greenhouse gas emissions had remained on their previous five-year trend, then the actual decarbonization for 2019-2020 is 5.5 points.

Figure 9. Decarbonization of buildings and construction using the Global Buildings Climate Tracker, 2020



Source: Adapted by the Buildings Performance Institute Europe

* *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 (2020a)*

ESTIMATING THE IMPACT OF THE COVID-19 PANDEMIC

To measure the impact of COVID-19 on the results and to understand how decarbonization would have developed in the absence of the pandemic, we attempted to estimate the GBCT's business-as-usual value. The impact of the pandemic can be best measured for CO_2 emissions and energy intensity indicators. For these two indicators, we extrapolated a five-year trend starting in 2015 to the year 2020. As a result, under the business-as-usual scenario, emissions would have increased 2 per cent, and energy intensity would have remained constant on a global average. Under these assumptions, without the COVID-19 crisis, the estimated decarbonization index would result in 5.5 points.

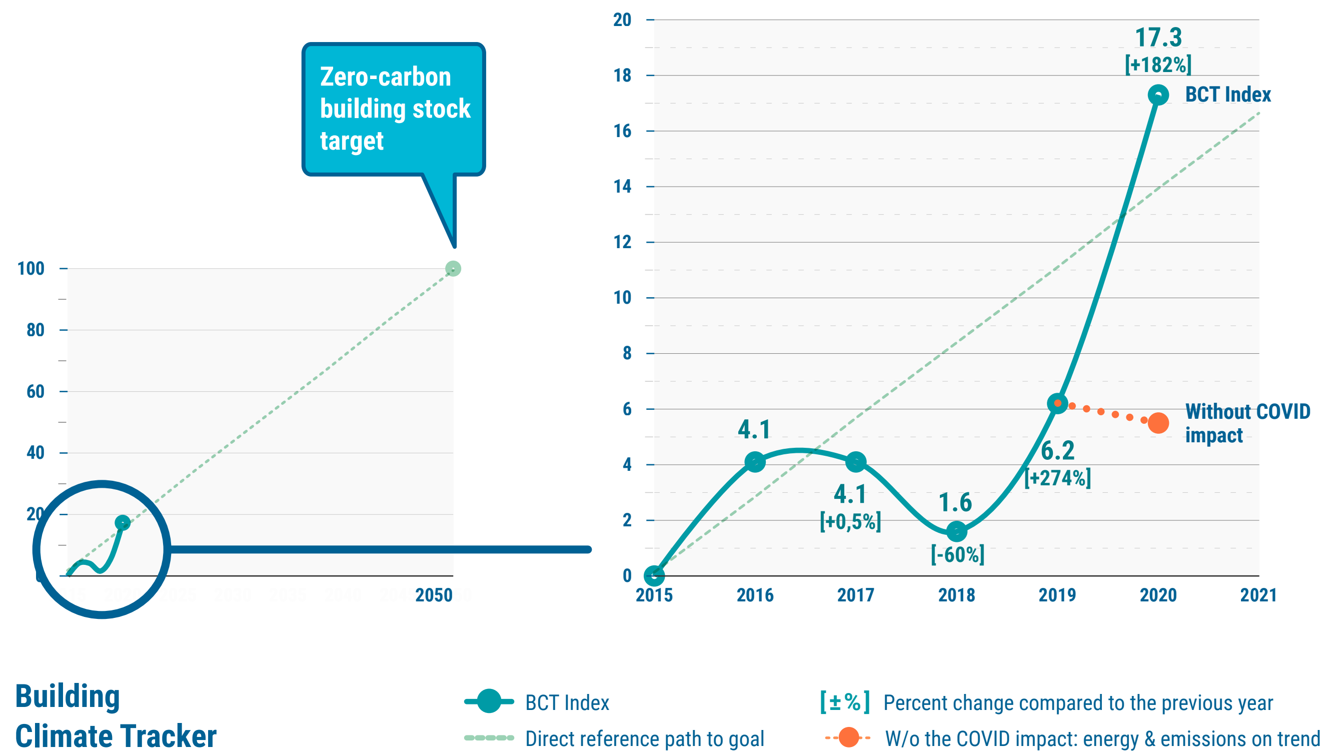
With the reduction in economic activity due to the pandemic, however, the data show that emissions from buildings decreased 10 per cent, while energy intensity decreased 2 per cent. The index, therefore, yields a result of 17.3 points. These observations will be validated only next year when 2021 data are available for verification.

DECARBONIZATION PROGRESS SINCE THE PARIS AGREEMENT

In line with the goals of the Paris Agreement, the GBCT assumes the target of a zero-carbon building stock by 2050. This target is indicated by the blue dot in the left graph of figure 7. The blue line is a direct reference path from the starting point “0” in 2015 (the year when the measurement of building sector decarbonization started) to the target point “100” in 2050 . The left graph of figure 7 illustrates the complete, 35-year path to the 2050 goal.

The graph on the right zooms into the period from 2015 to 2020. The blue line serves as a reference indicating whether building decarbonization is on track or not. To be on track, the orange line must be on or above the blue line. For 2020, the orange line is above the blue line, which can be interpreted as being “on track” (although these gains are mostly a result of the COVID-19 crisis). The grey dot reading “5.5” is where the decarbonization levels would have been in the absence of the pandemic – well below the desired levels.

Figure 10. Direct reference path to a zero-carbon building stock target in 2050 (left); zooming into the period between 2015 and 2020, comparing the observed Global Buildings Climate Tracker to the reference path (right)



Source: Adapted by the Buildings Performance Institute Europe

2.3 SUMMARY OF THE RESULTS

While the data for 2019-2020 show a temporary improvement in decarbonization levels, the observed emission reductions are mostly a result of a decrease in economic activity, and not an effect of actual efficiency or improvement measures. Given this "false positive", **decarbonization of the building stock is not on track to reach the goals of the Paris Agreement.** In a few years, emissions and energy consumption are estimated to rebound and to return to close to 2019 levels (IEA 2020b). The narrow window of time between now and until the global economy comes back on its feet presents a unique opportunity to make the construction industry more sustainable.

THE TEMPORARY PROGRESS REGISTERED AS A RESULT OF THE COVID-19 PANDEMIC MASKS THE REALITY THAT THE DECARBONIZATION OF BUILDINGS IS NOT ON TRACK.

That said, some positive developments have occurred in the buildings decarbonization index since 2019. For example, a 13.9 per cent increase was observed in green building certifications in those schemes that made their data transparent and available[7]. In addition, energy efficiency investments went up by 11 per cent (see section 6), 10 new countries introduced building codes (see section 5.2), and 16 countries improved the quality control in building construction[8].

These improvements, however, are still not contributing enough to the goal of decarbonizing the global buildings sector. Further, when the effects of the COVID-19 pandemic are removed, the decarbonization level in 2020, based on the GBCT, is only 40 per cent of the 2050 reference path goal.

7 *Schemes that made their certification data available were: LEED, MINERGIE, WELL, Passive House, EDGE, DGNB, IGBC (India), GREEN STAR (Australia), CASBEE, SGBC (Sweden), SGBC (Saudi Arabia), GRIHA (India) and BEAM Plus (Hong Kong).*

8 *Sixteen countries reformed their building quality control system, according to World Bank indicators that show quality control within construction permits before, during and after construction. However, only seven countries (China, Ethiopia, Georgia, India, Pakistan, Rwanda and Togo) could be identified from the report (World Bank 2019, p. 12).*

3. GLOBAL STATUS OF BUILDINGS AND CONSTRUCTION: THE SEVERE IMPACTS OF COVID-19

Global CO_2 emissions from buildings operations fell 10 per cent, although this decline appears to be temporary as emissions pick up again with increasing economic activity. Overall, buildings accounted for 36 per cent of global energy demand and 37 per cent of energy-related CO_2 emissions in 2020.

The year 2020 marked a consequential year for buildings and construction. The COVID-19 pandemic greatly impacted the construction of buildings, resulting in a historic drop in new building, and also led to a change in the way that existing buildings were used.

During the 18 months following the onset of the COVID-19 crisis, the global buildings and construction sector saw the depths of what a pandemic can affect, from construction sites being left empty for months during lockdowns, to the financing of construction being disrupted, to the way supply chains for materials reacted to sudden drops and surges in demand (International Labour Organization [ILO] 2021). The way buildings were used also changed rapidly, with the status quo of workplace-based employment for several sectors quickly transitioning to remote working arrangements and the abandonment of commercial and retail premises; meanwhile, there were substantial pressures on warehousing availability for a sudden upsurge for logistics and delivery.

These changes meant more people working in makeshift and home offices, resulting in adjustments in heating and cooling patterns, plug loads and digital infrastructure. Yet many of the business premises that saw changes in their operations still had to maintain a certain level of service, showing both how difficult and how damaging "turning off" systems and operations can be. For buildings that remained open to workers, changes in their operation to reduce the risk of virus transmission meant increasing the distance between workers and increasing ventilation rates of external air (versus recirculation), with implications for both space heating and cooling conditioning.

The changes in home and workplace activities also had a significant impact on energy and emissions (see sections 3.3 and 3.4); however, these changes affected households and businesses across the world in different ways. For millions of people worldwide, the situation turned precarious, with the pandemic leading to an estimated 97 million more people being in poverty in 2020 (Gerszon Mahler *et al.* 2021). As the global economy continues to be impacted by the pandemic and seeks to balance the need to protect lives and livelihoods, the way that buildings are used will continue to change and respond to local contexts. What is critical is that buildings are seen as part of the solution both to achieve economic recovery and to secure the decarbonization pathway needed to achieve the Paris Agreement goals.

3.1 CONSTRUCTION ACTIVITIES WORLDWIDE DECREASED IN 2020

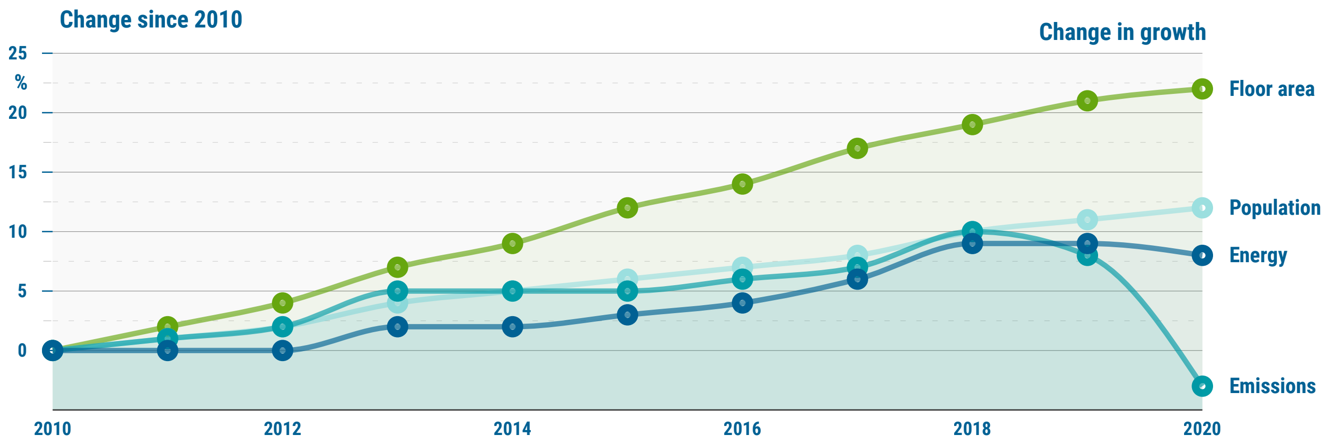
In 2020, the average annual growth rate in buildings and construction worldwide dropped an estimated 4 per cent from 2019 levels (OECD 2021). This decline in market growth was due primarily to the pandemic's profound impacts on construction activities, including the effects of lockdowns on the labour supply, the limited demand for new buildings, the slowdown in public and private procurement, and the disruptions in the supply chain.

The impacts of COVID-19 on the output value of the construction industry varied widely globally. For example, several economies in the European Union suffered considerable construction impacts, with the output value in real terms dropping an estimated 13.2 per cent in France and 14 per cent in the United Kingdom from 2019 levels, whereas Switzerland saw a more modest drop of 4.2 per cent (GlobalData 2021a; GlobalData 2021b; GlobalData 2021c). Germany, by comparison, experienced only a 1.8 per cent reduction in construction value in real terms in 2020 and was able to show a 2.8 per cent increase in the growth rate of construction for the year (GlobalData 2021d). Canada, meanwhile, experienced a decline in construction industry value of 3 per cent in 2020 (GlobalData 2021e).

Asia also experienced deep contractions in the construction industry in 2020, with the output value dropping an estimated 36 per cent in Singapore, 20 per cent in Malaysia, and 30 per cent in the Philippines, compared with only 3.3 per cent in Indonesia (GlobalData 2021f; GlobalData 2021g; GlobalData 2021h; GlobalData 2021i). The Middle East showed slightly greater stability in construction output, with Saudi Arabia contracting by 0.4 per cent and Qatar by 4.2 per cent (GlobalData 2021j; GlobalData 2021k). This regional variation in construction sector slowdown was due in part to differing pandemic response strategies and to changes in investment and financing for buildings projects, local market conditions and labour availability when the pandemic took hold.

In 2020, global building floorspace is estimated to be over 246 bn m^2 (IEA, 2020b). For new building construction, the IEA estimates that added floor space in 2020 was up 1 per cent from 2019 – a marked slowdown from the previous increases of around 2.0 to 2.5 per cent from 2010 to 2019 (see figure 8). This was accompanied by major slowdowns in the growth in energy demand for building services and in related emissions (IEA 2021a) (see sections 3.3 and 3.4). However, the major drivers of energy demand – floor area and population – continued to grow even during the pandemic (figure 8).

Figure 11. Change in global drivers of trends in buildings energy and emissions, 2010-2020



Source: IEA 2021a.

Box 2. RICS surveys of global construction activity

In 2021, more than 4,000 built environment professionals across the world shared their views on how the climate emergency is shaping trends and practices across the sector, as part of the RICS *Global Commercial Property Monitor* and the RICS *Global Construction Monitor* (RICS 2021a; RICS 2021b). The results of these surveys suggest that the industry seems to be moving towards growth in construction activities, although these conclusions remain tentative depending on pandemic conditions and global demand.

- **Waste minimization:** Minimizing waste was among the construction industry's priority areas, with nearly two-thirds of global respondents citing this as a leading concern for the sector. The majority of contributors (around 55 per cent) reported a rise in the demand for recycled and re-usable materials in the past year, although most deemed this growth to be modest.
- **Measuring carbon emissions, including embodied carbon:** Measuring carbon emissions remains a minority practice in the construction sector, with more than 70 per cent of industry professionals stating that they do not measure operational carbon emissions over the expected life cycle of projects. Further, more than 50 per cent of professionals reported that they make no measurement of embodied carbon emissions in their projects. Even if carbon measurement does occur, there is little evidence to suggest that this is having a meaningful impact on the choice of materials and components. Only 14 per cent of respondents stated that they do measure embodied carbon and use this to guide their selection of materials. Around 18 per cent suggested that they would like to measure embodied carbon if a standard approach to measurement existed.
- **Rising demand for green buildings:** More encouragingly, around three-fifths of respondents globally reported that occupier and investor demand for green buildings has risen over the past year. Even so, most contributors reported only a modest rise as opposed to a significant pick-up. Nearly half of respondents globally saw evidence of rent and price premiums for green buildings. Meanwhile, more than 30 per cent of respondents stated that in the absence of a premium, buildings not classified as green or sustainable are subject to a "brown discount".
- **Growing environmental, social and governance (ESG) investment:** Demand from clients, stakeholders and customers is seen as the principal factor behind the ESG investment boom. Increased awareness about ESG risks and opportunities is also noted to be a major driver. Across Europe, a sizeable share of respondents suggested that regulatory requirements are an important driver.

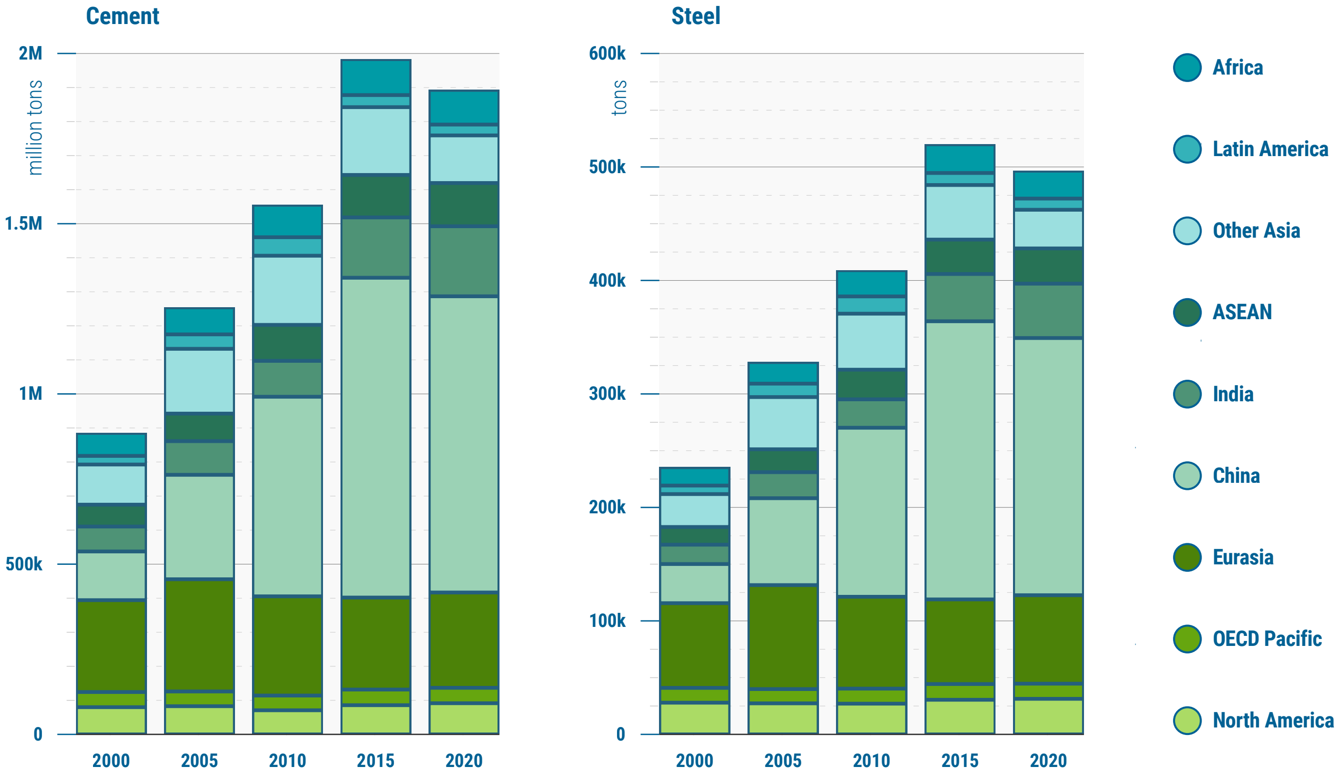
3.2 DEMAND FOR CONSTRUCTION MATERIALS DROPPED DUE TO THE PANDEMIC

The implications of the pandemic and associated measures to control the spread of COVID-19 have had wide-ranging impacts on the building construction supply chain and the costs of materials (ILO 2021). Local lockdowns have affected both the extractive industries that produce raw materials for buildings and construction, as well as the manufacturing of those materials for availability on the market. In some locations, such as China and Italy, the construction sector was deemed essential, whereas in places like South Africa or Canada, the sector was subject to partial shutdowns.

The impact of COVID-19 on the supply and demand of construction goods and services is complex and greatly affected by local market conditions. These impacts range from a backlog in construction projects that were planned and deferred, to local market disruption of contractors, to increases in the costs of skilled labour and its availability in local markets. Other impacts include health and safety protocols and laws for construction sites, as well as increases in commodity pricing and up-chain manufacturing pricing that reflect both reduced output and increased demand. These impacts are in addition to the above-mentioned slowdown in floor space growth, which further reduced the demand for construction materials.

Looking across different global regions, the constraints in supply showed a considerable drop in the production and availability of cement and steel. The IEA (2020a) estimated a global 3.5 per cent drop in cement and a 4 per cent drop in steel production for building construction in 2020 (see figure 9).

Figure 12. Steel and cement demand for buildings construction by region, 2000-2020



Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

Supply constraints, alongside increased demand for construction materials, greatly affects the availability of materials for construction projects within local markets, particularly if the materials are sourced internationally. Many construction materials used on-site are reliant on a complex supply chain that includes extraction, processing, material and technology manufacturing, and transport, such that the disruption of a single link or the whole chain can create a cascading effect on availability and costs. In Canada, lockdowns and market conditions led to a more than 340 per cent increase in [the price of softwood lumber, before falling to levels seen in early 2021, due to sawmill shutdowns and the increased demand for home renovation and new home construction, while steel and rebar were up 60 per cent over the same period (Cameron 2021);

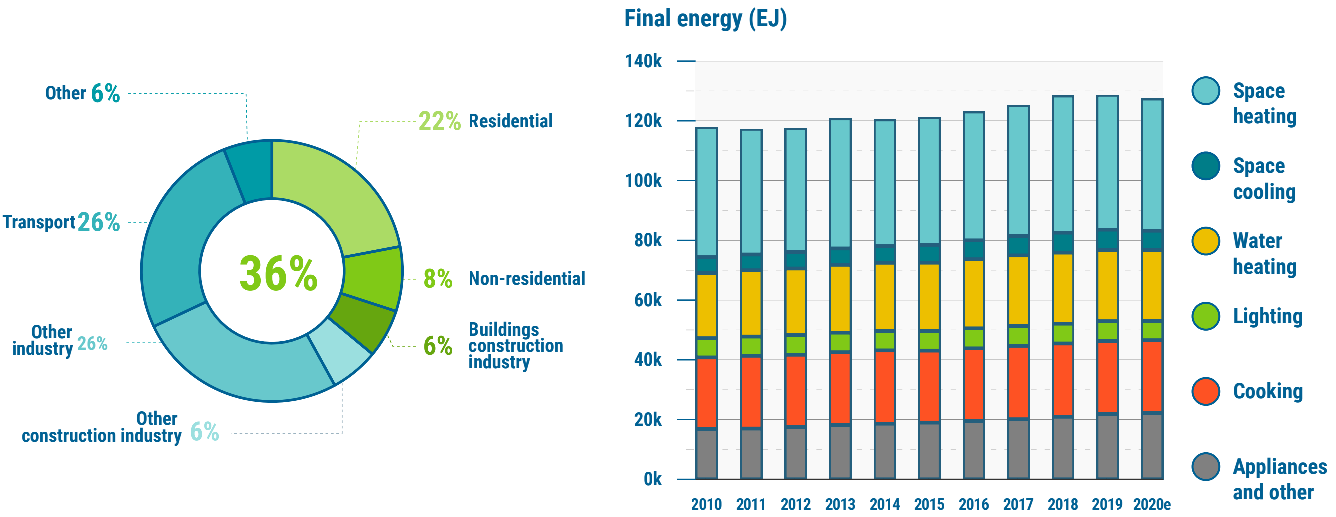
For markets that are able to afford increases in material costs due to factors such as available wealth or free trade, prices have increased more quickly (Statistics Canada 2021). In Sweden, the construction cost index for materials transport and contractors' costs in May 2021 increased an average of 7 per cent from a year prior, while labour and wages increased 12.6 per cent (SCB 2021). In the United Kingdom, a survey of contractors described continued supply constraints for cement, electrical components, timber, steel and paints, citing unprecedented levels of demand and trade friction (PBC Today 2021).

3.3 ENERGY IN THE BUILDINGS AND CONSTRUCTION SECTOR

In 2020, global building's construction and operations , together accounting for 36 per cent of global energy consumption at 149EJ, with an estimated 127 EJ of energy was consumed in building operations and 22 EJ was consumed for the manufacturing of building construction materials (see figure 10) (IEA 2021a). Overall, however, the global energy demand and emissions of the building stock dropped 1 per cent in 2020, following peak levels in 2019. The decline was due primarily to a reduction in the demand for space heating and a slowing in the demand for space cooling (IEA 2021a). Other energy end uses, such as water, cooking, lighting and appliances, were stable, although the energy demand for lighting has continued to drop with the uptake of more efficient LED lighting (see figure 10).

Because of the pandemic-induced changes in the patterns of construction and use of buildings, the development of energy demand in buildings in 2020 is complicated. While there was a slight overall drop (compared to 2019) in energy demand related to buildings operation, the change reflects a shift from the commercial and retail sectors to the residential sector, as well as a slowdown in services-related buildings energy demand during the first part of the year and a continued ramping up in the warehousing sector. Public buildings also showed drastically altered energy demand as schools intermittently opened and closed, while many civic and public amenity buildings remained closed for much of 2020 (IEA 2021a).

Figure 13. Global share of buildings and construction final energy (left) and by end use (right), 2020



Notes: "Buildings construction industry" is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Buildings construction industry related energy use not shown in Panel B.

Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

Box 3. Low-carbon-emission buildings and construction actions

Zero-carbon buildings in four steps

A recent analysis for the World Economic Forum (Nesler 2020) outlined four major trends driving the design of zero-carbon buildings and communities: efficiency improvements to reduce energy demand; decarbonization of the electricity grid; electrification of space and water heating; and digitalization to provide flexibility in meeting the needs of building occupants and the energy grid. Efficiency, particularly when enabled by digitalization at a systems level (i.e., active efficiency), is critical for dynamic peak demand reduction and affordability. The analysis found that every $1 spent on energy efficiency returns $3 over time and saves $2 in energy supply investment. Combined, these four good "DEEDs" (decarbonization, electrification, efficiency and digitalization) provide a comprehensive pathway for buildings and communities to contribute to a low-carbon future.

Digitalization of the built environment

The World Business Council for Sustainable Development's report *Digitalization of the Built Environment: Towards a More Sustainable Construction Sector* demonstrates the critical role of digitalization in establishing sustainable practices in the buildings and construction sector (WBCSD 2021a). Digitalization can improve sustainability performance and help develop new processes, services and markets, but despite the promising benefits, the sector has been slow to fully adopt emerging digital technologies. The report offers a set of recommendations at the company and sector levels for accelerating the deployment of digitalization.

The construction sector acts on science-based targets

The construction sector is strongly motivated to take action to reduce carbon emissions from the production, construction, maintenance and design of buildings. More than 200 companies from the sector have committed to the Science Based Targets initiative (SBTi) to reduce their emissions in line with climate science. This makes the construction sector one of the larger sectors committed to the SBTi. The Science Based Targets provide companies with a clearly defined path to reduce their emissions in line with the Paris Agreement goals, helping to prevent the worst impacts of climate change and to future-proof business growth. Targets are considered "science-based" if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement and pursuing efforts to limit warming to 1.5°C.

See: *https://sciencebasedtargets.org*

Race To Zero

Race To Zero is a global campaign to rally leadership and support from businesses, cities, regions and investors for a healthy, resilient, zero-carbon recovery that prevents future threats, creates decent jobs and unlocks inclusive, sustainable growth. All members are committed to the same overarching goal of halving emissions by 2030 and achieving net zero emissions as soon as possible, but no later than 2050. So far, more than 695 companies (66 from the construction sector) have signed the Business Ambition for 1.5°C, an urgent call to action from a global coalition of UN agencies, business and industry leaders in partnership with Race to Zero. See: https://unfccc.int/climate-action/race-to-zero-campaign

Advancing whole-life carbon

In September 2021, the World Green Building Council expanded the Net Zero Carbon Buildings Commitment to include whole-life carbon emissions (WGBC 2021a). To accompany the Commitment update and its reduction-first approach to decarbonization, the Council also published the report *Advancing Net Zero Whole Life Carbon: Offsetting Residual Emissions from the Building and Construction Sector*, providing guidance for how the sector should compensate for its total carbon impacts (WGBC 2021b).

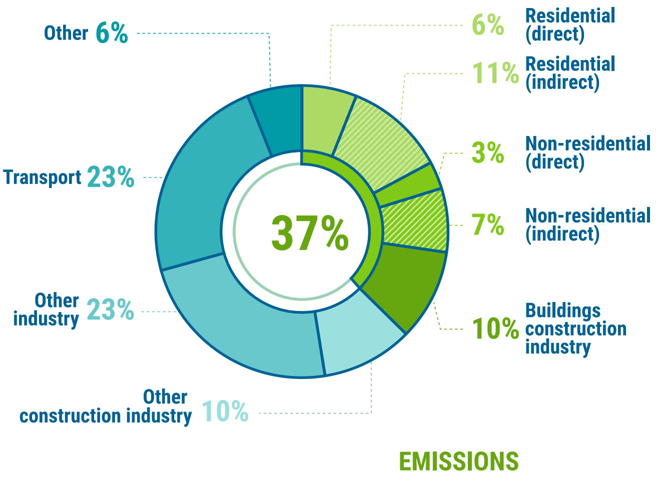
Building for a better world: how buildings contribute to the UN Sustainable Development Goals

The recent report by the DGNB, *Building for a Better World: How Buildings Contribute to the UN Sustainable Development Goals (SDGs)* aims to raise awareness of the SDGs within the construction industry (DGNB 2020). It seeks to provide building owners, architects, planners and key decision makers in the construction sector with a better understanding of the global challenges the world faces, and to encourage everyone to think more closely about the impact of the SDGs in areas they can influence. The report shows how construction in particular has a considerable influence on sustainable development and outlines how the construction industry overlaps with almost all SDGs. It investigates seven SDGs that are particularly relevant for building: SDG 1 on eliminating poverty, SDG 3 on good health and well-being, SDG 4 on quality education, SDG 6 on clean water and sanitation, SDG 7 on affordable and clean energy, and SDG 8 on decent work and economic growth.

3.4 EMISSIONS IN THE BUILDINGS AND CONSTRUCTION SECTOR

Total energy-related emissions from buildings operations and construction fell from 13.1 gigatons of CO_2 in 2019 to 11.7 gigatons in 2020, a decline of just over 10 per cent (see figure 13). Energy-related emissions from buildings and construction represented 37 per cent of the global total in 2020, down slightly from 38 per cent in 2019. This slight decline reflects changes in other sectors, such as industrial-related emissions, that occurred at different rates than in the buildings sector.

Figure 14. Buildings and construction's share of global energy-related CO_2 emissions, 2020



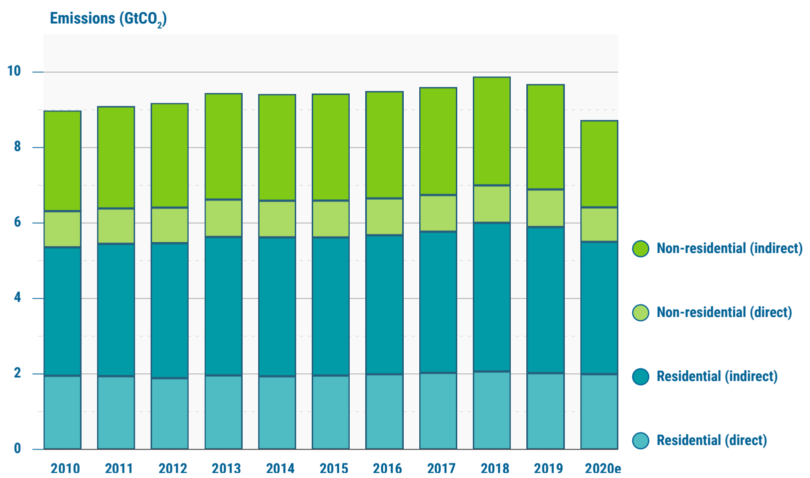
Notes:
"Buildings construction industry" is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.

Source:
IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

Total operational emissions from the global buildings sector – that is, direct and indirect emissions related to heating, cooling, lighting, etc. – fell 10 per cent in 2020, from around 9.6 gigatons of CO_2 in 2019 to 8.7 gigatons, reflecting the pandemic-induced shift in energy use patterns. Direct energy-related emissions for buildings operations fell to just under 3 gigatons of CO_2, and indirect emissions related to electricity use totalled 5.8 gigatons of CO_2 in 2020, down 13 per cent from 2019 (see figure 14). Emissions from buildings operations accounted for around 28 per cent of total global energy-related CO_2 emissions in 2020.

Energy-related emissions from the manufacturing of construction materials fell from 3.6 gigatons of CO_2 in 2019 to 3.2 gigatons in 2020, reflecting the overall drop in demand for materials due to the pandemic and the related construction slowdown. Construction emissions accounted for around 10 per cent of total global energy-related CO_2 emissions in 2020.

Figure 15. Global buildings sector energy-related emissions by building type and indicator, 2010-2020



Notes:
Direct emissions are those emitted from buildings, while indirect emissions are emissions from power generation for electricity and commercial heat.

Source:
IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

In 2020, energy demand related to buildings and construction dropped to just below its 2018 level; however, emissions from the sector dropped to a level not seen since 2007. This large drop in emissions but small drop in energy demand was due to a complex set of factors, including the switch in some households away from more carbon-intense and costly electricity towards traditional fuels; a shift from commercial to residential energy use related to home-based working and schooling; and a continued investment in decarbonizing electricity grids. Despite the overall drop in emissions, the share of total emissions related to buildings in 2020 was very similar to previous years, as other sectors also suffered declines during the pandemic, including in transport demand and industry outputs.

3.5 GLOBAL AND REGIONAL DIFFERENCES IN BUILDING STOCK EMISSIONS

Africa. In 2019, the building stock on the African continent accounted for 60 per cent of the region's total final energy consumption and for around 32 per cent of its total energy-related CO_2 emissions (IEA 2020a). Bioenergy represents the vast majority of energy use in African buildings (around 80 per cent), with almost all (95 per cent) being traditional biomass and a major source of air pollution – explaining the large difference between energy consumption and CO_2 emissions. Electricity demand in buildings accounted for a further 9 per cent of energy use, followed by oil (5 per cent) and natural gas (4 per cent). The implication for the African building stock going forward is a much-needed shift towards greater access to and use of clean fuels, which could see a shift of electricity to 32 per cent of total energy demand in buildings by 2030, according to the IEA's sustainable development scenario (IEA 2020a).

Central and South America. In 2019, buildings accounted for 24 per cent of total final energy consumption in Central and South America, and for around 21 per cent of total energy-related CO_2 emissions. Electricity use accounted for 44 per cent of total final consumption in buildings followed by biomass (25 per cent, with more than 90 per cent of this being traditional biomass), oil (18 per cent) and natural gas (12 per cent) (IEA 2020a).

Asia. Across Asia, buildings' share of energy use in 2019 ranged from 49 per cent in China, to 25 per cent in India, to 23 per cent in the Association of Southeast Asian Nations (ASEAN) region. However, the fuels used in buildings vary considerably: in China, electricity accounted for 35 per cent and biomass for 15 per cent of building energy use, while in India electricity accounted for 19 per cent and biomass for 55 per cent (IEA 2020a).

Across countries still in the phase of economic development and growth in new buildings, opportunities exist for significant reductions in energy and emissions in the buildings and construction sector, as well as supporting universal access to electricity and clean cooking.

Box 4. UNFCCC Compendium on Greenhouse Gas Baselines and Monitoring – helping policymakers track national emissions from the buildings and construction sector

The United Nations Framework Convention on Climate Change (UNFCCC) is extending its compendium series on greenhouse gas baselines and monitoring, adding the *Compendium on Greenhouse Gas Baselines and Monitoring: Buildings Sector* to its published volumes on national-level mitigation actions and passenger and freight transport. The *Buildings Sector* compendium provides an overview of the various emission sources in buildings and provides common methods and tools for quantification. National decision makers can gain a better understanding of their country's building emissions and improve and refine their quantification methods, as well as set mitigation targets and policies for buildings and construction more effectively.

The compendium provides an overview of the depth and extent of the sources of greenhouse gas emissions in the buildings sector and introduces methods and instruments for quantifying these emissions. This is important for developing effective national strategies and measures to reduce emissions based on a holistic understanding of the extensive sources of emissions over the entire building life cycle, along the four key stages:

1. the production of building materials,
2. the construction or retrofit of buildings,
3. the operation and, finally,
4. the demolition of a building at the end of its lifetime.

Based on this approach, national mitigation impacts of the buildings and construction sector can be fed into national greenhouse gas inventories and be incorporated into the relevant UNFCCC reporting processes. The development of the compendium has been supported by the Buildings Performance Institute Europe (BPIE) and the Programme for Energy Efficiency in Buildings (PEEB).

3.6 TRANSITION TO NET ZERO EMISSIONS BY 2050

To meet the Paris Agreement goal of keeping global temperature rise to well below 2°C, the global economy should aim to achieve net zero CO_2 emissions by 2050. A growing number of countries and organizations have committed to a net zero goal, including for the buildings sector (e.g. through the Race to Zero, Science-based target initiative, Zero Carbon Buildings for all, CEM GlobalABC, Buildings as Critical Climate Solution, etc.), although the scope and details vary. Yet despite these ambitions and a growing number of pledges, governments and the business sector across the world have fallen short of what is required to decarbonize their economies – and also the buildings and construction sector.

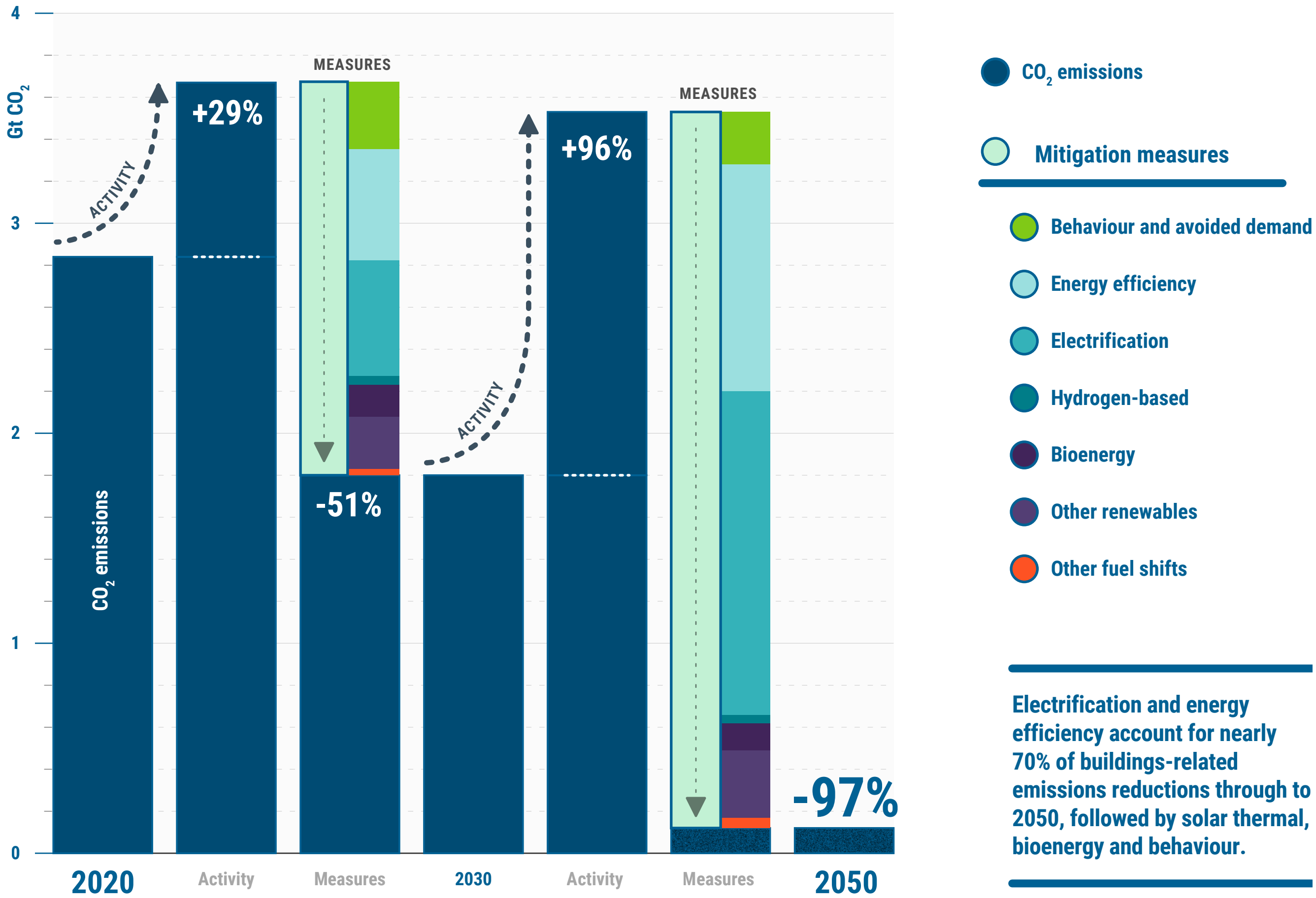
In its report, *Net Zero by 2050: A Roadmap for the Global Energy Sector,* the IEA recently illustrated the implications that meeting these ambitions would have for the global economy and the buildings sector alike (IEA 2021c). Figure 15 shows a possible a pathway towards net zero emissions for the buildings sector by 2050[9]. Currently, carbon emissions from buildings operations account for around 27 per cent of global energy-related emissions, and the added emissions from the manufacture of building materials and construction increase this to around 37 per cent (see section 3.4).

Looking at carbon from building sector operations, the net zero energy analysis shows that although building activity more than doubles by 2050 – i.e., more floor area, more access to energy services and higher living standards – emissions fall as a result of reducing energy demand (behaviour change, energy efficiency) and electrification, as well as other heating technologies. The net zero energy scenario suggests that, by undertaking these efforts, it could be possible to nearly eliminate carbon emissions from building sector operations by 2050.

9 *IEA's Net Zero Energy scenario is a scenario for the future, while the GBCT is a snapshot of the presence.*

Figure 16. Global direct CO_2 emission reductions by mitigation in building in the net zero energy scenario 2050

Electrification and energy efficiency account for nearly 70% of buildings-related emissions reductions through to 2050, followed by solar thermal, bioenergy and behaviour



Electrification and energy efficiency account for nearly 70% of buildings-related emissions reductions through to 2050, followed by solar thermal, bioenergy and behaviour.

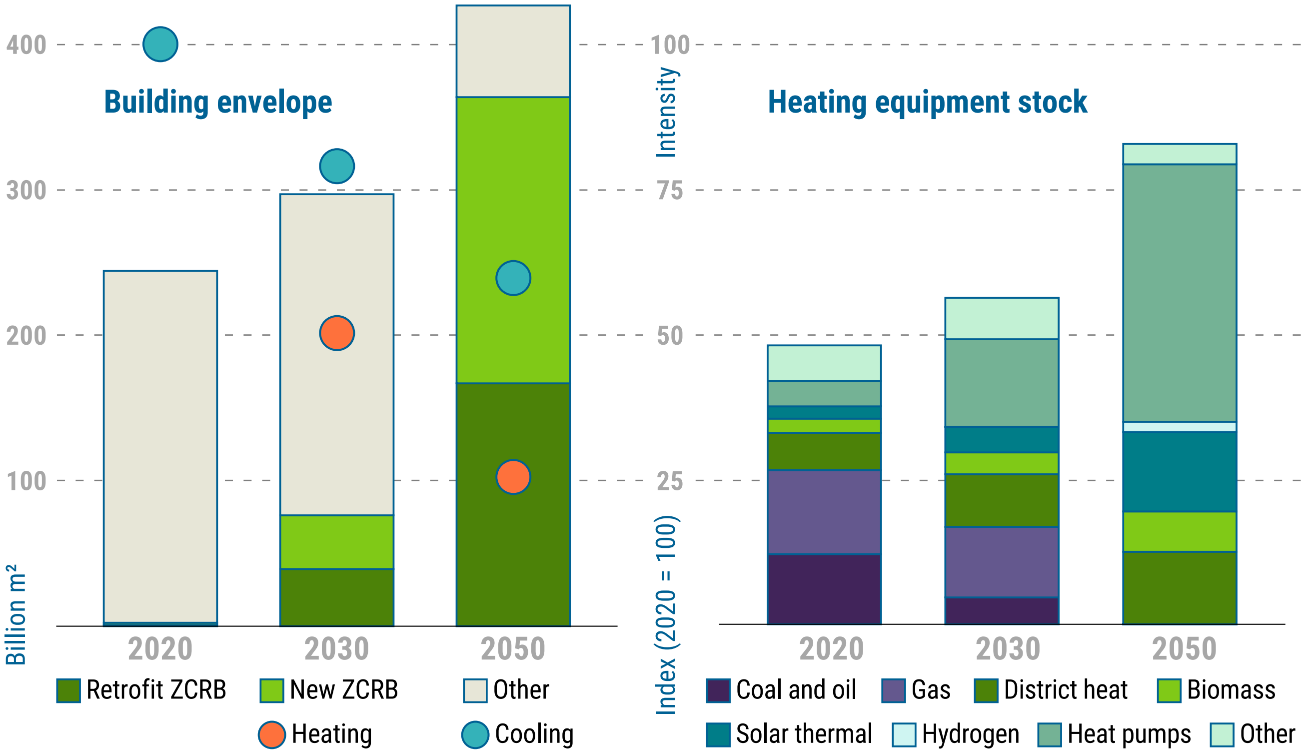
Notes: Activity = change in energy service demand related to rising population, increased floor area and income per capita. Behaviour = change in energy service demand from user decisions, e.g. changing heating temperatures. Avoided demand = change in energy service demand from technology developments, e.g. digitalisation.

Sources: IEA 2021c. All rights reserved.

The IEA report shows that the energy supply for space heating in buildings is transformed in the net zero energy scenario, with all coal and oil boilers being phased out in home heating by 2025, and homes heated by natural gas falling from nearly 30 per cent of the total today to less than 0.5 per cent in 2050. Meanwhile, homes using electricity for heating rise from nearly 20 per cent of the total today to 35 per cent in 2030 and around 55 per cent in 2050, with the remainder heated through district heating, solar thermal and biomass (see figure 16).

Bio-climate and adaptive building designs, along with building envelope improvements in zero-carbon-ready retrofit and new buildings account for most of the heating and cooling energy intensity reductions in the net zero energy scenario, but heating and cooling technology also makes a significant contribution. Through deep retrofits and the construction of highly efficient new buildings, cooling intensity could be reduced 25 per cent by 2030 and almost 50 per cent by 2050.

Figure 17. Final energy consumption by fuel and end-use in buildings in the net zero energy scenario 2050



By 2050, over 85% of buildings are zero-carbon-ready, reducing average useful heating intensity by 75%, with heat pumps meeting over half of heating needs

Note: ZCRB -= zero-carbon-ready buildings

Sources: IEA 2021c.

To set the global building sector on a pathway to net zero emissions by 2050, the IEA outlines a series of milestones that can serve as indicators to assess how on-track the buildings sector is and the scale of the transformation required (see figure 17). The indicators include: a near-term energy intensity improvement pathway; increasing the share of building stock that is zero carbon ready from less than 1 per cent today to 20 per cent by 2030 and almost 100 per cent by 2050; drastically increasing the stock of heat pumps and solar thermal systems, plus LEDs accounting for 100 per cent lighting by 2030; increasing appliance efficiency to consume 25 per cent less by 2030 and 40 per cent less by 2050; significantly growing solar PV generation; and finally, all new buildings need to be zero-carbon-ready by 2030.

Figure 18. Indicators for reaching net zero buildings within the net zero energy scenario

	2020	2030	2050
Energy intensity	Improve by 6% per year 2020-2030	Improve by 4% per year 2030-2040	Improve by 3% per year 2040-2050
Share of existing buildings net-zero ready	<1%	20%	>85%
Avoided demand in homes from behaviour	-	12%	14%
Stock of heat pumps	180 million	600 million	1 800 million
Dwellings with solar thermal	250 million	400 million	1 200 million
Appliances unit consumption (realtive to 2020)	-	-25%	-40%
Distributed PV generation	320 TWh	2 200 TWh	7 500 TWh

Sources: IEA 2021c.

To decarbonize the buildings and construction sector along those lines, while also addressing materials, governments need to put in place policy and technology measures in eight specific categories, as outlined in the GlobalABC global and regional roadmaps (GlobalABC/UNEP, 2020). These categories are: urban planning, new buildings, existing buildings, operations, systems, materials, resilience and clean energy (see figure 17).

Figure 19. GlobalABC regional decarbonization roadmaps: Eight key categories

Urban planning	Urban planning decisions and strategies not integrated across themes	**Prioritise integration in rapidly expanding cities** Integrate energy efficiency in urban planing policies, develop national and local urban plans and ensure collaboration among national and subnational levels and across themes
New buildings	Most construction occurring in places with no codes for mandatory minimum energy performance	**Prioritise high efficiency standards** Develop decarbonisation strategies, implement mandatory building energy codes, incentivise high performance
Existing buildings	Performance of existing buildings generally unknown, few energydriven retrofits	**Accelerate action on building retrofits** Develop and implement decarbonisation strategies for refurbishment and retrofit, increase renovation rates and depth, encourage investment
Building operations	Minimal use of tools for energy performance, disclosure and management	**Facilitate maintenance and building management** Sustained adoption of energy performance tools, systems and standards enabling evaluation, monitoring, energy management and improved operations
Appliances and systems	Average efficiency of appliance and systems much lower than best available technology	**Stimulate demand for energy efficient appliances** Further develop, enforce and strengthen minimum energy performance requirements, prioritise energy efficiency in public procurement
Materials	High embodied carbon of materials, low awareness of impact and options, little data and information	**Promote the use of low carbon materials** Develop embodied carbon databases, raise awareness and promote material efficiency, accelerate efficiency in manufacturing to reduce embodied carbon over whole life cycle
Resilience	Some planning strategies for natural disasters, but not widespread	**Build-in resilience for buildings and communities** Develop integrated risk assessment and resilience strategies to ensure adaptation of existing buildings and integrate resilience into new construction
Clean energy	Significant use of fossil fuels; 39% population no access to clean cooking, 11% no access to electricity	**Accelerate the decarbonisation of electricity and heat** Develop clear regulatory frameworks, provide adequate financial incentives, encourage on-site renewable energy or green power procurement, accelerate access to electricity and clean cooking

Box 5. Net zero emission commitments

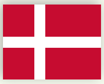
According to the Net Zero Tracker (2021), two countries – Bhutan and Suriname – have achieved net zero emissions status. Eleven countries plus the EU have enacted legislation to achieve net zero emissions by at least 2050, with Canada, Japan, New Zealand and the United Kingdom being the only non-EU nations of these to have done so. Below are examples of country net zero emissions actions decided in 2020 that are specific to the buildings and construction sector.

Bhutan

Bhutan has achieved net zero emissions after accounting for the carbon sequestration of its forests. The country's *Energy Efficiency Roadmap*, published in 2019, sets a target of saving nearly 700 terajoules of energy from the buildings sector through energy efficiency measures over the next five years (Royal Government of Bhutan 2019). Together with the emissions from industry and appliances, these savings should equate to emission reductions of 0.3 million tons of CO_2 equivalent per year between 2020 and 2034. Despite this, analysis by Climate Action Tracker suggests that Bhutan's efforts are only compatible with a global temperature rise of below 2°C, and further action is required to meet the safer limit of below 1.5°C.

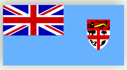
China

In a speech to the UN General Assembly in September 2020, China's President Xi Jinping set out a commitment to carbon neutrality by 2060 with an aim to see emissions peak before 2030 (UN News 2020). Within the scope of the 14th Five-Year Plan, new near-zero energy consumption building demonstration projects will be constructed, as well as the promotion of buildings renovation, prefabrication and low-carbon cities.



Denmark

Denmark enacted net zero legislation in June 2020 that seeks to reduce emissions 70 per cent from 1990 levels by 2030 and to achieve net zero emissions by 2050 (Government of Denmark 2020). Denmark is also covered by EU legislation calling for net zero emissions by 2050 (European Commission 2020b), which has a target of a reducing buildings-related emissions 39 per cent by 2030 (Klimarádet 2019). In December 2020, the Danish government published a medium- to long-term climate strategy, which aims to expand the EU's emissions trading scheme to cover buildings, phase out gas- and oil-powered heating systems after a mapping programme, and double the current rate of buildings renovations.



Fiji

As of September 2021, Fiji had yet to enact its legally binding net zero emissions commitment. However, the draft of the 2019 Climate Change Bill requires the Ministry of Health to oversee the enforcement of the National Building Code once the act comes into force and to review progress every five years towards the requirement of net zero emissions by 2050 (Government of Fiji 2019). Furthermore, the act acknowledges that "Fiji, the Pacific Region and the Earth are facing a climate emergency that requires a rapid and ambitious transformation towards a net zero emissions global economy". However, the specifics of how the National Building Code will reduce and ultimately eliminate Fiji's buildings emissions are yet to be specified.

United Kingdom

In 2019, the United Kingdom amended its greenhouse gas reduction target to net zero by 2050, across all domestic emissions. Specific measures to achieve net zero emissions from buildings are to be outlined in an upcoming Heat and Building Strategy, which has been delayed several times. This strategy will build on the Energy White Paper, which committed to improving energy efficiency in buildings (UK Government 2020). The Heat and Building Strategy paper is likely to set a date for the ban of new fossil fuel domestic boilers and outline the plan for improving the uptake of heat pumps (Woodfield 2021).

4. THE BUILDINGS AND CONSTRUCTION SECTOR PLAYED A MAJOR ROLE IN PANDEMIC RECOVERY PLANS

Buildings and construction sector plays a critical role in recovery plans. The impact of the pandemic on the construction sector has seen construction value drop across economies by around 4% and buildings have been an important part of stimulus plans.

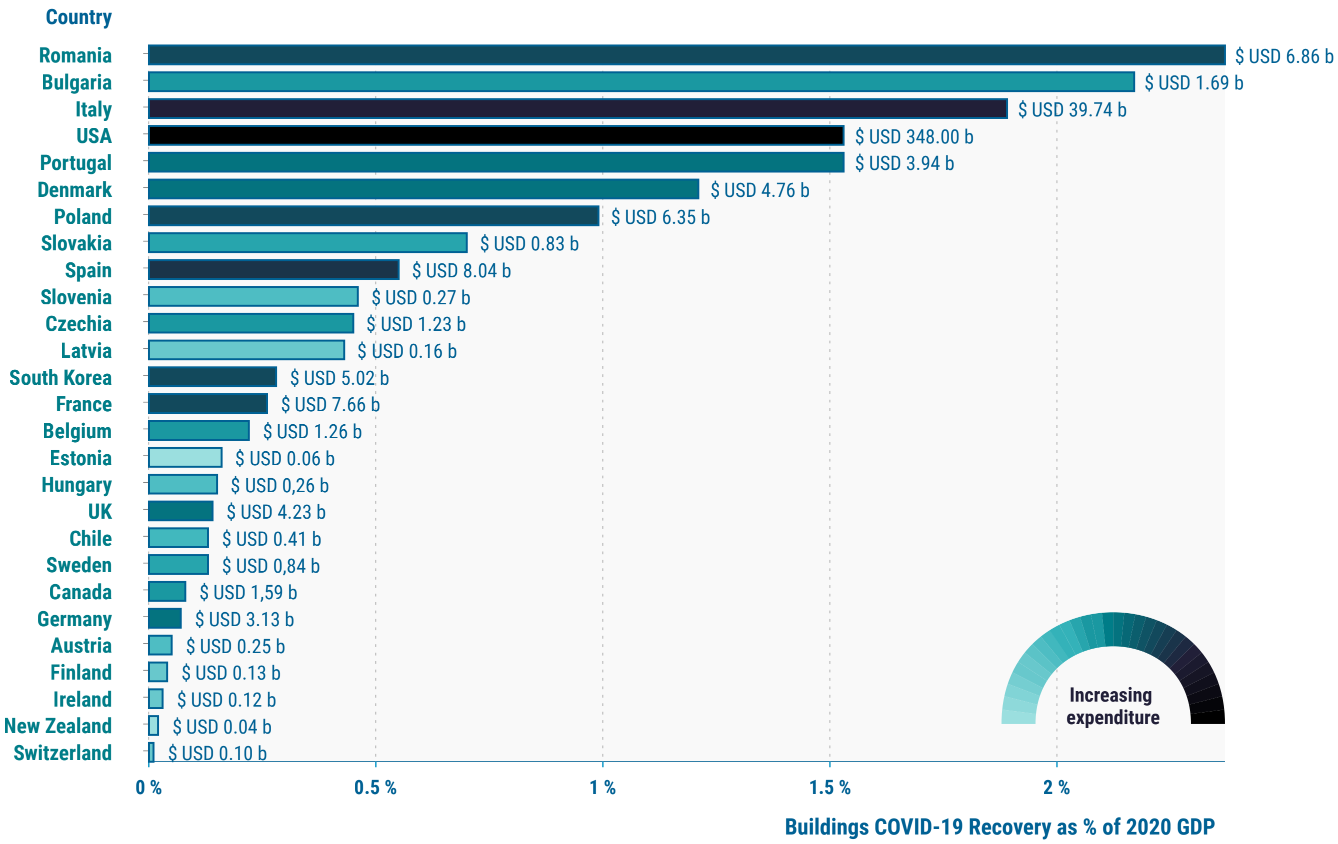
The economic impacts of the COVID-19 pandemic have been considerable, with the pandemic amounting to an estimated loss of around 6.7 per cent of global gross domestic product (GDP) in 2020 (Yeyati and Filippini 2021). The implications for the buildings and construction sector, which accounts for an estimated 4-7 per cent of the gross value added of most major economies (OECD 2021), has been severe (see section 3.1).

As was noted in the *2021 Global Status Report for Buildings and Construction*, the construction sector is essential for an economic recovery from the COVID-19 crisis and also offers a pathway forward to building a more sustainable future aligned with the goals of the Paris Agreement. The IEA's *Sustainable Recovery* report pointed out that stimulus programmes for the buildings and construction sector are a proven response to economic crises and will typically align to the needs that countries face for new buildings and renovation of existing buildings (IEA 2020c).

This section presents the economic policies that are aligned to supporting the transition towards a zero-carbon buildings and construction sector and draws on databases that have compiled commitments and actions.

Figure 19 provides a snapshot of recovery spending commitments focusing on buildings and construction as a proportion of 2021 GDP, by country. Selected countries are also discussed below. Analysis methods vary as to what policy measures are categorized as relating to buildings; here, the values reflect those compiled by Carbon Brief analysis, the Green Recovery Tracker and data for Switzerland from the Global Recovery Observatory (Evans and Gabbatiss 2020; Green Recovery Tracker 2021a; Smith School of Enterprise and the Environment 2021).

Figure 20. COVID-19 recovery funding relating to buildings as per cent of 2020 GDP, with total buildings commitment figures in billion US dollars



Source: Latest available data based on Carbon Brief (Evans and Gabbatiss 2020) and Green Recovery Tracker (2021a), with data for Switzerland from the Global Recovery Observatory (Smith School of Enterprise and the Environment 2021). Figures are liable to change as new policies are announced and programmes are cancelled.

Figure 19 shows that across all sectors (including buildings), Romania's recovery funding amounts to almost 17 per cent of GDP, with the EU recovery fund supplying 71 per cent of this. Around 14 per cent of total recovery funds are focused on buildings improvements. Analysis of Romanian spending by Green Recovery Tracker (2021b) found that 32 per cent of the around $5 billion in buildings spending will have positive climate impacts, with the effects of the remaining portion being uncertain. A key measure in Romania's recovery plan is the Renovation Wave, which commits to training contractors in historical building renovation techniques.

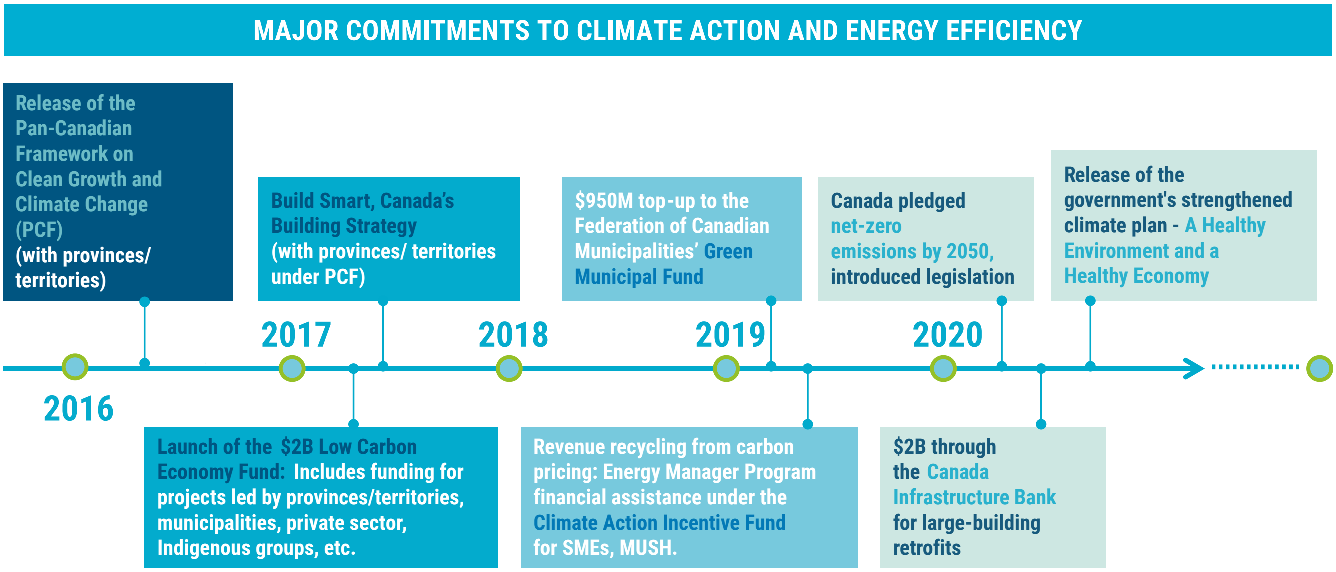
In Denmark, 30 billion Danish krone ($4.76 billion) has been allocated for green renovation of the public housing sector, around 72,000 dwellings, between 2021 and 2026 (Transportministeriet 2020). The funding also covers experimental approaches to improving the energy efficiency of buildings. Denmark is focusing more than 87 per cent of its COVID-19 recovery measures on buildings.

As of September 2021, New Zealand had largely prevented the spread of COVID-19 in the country and managed to keep its economy open during the worldwide pandemic. Recovery funding relating to buildings was limited to a $40 million expansion of the "warmer Kiwi homes" programme for low-income households, which provides heating retrofits and subsidized renovations (IEA 2021d).In Canada, the United States, and the European Union, recovery programmes are being implemented in different ways and with a variety of options for implementation and finance. The following sections provide an overview of the approaches and initial insights on these programmes in practice.

4.1 CANADA

In December 2020, the Government of Canada introduced Canada's strengthened climate plan, A Healthy Environment and a Healthy Economy (Government of Canada 2020). The plan builds on climate action efforts under way through the Pan-Canadian Framework on Clean Growth and Climate Change (Government of Canada 2016) and commits to new measures to address COVID-19 recovery and climate mitigation (see figure 20). Investments in the buildings sector include $1.5 billion for green and inclusive community buildings, with 10 per cent allocated to projects serving Indigenous communities (Government of Canada 2021a). The plan also provides $2.6 billion for home energy retrofit grants, evaluations, and support to recruit and train energy auditors (Government of Canada 2021b). This is in addition to $2 billion announced by the government in October 2020, as part of the Canada Infrastructure Bank's $10 billion Growth Plan (CIB n.d.), to finance large-scale private and public energy-efficient building retrofits.

Figure 21. Timeline of Canadian climate action

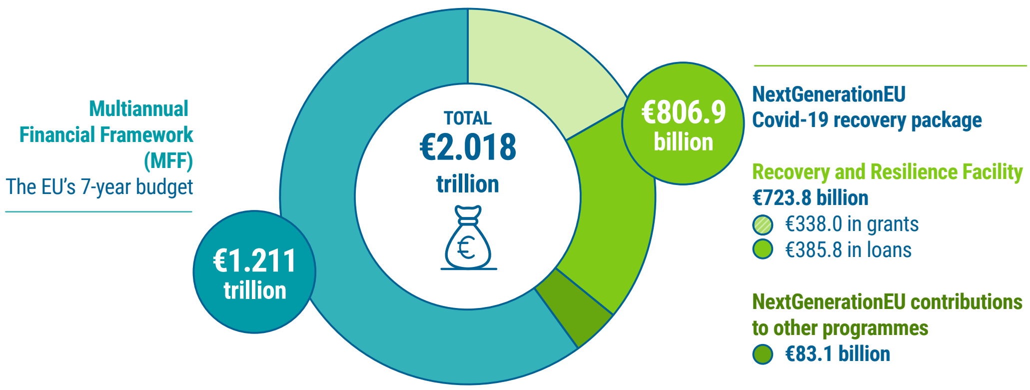


Source: BPIE 2021a

4.2 EUROPEAN UNION

In the European Union, under the EU Multiannual Financial Framework for 2021-2027 and NextGenerationEU (see figure 21), three main funding streams are addressing the COVID-19 recovery and climate mitigation in buildings: The Recovery and Resilience Facility under NextGenerationEU, the Cohesion Policy Funds and InvestEU. The three instruments target residential and non-residential buildings. The first two instruments target efficient construction, and all three support energy retrofits.

Figure 22. EU Multiannual Financial Framework for 2021-2027 and NextGenerationEU funding as of 7 July 2021



Note: All amounts are in current prices.
Source: European Commission n.d.a

Recovery and Resilience Facility (RFF). Investments and reforms to be financed under the RRF are aiming to have a lasting, positive impact on the economy and society, facilitate the green and digital transitions, and strengthen the growth potential, job creation, economic and social resilience of EU Member States. The renovation of buildings is one of the seven flagship recovery areas[10] identified by the European Commission.

Out of the RFF's €723.9 billion, 37 per cent (around €268 billion) is designated for climate initiatives, including the European flagships "Renovate" and "Power Up". Of this money, €125 billion will be available in the form of grants and €143 billion will be available for loans[47].

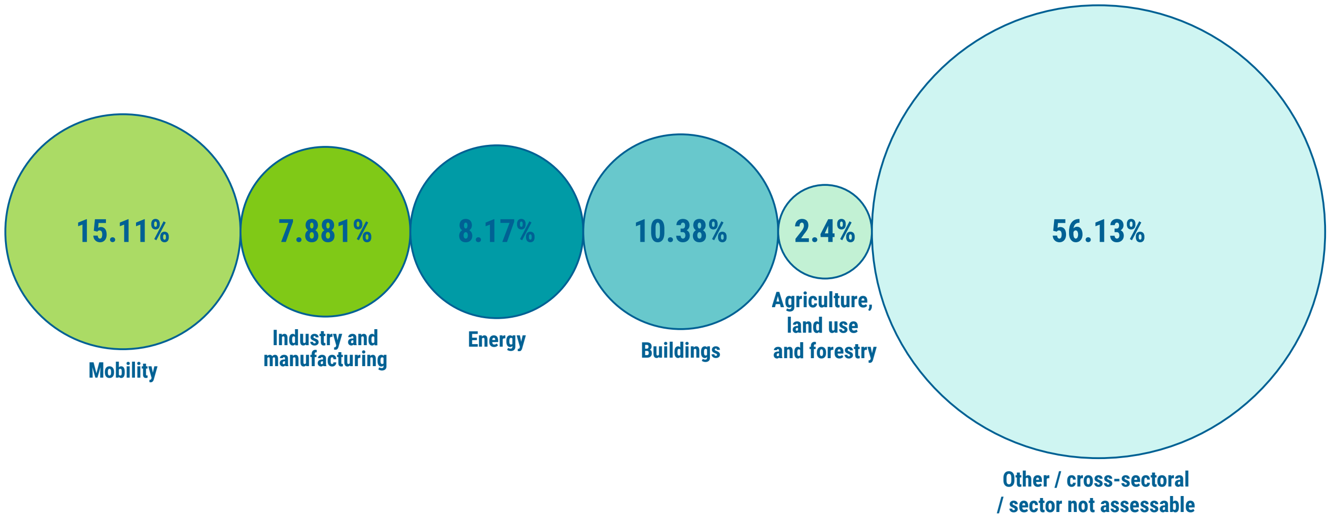
Under the RRF, EU Member States are required to submit National Recovery and Resilience Plans (NRRPs) and outline spending and recovery initiatives (see figure 22). NRRPs must support the objectives set out in the National Energy and Climate Plans (NECPs). Submission of the preliminary draft NRRPs was from 15 October 2020 to 30 April 2021, when 23 plans were put forward; they are now under review by the European Commission.

An independent analysis of the NRRPs shows that, on average, reports clearly define targets and ambitions, as well as outlining the implementation framework (Renovate Europe; E3G 2021). The same analysis finds that, on average, the plans are not well aligned with the long-term renovation strategies and could better address finance and investment, multiple benefits and integration as well supply chain and project support. Another analysis also found that in certain countries programs do not provide enough support to eradicate energy poverty and enable achieving the EU's green targets (Housing Europe, 2021)[11].In addition, there are challenges in managing the level of funding and accompanying procedures, due to the lack of the institutional capacity and skills in local governments.

10 *The seven flagship areas are: Power up, Renovate, Recharge and Refuel, Connect, Modernise, Scale-up, Reskill and Upskill. See European Commission (2020c).*

11 *According to Impact of the National Recovery Plans on the Affordable Housing Section, Housing Europe 2021*

Figure 23. Overview of the EU Member States' national recovery plans budget distribution



Note: The graph is based on the draft submitted by Member States in April 2021. The final submissions are currently under review and still subject to approval from the EC.

Source: Green Recovery Tracker 2021a

The Cohesion Policy Fund has a proposed budget of €330 billion. It targets to deliver high energy performance, in line with National Energy Climate Plans and Long-Term Renovation Strategies.

The Invest EU fund is a single fund combining several previous EU-level financial instruments. It is equipped with a €26.2 billion EU budgetary guarantee. The guarantee backs the investment of financial partners such as the European Investment Bank and increases their risk-bearing capacities. Of the EU budget (NextGenerationEU and the Multiannual Financial Framework 2021-2027), €10.5 billion is set aside in case calls are made on the guarantee. Up to €370 billion in additional investments across Europe will be mobilized for the four following thematic priorities ("policy windows"):

- **Sustainable infrastructure**
- **Research, innovation and digitalization**
- **Small and medium-sized companies**
- **Social investment and skills.**

At least 30 per cent of the InvestEU Programme should support finance for investments that contribute to the EU's climate objectives. At least 60 per cent of finance for investments under the "Sustainable infrastructure" window should contribute to the EU's climate and environmental objectives.

4.3 UNITED STATES

In mid-July 2021, the United States Senate passed a $1 trillion infrastructure bill to restore and invest in American roads, bridges and water infrastructure and to enhance broadband internet, as well as several other initiatives. The overall budget includes $550 billion in federal spending. While there is emphasis on environmental initiatives, mainly electric vehicles, transport, waste site management, upgrading water infrastructure, and updating power lines, the original budget allocated for building retrofits and for research and development was removed. The bill has yet to be passed by congress and signed into law.

The Biden-Harris administration has committed to producing and retrofitting more than 2 million affordable homes with $213 billion in funding. A further $100 billion has been allocated to building new and upgrading existing schools, with an additional $25 billion towards the construction and upgrade of new childcare facilities.

5 SUSTAINABLE BUILDINGS AND CONSTRUCTION POLICIES

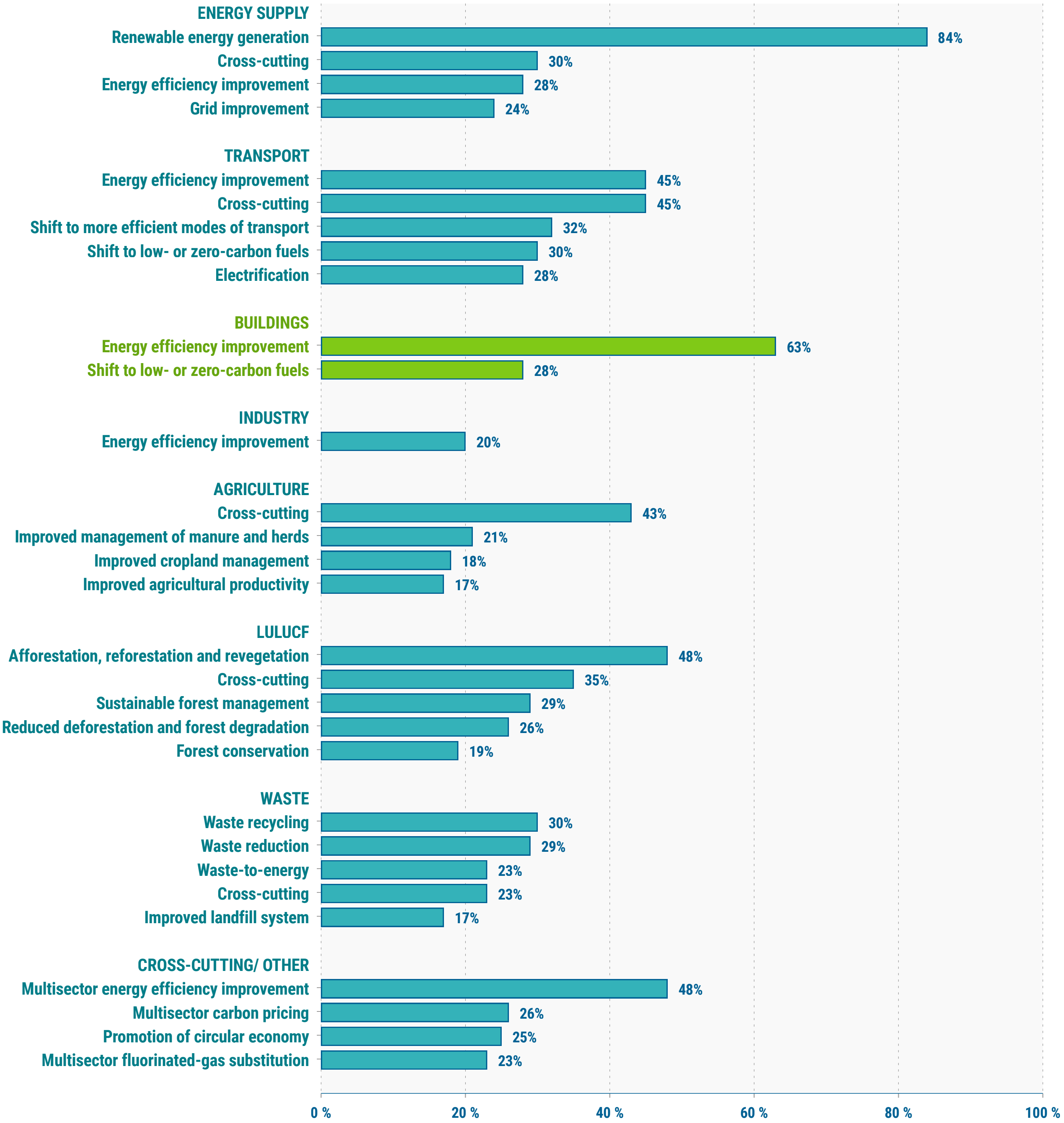
Energy efficiency and energy codes in buildings are the second most frequently cited actions within all Nationally Determined Contributions. Countries increasingly recognize that building energy codes are essential, yet their application remains low in Sub-Saharan Africa and in South and Central America.

The policy landscape for decarbonizing the global buildings and construction sector continues to change, through frameworks such as the UNFCCC's Nationally Determined Contributions, which rely on countries own commitments towards meeting the Paris Agreement, and through national policies and measures such as building codes and energy efficiency delivery programmes.

5.1 ENERGY EFFICIENCY IN BUILDINGS RANKS AMONG THE FIRST OPTIONS IN NATIONALLY DETERMINED CONTRIBUTIONS

This section provides updates on the NDCs since the *Buildings Global Status Report 2020*. Since December 2020, 80 countries have submitted new or updated NDCs on the UNFCCC central repository website (UNFCCC n.d.b). In total, 192 countries had submitted a first NDC, 113 of which have been updated, and 11 countries had submitted their second NDC as of September 2021. Across the NDCs that have been communicated, improvement in building energy efficiency is the second most frequently referred to policy after renewable energy for the power sector (see figure 23).

Figure 24. Share of Parties referring to the frequency indicated mitigation options in Nationally Determined Contributions



Note. If a Party communicated more than one measure for one of the frequently indicated mitigation options, it was counted as one Party communicating measures for that option.

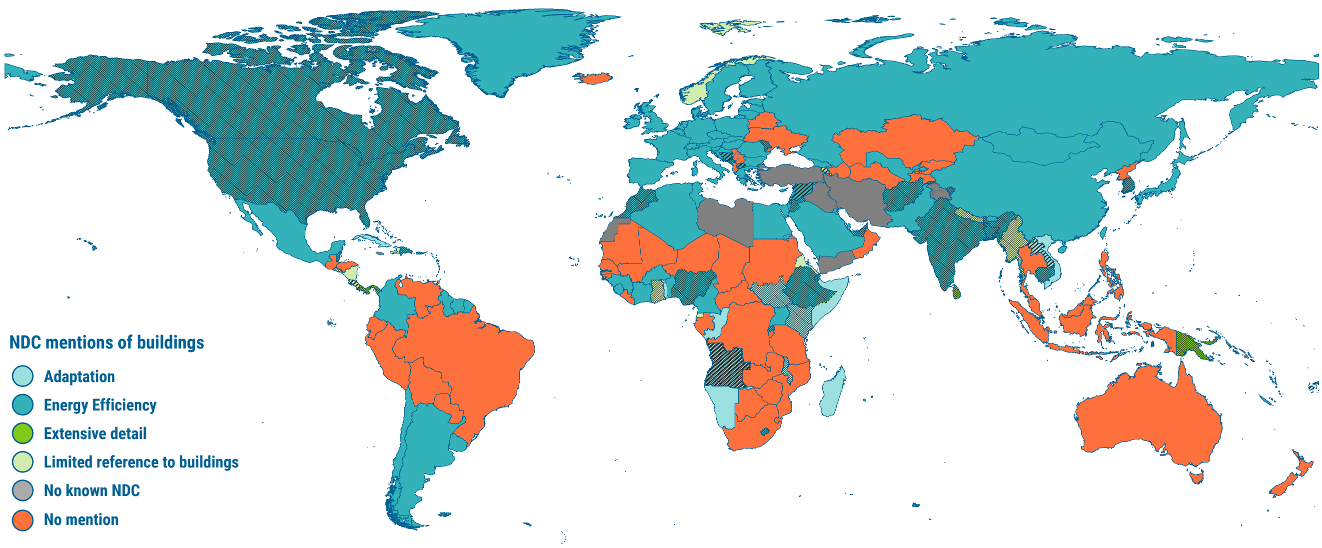
Source: UNFCCC 2021

The following section was created using text mining techniques to highlight mentions of buildings within each NDC.[12] False positive matches, such as "capacity building", were excluded. Appropriate translations were undertaken for the few NDCs that are provided in French or Spanish.

Of the 56 countries that have updated their first NDC, several observations are discernible (see figure 24 and table 1). Brazil, Honduras, Iceland, Peru, Sudan and Zambia still have no mention of buildings measures in their NDC updates. In contrast, Colombia, the EU, Lebanon, Maldives, Montenegro, Panama and Vanuatu all now mention efforts at either improving energy efficiency in buildings or reducing building-related emissions. Typically, if energy efficiency measures for buildings are mentioned in the first NDC, they will also be mentioned in the updated version. Notable exceptions are Armenia, Costa Rica, and Fiji, which, despite mentioning building-related emissions or energy use in the first NDC, do not provide further detail in the first NDC update.

12 Each NDC was converted into plan text format. A key word in context search was applied to each NDC for 'buildings'. False positives such as 'capacity building' were removed and the remaining matches coded using the categories shown in Figure 24. 'Extensive detail' includes mentions of energy efficiency and adaptation.

Figure 25. Mentions of buildings across all countries' latest Nationally Determined Contributions



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

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 broad right-hatching have less detail in updated NDCs than previous versions.

Source: UNFCCC.

Table 1. Selected countries' first, first updated and second Nationally Determined Contributions with building-focused actions, submitted since September 2020

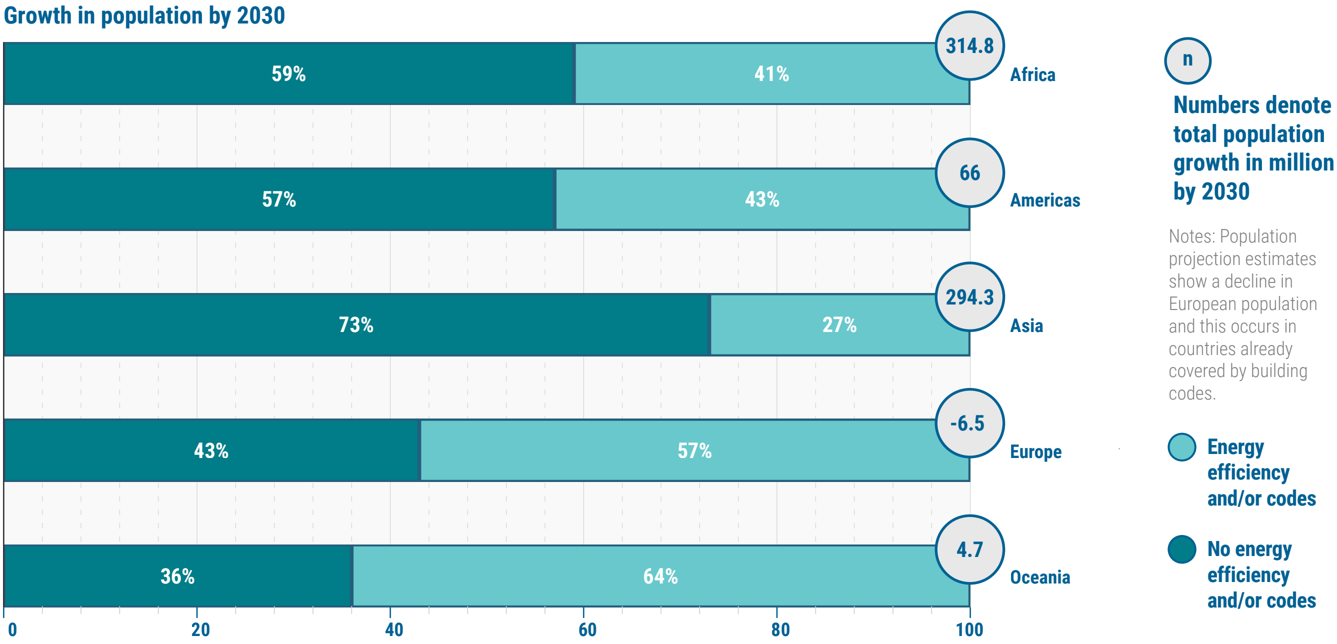
Country	Date	Description of measures relevant to buildings	Type
Sri Lanka	30/07/2021	Introduce mandatory building energy efficiency code in 2021-2022. Establish sectoral databases for eco-certification system, minimum performance and energy efficiency labelling programmes, green building and Building Management System (BMS).	First Updated NDC
Bhutan	24/06/2021	Energy Efficiency Roadmap 2030 covering buildings was launched in 2019 covering 155 gigawatt-hours annually in materials, appliances, and construction. Solar PV on buildings. Energy efficient building design.	Second NDC
South Sudan	22/02/2021	Investment in resilience of the building stock. Ensuring building codes are appropriate under climate change projections.	First NDC
Cambodia	31/12/2020	Building codes, enforcement/certification to for new buildings to reduce electricity consumption by 10% in 2030. Improve cooling in public sector buildings to reduce CO_2 by 43,000 tons per year. Passive cooling in buildings (reduction of 74.5 tons of CO_2 equivalent).	First Updated NDC
Marshall Islands	30/12/2020	No mentions of buildings, but the initial version of the second NDC mentioned buildings energy efficiency measures such as building codes and retrofits to reduce cooling demand.	Updated Second NDC
Dominican Republic	29/12/2020	Introduce a new building code to improve energy efficiency to be implemented between 2023 and 2030. Policy instruments to promote green buildings. Reduce new buildings emissions by 10% per year (for a total of 0.7 million tons of CO_2 equivalent).	First Updated NDC
United Arab Emirates	28/12/2020	Retrofit 30,000 buildings by 2030. Green building regulations have already been implemented.	Second NDC
Maldives	28/12/2020	Building labelling and building standards to improve energy efficiency. Improve building code for climate resilience.	First Updated NDC
Papua New Guinea	15/12/2020	Improved building insulation and energy efficiency. Introduce building codes to mitigate impacts of heat waves and cyclones and for adaption.	Second NDC
Tonga	09/12/2020	Introduce energy efficiency standards for buildings and energy performance audits (although no further details are given). Minimum energy performance standards for appliances in buildings.	Second NDC
Nepal	08/12/2020	Adopt national building code emphasizing low-carbon and climate-resilient urban settlements.	Second NDC
Grenada	30/11/2020	No mentions of buildings. The first NDC for Grenada mentioned energy efficiency measures, namely building retrofit to ensure a 20% reduction in energy use by 2025 and the adoption of energy efficiency building codes for all buildings sectors.	Second NDC
Russian Federation	25/11/2020	Development of buildings energy efficiency measures and risks of damage to buildings due to melting permafrost.	First NDC

Mention should be given to the updated first NDC of Bangladesh, which highlights the importance of LEED building certification in managing energy consumption in commercial buildings. Cambodia's updated first NDC is 158 pages long and outlines specific emission reduction targets within the construction sector: for example, a commitment to reducing brick production emissions by 44 per cent (1.799 million tons of CO_2 equivalent) by 2030, public awareness campaigns, and new building codes, enforcement, and certification for new buildings. The Ministry of Land Management, Urban Planning and Construction Cambodia with UNDP and the GlobalABC also developed an *'NDC Roadmap for Low-Carbon, Climate Resilient Buildings and Construction'* outlining priority action to increase the scale, pace and impact of climate action towards a zero-emission, energy-efficient and resilient buildings and construction sector.

While equivalent commitments exist for other countries, they are not necessarily outlined in the NDC update. The United Kingdom has submitted its first updated NDC since leaving the EU, which highlights its Net Zero Strategy ahead of the 2021 UN climate conference. However, as with New Zealand's short NDC update, the tendency of some countries to reference policy documents outside the formal NDC structure makes specific buildings-related policies difficult to compare. The United States has issued its first updated NDC since it committed to re-joining the Paris Agreement and makes mention of "high-performance" electrified buildings and the adoption of modern energy codes.

The predicted growth in population and demand for floor area presents and serios challenge to reaching a net-zero, energy efficient and resilient buildings and construction sector. Using UN Population growth estimates we show that 65% of projected population growth by 2030 will occur among countries that have NDCs that mention building energy efficiency and/or building codes to improve energy performance (Figure 27). The critical issue going forward is whether the ambition of NDCs might drive the adoption of building energy codes.

Figure 26. % of population growth 2021-2030 covered by NDCs which mention Energy efficiency and or/codes by UN Region using 2019 UN population projections[13].



Notes: Population projection estimates show a decline in European population and this occurs in countries already covered by building codes.

13 https://population.un.org/wpp/Download/Archive/CSV/

Box 6. Efforts to support Nationally Determined Contributions

Viet Nam: NDC roadmap for a low-carbon and climate-resilient building sector to 2050

Construction in Asia is booming, and by 2040 the region will be home to nearly half of all new construction in the world. Energy demand for cooling in buildings is expected to soar. Reaching net zero emissions in the buildings sector is possible but requires clear and ambitious policy signals and financing.

In Viet Nam, as in other Asian countries, the buildings and construction sector is key for meeting the climate mitigation targets set out in the Paris Agreement by 2050. The *NDC Roadmap for a Low-carbon, Climate-resilient Buildings and Construction Sector in Vietnam* identifies the aspirational targets, actions and timelines to enable Viet Nam´s transition towards a zero-emission, energy-efficient and resilient buildings and construction sector (PEEB 2021a).

The roadmap development, supported by the Programme for Energy Efficiency in Buildings (PEEB), builds in the methodology and structure of the *GlobalABC Regional Roadmap for Buildings and Construction in Asia 2020-2050*, developed by GlobalABC and the IEA in 2018. It identifies common goals, targets and timelines for key actions across eight “activities”, each of which represents a segment of the buildings and construction sector: urban planning, new buildings, existing buildings, appliances and systems, building operations, materials, resilience and clean energy (GlobalABC, IEA and UNEP 2020c).

The roadmap serves the Vietnamese government to create one common vision and provide orientation and guidance to the diverse public and private key stakeholders of the buildings and construction sector as well as non-governmental organizations and civil society. Going forward, the government intends to build up capacities and strengthen responsibilities for each key activity area such as sustainable urban development, new construction, rehabilitation and materials through the relevant ministries and government agencies for implementation. For this purpose, a steering structure in the form of an NDC implementation platform for the building sector is envisaged.

NDC Buildings Toolkit: practical guidance, examples and tools for setting up effective building sector actions

GlobalABC, the Global Buildings and Performance Network and PEEB are elaborating an NDC Buildings Toolkit, building on the *NDC Guide*. This toolkit is divided into three key steps – Mapping, Prioritizing, and Implementation and Monitoring – and describes individual actions for each step, referring to practical databases, tools, studies and examples from different countries. Thus, it helps to tackle the complex buildings sector systematically in small, manageable steps.

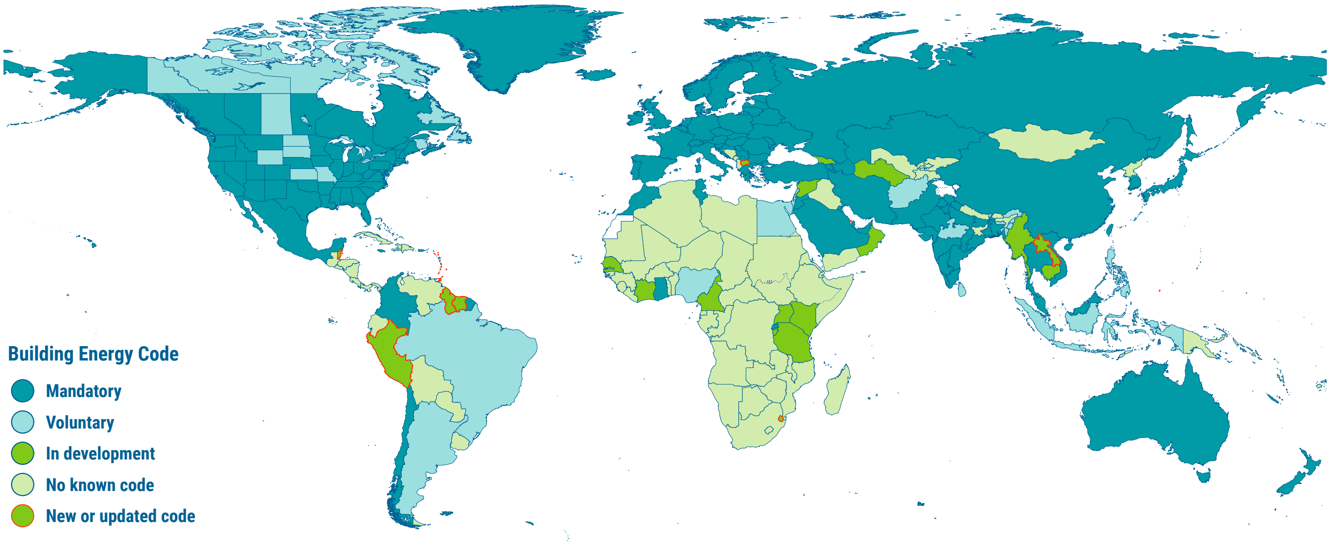
The users of this toolkit can find their appropriate entry step to suitable and meaningful activities, depending on how far they have progressed in concretizing the buildings actions for their NDCs. The toolkit is intended to be a living instrument into which further tools and country examples are added and that continues to grow. The NDC Toolkit provides governments with a practical guide to systematically take stock of the national building sector and analyse key barriers, to prioritize effective mitigation and adaptation actions for buildings and construction and to define concrete action as NDC contributions.

5.2 MORE COUNTRIES HAVE BUILDING ENERGY CODES, BUT CODES ARE STILL MISSING IN MANY AFRICAN COUNTRIES

Cutting building-related emissions by improving energy efficiency is a crucial aspect of meeting net zero by 2050 climate change goals. To do this, the energy use of buildings must be monitored and managed, and buildings must be built and retrofitted to use less energy over time. Building energy codes provide a tool for governments to mandate the construction and maintenance of low-energy buildings. However, current coverage of building energy codes is far from universal, and where they are implemented, they are typically incompatible with achieving net zero by 2050.

As of November 2021, 80 countries had mandatory or voluntary building energy codes on the national or sub-national level, out of which 43 countries had mandatory codes on the national level for both residential and non-residential buildings. Local governments and municipalities also may introduce building controls (REN21 2020, p. 59), although these are not included in the above estimates. Figure 25 shows the current extent of national and sub-national building codes worldwide. Sub-Saharan Africa and South and Central America have the least coverage of mandatory building energy codes. However, there are some signs of change, notably through the 2018 CARICOM Regional Energy Efficiency Building Code (CREEBC), which is currently being implemented throughout the Caribbean.

Figure 27. Building energy codes by country/state



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

Note: Recent updates are highlighted with a red border. Building energy codes relating to specific cities only are not shown.

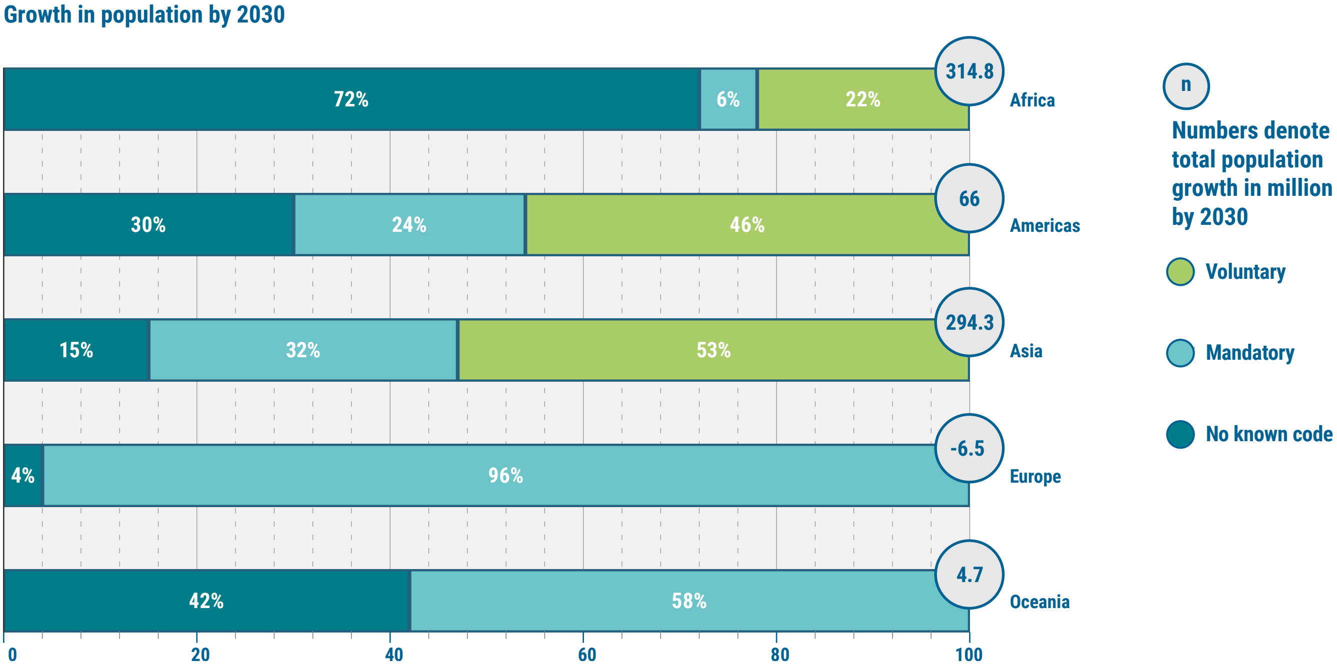
Source: IEA 2021e. All rights reserved.

In addition to the mandatory/voluntary distinction given in figure 25, building energy codes can be separated into prescriptive versus performance standards. Prescriptive standards require that each building component or material be manufactured to a particular standard. Performance standards require that the building in-use has specific characteristics, whether that be lighting levels, air flow rates or energy use (see box 7).

Due to the complexity of the built environment, its varied usage and age structure, and the diversity of materials and construction techniques that are employed, enforcing building energy codes is often a challenge for local and national governments. Recent improvements in in-use building monitoring technologies, such as smart meters for domestic and small-scale commercial operations and Building Energy Management systems for larger buildings, may provide tools for government to identify sectors of the building stock that use the most energy. However, these approaches are currently limited to highly developed economies and require advanced training for proper maintenance.

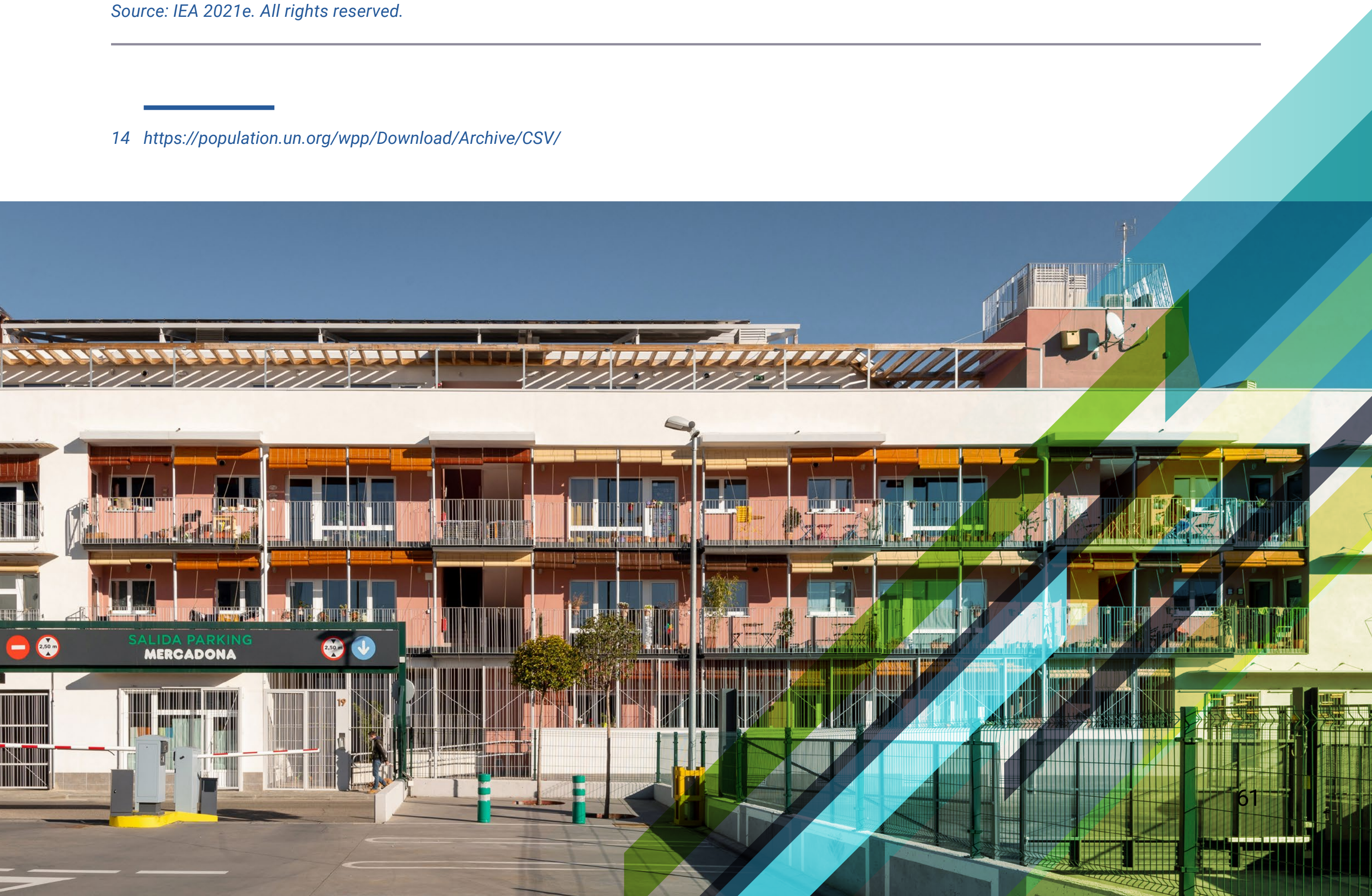
Using the same approach above, Figure 29 shows that 82% of the population that is to be added by 2030 are living in countries without any building energy codes or only voluntary codes. Of those, 44% currently have no building energy codes and 38% have only voluntary codes. Most of this global growth in population with no current codes is in Africa at 34% of total growth in 2030. An additional 33% of population growth in Africa and Asia will occur in countries that currently have only voluntary codes.

Figure 28. % of population growth 2021-2030 covered by mandatory, voluntary, or no known code by UN Region using 2019 UN population projections[14].



Notes: Population projection estimates show a decline in European population and this occurs in countries already covered by building codes.
Source: IEA 2021e. All rights reserved.

14 *https://population.un.org/wpp/Download/Archive/CSV/*



Box 7. Recent updates to building energy codes

National building energy codes – global update

Although no new national updates to building energy codes have been issued since the *2021 Global Status Report for Buildings and Construction*, several countries are currently in the process of developing a code. Notable among these is the second version (August 2020) of the 2018 CARICOM Regional Energy Efficiency Building Code, which is being adopted across the Caribbean nations. Building energy codes are also being developed in Bahrain, Eswatini, Laos, North Macedonia, Palau and Peru (Sustainable Energy Authority n.d.; Government of Eswatini 2019; Sustainable Energy for All 2017; Energy Community n.d.; Green Climate Fund 2019; Factor n.d.).

ICC's Energy and Climate Initiative

The International Code Council (ICC) is a member-focused association dedicated to helping the building community and the construction industry provide safe, resilient and sustainable construction through the development and use of model codes (I-Codes) and standards used in the design, construction and compliance processes. The ICC has recognized the essential role that I-Codes and supporting resources play in realizing energy efficiency and greenhouse gas reduction goals. In early 2021, the ICC Board of Directors released a new framework, Leading the Way to Energy Efficiency: A Path Forward on Energy and Sustainability to Confront Climate Change (ICC n.d.), leveraging the International Energy Conservation Code (IECC) and International Green Construction Code (IgCC), plus additional resources to help all levels of government advance these goals.

The IgCC provides the design and construction industry with the single most effective way to deliver sustainable, resilient, high-performance buildings beyond requirements contained in base codes. The ICC is building on technical solutions to address communities' energy efficiency and greenhouse gas reduction goals which include a new scope and intent for the IECC that integrates pathways to reach set targets, development of energy efficiency and greenhouse gas reduction resources, and an Energy and Carbon Advisory Council of governmental and built environment leaders. The 2021 IECC represents a roughly 40 per cent improvement in energy efficiency for residential and commercial buildings compared to the 2006 edition. The ICC, through the IECC, IgCC, and additional solutions, and collaboration with key stakeholders, will continue to lead change throughout the buildings sector to support resilience and mitigation in the face of a changing climate.

Stretch energy codes – New York City

New York City has become a national leader in sustainable construction policies and practices through the continual provisions to the New York City Energy Conservation Code (NYCECC). The New York State Energy Law authorizes New York City to enact its own energy code, considering that the City's code is more stringent than the requirements for the New York State Energy Conservation Construction Code (NYSECCC). Through the NYCECC, New York City has been regulating the energy consumption of its building stock since 2009 by way of periodical updates in compliance with Local Law 85 and a recent vote for provisions of the NYCECC to meet requirements of the 2018 International Energy Conservation Code and requirements of ASHRAE Standard 90.1-2016. To address the unique and dense construction environment of New York City and to align with the state's NYStretch Energy Code-2020, New York City continues to ensure that construction of new buildings, additions and alterations will achieve 80 per cent greenhouse gas reduction by 2050 through its local laws.

Zero Code

Architecture 2030 is a non-partisan, non-profit organization that developed the Zero Code in coordination with the American Institute of Architects and ASHRAE. The Zero Code provides a framework for the construction of zero-carbon buildings, through stringent energy efficiency standards and the incorporation of renewable energy sources into the buildings' energy use. It applies to the mid-/high-rise residential, commercial and institutional buildings that predominate in city centres. In summer 2020, renewable energy portions of the Zero Code were incorporated into a voluntary appendix to the International Building Code (Zero Code 2020).

6 INVESTMENT AND FINANCING FOR SUSTAINABLE BUILDINGS

Global investment in the energy efficiency of buildings increased an unprecedented 11 per cent, dominated by EU investments. The flow of finance to this area continues to accelerate.

Overall investment in energy efficiency increased significantly in 2020, primarily through targeted government support in Europe. However, this relative increase occurred as most economies slowed and as the buildings and construction sector faced unprecedented challenges in demand, delivery and supplies. The need to meet the global lack of housing alongside the need to decarbonize the building sector means that more investment in improving existing buildings and in constructing buildings that are net zero emission is needed from all actors in the finance and investment sector.

6.1 INVESTMENT ACTIVITIES (PUBLIC AND PRIVATE)

Despite the COVID-19 pandemic, global investment in energy efficiency in the buildings sector rose an unprecedented 11.4 per cent in 2020 to around $184 billion, up from $165 billion in 2019. For the first time since 2015, annual growth in energy efficiency investment has exceeded 3 per cent (IEA 2021b).

Despite the negative impact of the pandemic on investment in the global building construction sector, which fell an estimated 2 per cent to $6 trillion in 2020, increased investments in Europe supported the acceleration in global investments in buildings efficiency (IEA 2021b).

Efficiency investment is driven in part by the activity of the construction industry and its delivery of new buildings that are rated as low energy or sustainable, with their efficiency exceeding required codes. The second driver is investment in the renovation and refurbishment of existing buildings to have more efficient systems, which occurs either through direct investments by building owners, or through government policies using incentives and programmes. In major developing economies such as China, India and Southeast Asia, efficiency investments are mainly related to new construction, whereas refurbishment is the dominant activity in Europe and North America, where annual replacement of the building stock is low.

The global energy efficiency investment in buildings in 2020 was highly impacted by the accelerated return of spending in European economies, with large government-led initiatives, particularly in Germany, Italy, France and the United Kingdom. In Asian markets the picture was mixed, with some economies (e.g., India and the ASEAN region) showing declines in energy efficiency investment, whereas investments increased 5 per cent in China, 2 per cent in the Republic of Korea and 1 per cent in Japan. In the United States, a major contributor to global construction activities, energy efficiency investment increased 3 per cent in 2020. The global growth in spending shows a reversal from the 2019 trend, which saw limited energy efficiency investment in Europe and growth in Asian markets.

Economic stimulus related to the COVID-19 pandemic has not been the main source of increase in investment, although initial announcements have provided some additional funding support. Italy, for example, announced up to €500 million per year for municipalities to invest in the energy efficiency of public buildings as well as a Superbonus programme that offers a tax incentive worth 110 per cent of the investment for energy-efficient renovations.

The effect of government policies in Europe focused on meeting carbon emission reduction targets is beginning to take effect. Germany, for example, has seen a doubling in energy efficiency expenditure in buildings related to the ramp up of the development bank KfW's efficient construction and renovation programmes to €30 billion. The KfW investment represented nearly a fifth of the total global energy efficiency investment in 2020 and marks an important indicator of government investment in climate mitigation action. The United Kingdom increased efficiency expenditure by 18 per cent in 2020 through both established programmes such as the Energy Company Obligation (ECO) and the stimulus-related Green Homes Grant, although the latter was scrapped in March 2021. In addition, in September 2020 the French government announced nearly €7 billion for energy efficiency improvements in private homes, office buildings and public buildings such as schools and town halls. However, the subsidies will be available only from 2021 onwards.

Although COVID-19 stimulus efforts were committed in 2020, they largely had not yet begun to take effect in efficiency expenditure data for the year and will likely mark a further increase in spending for 2021. However, the scaling up of existing programmes in Europe has also shown the importance of strengthening long-term government climate mitigation efforts to accelerating the growth of efficiency investments. The key challenge for governments over the coming months will be to solidify the pandemic economic response towards securing a low-carbon, efficient and resilient building sector through both increased government support as well as strengthened energy performance regulations and codes.

Box 8. Public and private sector investment activities related to the energy efficiency of buildings

Green-certified warehouses in Romania

The warehousing logistics company WDP has adopted EDGE ("Excellence in Design for Greater Efficiencies") certification in Romania to quantify the performance of its portfolio in terms of energy, water and materials, and to establish a plan for reducing the carbon footprint of its entire portfolio of new and existing developments. EDGE has been applied to 48 logistics buildings across the country, with warehouses ranging in size from 2,500 square metres to more than 60,000 square metres (Property Funds World 2021).

EDGE fits ideally with WDP's desire to quantify and evaluate the sustainability performance of new and existing assets, and provides a level of detail on energy, water and material performance to continuously improve the performance of its assets. For example, around one-third of WDP sites in Romania are equipped with solar panels. EDGE helps quantify the value of solar and other technologies within the WDP Romania portfolio and provide comparative performance data that feed into the creation of future strategy.

By taking an analytical approach to managing and improving the sustainability performance of its portfolio, WDP can continuously improve its performance and use EDGE to develop a pathway towards a net zero ambition. The adoption of EDGE in Romania was linked to a green financing package from the International Finance Corporation (IFC) and a financial agreement between the European Bank for Reconstruction and Development and WDP. This green loan, in tandem with other financial support, was designed to enhance Romania's infrastructure and create jobs in a modern, healthy and sustainable working environment.

Green financing in Singapore

Real estate green financing has been gaining traction in Singapore since 2017, as the country pivots towards a green economy. Developers, asset owners and investors seeking to demonstrate sustainability in their corporate values are driving the trend, aiming to carve stronger value propositions for their investors and to uphold resiliency against risks. One of the most popular forms of green financing in Singapore's real estate industry is green loans, which are often used in buildings that have maintained a green building certification. Green financing could also drive demand for new buildings to be green and for green retrofits in existing buildings.

In addition to the market-driven green bonds and loans, the government provides financing support for energy efficiency retrofits in buildings. The Building Retrofit Energy Efficiency Financing (BREEF) scheme offers financing to support the upfront costs of retrofits through an energy performance contract (EPC) where the Building and Construction Authority of Singapore shares 40 per cent of the risk of any loan default with the participating financial institutions. The key condition of the credit facility leads to the existing buildings achieving the Green Mark certification standard, which is maintained throughout the loan tenure. To support this, the Singapore Green Building Council (SGBC) developed a template EPC for retrofit projects to serve as a standard reference document to help building owners and EPC firms achieve a hassle-free energy efficiency arrangement. The SGBC also has an accreditation scheme to list EPC firms and their financial capabilities.

6.2 INVESTMENT FLOWS ARE ON THE RISE

More and more asset owners are looking to certify their entire building portfolios as green, driven mainly by investors seeking to future-proof against climate transition risks, regulatory pressures and consumer sentiment. This shift has mobilized greater interest in green financing of both new builds and retrofits, as big firms are setting their sights on a pathway to carbon neutrality.

Like many sectors, building investment has suffered from the impacts of COVID-19, but green certification continues to gain market share. Warehouses, data centres and low-income housing have all proven to be strong green investment performers in a COVID economy. Supply chain uncertainties that require more inventory storage, in addition to the accelerated growth in e-commerce and the governmental perception of housing as a key lever to build back better and create jobs, has driven increased investor interest in these key markets.

In Mexico, the real estate investment trusts (REITs) Fibra Macquarie and Fibra Shop are in the process of certifying their entire portfolios green, through a combination of retrofit investments and setting higher quality-on-entry standards. Meanwhile, the real estate investment fund manager AshmoreAVENIDA announced that it would certify all its projects as green in 2021 and is courting investors with an all-green themed Latin American real estate fund.

Globally, institutional investors, banks and real estate fund managers are taking their cue from the European Union's taxonomy on sustainable economic activities and its sustainability disclosure requirements (see box 9), which kick in at the end of 2021. Beyond the EU, additional countries including Colombia, India, South Africa and Viet Nam are preparing similar green taxonomies to best position their markets for international investment. This approach will encourage widespread adoption of the EU's quantitative approach to defining green buildings, based on kilowatt-hour consumption per square metre.

Box 9. The EU Sustainable Finance Strategy and the taxonomy for sustainable building activities

The European Union is a major source of foreign direct investment globally including buildings and construction and has been championing approaches for sustainable financing through its EU Sustainable Finance Strategy (European Commission 2021a). The Strategy sets out a comprehensive framework to transform the financial and industrial sectors and mobilize the investments needed to move the EU towards climate neutrality. The strategy focuses on three main areas:

1. definitions, standards and labels for sustainable financial assets and products – this includes an EU taxonomy on sustainable economic activities and sustainability disclosure requirements;
2. pipeline development and scaling-up of investments as well as investment protection; and
3. better accounting of climate and environmental impacts and risks, and the revision of financial stability risk frameworks.

The Programme for Energy Efficiency in Buildings has put together a detailed description of the EU taxonomy and its implications for buildings and construction in the report *EU Sustainable Finance in External Action: An Opportunity to Promote Sustainable Buildings* (PEEB 2021b). The EU taxonomy is a classification of economic activities that can be labelled as environmentally sustainable and aims to shape finance flows, primarily within the EU. However, it is expected to also affect the rest of the world, due to the many EU-based private and institutional investors as well as insurers and commercial banks that operate globally.

These investors will be able to transfer their experience with identifying sustainable activities and analysing non-financial information disclosures abroad. The impact of the taxonomy will be further reinforced through a proposed new EU corporate sustainability reporting directive. The directive would require all large and listed companies to report sustainability information, including the percentage of capital expenditure on activities aligned with the EU taxonomy.

The regulation on the EU taxonomy provides a classification of activities in the buildings sector that can be considered "sustainable". This classification is supposed to guide investments towards activities that are in line with the EU's climate targets. The taxonomy outlines the activities defined as sustainable based on six environmental objectives: climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems. For each activity, it establishes technical screening criteria (see table 2) as well as "do no significant harm" criteria that must be fulfilled for the activity to be considered sustainable.

Table 2. Technical screening criteria for the buildings sector under the EU taxonomy

Type of activity	Technical screening criteria
Construction of new buildings	Primary energy demand of new construction is at least 10 per cent lower than nearly zero energy building requirements in national measures. Energy performance is certified by energy performance certificate. For buildings greater than 5 000 square metres, life-cycle global warming potential is calculated, and the level of performance is tested post-construction, with both disclosed to investors and clients.
Renovation of existing buildings	As applicable in national regulations for major renovations, or reduction of primary energy demand of at least 30 per cent.
Acquisition and ownership of buildings	Buildings built before December 2020 are at least EPC class A, or within the top 15 per cent of national building stock expressed in primary energy demand. Buildings built after December 2020 meet criteria for "construction of new buildings". Large non-residential buildings with HVAC output greater than 290 kilowatts are operated efficiently through energy performance monitoring and assessment.

The taxonomy addresses some of the key difficulties in increasing finance for green buildings while avoiding greenwashing – such as a lack of a common understanding of what sustainability and/or Paris alignment mean in the context of buildings, and by what metrics to judge the investment opportunities as well as the limited requirements (and capacities) for information disclosure. Due to this lack of information, transaction costs are usually high for non-specialist investing entities trying to assess risk and increase the available capital for sustainable buildings.

Box 10. Examples of investment flow actions for green and sustainable buildings

The EU taxonomy already reaches beyond Europe

Tour F, to be the tallest building in Côte d'Ivoire with 64 floors of office space, will be EDGE certified. The $451 million project, by Pierre Fakhoury Organization Africa and BESIX in Brussels, will receive funding from Société Générale France, one of the many banks that will shortly report its portfolio against the EU taxonomy.

Green retrofits

In June 2021, Business Partners Limited, a leading non-bank financial institution in South Africa, closed $44 million in green financing from the IFC to retrofit commercial properties, specifically targeting small and medium enterprises. This is the first green commercial building finance for such enterprises made available to the South African market.

In the Philippines, NEO Office and Menarco Development Corporation are retrofitting around 145,000 square metres of commercial space to attain EDGE zero carbon certification and better access to finance.

Industry leaders take aim at net zero carbon

The German multinational retail group Schwarz Group plans to reduce its greenhouse gas emissions (scope 1 and 2) 55 per cent by 2030 compared to 2019. A key part of the plan is green new building design and retrofits as well as certification for the group's entire fleet of buildings.

Balwin Properties in South Africa had the largest EDGE registration by a developer globally, with 2 million square metres of floor area and more 900,000 square metres certified so far. With this large green home pipeline, Balwin partnered with Absa bank to develop a green mortgage to provide home buyers with preferential rates for purchasing a green home. Balwin is now raising its sights to zero-carbon-ready projects by aiming for EDGE Advanced certification on all its new projects, which will put them in line for EDGE Zero Carbon certification.

In the Philippines, the first non-bank issuer of green bonds, Arthaland, is using its $60 million in green bond proceeds to finance a portfolio of upcoming EDGE Zero Carbon projects.

Under the Net Zero Asset Managers Initiative, a group of 128 institutional investors collectively representing $43 trillion in assets under management have pledged to reach net zero carbon emissions by 2050 (Net Zero Asset Managers Initiative 2021). These investors are actively seeking out green projects to finance, but the demand is much greater than the supply, leading to reduced capital costs for qualified green assets.

According to the Climate Bonds Initiative's report *Sustainable Debt: Global State of the Market 2020*, issuance of green bonds increased 9 per cent in 2020 – down from 49 per cent in 2019, but still sound considering general market conditions (Climate Bonds Initiative 2021). This growth rate brings the cumulative green bond volume to $1.3 trillion. The Climate Bonds Initiative projects that the annual issuance volume of green bonds could exceed $1 trillion in 2023. More than three-quarters of issuance comes from developed markets, but green bonds are increasingly being issued in emerging markets as well. Green bond quality assurance is also improving, with the share of new issuances providing external reviews rising from 82 per cent to 89 per cent.

Green buildings represent the second biggest use of green bond proceeds after energy investments. Out of total green bond issuance of $290 billion in 2020, more than a quarter ($76 billion) was tagged for green buildings. As the green bond market has matured, the Climate Bonds Initiative has recorded a growing body of evidence for a "greenium", or lower yield, on green bonds compared to similar traditional bonds. A study of 75 bonds issued in 2021 indicated better book cover and spread compression for green bonds.

Anecdotes from developing countries suggest that issuers are also seeing greater market access. This was the case in August 2021 when Emergence Plaza issued the first corporate green bond in West Africa, to refinance the Cosmos Yopougon retail complex in Abidjan, Côte d'Ivoire, lowering financing costs by 150 basis points. A partner at Hudson & CIE, which arranged the transaction, commented: "We have been trying to attract foreign investors into our market… this could be a direct route" (Squazzin 2021).

Growth in green bonds for energy-efficient buildings is just one indicator of the flow of capital into the sector. Banks are also increasing green building construction and mortgage finance.

Given the long tenure of real estate loans, future-proofing against energy regulations (such as the Dutch Housing Ministry's ban on renting inefficient residences set to take effect in 2023) is vital. About four years ago, ING and Barclays announced that they were evaluating the energy efficiency of their real estate portfolios. Their approach included encouraging green retrofits as well as controlling quality on entry for new building projects. ING now offers technical assistance and reduced rate loans for residential and commercial retrofits in the Netherlands, and is aiming for 100 per cent of its commercial portfolio to carry green certification by 2023.

In Colombia, banks' preference for green assets is fueling a green building revolution. No fewer than five Colombian banks – Bancolombia, Davivienda, BBVA, Banco Caja Social and Banco de Bogotá – are now courting the green building sector with preferential financing packages, including green mortgages. The IFC estimates that more than 15 per cent of the formal new build in Colombia was certified green in 2020. The local chamber of construction, CAMACOL, which pioneered EDGE certification for the mass market, is now encouraging market leaders to aim for zero-carbon-ready buildings. At the same time, global banks such as Standard Chartered are offering clients free green building certification advice worldwide.

The cadre of green mortgage providers is expanding globally (see box 11). In 2020, one of the biggest mortgage providers in the United Kingdom, Nationwide, launched reduced-rate mortgages for energy-efficient homes (EPC rated A or B), after completing a study showing that energy-efficient homes yielded lower risk mortgages. Other notable newcomers in the green mortgage market, in addition to the banks in Colombia, include Absa in South Africa and FNB Itau in Brazil, as well as the secondary market mortgage finance company National Home Mortgage Finance Corporation of the Philippines. The EU taxonomy and the efforts of the EU's Energy Efficient Mortgage Initiative (EEMI) are likely to lead to greater uniformity in green mortgage definitions globally and to a more clearly delineated asset class. Moving forward, this is likely to lead to greater flows of capital into the sector, as rating agencies can evaluate expected superior financial performance.

Alongside the EEMI, the Energy Efficient Mortgage (EEM) Label is a new quality instrument allowing transparent identification of energy-efficient mortgages for market stakeholders. The Label was launched in February 2021 with the support of the European Commission and denotes a further effort towards sustainability in the finance and real estate / building sectors in compliance with the EU legal framework. The Label allows easier access to energy efficiency financing and green bond markets and enables lending institutions that are committed to continuous progress and improvement initiatives to disclose energy efficiency data and thereby jumpstart the investment and mortgage market for energy efficiency finance. Drawing on the success of the Covered Bond Label, the EEM Label is proposed as a market intervention to support recognition of and confidence in energy-efficient mortgages and to facilitate access to relevant, quality and transparent information for market participants.

Multilateral development banks are increasingly supporting financial institutions developing green building products and services. For example, the IFC is supporting more and more financial institutions in growing their green building portfolios. Just over the last year, the IFC has begun support for the following institutions: HDFC and Aavas Financiers Ltd (India); OCBC NISP (Indonesia); Commercial International Bank of Egypt; and Business Partners Ltd (South Africa). The UK-IFC Market Accelerator for Green Construction (MAGC) programme has been a key lever, providing both technical assistance and concessional finance.

Box 11. The win-win-win of green mortgages is clear for even the humblest homes

With green mortgages, homebuyers win, developers win, and banks win. A green mortgage is simply a mortgage extended on a green building, but table 3 illustrates the many forms green mortgages may take and how each form delivers value. The example taken comes from a new paper published in in Journal of Enterprise Development and Microfinance (Vol. 32, Issue 3) and focuses on an affordable residence costing $15,000 (Music, 2021).

In Scenario 1, which presents a green home with a conventional mortgage, the monthly utility savings exceed the higher mortgage payments and decrease the overall cost of ownership by 6 per cent, despite a slightly higher selling price to cover the cost of green measures.

In Scenario 2, the developer sells the green home without any price premium to save financing costs by accelerating the pace of sales; this delivers a reduction in the cost of ownership of 7 per cent.

Scenario 3 illustrates the impact of a lower down payment, which is a particularly strong incentive for low-income homebuyers and can be enacted through government policies. The down payment in Scenario 3 is reduced from 20 per cent to 15 per cent without any increase in the cost of ownership.

Finally, Scenario 4 illustrates a lower interest rate offered by the bank, based on the lower risk of default and superior collateral value of a green home. This scenario reduces the total cost of home ownership by 8 per cent.

Table 3. Relative benefits of a conventional home and mortgage versus a green home and innovative mortgage scenarios

	Base case: Conventional home, conventional mortgage	Scenario 1: Green home, conventional mortgage	Scenario 2: Green home, developer absorbs incremental capital cost	Scenario 3: Green home, lower mortgage down payment	Scenario 4: Green home, lower mortgage interest rate
Price of conventional home ($)	15 000	15 000	15 000	15 000	15 000
Incremental cost of green measures ($)	–	150	150	150	150
Price of green home ($)	15 000	15 150	**15 000**	15 150	15 150
Down payment (% of price)	20%	20%	20%	**15%**	20%
Down payment ($)	3 000	3 030	3 000	2 273	3 030
Loan amount ($)	12 000	12 120	12 000	12 878	12 120
Interest rate	18%	18%	18%	18%	**17.5%**
Term (years)	10	10	10	10	10
Monthly mortgage ($)	216	218	216	232	214
Monthly utility savings ($)	–	−15	−15	−15	−15
Monthly cost of ownership ($)	216	203	201	216	199
Change in resident's monthly cost of ownership	–	**−6%**	**−7%**	**0%**	**−8%**
Change in bank's monthly income	–	**1%**	**0%**	**7%**	**−0.8%**

Source: Music, 2021

7 GLOBAL DATA MAPPING

The availability of data describing the global building stock is limited and lacks sufficiently high resolution to present a clear picture of the trends and changes experienced across regions and parts of the sector.

Policy that aims to manage and shift energy demand and use in buildings requires an evidence base to inform the shaping of instruments and mechanisms to achieve desired outcomes. The goal of achieving a sustainable built environment in terms of energy demand in buildings requires information on the many interacting drivers that extends beyond metrics of building energy use and emissions to more details on building construction types, materials and energy service systems (e.g., heating, cooling, ventilation, lighting and appliances).

Essential to the development of a strong evidence base is the use of empirically derived data from large populations that can represent the real-world conditions of a complex building stock and population. Evaluating policies and determining the effect of technologies *in situ* in millions of buildings then also means using techniques that support that level of analysis.

This section summarizes the data availability needed to support both the *Global Status Report for Buildings and Construction* and actions in the buildings and construction sector more broadly. It provides a review and evaluation of access, coverage and quality of data for indicators needed for tracking progress within the *Global Status Report for Buildings and Construction*. It also includes a targeted survey of GlobalABC members.

7.1 AVAILABILITY OF BUILDINGS DATA

Information about energy demand in buildings at the national level, and particularly among developing economies such as trends and patterns along with simple descriptions of population and stock segmentations – is limited or simply lacking (Summerfield and Lowe 2012). Without even basic descriptions and agreed metrics of energy demand in buildings, developing a policy framework to achieve change in demand is undermined by the general lack of a robust evidence base and a misunderstanding of consequential drivers. Historically, this lack of evidence is related to prioritization of funding and study, the transient nature of government and academic research, and a dearth of observed data and therefore reliance on models that suffer from lack of primary observation information.

Supporting the development of a strong evidence base on the energy performance of buildings requires having access to research from different "levels" of data. These include high-level aggregate ecological-style studies (i.e., using small area statistics), cross-sectional studies of individual units of observations (people, buildings, households, premises, meters, etc.), carefully constructed representative samples, and exploratory and investigative studies (which in turn need to be examined within the population again).

The energy and buildings field faces a major challenge in being able to draw together insights from existing conditions and applied technologies due to the absence of or limited access to high-quality data on people and buildings as well as to high-resolution energy data. The risk is that without detailed data collection and storage, and longitudinal analysis or systematic reviews of research findings, it is not currently viable to support project-by-project learning. The implication of this limited data collection and access is that empirical studies have had a limited impact on the policy process.

Without better data and more joined-up interdisciplinary research, we risk being unable to identify and mitigate the unintended consequences of our actions in the transition towards a sustainable built environment for energy demand and buildings. The objective of this section is to discuss the co-benefits of data in transitioning to a sustainable built environment for energy demand and buildings and the mechanisms needed to enable them.

7.2 BUILDINGS DATA ASSESSMENT

The availability of data describing the building stock at national levels and within sectors is limited and lacks sufficiently high resolution to present a clear picture of the trends and changes experienced across regions and parts of the sector.

This section presents for the first time a data mapping activity following an in-depth search and review of databases and datasets that can provide insights in describing the trends and drivers affecting energy performance and carbon performance within the building stock. The review focused on evaluating data sources that could provide a global picture with an appropriate level of detail for a range of indicators, as shown in table 4. These indicators were selected based on a review of existing resources, including the GlobalABC Roadmaps, a GlobalABC survey, IEA and UN publications, academic literature and industry reports. The selected indicators were drawn from a longer list of over 200 indicators potentially available to track the status and changes among the global buildings and construction sector towards aligning with the Paris Agreement. The final list was not meant to be exhaustive, but rather to focus on those indicators that would be of high priority for describing the overall sector experience and changes.

The purpose of the review was to present an in-depth review of indicators that would be available to support the overall reporting of the *Buildings Global Status Report* and related GlobalABC activities, along with a description of the current status of the data. The data review comprised first a review of more than 300 sources of information across the globe through internet and member survey identification. For each dataset, where available, the potential fit for acting as or supporting the indicators was established based on its definition and description. Then, each dataset was classified according to four criteria: coverage, quality, continuity and accessibility (see box 12). Finally, the indicators were evaluated with the perspective of identifying and evaluating data that were global, of a high quality, continuous and updatable, and accessible for research.

Box 12. Criteria used for assessing the indicators selected for the Global Status Report for Buildings and Construction

Each indicator was assessed using a three-level scale – high (green), medium (amber) and low (red) – subject to the four following criteria.

Quality: This assesses how robust the available information is, whether it is corroborated by multiple sources and methods, and whether it is backed up by peer-reviewed analysis. Since data quality often varies by country, this assessment covers all available countries in aggregate – if particular countries' data are unreliable, then the overall quality of the indicator is lower.

Coverage: This reflects the extent of geographic coverage of the indicator. A high level of coverage indicates that all or nearly all countries are covered, medium represents good coverage across major economies such as all OECD countries, and low corresponds to coverage of a few select countries or amalgamated regions.

Continuity: Ideally indicators are updated at least yearly (high continuity). Medium continuity corresponds to updates every few years or several consecutive years covered, and low continuity means that a single data snapshot of a given year is available.

Accessibility: This reflects the level of public access for the data underpinning the indicator. Under best practice, all data are publicly available for free (high accessibility). A medium score corresponds to some data being publicly available in a limited manner, such as annual reports. A low score corresponds to all data being either unavailable or behind subscription paywalls.

The review shows that some very basic information on buildings is largely lacking or incomplete (see table 4). Building stock characteristics at a global scale and national level are mostly unavailable, which means that tracking the changes in the composition and amount of building stock area constructed is very challenging. No global source of data yet exists to describe buildings in this form, and the knock-on implications are that activities related to economic activities, energy and CO_2 emissions, and materials are all open to uncertainty. Data covering the energy use and emissions of buildings are available for a fee from the IEA's database of energy and CO_2 emissions, although more specific estimates of emissions from global construction materials related to operational energy use during production are not available in a disaggregated form (IEA 2020d).

Table 4. Buildings and construction data mapping assessment

	Indicators	Quality	Coverage	Continuity	Public Access
Stock characteristics	Building stock by age				
	Total gross building floor space (m²)				
	Floor space area per capita (m²/person)				
	Total gross building floor space by sector (m²)				
	Annual growth in floor area (m²/year)				
	Annual growth in floor area by sector [residential, non-residential] (m²/year)				
	% cooled and heated floor space [residential vs non-residential] (%)				
	Annual rate of refurbishment (% of floor area/stock)				
Economic	Construction economic activity [gross value added] ($/year)				
	Total building investment (public and private) ($/year)				
	Total building investment (public and private) by residential and non-residential ($/year)				
	Incremental energy efficiency investment in buildings ($/year)				
	Investments in clean energy in building sector ($/year)				
Energy	Energy demand in buildings (GJ or MWh/year)				
	Access to electricity (% of population with access)				
	Proportion of population with primary reliance on clean fuels and technology (% of population reliant)				
	Building energy consumption per capita (MJ/person/year)				
	Total final energy supply intensity by floor area (MJ/m², kWh/m²)				
	Total final energy demand intensity by floor area (MJ/m², kWh/m²)				
	Share of renewables of buildings total final energy supply (%)				
	Share of renewables of buildings total final energy demand (%)				
	Renewable energy generation from buildings (GWh/year)				
CO_2	CO_2 intensity of newly built area ($kgCO_2/m^2/year$)				
	CO_2 intensity by floor space ($kgCO_2/m^2/year$)				
	Carbon intensity of construction activities ($kgCO_2/m^2/year$)				
Labels, certification and NDCs	Number of buildings with green certification (N)				
	Number of new buildings with energy performance labels (N)				
	Number of new buildings with green certification (N)				
	Number (list) of countries with NDCs with building sector actions (N)				
Materials	Total carbon emissions of construction goods production ($tCO_2/year$)				
	CO_2 intensity by construction material type ($kgCO_2/kg$)				
	Embodied energy-related carbon emissions of construction goods production ($tCO_2/year$)				
	Proportion of recycled or reused materials by type [wood, concrete, steel, glass, brick] in construction (%)				

The two main areas lacking data are building stock construction activities – i.e., how much floor space is added and of what type and construction quality – and building stock materials. For building floor space, although data from the UN's indicator on "construction of new buildings" provide some details on activities for specific countries across the world (UN Data n.d.), these data lack consistent detail on the breakdown of residential versus non-residential buildings, construction quality and information to determine potential energy performance levels. There are several proprietary or private sources of data, but such resources are available only through licence or purchase arrangements. Publicly available information on materials is also lacking, with either small-scale databases or selected global-level sectoral estimates of emissions and use of building materials, such as steel, concrete and glass. For example, the UN tracks cement production across 47 countries, but provides no further breakdown about final material end use (UN, 2021) [64].

Overall, the mapping and availability of relevant buildings and construction data – data that can showcase the current status and changes in trends and that can track the shift towards a net zero carbon, efficient and resilient building stock – is not promising. Considerable effort is needed to bring this sector into an improved state for tracking and analysis. Box 13 provides examples of existing data resources and platforms.

Box 13. Examples of existing data resources and platforms

IEA Energy in Buildings and Communities – Annex 70 Building Energy Epidemiology

The IEA EBC Annex 70 is an international collaboration of researchers, industry and government from across the globe who are working to develop methods for improving the empirical evidence on energy demand in the building stock. The Annex 70 is focused on identifying, reviewing, evaluating and producing leading-edge methods for studying and modelling the building stock, including: data collection techniques on energy use, building features and occupant features, and building morphology; analysis of smart meter energy data, building systems, and user behaviour; and modelling energy demand among sub-national and national building stocks. As part of the Annex 70 activities, a global registry of energy and building stock data has been developed with more than 1,000 datasets related to energy demand in buildings.

See: *https://energyepidemiology.org and http://www.iea.ierc.info/testing*

New York City energy and water disclosure and benchmarking

Through a collaboration with New York University's Marron Institute of Urban Management and the NYU Urban Intelligence Lab, the Mayor's Office of Sustainability for New York City has made data covering energy and water use in the city available for the years 2012 to 2017. The data cover over 20,000 of the city's largest buildings and are available for free via an online platform (NYC Mayor's Office of Sustainability 2021). Greenhouse gas intensity measured in kilograms of CO_2 per square foot is available alongside energy and water use intensity. The database was made possible following Local Law 84, which requires energy and water data to be disclosed (City of New York 2013).

Singapore Building Energy Submission System

The Singapore Government, through the Building Control Authority (BCA), has required that all building owners submit mandatory annual energy performance data to the Building Energy Submission System for use by the Authority in developing energy performance benchmarks. The energy performance data are released each year through the Singapore open data platform. The BCA has shown that in 2019, based on data from more than 1,000 buildings with a gross floor area of above 5,000 square metres, the overall energy use intensity of buildings improved by 10 per cent (BCA 2020).

Southern California Energy Atlas

The UCLA California Centre for Sustainable Communities developed the Energy Atlas 2.0 to present data for buildings in the greater Los Angeles metro area, including data on electricity use, natural gas use and estimates for greenhouse gas emissions aggregated by building age, size and type for the year 2006 to 2016 (UCLA 2021). These data are linked to estimates of residential income levels, allowing consumption patterns to be understood. Development is ongoing, and validation is expected to improve as the project continues.

EU Building Stock Observatory

The EU Building Stock Observatory (BSO) provides publicly available information on the building characteristics of EU countries (European Commission 2021b). Established in 2016, the BSO incorporates 250 indicators across 10 themes, including energy poverty, building shell performance and rates of renovation. Efforts have recently been made to improve the number of data points that make up the BSO, as consistent data availability across EU Member States has been a challenge. Future developments will include incorporating data from Eurostat, as well as procuring further datasets that help to close the existing data gaps (RICS 2020).

8 REGIONAL FOCUS: THE EU'S APPROACH TO WHOLE-LIFE CARBON

Some European countries have introduced policies to reduce whole-life carbon emissions from buildings and construction. Further national and EU-level initiatives can be expected in the near future.

Climate change action is time critical. There is an immediate need to focus policy and market actions on emission reductions across the entire life cycle of buildings (see also the triple strategy in Section 1) as these are very quickly using up the remaining carbon budget left before the tipping point of an irreversible climate crisis (referred to as the time value of carbon[15]). This provides a compelling reason for policymakers to address all sources of carbon emissions from the buildings and construction sector, including both embodied and operational carbon – together referred to as "whole-life" carbon emissions.

Reducing embodied emissions is a global challenge that offers significant carbon reduction potential. This section provides an overview of policy initiatives in Europe, one of the leading regions addressing this challenge through its approach to whole-life carbon.

15 For more on this concept, see Carbon Leadership Forum (2020).

8.1 EMBODIED VERSUS OPERATIONAL CARBON

Embodied carbon refers to emissions associated with materials and construction processes throughout the entire life cycle of a building or infrastructure. The majority of embodied carbon in buildings comes from the product stage, but it also includes the carbon footprint related to the maintenance and eventual demolishing of the building. This embodied carbon is both immediate and irrecoverable, and is different from the carbon emissions associated with operational energy use, which are long term. The bulk of embodied carbon is usually emitted in a short burst during the construction, renovation or end of life of buildings. Unlike operational carbon, it cannot be mitigated during the working life of the building. By the time the construction materials reach the project site, embodied carbon is already in the atmosphere.

Embodied emissions will increase significantly as more buildings are constructed as well as renovated towards higher energy efficiency standards. Also, in most buildings built today, embodied impacts will be nearly the same as the impacts of operational energy. In countries that have ambitious building regulations and a low-carbon-intensity electricity grid, such as Denmark or France, embodied carbon emissions can be 2-4 times greater, or more, than emissions associated with operational energy use (Zimmermann *et al*. 2021).

8.2 WHOLE-LIFE CARBON IN THE EU'S POLICY FRAMEWORK

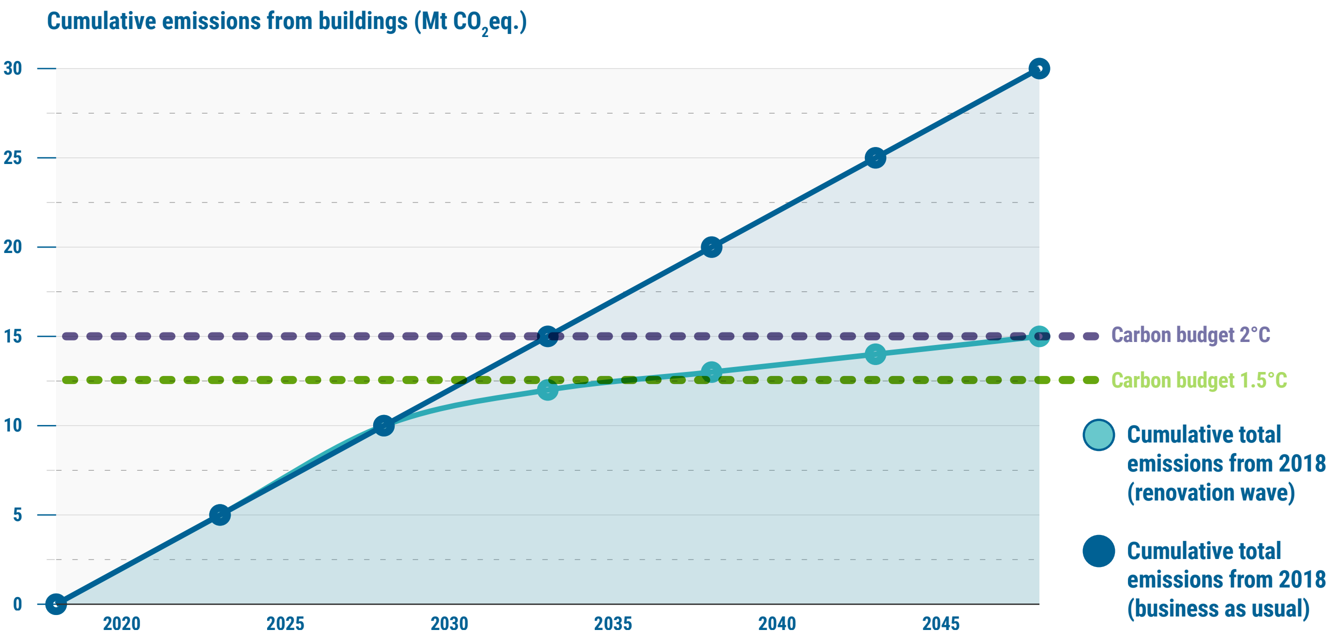
Until recently, embodied carbon in buildings has been addressed on the EU level only with voluntary measures. Cities, regions and countries in Europe have also put in place various provisions in the form of certification systems, regulations, standards, and guidelines. Studies suggest that the number of measures addressing embodied carbon have more than doubled over the last five years (Zizzo, Kyriazis and Goodland 2017; Bionova 2018). However, comprehensive, EU-level policy targeting the whole-life carbon footprint of buildings (including both embodied and operational carbon) remains largely missing.

The policy landscape is set to change. In the Renovation Wave strategy, the European Commission has adopted the principle of "lifecycle thinking and circularity" to make buildings "less carbon-intensive over their full life-cycle" (European Commission 2020a). The ongoing review of key policy and legislative files – such as the Energy Performance of Buildings Directive, the Energy Efficiency Directive and the Construction Products Regulation (European Commission 2021c; European Commission 2021d; European Commission n.d.b) – provides a significant opportunity for the EU to begin consistently integrating whole-life carbon in the policy framework. This requires building-level policies to be well coordinated and aligned with policy actions upstream on raw materials and construction products, as well as at the end of life.

Adding whole-life carbon objectives to the existing policy framework is not replacing ongoing climate efforts focused on increasing operational energy efficiency. Rather, it ensures that efficiency measures are fully aligned with carbon-neutrality goals and that greenhouse gas emissions are not being simply shifted between life-cycle phases. Energy efficiency remains an important tool aimed at avoiding the wasting of energy. Minimum energy performance requirements will still have an important role in making sure the quality of buildings is improved and to avoid easy substitutions, such as carbon offsetting.

The objective of the EU's Renovation Wave is to at least double the annual energy renovation rate over the next 30 years to set the entire building stock on a net zero emissions pathway. However, energy efficiency renovations do not simply contribute to reducing operational carbon emissions; they also increase embodied carbon by adding new materials and systems into the building. Without accounting for the cumulation of all embodied and operational carbon attributable to buildings over their entire life, there is a risk of exceeding the remaining carbon budget. The EU's buildings sector will only be able to stay on the 2˚C global warming scenario track if the embodied emissions produced by the renovations do not exceed around 125 kilograms of CO_2 equivalent per square metre (see figure 26) (EASAC 2021).

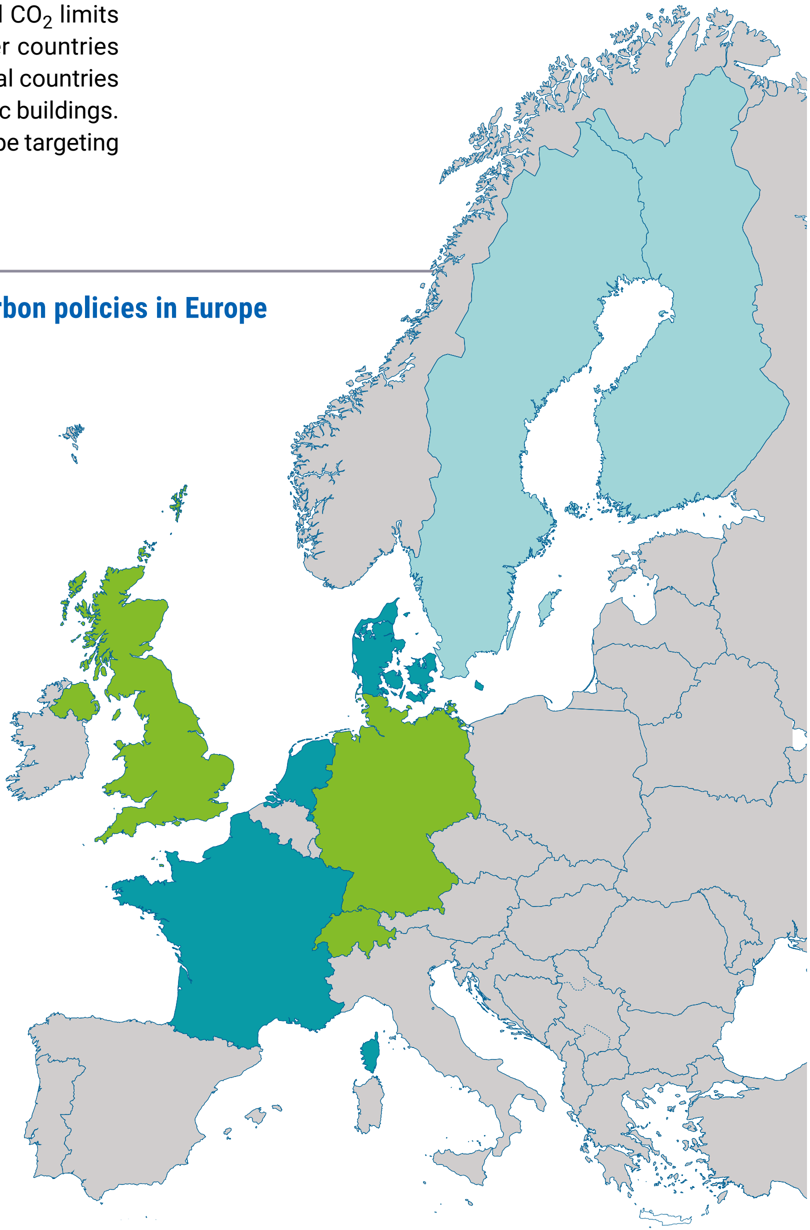
Figure 29. Comparison of cumulative greenhouse gas emissions assuming embodied greenhouse gas emissions of 125 kg CO_2eq/m^2: EU Renovation Wave and business as usual



Source: EASAC 2021, p. 35; Koninx 2020

A common EU policy on whole-life carbon is still in the making. So far, three European countries have introduced CO_2 limits for a large share of new buildings, and two other countries have plans to do so (see figure 30). Four additional countries have life-cycle assessment requirements for public buildings. For an overview of current national efforts in Europe targeting whole-life carbon in buildings, see box 14.

Figure 30. Map of the leading whole-life carbon policies in Europe



WLC regulation for all/non-residential buildings implemented/agreed

WLC regulation for all/non-residential buildings planned

LCA requirement for public buildings implemented/ agreed

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

Note: LCA = life cycle assessment; WLC = whole life carbon

Source: BPIE 2021b; BPIE 2021c, p. 11

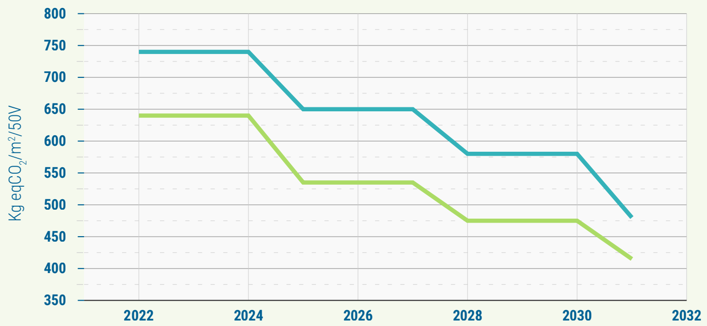
Map design: Showeet.

Box 14. Overview of national initiatives in Europe targeting whole-life carbon in buildings

Since 2017, the Netherlands has required all new residential and office buildings with surfaces exceeding 100 square metres to account for and report their embodied impacts based on a simplified life-cycle assessment using a national calculation method. All impacts are converted into a monetary value, which is used to set a "mandatory environmental impact cap" for new buildings since 2018.

France's new building regulation (RE2020) aims to reduce the climate impact of new buildings by integrating mandatory energy efficiency requirements and whole-life carbon considerations. Annex 3 of Decree 2021-1004 of 2 July 2021 sets progressive thresholds for houses and apartments that will apply as of 2022 (see figure 28) (Ministère de la transition écologique 2021). The requirements include maximum values for both operational energy (IcEnergieMax) and embodied carbon in materials and equipment (IcConstructionMax). Carbon emissions are to be calculated using a dynamic life cycle approach that takes into account the time factor of carbon emissions, e.g., emissions released now have a greater impact than those at the end of life, 60 years down the line.

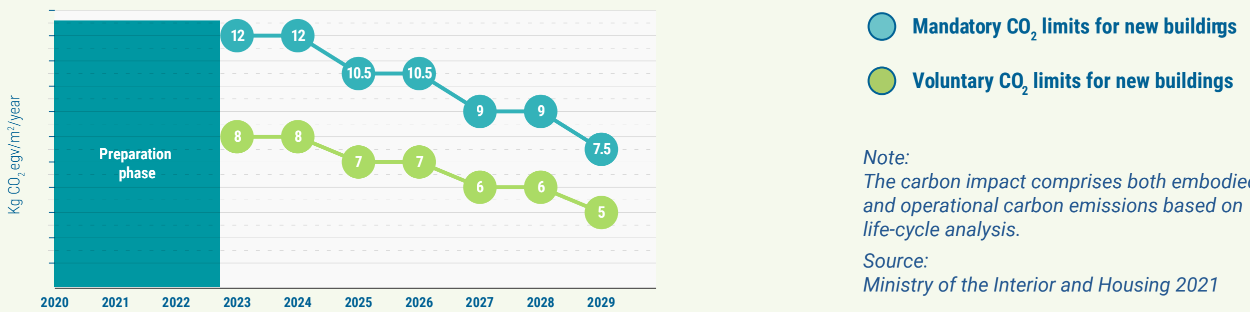
Figure 31. Embodied carbon average limit in France



Source: Ministère de la transition écologique 2021

A new regulation in Denmark under the agreement on sustainable construction sets whole-life carbon emissions for new buildings, encompassing both operational and embodied emissions, based on life-cycle assessment (Ministry of the Interior and Housing 2021). The regulation comes into effect in 2023 with plans for a progressive tightening of CO_2 limits, as depicted in figure 29.

Figure 32. Whole-life carbon minimum requirements in Denmark



Note: The carbon impact comprises both embodied and operational carbon emissions based on life-cycle analysis.

Source: Ministry of the Interior and Housing 2021

Finland and Sweden have developed simplified life-cycle assessment methodologies and whole-life carbon databases, intending to facilitate whole-life carbon accounting and regulation in the future. Finland plans to introduce CO_2 limits for new buildings by 2025, and Sweden by 2027.

Belgium has introduced a national environmental product declaration (EPD) database, and the three Belgian regions are working together to develop a common life-cycle assessment methodology for the built environment, which is expected to turn into legislation in the future. The region of Brussels is planning to introduce "sustainability requirements" for new buildings, including for indirect emissions from buildings.

Germany, Switzerland and the United Kingdom have all introduced life-cycle assessment requirements for certain public buildings and projects.

8.3 DEVELOPING WHOLE-LIFE CARBON LIMITS IN BUILDINGS

Embodied carbon is more difficult to measure and track than operational carbon, which is also the reason why it is more difficult to effectively regulate. The examples in box 14 demonstrate the critical importance of reliable and comparable data in the EU. Environmental product declarations (EPDs) can be a main source of carbon data in the region's whole-life carbon assessment and are increasingly available, although not yet mandatory. Even where relevant EPD carbon data are available, methodologies and reporting methods used to produce these data are not harmonized across EPD issuers, EU Member States, and products, making comparisons difficult. The use of different data sets and assumptions, and of generic data and proxies, introduces large uncertainties. For robust whole-life carbon assessment, there is a need for coherent and comparable results, which could then be used for benchmarking built assets.

Therefore, the first step in developing whole-life carbon limits in buildings is to work with the industry to agree on standardized approaches for calculating embodied carbon at the product and building levels. The next step is to set voluntary requirements based on common standards and agreed methodologies. New construction and public buildings should be required to assess and disclose information on embodied carbon emissions. Making whole-life carbon reporting mandatory will facilitate data collection and benchmarking, as well as allow the construction sector to become familiar with whole-life carbon accounting and the sourcing and supplying of EPDs, without placing an undue burden on the industry.

Setting a clear timeline for how embodied carbon limits for common building types will be introduced in the EU will provide the market with sufficient lead time to prepare. Public procurements and private certification schemes together with additional financial incentives could lead the market. Ultimately, the introduction of mandatory minimum whole-life carbon standards that strengthens over time and that have provisions to ensure standards are enforced is needed.

A few EU Member States that took early actions demonstrated that whole-life carbon policies are possible and desirable. A future common EU-level approach will yield additional benefits in terms of greater transparency, comparability and monitoring of progress across borders and industries.

9 SUSTAINABLE COOLING FOR ALL

This chapter is one of two spotlights in this report (the other one being whole-life carbon). It zooms in on the role sustainable cooling plays for zero-emission, efficient, and resilient buildings and construction, and gives an overview over trends and challenges, while highlighting good practice examples.

9.1 NEXUS OF SPACE COOLING WITH THE BUILT ENVIRONMENT AND CLIMATE CHANGE

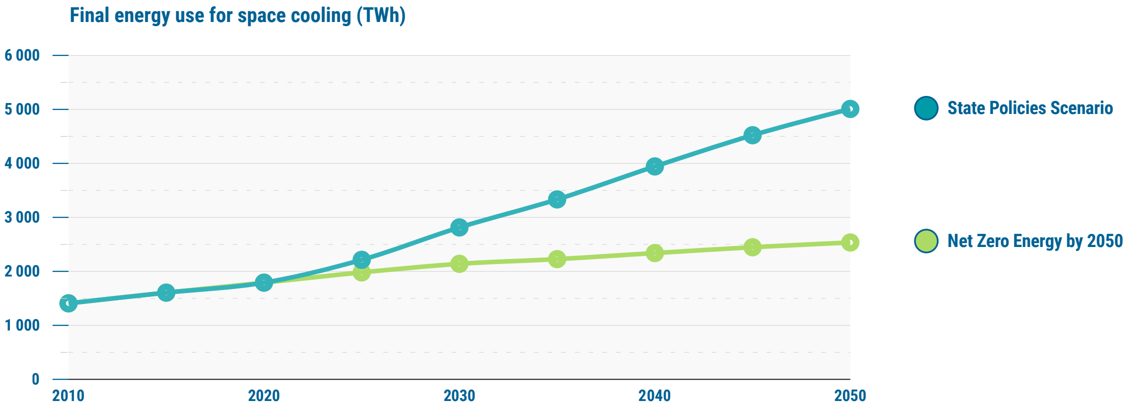
Space cooling is one of the major contributors to climate change due to its emissions attributes related to higher energy consumption and predominant use of high global warming potential refrigerants. Emerging economies such as India, Indonesia, China and Mexico exhibits high annual growth rate for room air-conditioners. Space cooling is also important from the perspective of access to cooling for vulnerable populations, water conservation and material circularity.

Space cooling is responsible for significant energy use and emissions, contributing around 1 gigaton of CO_2 and nearly 5 per cent of total energy consumption worldwide in 2020. The floor area of buildings globally is expected to increase 75 per cent between 2020 and 2050, of which 80 per cent will be in emerging and developing economies (IEA 2021c). This provides an opportunity to put in place the right interventions to curtail cooling energy by applying bio-climatic architecture and passive building design principles.

According to the IEA, energy use for space cooling has doubled since 2000 – from 1,000 terawatt-hours to 1,945 terawatt-hours – due to hotter weather, rapid urbanization, improved ownership of air conditioners and use of inefficient air conditioners (Cooling Post 2018). If the efficiency gains of climate-responsive design and space cooling equipment remain unrealized, energy use for space cooling is expected to double again from current levels by 2040. It is essential for countries to develop and adopt targets and cooling policies in their Nationally Determined Contributions (NDCs) that emphasize climate-adapted building designs, construction and operations aligned to the concept of "Avoid-Improve-Shift-Protect" (see discussion below). Under a net zero energy scenario, energy use for space cooling can be reduced 50 per cent by 2050 compared to the current "state policies" scenario[16] (IEA 2021c).

16 *The Stated Policies Scenario takes account only of specific policies that are in place or have been announced by governments*

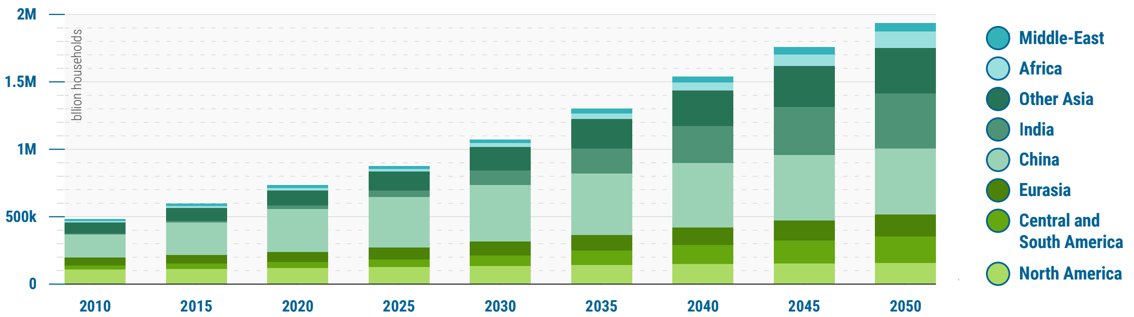
Figure 33. Final energy use for space cooling



Source: IEA 2020e

The demand for space cooling is often met by energy-intensive vapour compression systems that rely on refrigerants with high global warming potential and that are operated using energy from fossil fuels. In the last decade, the annual growth in air conditioners has been most prominent in emerging and developing economies such as India (growth rate of 15.7 per cent), Indonesia (13.1 per cent), China (7.9 per cent) and Mexico (7.8 per cent). By 2050, an estimated 54.5 per cent of the global air-conditioner stock will be located in three regions: China (491 million, 25.3 per cent), India (406 million, 21 per cent) and North America (158 million, 8.2 per cent) (see figure 31) (IEA 2020e).

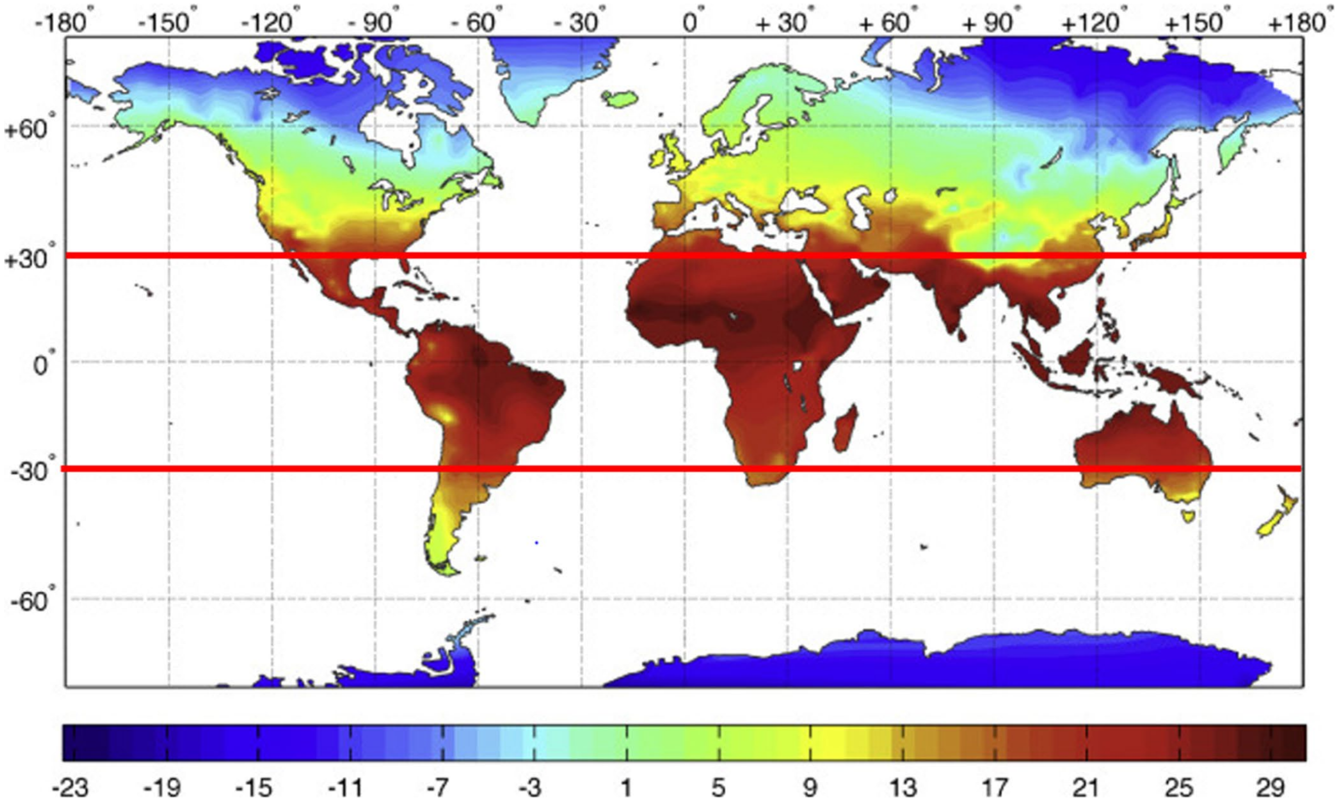
Figure 34. Number of households equipped with air conditioning by region, 2010-2050



Source: IEA 2020e

Challenges differ among global regions. The regions where cooling will be most dominant (with the annual mean temperature exceeding 25°C) are located between 30° North [near the Tropic of Cancer) and 30° South (near the Tropic of Capricorn) (see figure 32). These cooling regions can be found primarily in Saharan Africa, Asia, and South America. Within regions, the spatial variability of the temperature is attributed to the effects of latitude, elevation, land use, clear sky condition and nearness to the coastline.

Figure 35. Map showing annual mean temperature distribution



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: Monjur Mourshed, 2016

The context of current and future requirements for space cooling needs to be placed in the perspective of the population living in these cooling-dominant regions, the peak cooling demand, the duration of the summer season, the current level of air-conditioner penetration in the country and the efficiency of business-as-usual technologies used for space cooling.

The cooling-dominant regions are currently home to around 4.7 billion people. They include 26 low-income countries (17.8 per cent of the population, with a range of 3,000-5,000 annual cooling degree days[17]), 50 low-middle income countries (34.4 per cent; 1,500-3,000 annual cooling degree days), 41 middle-upper income countries (28 per cent; 2,500-4,000 annual cooling degree days) and 29 upper-income countries (19.8 per cent; 2,000-4,000 annual cooling degree days). Low-income countries[18] face issues related to access to cooling.

17 *Cooling degree days are a measure of how much (in degrees), and for how long (in days), the outside air temperature was higher than a specific base temperature. They are used for calculations relating to the energy consumption required to cool buildings.*

18 *Gross national income (GNI) per capita less than $1,036, classification based on World Bank (2020)*

For all regions, but especially those where much of the future construction will occur, a focus on "Avoid-Improve-Shift-Protect" is important, as well as the implementation of passive cooling strategies using local materials and low-energy cooling technologies to attain occupant thermal comfort. In middle-income countries[19] – which are expected to experience rapid urbanization and growth in the buildings sector – next to passive design, minimum performance requirements for the building envelope and space cooling equipment are important, along with shifting to district energy solutions. In high-inc   ome countries[20], next to design and energy source shifts, the focus needs to be on implementing high-performance requirements for cooling equipment; deep retrofitting of the building envelope and cooling equipment; and the deployment of digitalization to improve the efficiency of existing equipment.

Around 10 trendsetter countries[21], working with the Clean Cooling Collaborative, as well as an additional 45 countries, have mentioned improvements in the efficiency of space cooling equipment and the use of climate-friendly refrigerants as greenhouse gas mitigating strategies in their revised NDC documents (Kigali Cooling Efficiency Program *et al*. 2021). As of November 2020, six countries[22] had published National Cooling Action Plans (NCAPs), and 23 additional countries were in the process of finalizing their NCAP documents, which mention space cooling as the priority cooling sector.

In addition to the energy performance and refrigerant use, it is important to recognize the nexus of space cooling with both water consumption and materials use.

- **Water:** Commercial buildings worldwide commonly use water-cooled chillers, which consume large amounts of water in their cooling towers, although this use varies by climate and building type. Make-up water is required for these systems due to evaporation, blow-off and drift losses. As water resources become scarcer in many regions, there is a need to improve the water use efficiency in cooling towers. Losses can be reduced by using building automation system technology to control tower operations, monitoring water levels in the cooling tower reservoir to prevent overflow, and using drift eliminators to redirect airflow and minimize water loss.

- **Materials:** Air-conditioning systems are manufactured with components made up of metals such as steel, copper, and aluminium, as well as electronic components, and are charged with refrigerants; these in turn are manufactured using energy-intensive operations such as mining and processing. Recycling and reprocessing these components are essential measures to reduce the carbon footprint of cooling systems in primary energy use. Scraping metals, refabricating electronic components, recovering refrigerants and repressurizing are among the most straightforward measures that could form an integral part of the air-conditioning industry.

19 GNI per capital between $1,036 and $12,535, classification based on World Bank (2020)

20 GNI per capital greater than $12,535, classification based on World Bank (2020)

21 Burkina Faso, Cambodia, Chile, Ethiopia, Jordan, Morocco, Nigeria, Pakistan, Tunisia and Viet Nam.

22 China, Cuba, India, Panama, Rwanda, and Trinidad and Tobago.

9.2 APPROACH TO SUSTAINABLE BUILDING SPACE COOLING: AVOID–IMPROVE–SHIFT–PROTECT

Environmental impact of space cooling can be reduced by following integrated design and delivery method aligned with the concept of 'Avoid-Improve-Shift-Protect' during the entire life cycle of the building projects.

INTEGRATED DESIGN AND DELIVERY (IDD)

Integrated Design and Delivery (IDD) is central to the conceptualization and implementation of high-performance space cooling strategies. To implement IDD, all of the stakeholders involved with a buildings project – such as urban planners, architects, mechanical and electrical engineers, contractors, clients, operators and end users – should work collaboratively from the project inception stage to define the performance goals and objectives of high-performance space cooling. The process is complemented by using integrated design charrettes, state-of-the-art simulation tools, continuous commissioning practices and efficient management of space cooling systems. The stakeholders should take shared responsibility to iteratively synthesize the evaluation of weather parameters, building design, building function and cooling equipment design.

IDD will become more visually pronounced when one building component contributes to multiple functions, for example when a structural system such as a beam becomes a duct for cool air distribution or when a floor becomes a radiant cooling system.

AVOID

The "Avoid" approach to cooling action refers to reducing the demand for active cooling in buildings through passive cooling solutions, nature-based solutions and reductions in internal heat gains from artificial lighting and indoor equipment. At the site level, the designer can deploy strategies such as the optimal orientation of buildings as well as spatial configuration with consideration of open spaces, vegetation, mutual shading, water bodies and compact building design. At the building level, implementing the three simple strategies of insulate well, shade well and ventilate well can lead to substantial reduction of cooling demand.

For example, ventilation corridors can be used in cities to improve wind flow so that the wind can blow away heat and pollutants, relieving the urban heat island effect and air pollution. In Beijing, China, ventilation corridors are being designed to reduce urban heat, augment ventilation, and protect the land used for climatic and environmental enhancement. Five primary corridors, each 500 metres wide, will connect the city's parks, rivers, highways and low-lying areas. Several secondary corridors of 80 metres will feed into them to create a ventilation system meant to keep smog from accumulating. Similar systems have been developed in other Chinese cities since 2014 – including Shanghai and Fuzhou.

Box 15. Best practices for cities: Cool Cities network and cooler buildings study

Cool Cities Network

The C40 Cities Climate Leadership Group, through its Cool Cities Network, has demonstrated best practices for cities by designing and implementing solutions-oriented approaches to promote sustainability by lowering urban temperatures and sharing the benefits of cooling (C40 Cities n.d.).

- London aims to green half of its city area by 2050 and has created a 12 million British pound Greener City Fund to support these efforts. The Greater London Authority is working with Business Improvement Districts in central London to identify and then deliver opportunities for increasing green cover. In total, more than 500 hectares have been audited to identify the potential for over 300 rain gardens, 200 green walls and more than 100 hectares of green roofs (UK Government and Cool Coalition 2021).
- Tokyo Metropolitan Government in Japan is promoting cool pavements by including thermal-barrier coating and water-retentive pavement installation as a part of road maintenance and construction within the priority areas in central Tokyo.
- Melbourne, Australia released the *Growing Green Guide* in February 2014 to promote green surfaces and provide technical advice on how to design, build and manage green roofs, walls and façades so they can provide multiple long-term benefits for building owners and the wider community.
- The NYC Cool Roofs Programme in New York City, launched in 2009, has coated around 530,000 square metres of rooftop (626 buildings) with a white, reflective coating, offsetting the urban heat island effect and thereby cooling the city.
- The City of Toronto, Canada launched its Eco-Roof Incentive Programme in 2009 to encourage the uptake of eco-roofs by building owners, make buildings more sustainable and promote the creation of green jobs.

Cooling in hot climates

The Programme for Energy Efficiency in Buildings (PEEB) and the Programme for Energy Efficiency for Sustainable Urban Development (EEDUS) conducted a study to define baselines and conduct simulations on energy-efficient scenarios for the main building types in major hot climate zones, highlighting effective approaches to decarbonize buildings in hot climates.

In the case of shading, Safal Profitaire, a multi-tenanted office complex located in Ahmedabad, India, is a great example of applying an external moving shading system (see figure 33). The architect designed the moveable vertical fins on the exterior to serve as shading for the glazed façades of the building and to cut the excess solar radiation going inside. The Vertical Rigid Louver System (VRLS) is mounted on a 600-millimetre-wide ledge that runs on each floor along the entire perimeter of the building. Each louver within the system extends from slab to slab (approximately 3 metres) and is 400 millimetres wide. A simple handle and stopper arrangement allows the user to change the position of the louvers in response to the angle of the sun at different times of the day and in different seasons.

Figure 36. Safal Profitaire building in Ahmedabad, India with vertical external moveable shading system Improve

The "Improve" approach to cooling action refers to improving the energy performance of individual cooling equipment, using overall centralized air-conditioning systems and applying low-energy active cooling strategies. For room air conditioners, energy efficiency improvement can be attained primarily through right-sizing of the cooling equipment, choice of highly efficient compressors, use of inverter technology and use of water-cooled or ground-coupled condensers. For centralized air-conditioning systems, consideration of low-energy active cooling strategies such as radiant cooling systems, evaporative cooling, displacement ventilation, demand control ventilation, air-side and water-side economizers, and enthalpy recovery can further improve the energy performance.

Digitalization in the deployment of monitoring and controls can also improve the energy performance of a centralized cooling system. Operators can deploy state-of-the-art technologies such as digital twins, which includes the power of the Internet of Things and data analytics (based on artificial intelligence and machine learning) to run the overall system at its optimal efficiency point and maintain the health of the cooling equipment.

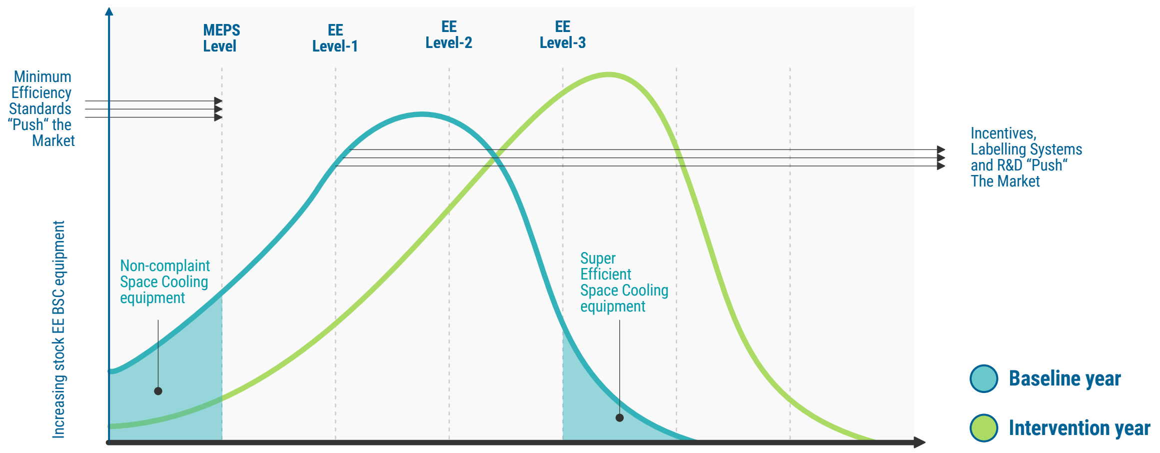
The Research Support Facility of the US National Renewable Energy Laboratory (NREL) is a 20,600 square metre, four-storey office building located on the campus of the US Department of Energy in Colorado. The project uses thermally activated building systems (TABS) as a viable heating and cooling strategy. Sixty-eight kilometres of radiant tubing routes through the ceiling slabs on each level of the building, covering more than three-quarters of the conditioned floor area. The use of innovative customized radiant mats instead of conventional radiant tubing saved 85 per cent of the construction time compared to the conventional radiant tubing method.

The chilled water for the radiant cooling system is provided from the campus' central cooling plant, consisting of water-cooled centrifugal chillers with a waterside economizer. Hot water is provided by a central woodchip boiler at NREL's Renewable Fuels Heating Plant. Non-office spaces are conditioned with a traditional variable-air-volume reheat system, supported by perimeter heating units to accommodate quick response to changes in occupancy levels. Thermal comfort is also provided by desktop fans and windows, allowing occupant control and mixed-mode ventilation.

Figure 34 shows how regulatory and market-based mechanisms complement each other for improving the efficiency of space cooling equipment in a country. The area under the graph shows the stock of cooling equipment in a country. On the extreme left of the inverted bell curve is the diminutive number of cooling equipment stock, which is non-compliant with minimum energy efficiency performance standards (MEPS) requirements; at the centre of the curve is the bulk of the stock, which complies with MEPS and forms the business-as-usual technologies of space cooling in the country; on the extreme right is the few super-efficient cooling equipment stocks.

The MEPS raise the baseline efficiency of cooling equipment in the country and "push" the market towards regulatory compliance, while the labelling systems, incentives, and research and development "pull" or motivate the space cooling market to move towards higher energy efficiency. The role of labelling of cooling equipment is crucial as it inspires the building proponents to purchase energy-efficient cooling equipment of a high standard. This impacts the increased market demand for such products, making them more affordable. The energy performance of the country's space cooling stock will continuously improve in the presence of a favourable ecosystem such as effective enforcement of cooling equipment MEPS, incentives for purchasing efficient equipment, availability of equipment efficiency testing laboratories and continuous research and development facilities.

Figure 37. Role of regulatory and market-based mechanisms to improve the energy efficiency of space cooling stock in a country



Source: Developed by UNEP 2021

SHIFT

The "Shift" approach to cooling action refers to the use of renewable or waste resources for space cooling and the reduction of direct greenhouse gas emissions from the refrigerants used in the cooling equipment.

The integration of renewable energy sources with space cooling requires careful planning, design, implementation and operation. Commonly applied combinations include geothermal energy, solar heat or waste heat coupled with absorption- or adsorption-based chilling systems. These cooling systems consume much less electrical energy and use refrigerants and absorbents/adsorbents that do not emit greenhouse gases.

The multi-stage evaporative cooling system can be applied in locations where hot and dry climates prevail and can be used to lower the temperature of indoor spaces. The free cooling available from underground earth tubes can also be used to minimize the need for conventional cooling in buildings.

Thermal energy storage (TES) is a technology that helps store thermal energy by means of heating or cooling a storage medium so that it can be used at a later time for heating and cooling applications and power generation. TES can aid individual building air-conditioning systems and district cooling systems (see box 16) as an option to store thermal energy whenever available at free or at lower tariffs.

Box 16. Innovative technology: district cooling systems

A district cooling system generates the cooling at the central plant and distributes it in the form of chilled water to multiple buildings through insulated pipes underground. The potential of district cooling is enhanced when the designer integrates free cooling (from rivers, lake or sea), waste heat (from industry, data centres, sewage system and waste incinerators), and the use of high-efficiency chillers or absorption chillers connected to renewable energy sources (such as solar thermal, geothermal, biofuel-based boilers and/or trigeneration plants). District cooling systems can be optimally sized considering the diversity of building usage patterns.

District cooling systems can reduce energy consumption by around 35 per cent compared to conventional air-cooled chilled water systems, and 20 per cent compared to individual water-cooled systems. The economy of scale also makes many renewable energy, not-in-kind[23] technologies and the use of climate-friendly refrigerants viable, which are sometimes not cost-effective to integrate at the individual building level. District cooling also allows the building owners to outsource cooling altogether to a specialized agency, which forms a large part of the operational budget and requires technical know-how and human resources.

Emirates Towers in Dubai, United Arab Emirates is a mixed-use building complex with offices, hotels and retail stores with a total built-up area of 227,600 square metres. The towers were served by an heating, ventilation and air-conditioning (HVAC) system with a capacity of 6,300 refrigeration tons with air-cooled chiller systems. Empower (the Emirates Central Cooling Systems Corporation), a district cooling service provider, retrofitted the HVAC system of the complex to connect the chilled water supply to the district cooling plant at Dubai International Financial City.

The project consisted of 300 metres of chilled water pipe network and an energy transfer station. Empower reassessed the cooling demand of the towers, estimated a reduction of around 1,300 refrigeration tons from the existing capacity, and signed a contract for 5,000 plus 1,000 refrigeration tons as a back-up for three years. The project achieved zero downtime of cooling requirements in the towers. This retrofitting achieved a 40 per cent reduction in energy consumption and realized a net savings of 4 million kilowatt-hours in 2015, reducing greenhouse gas emissions by around 6,400 tons of CO_2 equivalent annually. Other benefits from the project included the elimination of noise from the existing HVAC system, re-use of the land occupied by the HVAC plant, and a 10 megawatt reduction in power generation demand.

23 Not-in-kind is any alternative cooling system other than the vapor compression cooling systems that are most commercially dominant today.

The use of alternative refrigerants with low or no global warming potential can lead to a higher reduction in direct emissions from the refrigerants. The transition to alternative refrigerants should consider their thermodynamic performance in cooling along with other refrigerant properties such as flammability and toxicity. The transition from hydrofluorocarbons (HFCs) is being supported by developments in the use of hydrofluoroolefins (HFOs) and hydrocarbons, along with CO_2 as a refrigerant in building space cooling applications.

China ratified the Kigali Amendment to the Montreal Protocol in 2021 and is committed to phasing down HFC production and use 20 per cent by 2045 compared to 2020-2022 levels. The China Household Electrical Appliances Association provides technical support to the country's leading air-conditioner suppliers to help them transform their production lines and replace ozone-depleting refrigerants with propane (R290) to improve the units' energy efficiency. In this programme, the Chinese government partnered with the United Nations Industrial Development Organization (UNIDO) and leading air-conditioner manufacturers to find sustainable cooling solutions (Arthur 2021).

PROTECT

The "Protect" approach to cooling action refers to the need to shield vulnerable populations, who often live in poorly designed and maintained housing stock, from the adverse impacts of hot weather. Worldwide, around 1.09 billion people are at high risk of heat stress due to a lack of access to cooling (Sustainable Energy for All 2021). This population includes both rural and urban poor who have little means of affording refrigerant-based space cooling.

Although the urban poor have some access to reliable electricity, their condition is exacerbated due to the urban heat island effect. "Protect" cooling actions to reduce urban heat and improve the health of low-income populations include: well-ventilated urban planning, mutual or self-shading, cool roofs and walls (see box 17), pervious pavements, non-motorized or congestion-free transport, and the use of vegetation and local water bodies to improve the micro-climate. Both urban and rural poor can deploy affordable solutions such as shading, natural ventilation, ceiling fans and evaporative/mist cooling (in dry climates) to attain partial or complete thermal comfort.

Box 17. Million Cool Roofs Challenge

Launched in 2019, the Million Cool Roofs Challenge was created to rapidly accelerate the deployment of cool roofs in countries where populations are particularly vulnerable. This first-of-its-kind global initiative is a joint effort by the Kigali Cooling Efficiency Program (K-CEP), the Global Cool Cities Alliance, Sustainable Energy for All and Nesta's Challenge Prize Centre.

Ten teams across Africa, Asia and Mexico were selected to each receive a $125,000 grant to install cool roofs; establish markets; demonstrate and evaluate local performance; and raise awareness among policymakers and local leaders. In most cases, the Million Cool Roofs teams were introducing the concept for the first time to local audiences. Over a two-year period, the 10 teams worked hard to demonstrate the best sustainable and transferable model for rapid deployment of cool roofs, competing for a final prize of $750,000*.

As the challenge neared its end, the teams' efforts and progress showed signs of promising results in reducing temperatures. In Indonesia, where the team applied cool roofs to a range of buildings, including schools and low-income housing, the internal temperature of an industrial building dropped by 10.4°C. Similar results were seen in Bangladesh, where surface and indoor temperatures during peak heat dropped by 12.3°C and 7.7°C, respectively. In Kenya, a pilot project at an orphanage and school cooled the building enough to allow students to learn indoors on hot summer afternoons, which was typically not feasible before the application of the cool roof.

For details, see https://www.coolroofschallenge.org.

** Each team was initially granted $100,000, but due to delays caused by the COVID-19 pandemic, the challenge was extended, and funds were increased to help teams adapt and cover additional costs. The full results of the Million Cool Roofs Challenge, and the winning team, were planned to be announced in 2021.*

In Delhi, India, the Mahila Housing SEWA Trust (MHT) won the urban innovation challenge to improve the lives of the urban poor through use of a cool roof strategy. Under this project, MHT applied solar reflective paint on 250 low-income houses. Researchers at the University of Chicago in the United States are working with MHT to evaluate the positive impact of the paints on indoor temperatures, energy expenditures and overall well-being. Given the positive scientific results, MHT plans to implement the programme in other cities in India (Jina n.d.).

9.3 ENABLERS FOR SUSTAINABLE SPACE COOLING

The environmental impact of space cooling systems can be mitigated by reducing their energy use intensity and by using climate-friendly refrigerants. This will require coherent drivers such as international commitments and collaborations, regulatory and market-based policies, financial mechanisms and awareness/capacity-building (UNEP and IEA 2020).

INTERNATIONAL COMMITMENTS AND COLLABORATIONS

At a high level, countries can show commitment to sustainable space cooling by adopting or ratifying international commitments such as the Paris Agreement, the Kigali Amendment to the Montreal Protocol and the UN Sustainable Development Goals. Further, countries can foster international collaborations, which will provide national governments with the opportunity to work jointly with international experts and institutions on accelerating the uptake of sustainable space cooling (see boxes 18 and 19). Such initiatives include, but are not limited to: Cool Coalition[24], Climate and Clean Air Coalition[25] Clean Cooling Collaborative[26], the World Bank's Sustainable Cooling Initiative[27] and the Sustainable Cooling Innovation Program of the International Finance Corporation[28].

24 https://coolcoalition.org
25 www.ccacoalition.org
26 https://www.cleancoolingcollaborative.org
27 https://esmap.org/node/181474
28 https://www.techemerge.org/basic-page/sustainable-cooling

Box 18. Country leadership: Cambodia

Cambodia has shown leadership in accelerating the uptake of sustainable cooling by mentioning space cooling of buildings as a priority sector for greenhouse gas mitigation in its revised Nationally Determined Contribution, released in 2020. The NDC mentions passive cooling strategies as a mitigation measure to reduce energy consumption in buildings and to reduce the urban heat island effect in cities. Cambodia is also implementing activities for phasing out HFCs in light of its commitments under the Kigali Amendment to the Montreal Protocol. The Ministry of Environment, in collaboration with the UN Economic and Social Commission for Asia and the Pacific (ESCAP) and the UN Environment Programme, is developing Cambodia's forthcoming National Cooling Action Plan (NCAP) and has identified space cooling as the priority sector for reducing both direct and indirect emissions.

In line with the framework of the GlobalABC, UNEP and the UN Development Programme initiated work with the Ministry of Land Management, Urban Planning and Construction to prepare an *NDC Buildings and Construction Roadmap for Cambodia* to increase the scale, pace and impact of climate action towards a zero-emission, energy-efficient and resilient buildings and construction sector. In this regard, the country is developing a green standard for new buildings supported by capacity-building programmes for buildings professionals and the public.

Through the K-CEP NDC support facility for efficient, climate-friendly cooling, the Ministry of Environment of Cambodia, ESCAP and UNEP will be implementing a technical assistance programme on "Passive cooling strategies implementation in Cambodia" by the end of 2021. The project will consider activities related to the inclusion of passive cooling strategies in Cambodia's building energy code, the development of design guidelines for including passive cooling in buildings, implementing two demonstration projects showcasing the integration of passive cooling strategies, and conducting awareness- and capacity-building programmes.

REGULATORY AND MARKET-BASED POLICIES

The development and implementation of successful sustainable cooling policies requires clear "ownership" and effective collaboration among various stakeholders including government, manufacturers, designers, civil society, academia and end users (UNEP Cool Coalition 2021).

A country can develop a National Cooling Action Plan (NCAP) with adequate emphasis on sustainable space cooling and follow up with effective implementation mechanisms. Building energy codes should include provisions for minimum performance requirements for passive cooling strategies and cooling equipment, and promote the adoption of low-energy and not-in-kind technologies such as evaporative cooling, vapour absorption cooling, vapour adsorption cooling, deep lake and seawater cooling, etc. Cities can identify heat stress as one of their disaster risks and develop an urban heat action plan for mitigating the urban heat island effect.

Market-based mechanisms, such as bulk procurement of air conditioners and other cooling equipment, can bring economies of scale to reduce costs and lead to accelerated adoption of super-efficient air-conditioning equipment. Similarly, utility engagement can lead to the implementation of successful demand response programmes, such as imposing higher tariffs for electricity during peak periods, offering subsidies/incentives for the purchase of more-efficient systems, encouraging large-scale use of thermal storage (ice or chilled water) and promoting renewables and awareness campaigns.

Box 19. Cool Coalition: The experiences of Panama

Since 2012, the National Energy Secretariat of Panama (SNE) has worked to improve the country´s energy efficiency, starting with the publication of Law 69 of 12 October 2012. One of the mandates of this Law was the creation of the Index Developer Committee, whose objective is to define the minimum energy efficiency indexes for various types of equipment and machinery. In total, Panama has defined 14 minimum energy efficiency indexes for different types of air conditioners, refrigerators, electric motors, lighting, televisions, and thermal insulation, among others. Following this process, since 2017, Panama has adopted six national standards and regulations – four for air conditioners and one each for refrigerators and electric motors – and developed its national energy efficiency label.

Another relevant action was the approval of the Sustainable Building Regulation (RES), through Resolution No. 035 of 26 June 2019 by the Technical Council of Engineers and Architects (JTIA). The RES takes as a reference the Sustainable Construction Guide adopted by the SNE in 2016 and the Guide Implementation Method adopted in 2018. Implementation of the RES is expected to reduce building energy consumption by 15-20 per cent, as it seeks to implement good design techniques, including limiting the entry of heat into a building’s interior space, thereby reducing the thermal load and consequently the demand for refrigeration equipment to generate comfort for occupants.

The Energy Transition Agenda of Panama is being used as a tool for decision making on the climate, sectoral and economic agenda, which enables evaluating the most optimal way to use economic, human and natural resources in order to address them efficiently, to stimulate the progress of the whole nation.

FINANCIAL MECHANISMS AND INNOVATIVE BUSINESS MODELS

Domestic funds and public finance can be used to leverage international funds and private investments, respectively, for sustainable space cooling. This will help in initiating related programmes and raise investor confidence. Countries where public investment is a challenge can explore mobilizing finance through multilateral funds, bilateral funds, philanthropies and private sector participation. The government can carefully select the appropriate financial mechanisms and business model to mainstream the affordability of sustainable space cooling solutions, such as cooling-as-a-service (CaaS), a revolving fund[29], energy performance contracts, on-bill financing programmes[30], etc.

AWARENESS AND TRAINING PROGRAMMES

Extensive awareness- and capacity-building efforts by designers, contractors, commissioning professionals, service technicians, air-conditioning operators and building users are needed to reduce energy consumption and refrigerant leakages during the service life of space cooling equipment. For air-conditioning designers, capacity-building related to the use of hourly cooling load simulation tools, high-performance air-conditioning design and the selection of climate-friendly alternative refrigerants will enable them to select an appropriate air-conditioning system for a project. Training of contractors and commissioning professionals will ensure that the air-conditioning system for a given project is commissioned as per design specifications. Training service technicians on the best practices for installing and servicing air-conditioning systems will result in improved energy performance of space cooling equipment and reduced refrigerant loss during the manufacturing, installation and servicing of equipment. Special emphasis should be given to enhancing awareness and behavioural training among household customers to engage them in cooling demand response programmes.

The Climate and Clean Air Coalition is a voluntary partnership of governments, intergovernmental organizations, businesses, scientific institutions, and civil society committed to improving air quality and protecting the climate. The coalition’s HFC Initiative[31] focuses on disseminating information on and strategies for developing, deploying and promoting climate-friendly technologies. Activities include capacity-building, technology conferences and exhibitions, interactive partner tools and many other knowledge-sharing activities.

29 *A revolving fund is a fund or account that remains available to finance an organization's continuing operations without any fiscal year limitation, because the organization replenishes the fund by repaying money used from the account.*

30 *On-bill financing allows the utility to incur the cost of the clean energy upgrade, which is then repaid by the customer on the utility bill.*

31 *Lien https://www.ccacoalition.org/en/initiatives/hfc*

10. GLOBALABC MEMBER ACTIVITIES AND INITIATIVES

This section provides information on selected activities and initiatives from across the GlobalABC membership that support the shift to a net zero carbon, energy-efficient and resilient buildings and construction sector.

10.1 LOW-CARBON CONSTRUCTION ACTIVITIES

Advancing health and social sustainability

Released in November 2020, the World Green Building Council's Health & Wellbeing Framework[32] is redefining the scope of health, wellbeing and social value in the buildings and construction sector and catalysing action in the wider industries through its global network. The six principles of the Framework are innovative in their cross life-cycle approach, considering all people throughout the value chain, from building occupants and the local community, to construction and supply chain workers. Equity and justice are presented alongside health and resilience, challenging the productivity co-benefit model that has underpinned the green building sector's emphasis on occupant wellbeing.

Management of construction waste materials in Medellín, Colombia

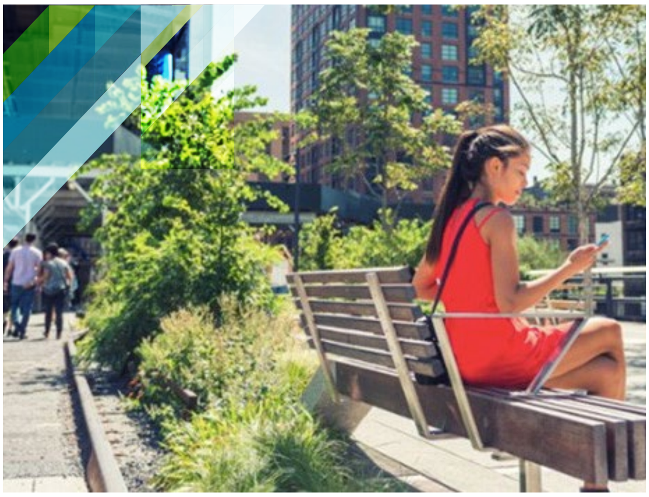
The management of construction waste as well as the recycling of all types of solid waste in the city of Medellín has boomed in recent years (City of Medellín 2014). Construction waste materials were previously considered as waste or garbage and were deposited in piles or landfills. Today these materials are reused and recycled by construction companies, producers of cements and concrete mixtures, firms producing pavements, and quarries, which transform the wastes into stone, granular and crushed components to incorporate into their construction materials and works. In addition to the stone and earth components of the construction wastes, other types of companies have specialized in the transformation and reuse of contents such as glass, wood, iron, steel, and plastics, which are reprocection or other materials.

Sustainable urban planning in Norfolk, United States

The City of Norfolk, Virginia has adopted a resilience strategy that is driven by three main goals: design the coastal community of the future, create economic opportunity by advancing efforts to grow existing and new industry sectors, and advance initiatives to connect communities, deconcentrate poverty and strengthen neighbourhoods (City of Norfolk n.d.). The diverse actions and strategies harnessed through the resilience strategy range from developing the gold standard in resilient land use codes, to collaborating with global partners to innovate the next generation of water management techniques, to exploring new financing models such as catastrophe bonds and social impact bonds. Through the resilience strategy, Norfolk is embracing its challenges head-on: sea-level rise and recurrent flooding, a shifting economy, and the need to build strong, healthy neighbourhoods. As an inaugural member of the 100 Resilient Cities network, Norfolk has become a model for resilience in a changing world.

Low-carbon construction in Benin

The Xewa Sowé Children's Center in Benin includes an emergency housing hub that can accommodate 24 children and a food hub to ensure self-sufficiency for 30 children, with a large vegetable garden, a field of artemisia (an anti-malarial plant) and other amenities that enable the formation of a community hub. All the buildings are built from clay, and the roof forms and materials differ according to their use. The technical buildings are covered with corrugated iron, while the inhabited buildings are covered with straw, guaranteeing coolness inside the spaces. The Center uses local building practices and techniques, and the chief mason ensured the transmission of know-how on the raw earth mixtures to the younger masons who participated. The materials selected are well adapted to the climate, and through knowledge and accessibility of the material, the buildings can be maintained by the local communities, who are not dependent on imported and expensive industrial materials. The use of "bauge" construction has also further reinforced a traditional construction technique used in the village, and the project worked with local craftsmen and craftswomen in consultation with the village authorities, who have embraced the project.



US federal buildings: net zero energy strategy

The Biden administration in the United States has set a goal for zero energy in new construction by 2030 and for all buildings by 2050 (US General Services Administration [GSA] 2021), which align with the country's Nationally Determined Contributions. Although energy is the first targeted resource, the net zero concept also applies to other resources including water and waste, to achieve a sustainable building stock. The GSA currently has more than 8,800 federal assets under management and is working to create the pathway towards sustainable buildings for the government and the US private sector. The GSA is driving innovation for net zero design, green building certifications, green roofs, and advanced building technologies, creating a model for healthy and productive workplaces, a smaller environmental footprint and reduced costs in the building sector.

Energy-efficient hotels: low-cost measures with great Impact

In Mexico, an additional 40 million square metres of hotels are projected to be built by 2030. Following awareness-raising by the Programme for Energy Efficiency in Buildings, the Mexican hotel chain Grupo Misión plans to build 20 new energy-efficient hotels, which will save an estimated 124 kilotons of CO_2 over a 30-year lifespan (PEEB 2020b). Potential improvements range from "no-cost" measures such as changing the building orientation, to measures that would cost under €100,000 per hotel, including low-emissivity glass or solar control properties, rooftops with thermal insulation, more-efficient air conditioners and water heaters as well as solar-powered water heating.

10.2 COUNTRY INITIATIVES TO REDUCE GREENHOUSE GAS EMISSIONS IN BUILDINGS

Driving the Renovation Wave in cities and regions

The BUILD UPON[33] project, funded by EU Horizon 2020, is empowering cities across Europe to decarbonize their existing building stock by 2050 and to unlock the ambitions of the European Green Deal's flagship policy, the Renovation Wave. The project brings together green building councils in Croatia, Hungary, Ireland, Italy, Poland, Spain, Turkey and the United Kingdom, and creates impact through a new Framework that quantifies the environmental, social and economic benefits of building renovation. The Framework has been implemented in at least 32 cities across Europe.

Industry actions towards carbon-neutral production

Through its Sustainability Strategy 2030, the VELUX Group, a Danish manufacturing company that specializes in windows, skylights and related accessories, is transforming the way it does business, including the products and solutions that it brings to the market (VELUX n.d.). The new strategy, "It's our nature", replaces the Climate and Energy 2020 strategy that successfully reduced the company's CO_2 emissions by 50 per cent. With the new strategy, the VELUX Group will pioneer climate and nature action to become Lifetime Carbon Neutral and showcase sustainable buildings and communities. This will include a Lifetime Carbon Neutral Commitment to take responsibility for the company's own emissions (scope 1 and 2) and those of its value chain (scope 3). By 2030, the VELUX Group aims to become a carbon-neutral company and to halve the carbon emissions of its value chain. It is committed to following the most ambitious reduction path outlined in the Paris Agreement and to establishing carbon reduction targets based on the globally recognized method of the Science Based Targets initiative (SBTi).

33 https://www.worldgbc.org/build-upon

ULI Greenprint's goal of net zero operations

The ULI Greenprint Center for Building Performance is a worldwide alliance of real estate owners, investors and strategic partners committed to improving the environmental performance of the global real estate industry. Across ULI Greenprint's global membership, 17 real estate firms representing more than $570 billion in assets under management, more than 65 million square metres and over 3,300 properties across 20 countries have aligned with a goal of reducing the operational carbon emissions of members' collective buildings under operational control to net zero by 2050[34].

Blueprint for a sustainable built environment

In a collection of case studies, "Blueprint for a sustainable built environment", the World Business Council for Sustainable Development (n.d.) aims to illustrate its vision for living spaces and the built environment, as set out in its *Vision 2050: Time to Transform* (WBCSD 2021b). The case studies provide evidence from the experiences of WBCSD member companies on the value created by investments in a sustainable urban built environment. The case studies showcase existing or emerging sustainable solutions in the built environment, as well as the finance and governance models used to enable such solutions. Together, they form a narrative, or "blueprint", aligned with the WBCSD's vision, exhibiting the key principles of the sustainable built environment.

Guide for energy efficiency in healthcare facilities

Healthcare facilities that are energy efficient are important for patient comfort and can save costs that can be reallocated to patient care. The Tunisian Ministry of Health and the Tunisian Energy Management Agency (ANME), with support from the Programme for Energy Efficiency in Buildings, developed an energy efficiency guide for healthcare facilities in Tunisia (PEEB 2020c). This detailed guide gives concrete recommendations to energy managers and architects working in the health sector. It covers areas such as the orientation of waiting areas and patient rooms, energy efficiency and management of different hospital installations, and the integration of renewable energy sources to provide a safe and secure power supply for day-to-day functioning.

NHS green hospitals in the United Kingdom

The United Kingdom's NHS has committed to becoming the world's first net zero health service by 2040, with an ambition to cut emissions 80 per cent from 1990 levels by 2032. A high-level plan to enact these emission reductions was published in 2020 in *Delivering a 'Net Zero' National Health Service* (NHS 2020). Given that the NHS accounts for 7 per cent of the UK economy and employs more than 1 million people, this target presents substantial challenges.

Total emissions in 2019 from the NHS exceeded an estimated 25 million tons of CO_2 equivalent, approximately equal to the national emissions of Jordan. The emissions come mainly from the supply chain (62 per cent), followed by care delivery (24 per cent) and travel to and from healthcare locations (10 per cent) (Tennison *et al*. 2021). However, carbon emissions associated with the NHS' 24 million square metres of estates account for 15 per cent of total emissions. Of this, 2.3 million tons of CO_2 equivalent come from larger facilities such as hospitals, with a further 0.7 million tons from smaller buildings, such as general practitioner practices.

As a first step, upgrading building envelopes and introducing better building controls systems and appliances has the potential to reduce emissions by 40 per cent. Typically, the costs associated with these upgrades are recovered through energy savings in relatively short periods. For example, achieving 100 per cent LED lighting would require an estimated investment of nearly 500 million British pounds, but doing so would save more than 3 billion pounds over the next 30 years. Once the efficiency of buildings is improved and primary fossil fuel use associated with boilers is phased out, further emission reductions are expected through a reduction in the carbon intensity of the electricity grid. Finally, there is potential to generate electricity on-site through renewable energy projects.

A new Net-Zero Carbon Hospital Standard is being introduced to ensure that the construction and operation of healthcare buildings is compatible with the NHS target. However, the scale and condition of the NHS building estates will require substantial investment if energy efficiency goals are to be met. Some initiatives have been put in place, such as a 50 million GBP NHS Energy Efficiency Fund pilot fund that aims to upgrade lighting across the estates. Of the existing capital funding of 1.5 billion pounds, 600 million pounds has been allocated for hospital maintenance programmes (Department of Health and Social Care 2020); however, only a portion of this has the potential to deliver efficiency savings.

34 *For details, visit http://uli.org/netzerogoal.*

10.3 WHOLE-LIFE CARBON AND CIRCULAR ECONOMY ACTIONS

Whole-life carbon policy roadmaps in Europe

#BuildingLife[35], a European regional project led by the World Green Building Council and 10 green building councils across Europe, is using private sector action and public sector policy to drive decarbonization of the whole life cycle of buildings. The project is building consensus on and steering the direction of the EU Policy Roadmap for Whole Life Carbon as well as 10 national roadmaps, and is the first region-wide response to the vision of a net zero embodied carbon built environment. Showcasing the roadmaps at the 2021 UN climate conference, the project aims to provide educational tools and an advocacy platform for advancing whole-life decarbonization of the built environment across Europe and beyond.

Net zero case studies on whole-life carbon

The report Net-zero Buildings: Where *Do We S*tand?, developed by the WBCSD (2021c) in collaboration with Arup, discusses six case studies on whole-life carbon buildings based on the WBCSD Building System Carbon Framework (WBCSD 2020) and presents an analysis of the results. The report calls on the built environment industry to adopt a whole-life-cycle approach to assessing the greenhouse gas emissions from buildings. It argues that by setting explicit targets from the start of a building project, through collaboration along the value chain and by sharing data openly and widely, it will be feasible to halve whole-life carbon emissions by 2030.

35 See: https://www.worldgbc.org/buildinglife

Decarbonizing construction: guidance for reducing embodied carbon

The report Decarbonizing Construction: Guidance for Investors and Developers to Reduce Embodied Carbon, authored by the WBCSD (2021d) together with OneClickLCA, explains how developers and investors can set requirements for reducing upfront carbon emissions at different stages of project development, based on 50 proposed measures and 12 core requirements. The influence over reducing carbon emissions from buildings projects is highest at the earliest stage of decision making, and the report provides practical recommendations for doing that.

Circular economy: closing loops to be fit for the future

In its report *Circular Economy: Closing Loops Means Being Fit for the Future*, DGNB (2019) provides building owners, planners and other interested parties with an overview of the challenges and opportunities related to implementing circular economy principles in the construction and real estate industry. The toolbox was developed in collaboration with experts in the field during a series of workshops. It offers a practical resource in the form of strategies, checklists and concrete examples on design for deconstruction, urban mining, reuse and recovery, as well as mixed use and shared spaces.

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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[36] 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 an extensive data research using global datasets 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, also for the sensitivity to change[37] and data continuity.

The decarbonization index is currently composed of seven indicators:

1) Global buildings sector energy-related emissions ($GtCO_2$/year)
2) Global building sector energy intensity (kWh/m^2 year)
3) Renewable energy share in final energy in buildings, globally (%)
4) Building codes and regulations (cumulative growth)
5) Incremental energy efficiency investments in buildings, globally (billion dollars/year)
6) NDCs with building 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 CO_2 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 or enable the reduction of CO_2 emissions such as policy and industry actions.

To form the decarbonization index, all indicators are aggregated. A weight 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).

36 A composite indicator is formed when individual indicators are compiled into a single index.

37 Sensitivity for change describes how well and fast an indicator reflects changes in the current year. This sensitivity depends on the speed of collecting observed data and on the methodology used for estimations and filling data gaps.

Updated indicators in the decarbonization index in the *2021 Global Status Report for Buildings and Construction*

Green building certification

In addition to certification schemes previously used in the indicator composition, several additional ones now enable a better global representation of the indicator.

The rising trend of green building certification in the building 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 13 datasets. These include the five global frontrunners – LEED[38], DGNB[39], Passive House[40], WELL[41] and EDGE[42] – as well as six relatively developed national schemes: MINERGIE[43] (Switzerland), IGBC[44] (India), Miljöbyggnad[45] (Sweden), BEAM Plus[46] (Hong Kong), GREEN STAR[47] (Australia) and CASBEE[48] (Japan). They also include two more locally adopted schemes: SGBF[49] (Saudi Arabia) and GRIHA[50] (India).

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

Building codes and regulations

The first version of this indicator, known as "Building energy codes and standards", considered only the number of countries with building energy codes and standards in place. This count provided an approximate assessment of the building sector efforts towards decarbonization. This is due to the impact of building codes and standards on the quality of construction and consequently on energy and emissions. For a better representation of the quality of construction, the indicator is now renamed and complemented with an additional element "Quality control before, after and during construction"[51], which essentially observes regulatory measures in place in a country to ensure quality management in construction.

38 *https://www.usgbc.org/resources/country-market-brief*

39 *https://www.dgnb.de/en/index.php*

40 *https://passivehouse-international.org/index.php?page_id=183*

41 *https://www.wellcertified.com*

42 *https://edgebuildings.com*

43 *https://www.minergie.ch/de*

44 *https://bpie.sharepoint.com/Proposal/P003 GSR2021/2 work_packages/3 Global Building Climate Tracker (BCT)/Methodology update/IGBC*

45 *https://www.sgbc.se/certifiering*

46 *https://www.hkgbc.org.hk/eng/beam-plus/beam-plus-new-buildings/index.jsp*

47 *https://new.gbca.org.au/rate/green-star*

48 *https://www.ibec.or.jp/CASBEE/english*

49 *https://www.sgbf.sa*

50 *https://www.grihaindia.org*

51 *Available from World Bank (2019). However, in September 2021 the World Bank announced the discontinuation of its Doing Business report, which will affect next year's indicator.*

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