Global Alliance for Buildings and Construction

GlobalABC Roadmap for Buildings and Construction

2020-2050

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

International Energy Agency

UN environment programme

UN environment programme

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Global Alliance for Buildings and Construction

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Executive summary

With the Paris Agreement countries have agreed to a common goal of maintaining the global temperature increase to well below 2 degrees, and preferably no more than 1.5 degrees, by the end of the century. According to the latest UNEP Emissions Gap report, to be on track for the 1.5° degree goal, the world needs to reduce global emissions by over 50% by 2030 and work towards carbon neutrality by 2050. As the buildings and construction sector accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide (CO_2) emissions, globally, in 2018, it will have to play a major part in achieving this vision.

However, in 2018, buildings-related CO_2 emissions rose for the second year in a row, to an all-time high of 9.7 Gt CO_2 (GlobalABC/IEA/UNEP, 2019). Rapid increases in floor area and demand for energy-consuming services are driving this growth, outpacing efficiency improvements and the decarbonisation of electricity and heat. At present, mandatory policies on building and equipment performance cover less than 40% of energy use and less than half the CO_2 emissions from buildings. Progress on building energy codes, in particular, is lagging, as more than two-thirds of the buildings constructed between now and 2050 are expected to be built in countries lacking building energy codes (IEA, 2017).

Decarbonising buildings across the entire life cycle would require a transformation of the buildings and construction sector. Reaching net-zero operational and embodied carbon emission buildings is possible, but requires clear and ambitious policy signals to drive a range of measures including passive building design, material efficiency, low-carbon materials, efficient building envelope measures, and highly efficient lighting and appliances.

According to the *World Energy Outlook* (IEA, 2019a), cost-effective, proven, energy efficiency and decarbonisation measures in buildings could contribute over 6.5 Gt CO_2 reductions in annual emissions by 2040, compared to the current course of action under the Stated Policies Scenario.[1] Reductions in emissions from buildings represent one-third of the total reductions required to align with the IEA's Sustainable Development Scenario[2] (IEA, 2019a). This Scenario is designed to achieve the outcomes of the UN Sustainable Development Goals most closely related to energy: to achieve universal access to energy (SDG 7), to reduce the severe health impacts of air pollution (part of SDG 3) and to tackle climate change (SDG 13).

Achieving these outcomes at pace and scale will require greater collaboration among policy makers at all jurisdictional levels, as well as with urban planners, architects, developers, investors, construction companies and utility companies. In addition to providing healthier, more resilient and more productive environments, the decarbonisation of the buildings sector presents a business opportunity in emerging markets with an estimated value of approximately USD 24.7 trillion by 2030 (IFC, 2019). Decarbonising buildings is also in full alignment with the aims of SDG 12, to ensure sustainable consumption and production patterns.

The purpose of this roadmap is to support a common language and vision for the complete decarbonisation of the buildings across their life cycle and to support the development of national or subnational strategies and policies, including for example, Nationally Determined Contributions (NDCs). It outlines the range of actions that stakeholders can take in the short, medium and long term to achieve a built environment that is zero-emission, efficient and resilient. It covers eight "activities": urban planning, new buildings, existing buildings, building operations, appliances and systems, materials, resilience and clean energy, and for each of these proposes key actions, targets

[1] The Stated Policies Scenario (STEPS) reflects the impact of existing policy frameworks and today's announced policy intentions.
[2] As well as meeting the energy-related UNFCC Sustainable Development Goals in full, the Sustainable Development Scenario (SDS) is fully aligned with the Paris Agreement, holding the global average temperature rise to below 1.8°C with a 66% probability without reliance on global net-negative CO_2 emissions.

for policies and technologies, and enabling measures with the aspiration of reaching net-zero carbon emission buildings by 2050.

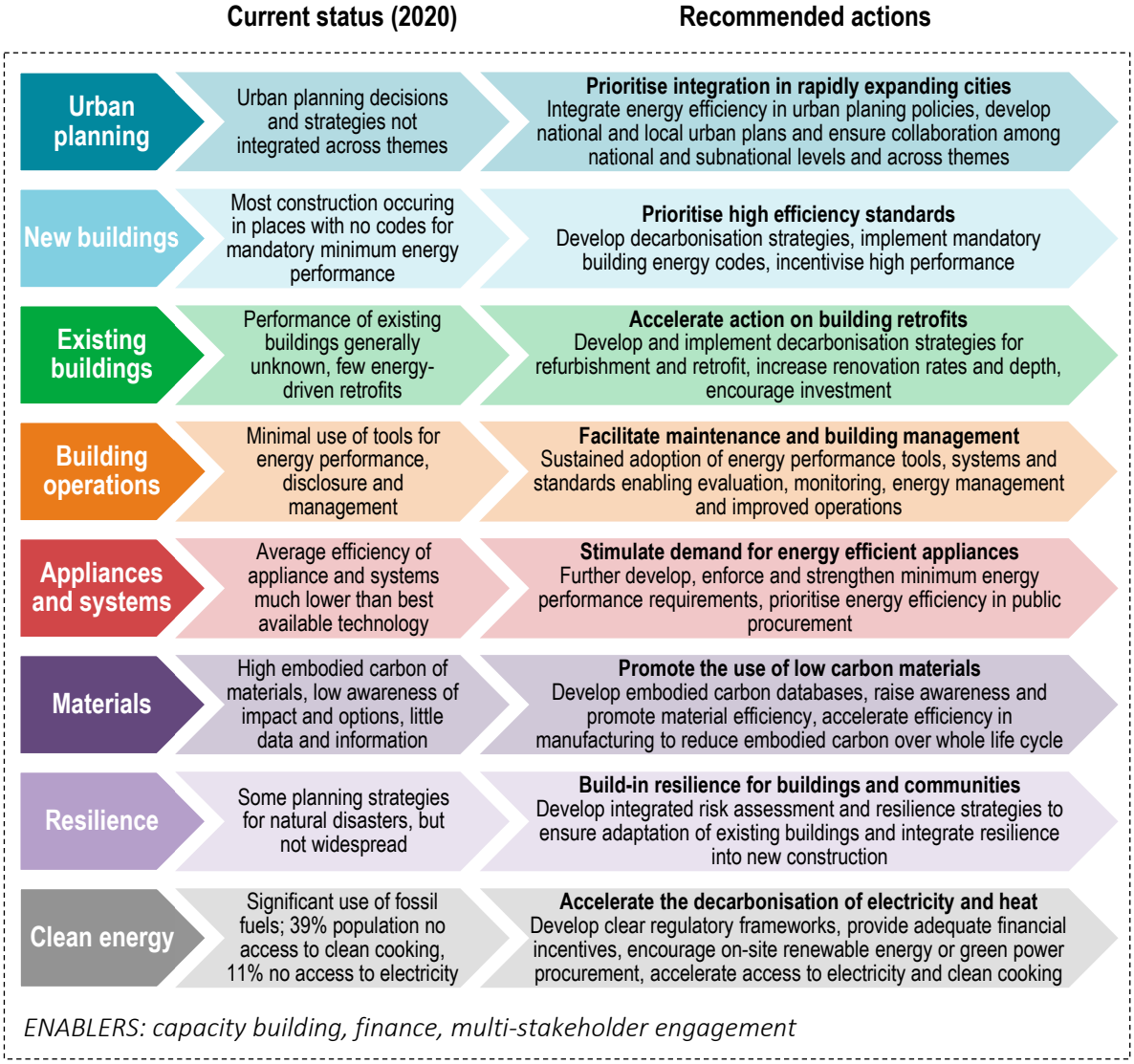
The Global Roadmap builds on consultation with over 700 stakeholders and buildings experts around the world who provided input to collectively build the timelines across the eight buildings and construction activities.

The IEA and the GlobalABC have also developed a series of regional roadmaps to identify region-specific priority actions and pathways: the GlobalABC Regional Roadmaps for Buildings and Construction for Africa, for Asia and for Latin America.

Getting to zero-emission, efficient and resilient buildings by 2050

The timelines below describe the actions identified by stakeholders as being key to delivering zero-emission, efficient and resilient buildings by 2050.

Figure 1 • Roadmap summary timelines



The Roadmap chapters “Activities 1-8” and the chapter on “Roadmap support: Enablers” develop the strategies that could support delivering these long-term objectives.

Key actions

To support decarbonising new and existing buildings, effective policies and regulations need to cover the entire building life cycle, including the design, development, operation and decommissioning stages, and also act beyond site boundaries through neighbourhood planning and clean energy. To accelerate action, greater collaboration involving a range of stakeholders is needed, including policy makers, urban planners, architects, construction companies, materials suppliers, utility companies, developers and investors.

Based on extensive stakeholder consultation and analysis, the following actions would need to be undertaken in order to achieve progress towards zero-emission, efficient and resilient buildings.

National roadmaps and strategies set priorities for the sector

National ministries and city agencies should develop ambitious, comprehensive strategies and roadmaps to outline the pathway to a zero-emission, efficient and resilient buildings and construction sector. These should be developed through consultation and engagement, address the multiple dimensions of urban planning, new and existing buildings and their operation, appliances and systems, embodied carbon of materials, resilience and clean energy.

Governments should partner with key stakeholders to develop metrics which include energy performance benchmarks and sector targets and data collection mechanisms that include the use of materials with low-embodied carbon, building energy performance, building ratings systems, and building resilience.

Governments and industry coalitions should work to close key information gaps by establishing data collection systems and methodologies which can provide essential evidence to inform decarbonisation and efficiency planning, as well as highlight the concrete, quantifiable benefits of efficiency and sustainability interventions.

Local agencies should undertake risk mapping and resilience assessment and develop integrated strategies to improve the resilience of the building stock and develop strategies to address resilience risks in new building developments to inform zoning and building performance standards.

Standards and codes gradually drive up performance

Regulators should develop or expand Minimum Energy Performance Standards (MEPS) to set ambitious product energy performance requirements which cover all major appliances and systems. MEPS could be especially effective if developed in collaboration across regions to enable cross-border applicability. To support energy efficient purchasing decisions, regulators should implement voluntary and mandatory energy ratings and labelling programmes.

Regulatory frameworks to facilitate integrated action

City-level actors should collaborate across sectors and government levels to develop integrated urban planning policies and frameworks that address land-use efficiency, transit-oriented design, access to green spaces, resilience, and district clean energy planning.

National and local agencies should develop ambitious regulatory and incentive frameworks to increase investment in energy efficiency improvements and reduce carbon emissions from the production of major building materials.

National and local agencies should develop clear regulatory and incentive frameworks to promote the use of on-site and building-integrated renewable energy, including solar photovoltaics (PV), solar thermal, geothermal, micro-wind and advanced biofuels, where appropriate.

Narratives and engagement to drive demand

National and subnational governments, industry coalitions and civil society should promote the multiple benefits that zero-emission, energy efficient and resilient buildings have for different stakeholders.

National and subnational governments and large organisations can take leadership in zero-carbon procurement and standards to promote investment in low-carbon building construction and renovation and encourage adoption of efficient technologies at scale.

Governments and industry coalitions should craft narratives that promote good practices, such as the use of digital information systems for building operations and energy use, effective data collection, or the use of traditional low-carbon materials.

Capacity building

Governments and industry coalitions should promote opportunities for capacity building on topics like embedding circular economy concepts into building design through life-cycle assessment, data collection for efficiency improvement, reuse of construction materials, and phasing out high global warming potential refrigerants.

Government and industry coalitions should promote the adoption of existing efficient building construction and operation techniques and low-cost technologies that can improve building performance and lower embodied carbon.

How to use the Global Roadmap document

This section describes how to read the document and how to interpret the targets and timelines.

This document is intended to identify common goals, targets and timelines for key actions across eight "activities". These suggestions are not intended to be prescriptive but to act as guidance to governments seeking to establish their own action plans. Each activity 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 as each of these represents a key ingredient of how buildings influence our environment and vice versa.

Table 1 • Roadmap definitions

Activity 1: **Urban planning**. This activity covers land use, zoning and other planning associated with how buildings, transport and energy systems interact.

Activity 2: **New buildings**. This activity covers all aspects of new buildings, including the design process, design strategies, codes and labels.

Activity 3: **Existing buildings**. This activity covers all aspects of the improvements of existing buildings.

Activity 4: **Building operations**. This activity covers all aspects of the operations and management of buildings.

Activity 5: **Appliances and systems**. This activity covers lighting, appliance and equipment systems that are used in both new and existing buildings.

Activity 6: **Materials**. This activity covers envelope, structural and product materials used in buildings.

Activity 7: **Resilience**. This activity covers all aspects of building resilience that enables increased capacity to adapt to and mitigate the effects of changing climates and other natural disasters.

Activity 8: **Clean energy**. This activity covers the clean energy transition away from carbon-intensive fuels to renewable energy resources.

Roadmap support: **Enablers**. These document the key success factors for capacity building, financial tools and multiple benefits and how they can support the achievement of the targets and timelines for the activities.

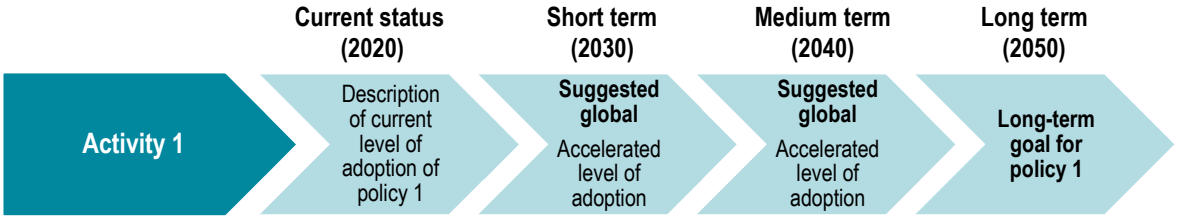
Each of the activities is structured in a similar manner, illustrated by relevant examples, and can be read in isolation or in conjunction with the other parts of the document.

Each of the activities covers:

- **Key actions:** a summary of key actions and timelines identified for the activity.
- **Stakeholders:** a map of the different stakeholders relevant to the activity and their relative importance.
- **Recommended policy action:** a list of recommended policies with a description of the current status of that policy in the region, and proposed targets for short, medium and long term. These are shown as a set of timelines, with a description of each below. See note below about how to read the timelines.
- **Recommended technology action:** a list of recommended actions related to particularly technologies, with a description of the current status of that technology in the region, and proposed targets for short, medium and long term. These are shown as a set of timelines, with a description of each below. See note below about how to read the timelines.
- **Finance action:** a list of recommended financial tools particularly relevant to the activity, followed by a series of local examples of current practice.
- **Capacity building:** a list of recommended capacity-building actions particularly relevant to the activity, followed by a series of local examples of current practice.
- **Multiple benefits:** a catalogue of the types of multiple benefits most relevant to the activity.

Figure 2, and the paragraph that follows, provides guidance on how to interpret the timelines:

Figure 2 • Demonstration timeline



Note: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

The target written in bold represents a global target. The accelerated target, given below the global target, represents a “stretch target” for countries to aim for to go further, and quicker, if desired. The 2050 target represents the ultimate desired long-term outcome. Some indicators do not contain accelerated targets due to a lack of data or input.

Introduction

The year 2015 was pivotal in addressing the critical need to tackle climate change, with the adoption of the Sendai Framework for Disaster Risk Reduction, the 2030 Agenda for Sustainable Development and the Paris Agreement reached at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC). Decarbonising the buildings and construction sector has a significant role to play in achieving these objectives and the related Sustainable Development Goals.

The buildings and construction sector is responsible 36% of final energy demand globally, representing 39% of energy- and process-related emissions. Climate scenarios show that emissions in this sector will have to be significantly reduced in order to achieve the Paris Agreement goals. Yet the *2019 Global Status Report* of the GlobalABC highlights that today's progress on emissions reductions are not on track as energy efficiency improvements are outpaced by floor area and demand growth. To counteract these trends, the global average building energy intensity per unit of floor area would need to be at least 30% lower than 2018 levels by 2030.

As identified in the *2019 Global Status Report for Buildings and Construction*, and, building on the *Guide for Incorporating Buildings Actions in NDCs* actions (including sustainable material choices and building design; urban planning measures, adaptation and resilience plans; clean energy transitions; and building operations and renovation), all provide opportunities to realise the goals of the Paris Agreement, i.e. maintaining the global temperature increase well below 2 degrees, and preferably no more than 1.5 degrees, by the end of the century. The GlobalABC Regional Roadmaps for Africa, Asia and Latin America cascade this methodology for the regions, incorporating relevant key insights and examples of best practice.

The buildings and construction sector is a highly "local" and "fragmented" industry, with no single group of large businesses having significant control of the stock and value chain. Innovation is slow, largely due to this fragmentation, and there is a lack of a common and international vision from the disparate actors in the sector. Thus, it is crucial to facilitate a common language and vision, foster transparency, promote inclusion and co-operation among stakeholders to implement effective long-term policies, and integrate emerging and innovative technologies into everyday practices.

This roadmap is the result of a stakeholder-driven process where buildings experts around the world were consulted to collectively build the timelines for each of the activities. which serve as a framework for the buildings and construction sector to align with the climate related objectives set out in the Paris Agreement.

The Global and Regional Roadmaps intend to guide policy makers when designing their national buildings and climate strategies, for example, when undertaking a review of their 2020-25 nationally determined contributions (NDCs). They are also intended to help organisations in determining their long-term and medium-term investment strategies. They do not replace a more detailed national or local buildings and construction roadmap that would take into account individual country circumstances.

Decarbonising the buildings sector

The buildings sector will play a major role in supporting the decarbonisation of the global economy, through improvements in energy efficiency to reduce energy demand, reducing use of materials and reducing their embodied carbon, and supporting adoption of distributed low-carbon and renewable energy generation.

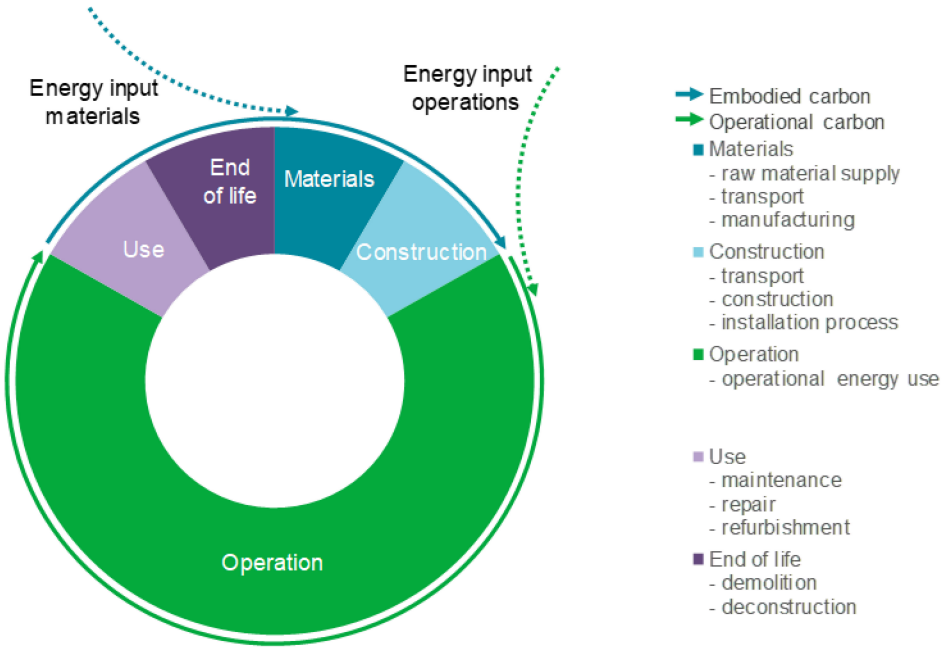
Over its lifetime, a building's carbon footprint consists of the embodied carbon from the manufacture and processing of building materials and construction as well as the operational carbon from their energy consumption. **Whole-life carbon** is described as **operational carbon + embodied carbon,** as calculated over the whole life cycle of the building (Figure 3).

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, this roadmap uses the following definitions, 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.

Figure 3 • Whole-life carbon: Definitions, adapted from European standard EN 15978



The electricity sector will have a crucial role in reaching a net-zero carbon buildings sector, with particular challenges in each region given the fuels used to generate electricity. Indeed, the decarbonisation of the electricity sector could represent over 30% of the emissions reductions needed to reach the IEA Sustainable Development Scenario pathway (IEA, 2019b).

Finally, to reach the ultimate goal of whole-life net-zero carbon in buildings, the embodied carbon of building materials must be reduced and offset through low-carbon materials, more efficient manufacturing techniques and the optimisation of materials usage. Indeed, material efficiency strategies could reduce the whole life-cycle emissions of residential buildings by up to 35-40% in Group of Seven (G7) countries[3] (IRP, 2020). Increased data collection, labelling, the development of new construction techniques and disclosure of building performance will be essential tools for enabling this transformation at scale, in all regions.

All eight activities described in this roadmap have an essential part to play in decarbonising buildings across their life cycle.

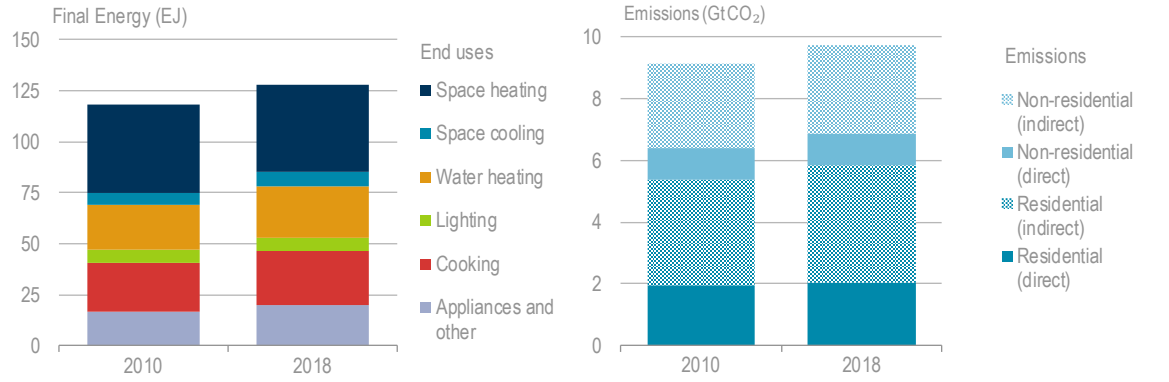
[3] Estimate for G7 countries.

Global overview

Energy and emissions

Recent trends in energy consumption and energy-related carbon emissions for the buildings and construction sector are varied, with increasing energy use but limited growth in buildings-related emissions. In 2018, the buildings and construction sector accounted for 36% of final energy use and 39% of energy-related CO_2 emissions, 11% of which resulted from manufacturing building materials and products such as steel, cement and glass (GlobalABC/IEA/UNEP, 2019). The indirect emissions from buildings are more than twice the direct emissions and are associated with fuels used for electricity generation.

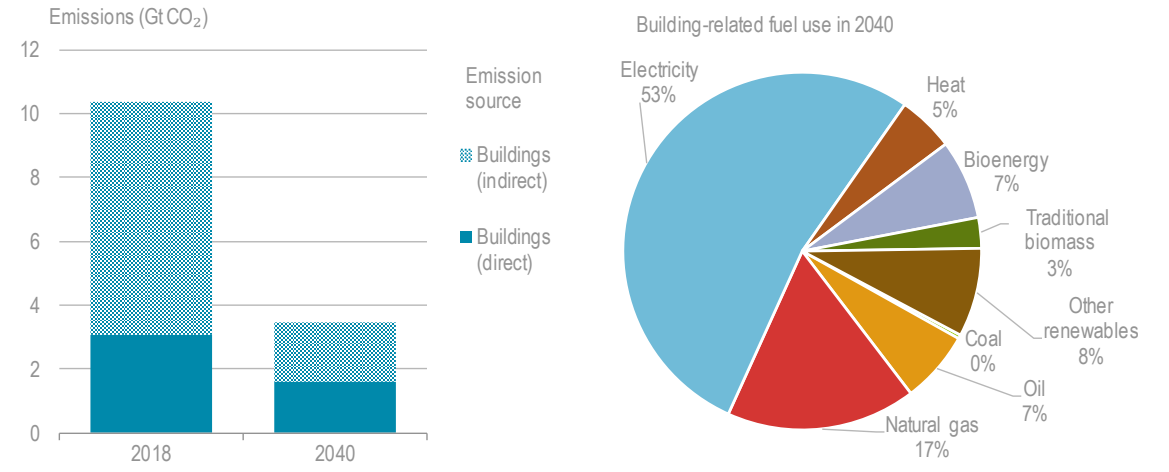
Figure 4 • Global share of buildings and construction final operational energy and emissions, 2018



Notes: EJ = exajoules. Indirect emissions include emissions from the energy system for power production.
Source: Adapted from GlobalABC/IEA/UNEP (2019), *2019 Global Status Report for Buildings and Construction*.

To achieve the energy savings and emissions reductions in the buildings and construction sector, the outlook to 2050 requires significant energy savings from net-zero carbon buildings, deep renovations, low-emissions energy supply and low-emissions materials. The emissions reductions from these four components are broadly captured by the eight key activities in this Global Roadmap.

Figure 5 • Emissions from buildings in the SDS and fuel mix in 2040



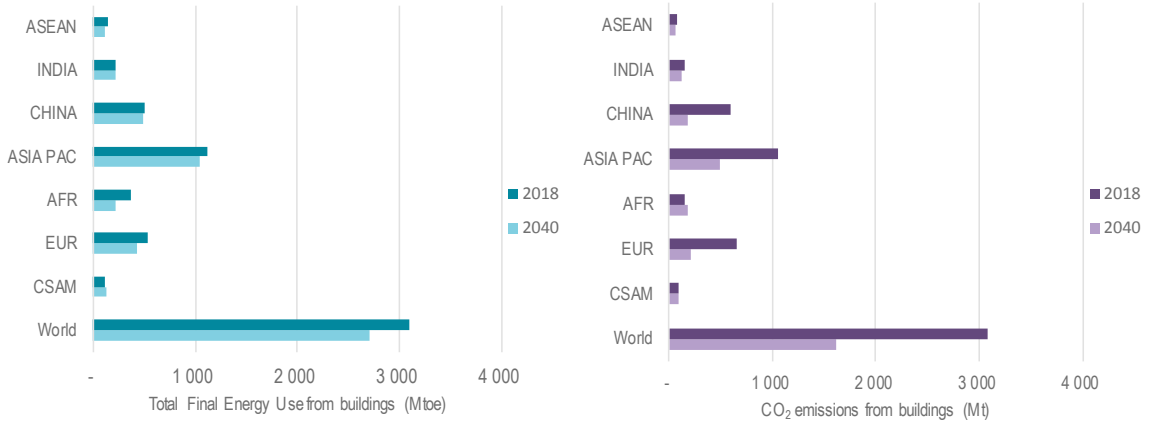
Note: Includes operational emissions only.

Sources: Adapted from IEA (2019a), *World Energy Outlook 2019*, and IEA (2020), *World Energy Statistics and Balances* (database), www.iea.org/statistics.

As shown in Figure 5, as a milestone towards the Paris goals, the IEA *World Energy Outlook* shows that overall emissions from the buildings and construction sector could fall by 70% by 2040 (IEA, 2019a), primarily due to a reduction in indirect emissions.

As shown in Figure 6, according to the IEA *World Energy Outlook*'s SDS, global energy use could see a reduction of 13% between 2018 and 2040. This change in energy demand would come alongside an overall growth in floor space and economic activity. Yet some regions would see much greater changes. Europe could see a 19% reduction in energy use, while Africa could see a 40% reduction primarily due to fuel switching. Global carbon emissions, however, could reduce by nearly 50% by 2040 from 2018 levels. Under the SDS, Europe and the People's Republic of China (hereafter "China") could see a reduction of around 68%, while Africa could see an increase in emissions by 20%.

Figure 6 • Buildings total final energy use and carbon emissions in 2018 and in 2040 SDS



Notes: ASEAN = Association of Southeast Asian Nations; ASIA PAC = Asia Pacific; AFR = Africa; EUR = Europe; CSAM = Central and South America.

Sources: Adapted from IEA (2019a), *World Energy Outlook 2019*, and IEA (2020), *World Energy Statistics and Balances* (database), www.iea.org/statistics.

For materials, at a global level, under a scenario in which material efficiency is maximised, (the IEA Material Efficiency variant Scenario [MEF]), the IEA estimates that by 2060, compared with the Reference Technology Scenario (RTS), demand for steel and cement in buildings could be reduced by almost 40%.

Specific actions in the buildings sector capable of providing significant savings include switching to composite frames, optimising frames and structures to use less steel and cement, using best available steel and cement, prioritising the development and use of local materials, reducing waste, and extending the lifetime of buildings.

Global context

The global population is estimated to be 7.7 billion people, of which the vast majority live in Asia, Africa and Latin America. Global population is expected to grow to 8.5 billion in 2030 and up to 9.7 billion in 2050 (UN DESA, 2019).

The median age of the global population is approximately 30, meaning that the majority of people are entering their most economically productive period, and population is also expected to increase (with an average birth rate of 2.5). Although there is a declining birth rate across

most countries (i.e. below the replacement rate of 2.1), life expectancy has continued to increase (73 years) (UN DESA, 2019).

These factors mean that there will continue to be a sustained growth in demand for buildings and energy-using services, but these will be in regions of the world that have the lowest demands to date. This phenomenon presents an opportunity to change the way in which buildings are constructed and operated towards a sustainable and low-carbon pathway.

Issues and challenges

Global poverty remains a substantial problem though it has seen a positive change since 2010, with a 40% reduction of the global population in extreme poverty, from 16% to 8.6% by 2018.Many of the fastest-growing populations are in the poorest countries (UN DESA, 2019), which presents challenges to addressing poverty and supporting economic prosperity. Alongside this, protecting the environment and combating climate change remain a central challenge for achieving sustainable development. For example, conditions of extreme heat in many parts of the world were responsible for a considerable portion of electricity demand growth in 2018 (IEA, 2019c). As the world becomes warmer under a changing climate, buildings will need to adapt to become more resilient while meeting the needs of a changing demographic. Furthermore, urban poverty has led to the formation of pockets of informal settlements in cities, particularly in high-risk and vulnerable areas. As extreme weather events become more frequent, buildings and cities will need to adapt to become more resilient and safer for all urban dwellers.

Investment environment

A significant scale-up in investment will be needed to unlock the benefits associated with zero emission, efficient and resilient buildings. The International Finance Corporation estimates that investing in green buildings presents a USD 24.7 trillion opportunity in emerging markets by 2030 (IFC, 2019).

Globally, the buildings sector offers great potential for climate-smart investments. Supporting sustainable buildings requires an increase in annual investment to an average of USD 27 billion over the next decade. Overall, this is a small additional investment compared with the USD 4.9 trillion already being invested each year in buildings globally (IEA, 2019c). The IEA estimates that under a fast clean energy transition scenario, the cumulative household energy spending to 2050 is around USD 5 trillion lower, with the average share of household income spent on energy falling from 5% today to around 2.5% by 2050. Yet the *2019 Global Status Report for Buildings and Construction* points out that, although the buildings sector continues to receive the largest portion of energy efficiency investments, they levelled off between 2017 and 2018 (GlobalABC/IEA/UNEP, 2019).

An enabling policy framework for investment and finance is thus critical to mobilise and effectively channel finance to investments in the low-emissions buildings and construction sector. This includes support for low-carbon technologies, removing fossil fuel subsidies, building capacity among policy makers and financial institutions, and establishing effective retail channels. In this roadmap, each of the following sections provide an overview of tools that can be used to stimulate investment.

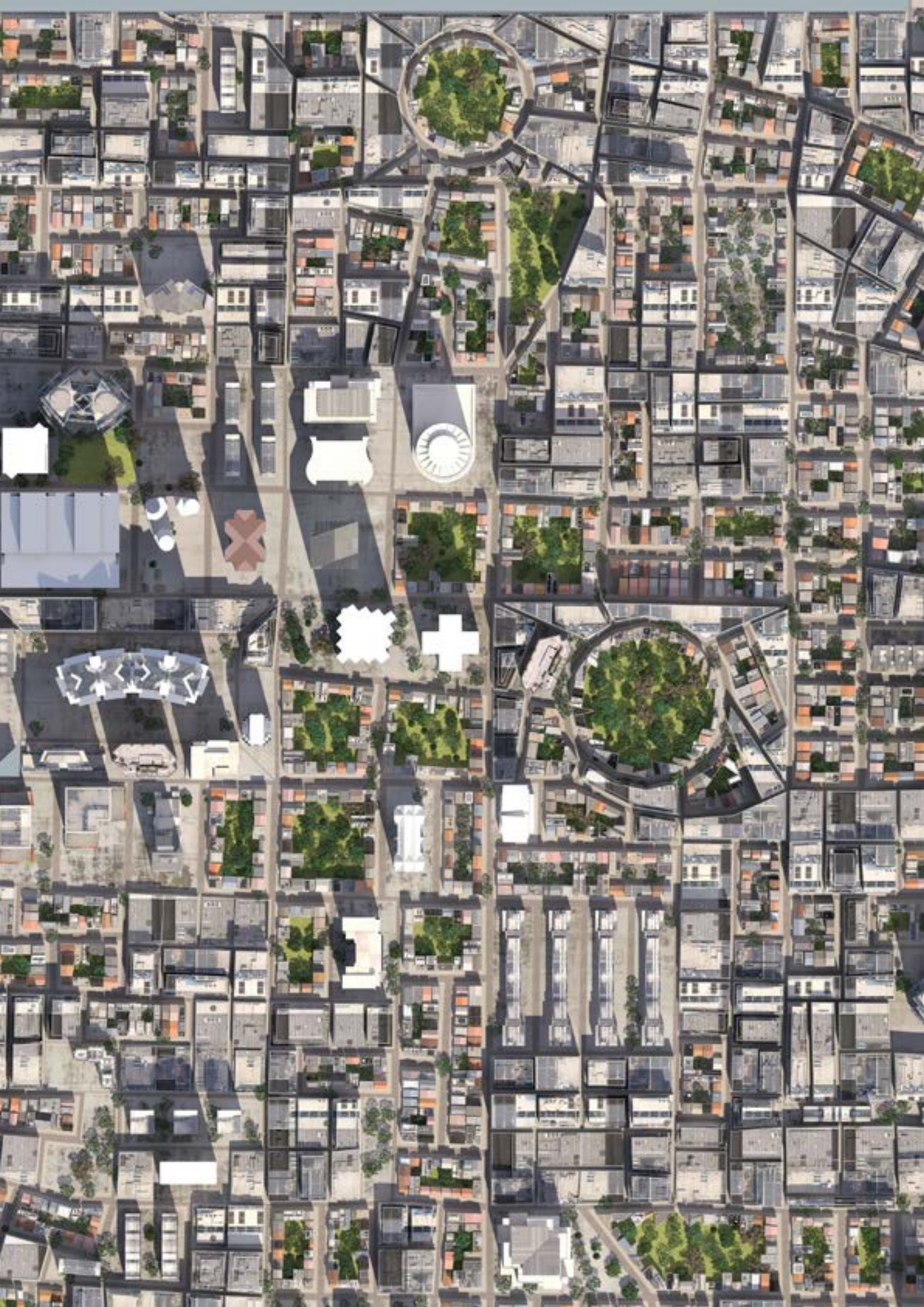
Policy

Overall, while 136 countries mention buildings in some form in their nationally determined contributions (NDCs), the majority do not include specific actions for the buildings and construction sector (GlobalABC/IEA/UNEP, 2018). According to the GlobalABC's *A Guide for Incorporating*

Buildings Actions in NDCs (UNEP, 2018), most NDCs do not include net-zero energy performance in buildings, or building decarbonisation strategies. Certain areas such as building design and cooling are included in only a small minority of countries' NDCs. Inclusion of low-carbon materials, reducing embodied carbon and links to urban-scale policies are also often missing (UNEP, 2018). According to the 2019 Emissions Gap Report, many national and subnational governments have to yet to adopt targets for the buildings sectors (UNEP, 2019).

Globally, many countries have MEPS and energy labels in place, although their coverage and stringency varies. Across the globe, there is work ongoing towards regional harmonisation, which can assist manufacturers, importers and retailers in streamlining their product offerings and collectively improving efficiency across a group of neighbouring countries (Braungardt & Göthner, 2017). Regional harmonisation of MEPS and labels, including strengthening of standardisation bodies, assessment institutions and regulatory agencies, can make these programmes more effective. For example, the ASEAN SHINE initiative, a public-private partnership between the ASEAN Centre for Energy, UNEP and the International Copper Association, is helping Southeast Asian countries to move their markets to energy-efficient appliances and equipment. Shifting all markets to adopt more energy-efficient lighting, appliances and equipment would bring significant environmental, economic and financial benefits for governments, businesses and consumers.

Each of the following sections of this roadmap describes policies that are able to support the implementation of technologies, and actions to realise zero-emission, efficient and resilient buildings.



Targets and timelines

Activity 1: Urban planning

Sustainable urban planning frames the supply and demand for urban energy with a view to: 1) protecting the environment (including mitigating climate change, reducing air pollution and limiting resource depletion); 2) achieving economic and human development goals; and 3) improving the resilience of local communities and urban energy infrastructure to disasters (IEA, 2016).

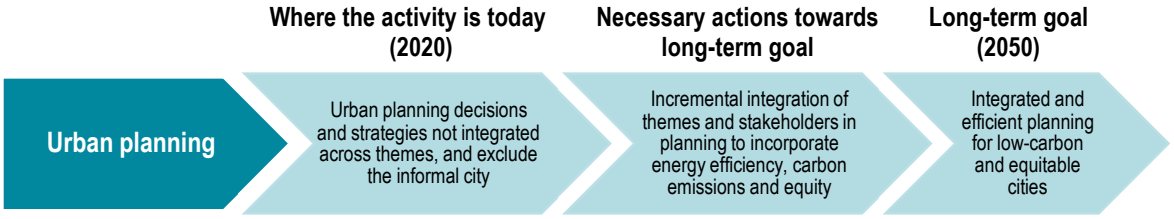
In the wake of the Paris Conference (COP21) and the Climate Summit for Local Leaders in November 2015, and the Habitat III United Nations Conference on Housing and Sustainable Urban Development, which took place in Quito in October 2016, cities are becoming increasingly central to the transition towards sustainable energy systems. Greater alignment among governance structures, both between national and local policies (vertical integration) and between local sectoral institutions (horizontal integration), plays an essential role in meeting environmental, economic and social objectives simultaneously (IEA, 2016).

The New Urban Agenda, adopted at the Habitat III conference in October 2016, lays out a 20-year collective vision to achieve sustainable cities in line with Sustainable Development Goal 11 and elevates the role of cities in addressing climate change and in disaster risk management. It promotes compact cities, polycentric urban growth, transit-oriented development, sprawl containment and vibrant public spaces (UN, 2017).

The siting of buildings has both direct and indirect impacts on urban energy use. Urban form is an important determinant of urban energy demand, which encompasses the overall physical characteristics of the built environment, such as shape, size, density and configuration; the street network; and public spaces. Likewise, at the building scale, compactness, height, orientation and mutual shading have a great influence on energy demand in buildings and local renewable energy potential. Buildings are governed by rules set in urban planning policies. Their impact on energy consumption and potential for local energy production should be taken into consideration when defining urban planning policies and urban development projects (e.g. new urban districts, rezoning, and district energy planning).

Key actions for urban planning

Figure 7 • Key actions for urban planning globally



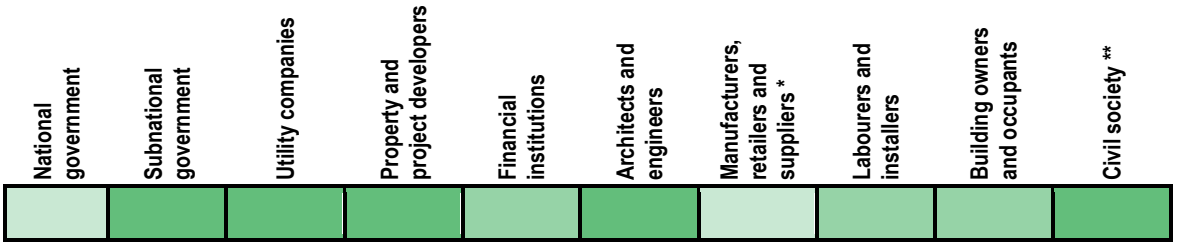
Key actions for urban planning include:

- **Integrated urban planning policies**. Cities are complex and dynamic systems. As such, urban planning policies can achieve maximum impact when they are systemic and integrated rather than isolated and sectoral. Enacting urban planning policies on a national and local level that takes into account the multi-faceted nature of urban planning is central to ensuring the decarbonisation of buildings and construction. Cities experiencing the highest and fastest population growth should be prioritised. Involve citizens and favour their active participation in the planning process so as to improve their understanding of urban issues and foster knowledge sharing.
- **Local and national urban plans underpinned by location efficiency**. These should include a focus on location efficiency, transit-oriented design, green space for the mitigation of the heat island effect, and net-zero carbon building codes and resilience.
- **District energy planning**. Enable a systemic approach that can plan for integrating energy demand and supply at district level to deliver more efficient and low-carbon solutions.
- **Institutional co-ordination**. Ensure collaboration among national, subnational and city levels, and across dimensions including transport, spatial planning, energy supply and housing based on good communication and awareness of the multiple benefits of decarbonising buildings and construction.

Stakeholders for urban planning

Globally, the key stakeholders for sustainable urban planning include those who can influence urban planning and those who can deliver the results of zero-emission, efficient and resilient buildings through urban planning. Additional stakeholders include those who can support the process through research, funding, training and making technologies available. These stakeholders are mapped in Table 2, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 2 • Stakeholder mapping for urban planning globally

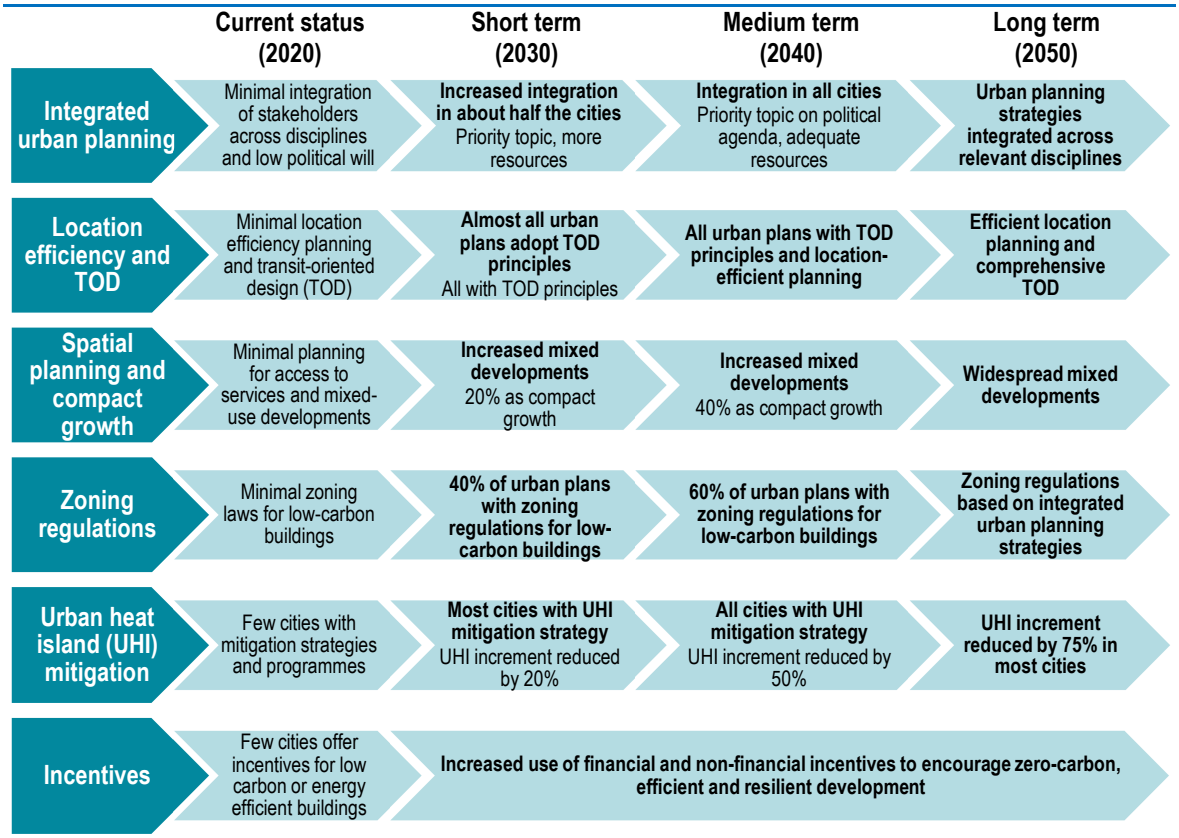


* of appliances and materials. Includes product testers and certifiers.
** including academia, non-governmental organisations (NGOs), research institutions, social networks and community associations.
Notes: *How to read*: The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for urban planning

Urban planning policy can support goals for zero-emission, efficient and resilient buildings by enabling a local environment that uses resources sustainably and where designers, developers and owners have the support to invest in the broader sustainable development goals. The following sub-targets and timelines offer more details:

Figure 8 • Policy timelines for urban planning globally



Note: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Urban planning policy target details:

- **Integrated urban planning**: Integrated urban planning creates a formal framework to encompass multidisciplinary issues, such as climate change, disaster risk reduction and emergency response, as well as land use and transport, location of services and infrastructure, social housing, and digital and open data information frameworks. A critical aspect of delivering this planning framework is the articulation of a clear city vision, developed in collaboration with citizens to reflect citizens' needs. Institutional co-ordination can start with the ministries in charge of land use, transportation, buildings, and energy and environment, and progressively integrate more sectors as priority areas are defined (e.g. health, education, water and sanitation, waste, public parks). The development of a shared and integrated city vision requires alignment between different levels of government and across the motivations of different stakeholders involved in designing and implementing projects at the city level. Integrated planning is therefore underpinned by active and ongoing processes of communication and co-ordination among stakeholders at all stages of planning. Such integration can help to mainstream energy efficiency strategies across all departments of local governments.

- **Location efficiency and transit-oriented design (TOD)**: There is growing consensus on the importance of strategically integrating urban infrastructure and land-use planning to achieve zero-carbon emissions, efficiency and resilience goals. Urban form is a key determinant of travel needs and behaviour. Housing location decisions have a huge impact on overall energy use and emissions. Households can reduce their transportation-related energy use by opting for compact, mixed-use communities that are "location efficient", i.e. accessible through multiple modes of active and public transportation (EPA, 2011). The majority of location efficiency strategies are controlled by local government authorities. Zoning regulations that support location efficiency promote mixed-use zones, adjust zoning standards to allow compact urban development, raise the threshold of building density in urban cores and around transit nodes that can support denser development, encourage walkable communities, and designate strategic growth areas to direct urban expansion and property development (IRP, 2018). Zoning mechanisms to promote location efficiency include the use of overlays that add transit-related and density requirements to existing codes (ACEEE, 2019).

- **Spatial planning and compact urban growth**: Planners, developers and designers can work together to increase the mixed-use nature of compact urban districts that provide easy access from residential areas to transit, retail, employment and entertainment to limit energy use and emissions from avoidable transport and to enhance quality of life. Compact urban configurations can improve living conditions of urban residents through: spatial restructuring of the urban form to achieve "strategic intensification" (IRP, 2018); human-scale design that creates socially mixed neighbourhoods, with a diverse mix of housing types and social functions, and strengthens access to employment opportunities near residential areas; and sustainable mobility options such as light rail and bus rapid transit systems, bike lanes, and overall walkability (IRP, 2018). Additional aspects can also be integrated in sustainable spatial planning such as district energy planning, electric distribution networks and air corridors to channel flow of air at the urban level, among others.

- **Zoning regulations for low-energy and low-carbon buildings**: Local jurisdictions have an important role to play in integrating energy-related requirements into zoning regulations and streamlined "form-based" codes that increasingly link urban planning to sustainable buildings and communities not only in terms of controls on density and land use, but also in terms of the physical form of the built environment. The objective is to create a specific type of urban fabric that promotes energy-resilient, low-resource, compact, walkable and community-driven neighbourhoods. For example, form-based codes can promote shared parking, integrated storm-water run-off solutions, quiet and clean spaces to allow for natural ventilation strategies to be used, or shared solar PV rooftop installations. These approaches can promote efficient systems by maximising synergies between highly efficient buildings and renewable energy sources and demand response. This initially could include special zoning districts that require increased sustainability and expand over time to include all zoning districts.

- **Urban heat island (UHI) mitigation**: Un-vegetated, impermeable and dark surfaces in cities tend to generate UHI effects, i.e. higher ambient temperatures. Buildings, parking lots and paved surfaces absorb more heat than moist vegetated surfaces, which release water vapour and provide shade to cool the surrounding air. Consequently, the annual mean air temperature of a large city can be up to 3°C warmer or more than surrounding rural areas (EPA, 2019). These temperature increases will add to the warming that cities are experiencing from climate change. To minimise this effect and mitigate extreme heat events, cities are establishing goals for UHI reduction and implementing a variety of programmes and policies. Local authorities may aim at reductions in impermeable surface areas,

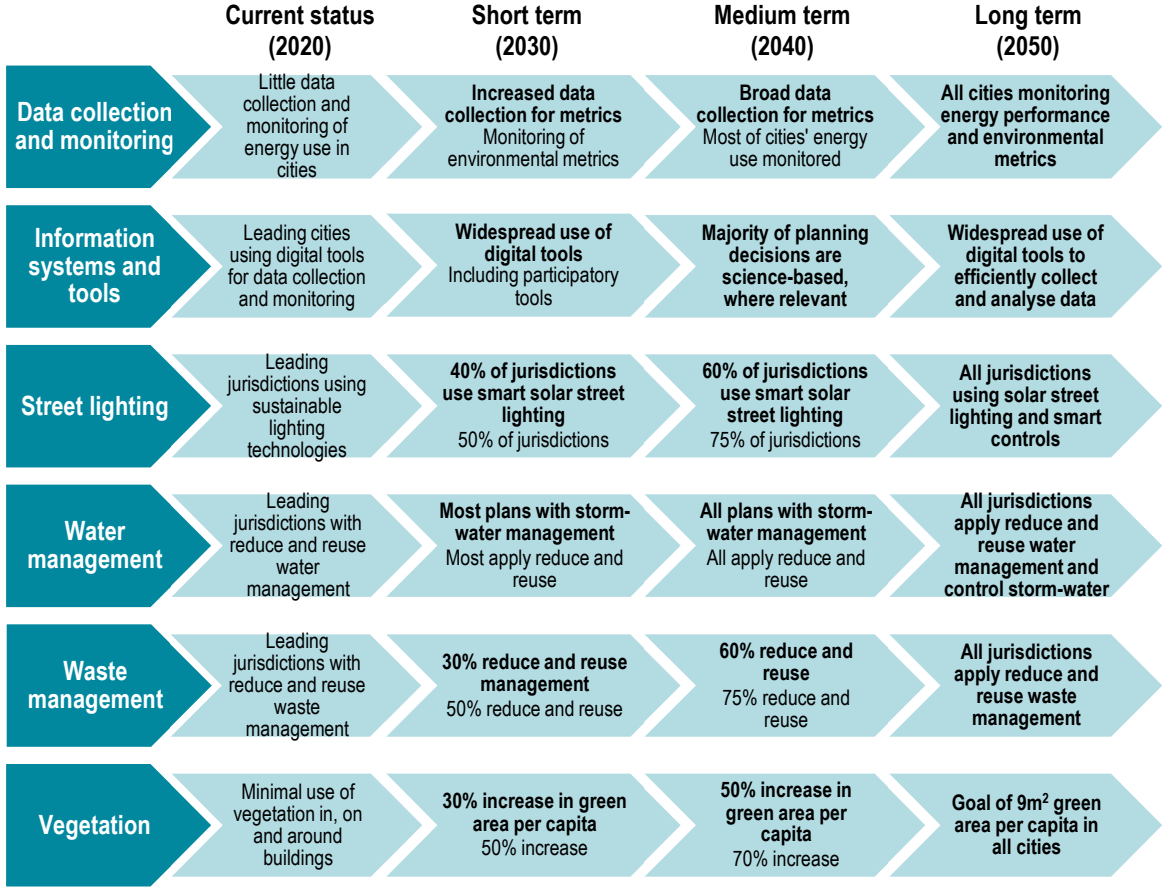
increases in the tree canopy, deployment of cool or green roofs and facades, or the expansion of wetlands. Quantitative goals should be included in formal city plans and specify a future target date or annual commitment (ACEEE, 2019).

- **Incentives**: Financial and non-financial incentives such as tax rebates, expedited permitting or increased project scope can be used by cities to encourage development that is in line with the aim of reaching zero-emission, efficient and resilient buildings and cities.

Technology for urban planning

Technology can enable increased action toward zero-emission, efficient and resilient buildings when coupled with urban planning. Specific targets and timelines for sustainable urban planning technologies are outlined below:

Figure 9 • Technology timelines for urban planning globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Urban planning technology target details include:

- **Data collection and monitoring**: Improved access to data helps cities measure, monitor and manage energy use and environmental impacts. Regular tracking of energy-related metrics allows cities to set a benchmark for energy usage and target specific areas where savings can be quickly achieved (ACEEE, 2019). Local government authorities should collect energy data covering public buildings and infrastructure, private buildings, and transport, through tools such as property registers.

- **Digital tools**: Support the increased use of tools that use data and information, such as geographic information system (GIS) data and mapping, satellite images, cost data, benefits analysis, and life-cycle analysis to facilitate science-based decision-making in the urban planning process, and ensure cities are not only "smart" but also efficient.
- **Street lighting**: Support the switch to smart and efficient lighting, including promoting solar street lighting technologies on the exterior of buildings and streets where relevant and effective on a whole life cycle basis. Smart lighting can include sensors and controls and can be integrated with other environmental and site condition information, such as traffic. Appropriate measures should be taken to minimise impact on population health and biodiversity by using appropriate light diffusion devices and lighting schedules.
- **Water management**: Support the increased use of water management technologies that reduce water run-off, increase landscape permeability and rainwater retention. This can support resilience against floods and improve health of soil and underground aquifers. The measurement of rainwater flows through downpipes, into tanks, and drains through smart sensors can enable urban planning authorities to identify places where green infrastructure is needed to improve drainage and mitigate urban heat island effects.
- **Waste management**: Support the increased use of waste and wastewater storage and treatment technologies that can reduce energy use for waste from buildings. The "3Rs" (reduce, reuse and recycle) principle should be embedded into the municipal solid waste strategies of all cities.
- **Vegetation**: Landscaping and vegetation can support improved resilience to excess stormwater run-off, reduced need for heating and cooling and improved air quality through measures such as green roofs, green walls, trees and parks. In particular, urban parks are critical in improving urban quality of life, in cooling cities, and acting as a sink for greenhouse gas (GHG) emissions and other atmospheric pollutants. Vegetation measures should prioritise the use of indigenous plant species.

Finance for urban planning

Finance can enable increased action towards zero-emission, efficient and resilient buildings when coupled with urban planning. Financial tools particularly relevant to urban planning include:

- **Urban development funds**: Dedicated funding for urban development projects, which can be directed towards sustainable urban development projects.
- **Infrastructure funds**: Dedicated funding for infrastructure projects, which can be directed towards sustainable infrastructure projects.
- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, such as sustainable buildings, construction or development projects. Dedicated credit lines to national or local governments can also be used to establish a revolving loan fund, which collects repaid loans for energy efficiency projects and reinvests them in additional energy efficiency projects.
- **Risk-sharing loan/loan guarantee/concessional loan**: Large organisations (such as a government, international bank or aid organisation) that cover the risk of payment default, offering below-market interest rates or offering longer grace periods for repayment to enable banks to fund projects with lower costs and therefore better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding for projects with climate or environmental benefits.

- **Preferential tax**: Direct funding from the government to reduce or eliminate the tax for sustainable products and services.
- **Grants and rebates**: Direct funding to overcome upfront cost barriers, provided by the government, organisation or programme either through a competitive process (grants) or during or after the purchase of a sustainable product or service (rebates).
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy-efficient products on a rental basis to reduce a capital expenditure.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.
- **Participative budgeting**: Citizens engage in multiple rounds of debates and deliberations, and ultimately vote on how a certain percentage of the municipal budget gets spent. This can contribute to a more equitable distribution of city services.

Capacity building for urban planning

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver sustainable urban planning. The types of capacity-building activities relevant to urban planning are mapped in Table 3, where the darker the colour, the higher the impact that capacity-building type has for this activity.

Table 3 • Capacity building for urban planning globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most relevant capacity-building activities are explained below:

- **Training within government**: Provide training on the integration of sustainable urban planning strategies across all relevant departments and levels of government, including those responsible for spatial planning, zoning regulations, and procuring and managing services such as waste and water management. Build capacity in collecting and using data to inform policies and urban plans. Finally, training on how to work in collaboration across stakeholder groups including governmental and non-governmental actors.
- **Training of professionals**: Build capacity and awareness among service providers, including urban planners and designers, as well as technology providers about the broader framework of sustainable development goals and the implications for urban planning solutions. This will be important to ensure co-ordination and shared goals among relevant government and non-government organisations for better implementation and enforcement of urban planning policies.

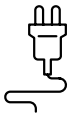
Further details regarding capacity building activities are provided in the section “Roadmap support: Enablers”.

Multiple benefits of sustainable urban planning

Many benefits can be achieved through sustainable urban planning, and many of these are aligned with several Sustainable Development Goals, especially with Goal 11 (sustainable cities and communities).

Some of these benefits are described below, although many of them require further analysis to quantify them:

Table 4 • Multiple benefits of urban planning

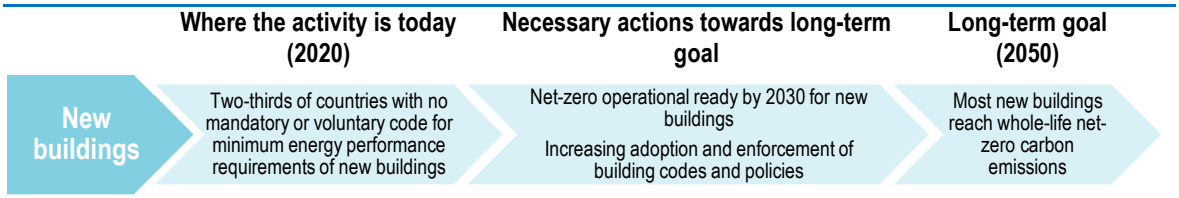
Environment
 • **Emissions reductions** – sustainable urban planning delivers emissions reductions through the reductions in emissions from transport thanks to TOD and encouraging walking and cycling, and absorption of CO_2 through open green spaces. • **Air quality – sustainable urban planning** reduces air pollution through the reductiono of transport-related emissions through TOD, open green spaces, and encouraging **walking and** cycling.
Energy
 • **Energy savings** – sustainable urban planning through mixed-use developments and TOD reduces commutes and supports mass transit, walking and cycling. • **Energy security** – sustainable urban planning delivers buildings, cities and transport systems that put less strain on energy systems by reducing energy demand and favouring local renewable energy sources. • **Energy prices** – sustainable urban planning supports integrated buildings, transit and energy systems that optimise potential synergies and energy flows so as to reduce energy demand and peak loads, lowering network infrastructure and system costs.
Economy
 • **Productivity** – sustainable urban planning increases the efficiency of the urban infrastructure and enables increased productivity through reduced commuting times, also improving health and well-being. • **Asset value** – sustainable urban planning can increase the asset value of homes, businesses and transit systems by saving time and money and creating more liveable cities.
Society
 • **Poverty alleviation** – sustainable urban planning reduces building operation and transport costs, and can deliver improved access to employment and other services for vulnerable populations. • **Health and well-being** – sustainable urban planning can support increased physical and mental health through improved access to employment, transit, greater use of active modes for commuting (walking, biking), reduced air and noise pollution, reduced time spent in transport, green spaces, and other amenities. • **Safety and security** – sustainable urban planning by mixed-use and transit-oriented planning can support improved social integration and urban lighting enhancing safety and security.

Activity 2: New buildings

This section addresses measures to reduce the operational energy (and consequentially operational carbon) in new buildings. Integrated policies for new buildings can avoid locking-in emissions from inefficient buildings for multiple decades. Fully decarbonising buildings over their whole life cycle will also require measures to reduce the embodied carbon of materials, addressed in "Activity 6: Materials", and measures to increase the share of renewable energy, both in distributed generation and in the electricity sector, as described in "Activity 8: Clean Energy".

Key actions for sustainable new buildings

Figure 10 • Key actions for new buildings globally



A series of key actions will be needed to achieve sustainable, zero-emission, efficient and resilient new buildings:

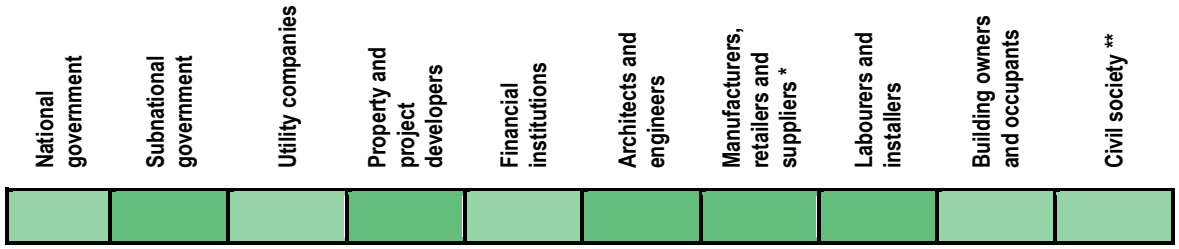
- **Develop a roadmap strategy**. Develop locally appropriate strategies for decarbonising buildings using an efficiency-first and whole life-cycle carbon assessment approach, including a strategy for decarbonising construction materials and energy aiming to reach new buildings that are ready to operate at net-zero carbon by 2030.
- **Develop and implement mandatory building codes**. Transition from voluntary to mandatory building codes that set the minimum energy efficiency standards in new buildings. Codes should set or refer to guidelines for locally adapted bioclimatic design principles, and increasingly incorporate climate resilience and low embodied carbon materials. Building codes should also include or refer to requirements for resilience and adaptation, requirements regarding the embodied carbon of materials, clean energy and urban planning strategies.
- **Strengthen building codes**. Ensure that there is a building code improvement cycle that strengthens the performance requirements every three to five years with aspirations of achieving zero-carbon codes by 2030.
- **Minimise the need for space conditioning**. Global cooling demand is the fastest-growing service demand. Focus on using highly efficient cooling systems where necessary but prioritise the use of passive design in order to maintain thermal comfort.
- **Governments lead by example**. Develop policies that ensure all new government buildings are low-emission and highly efficient, aiming in the first instance for near-zero energy.
- **Reduce embodied carbon** through materials measures (see "Activity 6: Materials") and **reduce operational carbon** through better operation and maintenance ("Activity 4: Operations") and the provision of clean energy (see "Activity 8: Clean energy").
- **Increase awareness and information**. Awareness of the benefits of more sustainable buildings will enable consumers to make better choices and can facilitate more advantageous financing.

Stakeholders for sustainable new buildings

Globally, the key stakeholders for sustainable new buildings include those who can influence new buildings and those who can deliver the results of zero-emission, efficient and resilient buildings. Additional stakeholders include those who can support the process through research, funding, training and making technologies available.

These stakeholders are mapped in Table 5, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 5 • Stakeholder mapping for new buildings globally



* of appliances and materials. Includes product testers and certifiers.

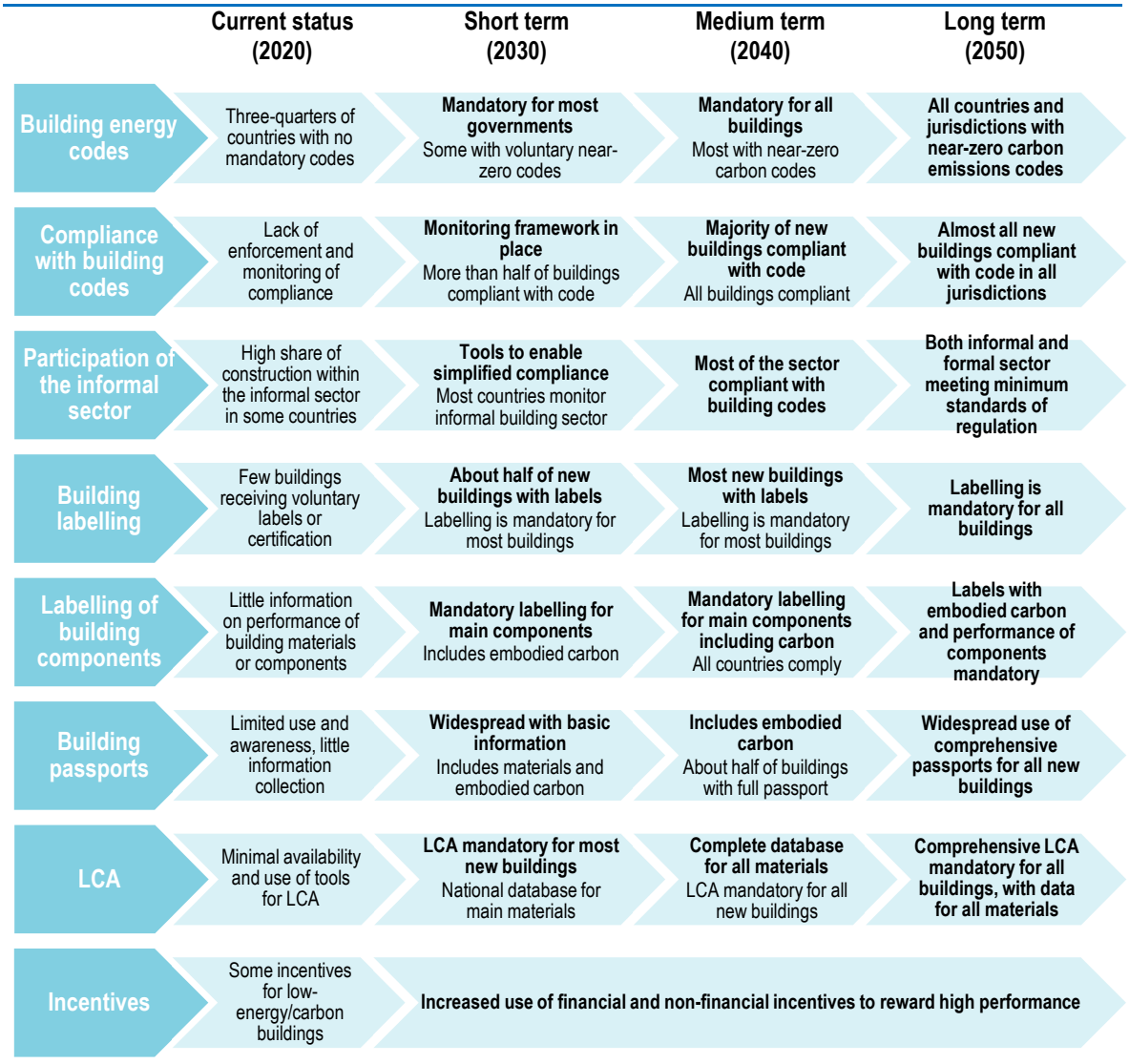
** including academia, NGOs, research institutions, social networks and community associations.

Notes: *How to read*: The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for sustainable new buildings

The policies listed in the timelines below represent key tools that policy makers have at their disposal to increase the performance of the new buildings that are built, to reach zero-emission, efficient and resilient buildings as soon as possible. These policies are applicable both at national and subnational levels, and will need to be supported by enabling policies and programmes as detailed in the subsections below.

Figure 11 • Policy timelines for new buildings globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

New building policy target details include:

- **Building energy codes**: Building energy codes or standards provide minimum requirements for building components or for building performance that can enable zero-emission, efficient and resilient new buildings, and upgrades to existing buildings during major renovations and refurbishments. Building codes should be mandatory and cover all types of building, and be based on a whole life-cycle carbon approach (including operational carbon and embodied carbon). These aim towards net-zero emission buildings at lowest cost by

ensuring highest efficiency levels first. Building codes should include, or refer to, locally adapted bioclimatic design principles to optimise passive design. First building codes should be prescriptive in format, evolving into performance-based codes. Specific standards and guidelines and tools for social housing and the informal sector can be used to facilitate compliance within this sector. More information on building codes can be found below in Box 1.

- **Building energy code compliance**: Compliance with, and enforcement of, building codes is crucial yet challenging, as it is often up to subnational governments to enforce, despite variations in human and financial resources. A monitoring framework for compliance checking, accessible tools and extensive capacity building will facilitate compliance and even enable compliance within sectors such as the informal sector and the social housing sector.
- **Informal sector**: Capacity building, accessible construction guidelines and tools, and wide stakeholder engagement will be key to increasing the compliance with codes within the informal building sector.
- **Building labelling**: Quantitative building energy labelling can be used to assess "as designed" building performance on a scale of less to more efficient. Labelling enables increased information sharing and awareness for consumers and investors. Labelling can also be linked to incentives and financial tools. Certification such as green building certification is included in this policy as another form of assessing performance. Labelling and certification systems should be continually monitored and revised to ensure the top rating is truly reserved to the top performing buildings of the market.
- **Labelling of building components**: The availability of robust performance information of individual building components and materials is key for designers to optimise building design, and perform robust LCA based on whole-life performance. Key performance parameters include the thermal transmittance of materials, the solar heat gain coefficient or solar factor of glazing, and the reflectance of surface finishes. Additional information should eventually include embodied carbon, particularly for materials whose embodied carbon can be significant (insulation, glazing, window frames, etc).
- **Building passports**:[4] Building passports can be used to track information about the building, materials, systems, energy use, renovations and other relevant information to improve decision-making processes. At the time of handover of a new building, a new building passport could include: floor area, bill of quantities, embodied carbon of materials, description of systems, maintenance schedules and estimated energy consumption. During its operational phase it may be completed with further information (see "Activity 4: Building operations").
- **Life-cycle analysis**: Decisions regarding the building use, design and choice of materials should consider the entire lifetime of the building and its components. National databases containing information on the embodied carbon of construction materials will be necessary to undertake comprehensive life-cycle impact analysis of design choices.
- **Incentives**: Fiscal incentives should be awarded to the very best performing buildings to enable the uptake of the most effective novel technologies and tools. Criteria for obtaining fiscal incentives must be updated over time. Non-fiscal incentives, such as expedited

[4] A building passport is defined as a document or logbook that is used to store and track information about the building: basic characteristics, materials, systems, energy use, renovations and other building information.

permits or increased floor area allowances, are other tools for encouraging the construction of higher performance buildings.

Box 1 • What is a building code?

Building energy codes, also known as “energy standards” for buildings, “thermal building regulations”, “energy conservation building codes” or “energy efficiency building codes”, are the key policy instrument used by governments to reduce the energy consumption of buildings. Such codes consist of a set of mandatory minimum energy performance requirements designed to regulate energy use in buildings. They can cover both new buildings and existing buildings undergoing renovation or alteration. Architects and engineers use the functional energy requirements stated in building energy codes to design buildings that meet the required standards (IEA, 2013).

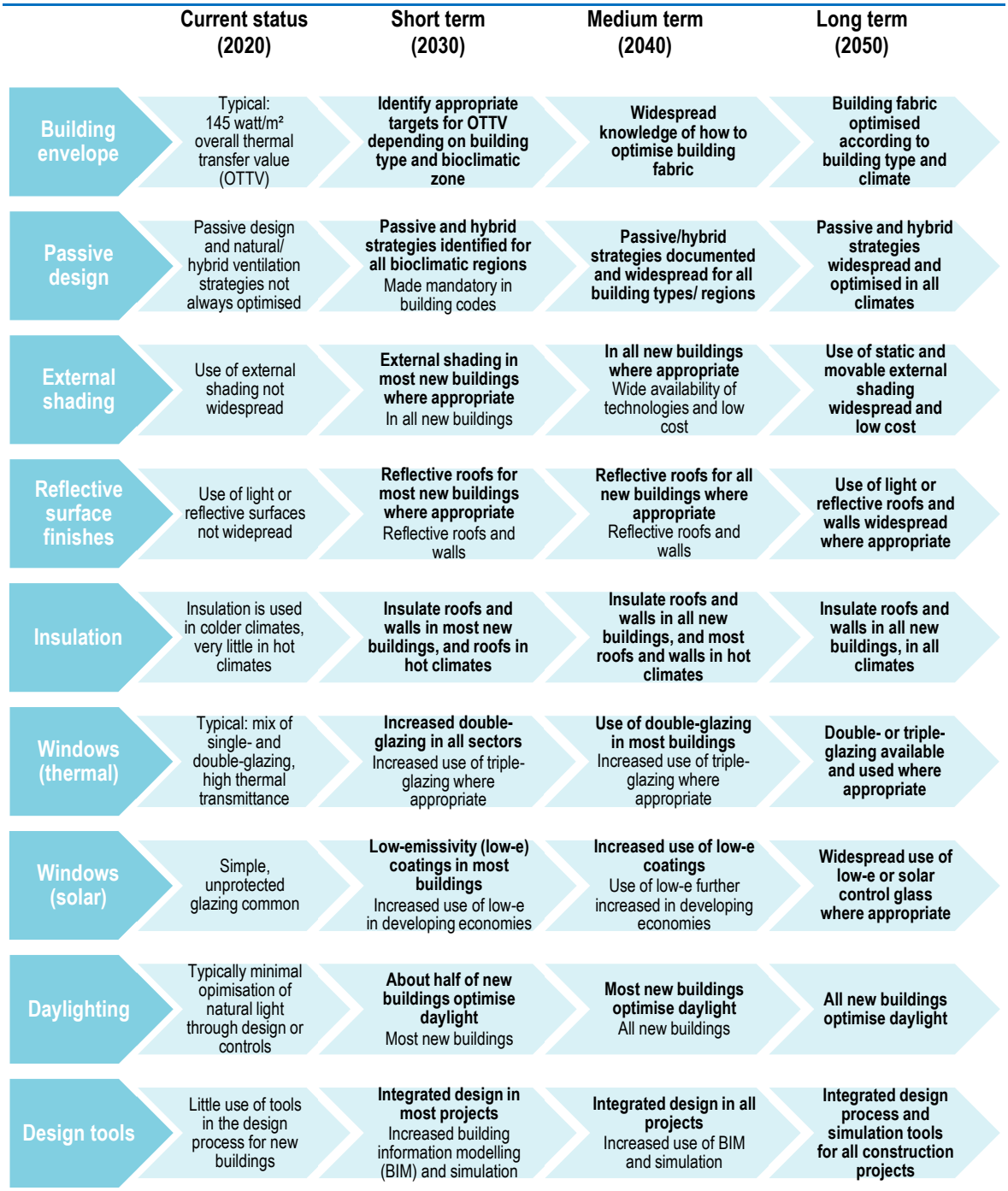
Building energy codes can be adopted as part of the larger body of building codes and required to be satisfied as a condition for approval to construct and occupy buildings.

Technology for sustainable new buildings

The technologies listed below have been identified as the key technologies or strategies needed to reach the long-term objective of decarbonising the buildings sector.

Specific targets and timelines for sustainable new building technologies are outlined below:

Figure 12 • Technology timelines for new buildings globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Sustainable new buildings technology target details include:

- **Building envelope**: The OTTV is a measure of the building envelope performance including conduction and radiation heat transfer. This includes the performance of the building structure, insulation and windows. Lower OTTV can be achieved through optimised material choices and passive design strategies including building form, orientation, thermal mass, shading, the use of reflective surfaces to limit solar gain and the use of vegetation for example in cool roofs.
- **Passive design**: Strategies for the most cost-effective combination of thermal performance of the building fabric, control of solar gains and ventilation, and daylight are highly dependent on the building type, how it will be used, and the macro- and micro-climate in which it is situated. Therefore, passive design strategies must be developed for specific bioclimatic regions and specific building types. These locally adapted design guidelines can ensure that passive strategies can be optimised before relying on active systems.
- **External shading**: External shading in the form of horizontal, vertical, fixed or movable elements can be the most cost-effective method of blocking out solar radiation. Good shading can have the same effect on reducing the solar heat gain coefficient (SHGC) of windows as solar-performance glazing.
- **Reflective surface finishes**: Light-coloured surfaces or surfaces with reflective pigments reflect incoming solar radiation, therefore reducing the temperature of the surface. Reflective surface finishes are most effective on the surfaces most exposed to direct sunlight (generally the roof).
- **Insulation**: Insulation is one of the components of OTTV that should have specific targets for hot locations and cold locations. A material's insulation performance is determined by its thermal conductivity. "U-value" is also commonly used to express how much heat will transfer through a given thickness of a particular material, where the lower the U-value, the better the material is as an insulator. It is important to note that insulation is important in hot climates as well as in cold climates, and is most effective in the component of greatest surface area (i.e. the roof for low and flat buildings, walls for tall buildings). Note: the benefits of increased insulation must be assessed over a whole life-cycle carbon assessment, given the high embodied carbon of traditional insulating materials.
- **Windows (thermal)**: Heat transfer by conduction through windows can be reduced through a transition to double- or triple-glazed windows, which have lower thermal transmittance, or U-value. When produced at scale, these types of windows can be cost-effective. These windows also provide noise protection, improve thermal comfort and can enable passive design strategies to be sufficient. Note: the benefits of double- or triple-pane glazing must be assessed over a whole life-cycle carbon assessment, given the high embodied carbon of traditional glass manufacturing.
- **Windows (solar)**: The dominant source of heat transfer through windows is through solar radiation. This can be reduced with low-e and low-SHGC windows. Building design and advanced technologies can enable low solar heat gain during hot weather, while allowing visible light transmittance for natural daylighting; however, the most cost-effective way of avoiding excess solar gain is reducing the size of windows and providing shading.
- **Daylighting**: Access to views and to daylight are essential for building occupant well-being, health and productivity. Building design should ensure that all spaces have access to natural light and views, and have glare-free, adequate daylight levels for large portions of the day

through improved control. However, there is a need to optimise the ingress of natural light with the control of excessive solar radiation.

- **Design tools**: The integrated design process of involving all disciplines of a building project (e.g. architect, lighting engineer, structural engineer, facilities manager, etc..) from the early stages of the project enables the adoption of many more passive design measures than when disciplines are brought on at later stages. Other tools with significant potential to optimise passive measures and design choices include thermal and energy dynamic simulation, daylight simulation, and BIM.

Finance for sustainable new buildings

Finance tools relevant to increasing the performance of new buildings may include:

- **Urban development funds**: Dedicated funding for urban development projects, which can prioritise sustainable urban development projects.
- **Infrastructure funds**: Dedicated funding for infrastructure projects, which can prioritise sustainable infrastructure projects.
- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, which can prioritise sustainable buildings, construction or development projects. Dedicated credit lines to national or local governments can also be used to establish a revolving loan fund, which collects repaid loans for energy efficiency projects and reinvests them in additional energy efficiency projects.
- **Risk-sharing loan/loan guarantee/concessional loan**: Large organisation (such as a government, international bank or aid organisation) covering the risk of payment default, offering below-market interest rates, or offering longer grace periods for repayment to enable banks to fund a project with lower costs and therefore better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding for projects with climate or environmental benefits.
- **Preferential tax**: Direct funding from the government to reduce or eliminate taxes for sustainable products and services.
- **Grants and rebates**: Direct funding to overcome upfront cost barriers, provided by a government, organisation or programme either through a competitive process (grants) or during or after the purchase of a sustainable product or service (rebates).
- **Green mortgages**: Prospective homeowners can solicit additional finance as part of their mortgage to install efficient features and technologies in their future homes.
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy-efficient products on a rental basis to reduce a capital expenditure.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Capacity building for sustainable new buildings

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver sustainable new buildings.

The types of capacity-building activities relevant to new buildings are mapped in Table 6, where the darker the colour, the higher the impact that capacity building type has for this activity.

Table 6 • Capacity building for new buildings globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most critical capacity-building activities are explained below:

- **Training within government**: Provide training programmes for central and local government on:
    - How to collaborate across multi-stakeholders, including how to communicate the multiple benefits of zero-carbon, efficient and resilient buildings. This will require data collection and analysis on the outcomes of policies and programmes.
    - How to implement and monitor policies through the development of tools, checklists, databases.
- **Training of professionals**: Provide training programmes for service and product providers of buildings and construction (architects, engineers, contractors, etc.) and building owners regarding how to design more sustainable buildings, and how to comply with new building policies, programmes or incentives for sustainable buildings and construction. Develop educational programmes including primary, secondary, vocational, university and adult education, to enable increased knowledge of sustainable new buildings. Provide certification or accreditation for professionals in the sustainable construction sector.
- **Training of financiers and developers**: Develop tools and provide training for developers and financiers to be able to assess the relative benefits of zero-carbon, efficient and resilient buildings, to enable increased access to funding and increased demand for high-performance buildings.

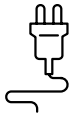
Further details regarding capacity-building activities are provided in the section “Roadmap support: Enablers”.

Multiple benefits of sustainable new buildings

Many benefits can be achieved through sustainable new buildings, and many of these are aligned to the Sustainable Development Goals, in particular Goal 7 (affordable and clean energy), Goal 11 (sustainable cities and communities), Goal 12 (responsible consumption and production) and Goal 13 (climate action).

Some of these benefits are described below, although many of them require further analysis to quantify them:

Table 7 • Multiple benefits of sustainable new buildings

Environment	
	• **Emissions reductions** – sustainable new buildings and zero-emission buildings deliver GHG reductions. • **Air quality** – sustainable new buildings and zero-emission buildings reduce air pollution. • **Resource efficiency** – sustainable buildings reduce the use of materials used in construction and increase the useful life of buildings and their components.
Energy	
	• **Energy savings** – sustainable new buildings are more energy-efficient. • **Energy security** – sustainable new buildings use less energy and put less strain on energy systems. • **Energy prices** – sustainable new buildings reduce energy consumption and peak loads, lowering network infrastructure and system costs.
Economy	
	• **Economic performance** – sustainable new buildings create employment for sustainability services and reduce building operation costs, freeing up resources to invest in other parts of the economy. • **Productivity** – sustainable new buildings can increase the productivity of students and employees through improved thermal comfort, lighting and noise. • **Asset value** – sustainable new buildings have strong asset values and flow on effects for nearby properties and investment attraction.
Society	
	• **Poverty alleviation** – sustainable new buildings reduce building operation costs. • **Health and well-being** – sustainable new buildings deliver increased thermal comfort, light, noise and indoor air quality, improving physical and mental health and well-being.

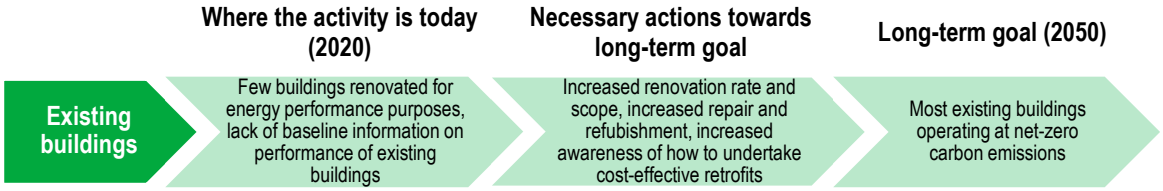
Activity 3: Existing buildings

The performance of existing buildings can be assessed in terms of its operational use compared with benchmarks, which is covered in "Activity 4: Building operations", and in terms of the efficiency of the appliances and systems it is equipped with, covered in "Activity 5: Appliances and systems".

In order to reduce operational carbon emissions in existing buildings, renovations to the building envelope and systems will be crucial, and these should increasingly reach the standards of new buildings. Operational carbon can also be reduced by ensuring improved repair and refurbishment to extend the life of the building and increasing intensity of use of buildings, and through increased occupancy and utilisation rates, and especially by combining all three (IRP, 2020).

Key actions for sustainable existing buildings

Figure 13 • Key actions for existing buildings globally



Key steps to improving the performance of existing buildings include both increasing the number of buildings that are improved and increasing the amount of improvement that is achieved.

- **Decarbonisation strategy for existing building stock**. In developed economies, the majority of buildings are already built. Globally, adopting strategies to refurbish and retrofit existing buildings will make a big impact on existing energy use and emissions. Improving the availability of data on the performance of existing buildings will enable the creation of baselines and strategies for their decarbonisation.
- **Increase renovation rates**. Annual renovation rates globally should reach 4% by 2050.
- **Increase the depth of renovation**. Enable deep energy renovations that reduce energy consumption of existing buildings by 50% or more in developed economies and 30% or more in developing economies.
- **Enable renovation investments**. Enable increasing renovation rates by increasing access to and use of finance to enable private investment in renovations.
- **Governments lead by example**. Develop policies that ensure existing government buildings are renovated to be low-emission and efficient.

Stakeholders for sustainable existing buildings

Globally, the key stakeholders for building retrofits include those that can influence existing buildings and those that can deliver the results of zero-emission, efficient and resilient buildings through retrofits. Additional stakeholders include those that can support the process through research, funding, training and making technologies available. In general, multi-stakeholder dialogues are essential to ensure more and better engagement along the whole value chain. Efforts and signals for full decarbonisation must come from all sides, including the demand side.

These stakeholders are mapped in Table 8, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 8 • Stakeholder mapping for existing buildings globally

National government	Subnational government	Utility companies	Property and project developers	Financial institutions	Architects and engineers	Manufacturers, retailers and suppliers *	Labourers and installers	Building owners and occupants	Civil society **

* of appliances and materials. Includes product testers and certifiers.

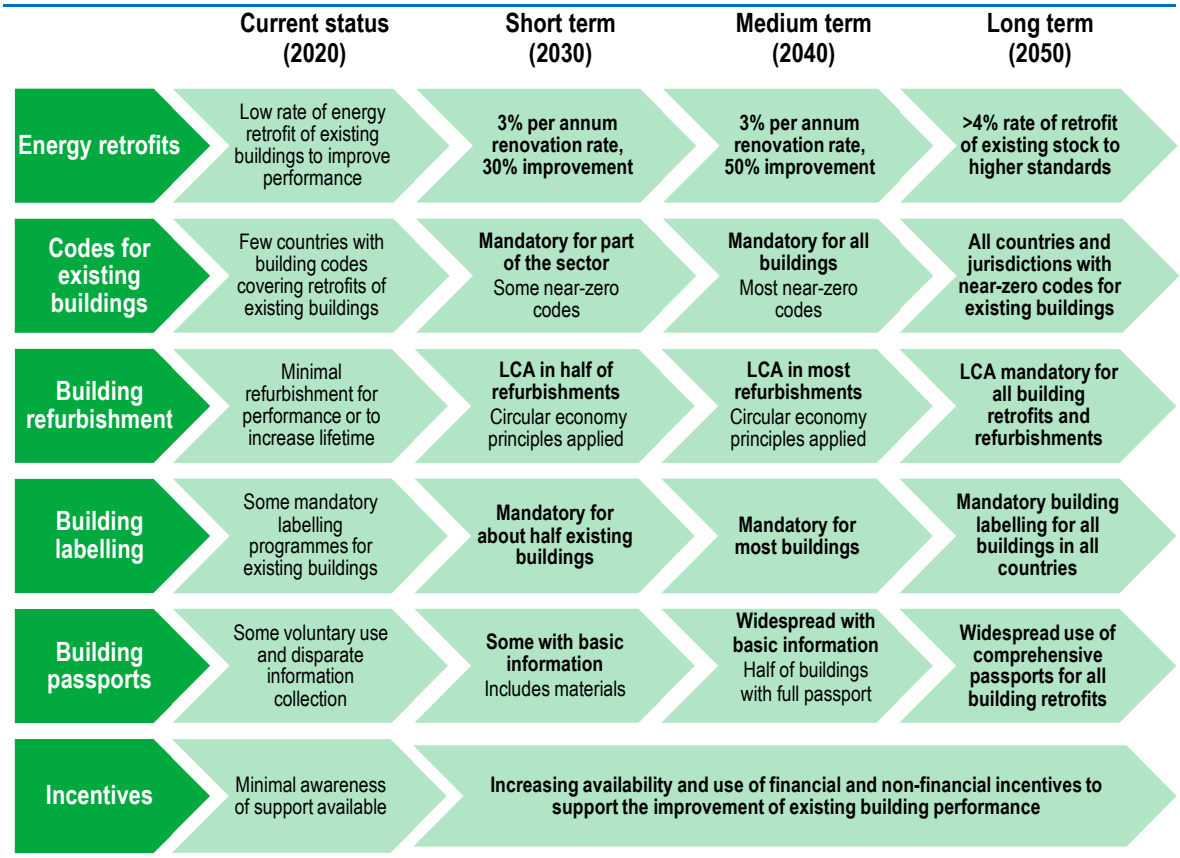
** including academia, NGOs, research institutions, social networks and community associations.

Notes: *How to read*: The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for sustainable existing buildings

The key policies for driving the performance of existing buildings are outlined below:

Figure 14 • Policy timelines for existing buildings globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the policy targets for existing buildings are outlined below.

- **Energy retrofits**: An energy retrofit can be defined as an undertaking of structural, architectural, mechanical or electrical works with the aim of improving the energy performance of an existing building. While these types of works are rarely carried out for their energy benefits alone, they should become increasingly widespread, and be more

ambitious in their performance improvement targets. Buildings should be retrofitted to their cost-effective potential as rapidly as they can, even if the works happen over the course of several years.

- **Codes for existing buildings**: These refer to standards requiring improvements to the building's envelope or systems in the event of significant works, whether they were part of an energy retrofit or not. Codes should be developed with respect to particular segments (e.g. commercial, multifamily residential, single homes) and should ensure that refurbishments are carried out to align the performance of existing buildings to their cost-effective potential.

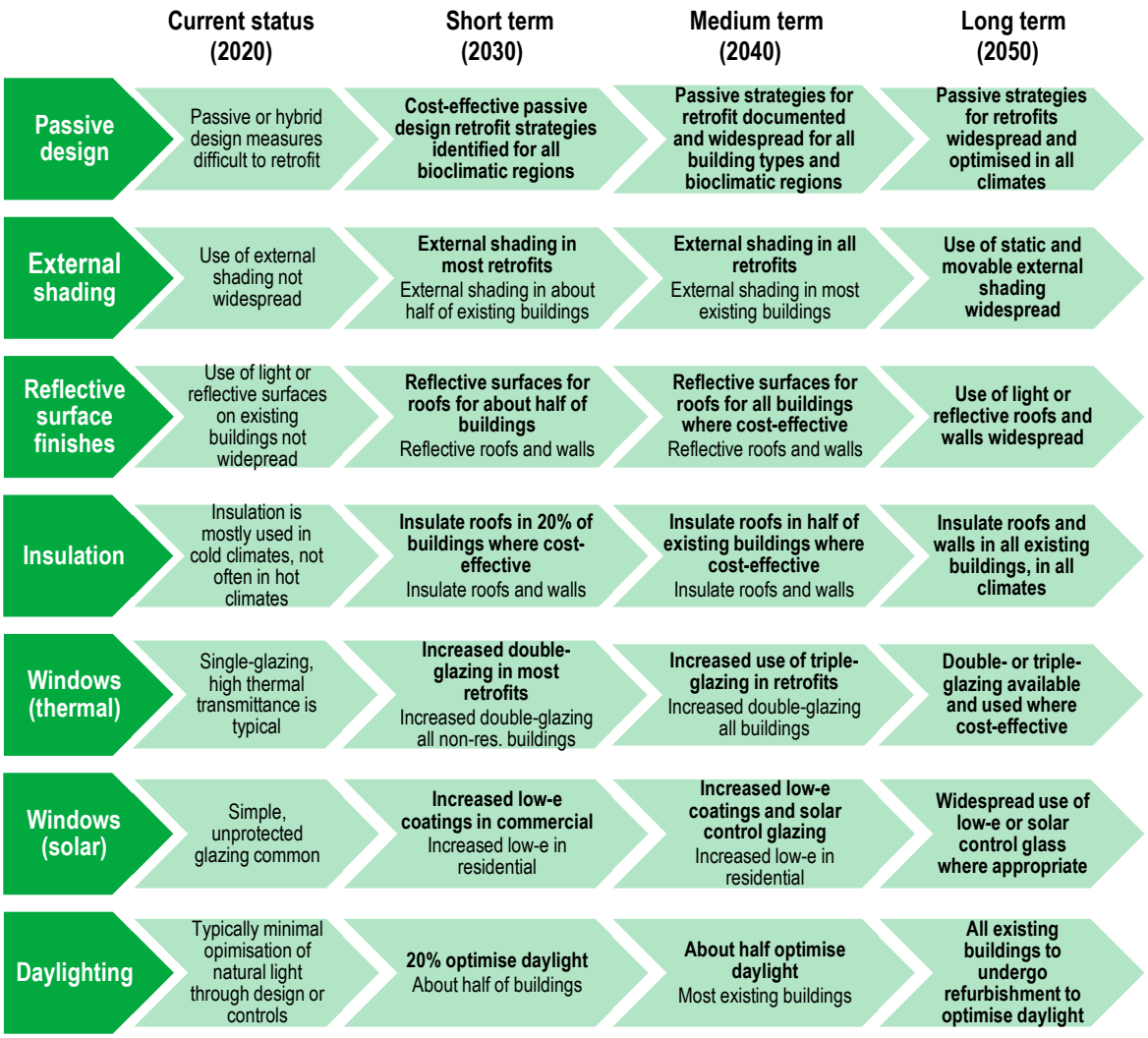
- **Building refurbishment**: Refurbishment works include ongoing works a building owner or manager may carry out on an existing building, without being so substantial it would qualify as a retrofit. Existing buildings should be gradually refurbished to meet the performance standards of new buildings, and maintained to increase their lifetime. Tools to assess the most cost-effective set of measures and plan for their implementation should be developed in order to facilitate planning of works (i.e. to assess whether works should be done step by step or in a deep energy retrofit). Labelling of components, incentives, LCA and energy management are examples of tools that will enable effective maintenance and refurbishment of existing buildings.
- **Building labelling**: Quantitative building energy labelling can be used to assess building envelope and system characteristics on a scale of less to more efficient. Labelling enables increased information sharing and awareness for consumers and investors, and should become widespread in existing buildings as well as new buildings, and should increasingly disclose the embodied and operational carbon of buildings with reference to a benchmark (see "Activity 4: Building operations").
- **Building passports**: Building passports can be used to track information about the building, its materials, systems, energy use, renovations and other relevant information to improve decision-making processes. Basic information includes floor plans, activity information, past retrofit of refurbishment works, and monthly energy consumption and peak demand.
- **Incentives**: Financial and non-financial incentives such as increased scope or special permits can be significant enablers of the refurbishment and retrofit of existing buildings.

Technology for sustainable existing buildings

The energy use and emissions from existing buildings are influenced by whether the building has undergone a building retrofit, the quality of that retrofit with respect to design, choice of technologies and materials, and what gradual improvements it has undergone over time.

Specific targets and timelines for sustainable existing building technologies are outlined below:

Figure 15 • Technology timelines for existing buildings globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the technology targets for existing buildings are outlined below.

- **Passive design**: Strategies for the most cost-effective implementation of passive design measures such as upgrade of the building fabric, control of solar gains and ventilation, and daylight are highly dependent on the building type, how it will be used, and the macro- and micro-climate in which it is situated. Therefore, passive design strategies must be developed for specific bioclimatic regions and specific building types, and special considerations must be taken when applied to existing buildings. These locally adapted design guidelines specific to the retrofit of existing buildings can ensure that passive strategies can be optimised before relying on active systems.

- **External shading**: External shading in the form of horizontal, vertical, fixed or movable elements can be the most cost-effective method of blocking out solar radiation, and can be incorporated to existing buildings relatively easily. Good shading can have the same effect on reducing the SHGC of windows as solar-performance glass.
- **Reflective surface finishes**: Light-coloured surfaces or surfaces with reflective pigments reflect incoming solar radiation. Reflective surfaces are most effective on the largest surfaces exposed to the sun, which normally will be the roof. Painting building surfaces can also be an effectively and relatively low-intrusion retrofit measure.
- **Insulation**: Insulation is one of the components of OTTV that should have specific targets for hot locations and cold locations. A material's insulation performance is determined by its thermal conductivity. "U-value" is also commonly used to express how much heat will transfer through a given thickness of a particular material, where the lower the U-value, the better the material is as an insulator. It is important to note that insulation is important in hot climates as well as in cold climates, and is most effective in the component of greatest surface area (i.e. the roof for low and flat buildings, walls for tall buildings). Note: the benefits of increased insulation must be assessed over a whole life-cycle carbon assessment, given the high embodied carbon of traditional insulating materials.
- **Windows (thermal)**: Heat transfer by conduction through windows can be reduced through a transition to double- or triple-pane windows, which have lower thermal transmittance, or U-value. When produced at scale, these types of windows can be highly cost-effective. These windows also provide noise protection, improve thermal comfort, and can enable passive architecture and natural ventilation.
- **Windows (solar)**: The dominant source of heat transfer through windows is through solar radiation. This can be reduced with low-e and low-SHGC windows. Building design and advanced technologies can enable low solar heat gain during hot weather, while allowing visible light transmittance for natural daylighting. However, the most cost-effective way of avoiding excess solar gain is reducing the size of windows and providing shading.
- **Daylighting**: Access to views and to daylight are essential for building occupant well-being, health and productivity. Building design should ensure that all spaces have access to natural light and views, and have glare-free, adequate daylight levels for large portions of the day through improved control.

Finance for sustainable existing buildings

Finance tools particularly relevant to existing buildings may include:

- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, such as sustainable buildings or development projects.
- **Risk-sharing loan/loan guarantee**: Large organisations, such as a government, international bank or aid organisations, covering the risk of payment default to allow banks to fund projects with lower costs and better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding associated with sustainable projects.
- **Preferential tax**: Direct funding from the government to reduce or eliminate the tax for sustainable products and services.

- **Grants and rebates**: Direct funding provided by the government, organisation or programme during or after the purchase of a sustainable product or service.
- **Energy performance/energy service contracts**: Contracts for services or delivered savings that typically are delivered by an energy services company (ESCO) and can include a range of energy efficiency services and products.
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services, e.g. green lease. Leasing enables the ability to use energy-efficient products on a rental basis to reduce a capital expenditure.
- **On-bill/tax repayment**: An approach where any recurring bill, such as utility bills, insurance bills or home improvement store bills, can collect small amounts of money over a long period of time to pay for energy efficiency purchases in smaller payments. An offshoot of on-bill finance, tax repayment is where the tax authority uses recurring tax payments as a means for collecting money over time. The most common of these is called PACE (property-assessed clean energy) finance and is able to use low-interest-loan repayments on the property tax bill until the purchase is full paid.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Capacity building for sustainable existing buildings

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver sustainable building retrofits.

The types of capacity-building activities relevant to existing buildings are mapped in Table 9, where the darker the colour, the higher the impact that capacity building type has for this activity.

Table 9 • Capacity building for existing buildings globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most critical capacity-building activities are explained below:

- **Training of professionals**: Provide training programmes for service and product providers of buildings and construction (architects, engineers, contractors, building managers, etc.) regarding how to undertake the most cost-effective retrofits in buildings, and how to comply with policies for existing buildings, programmes or incentives for the retrofit of building. Develop educational programmes including primary, secondary, vocational, university and adult education, to enable increased knowledge of sustainable buildings. Provide certification or accreditation for professionals in the sustainable construction sector.
- **Training of general public**: Develop information and awareness campaigns regarding the cost-effective building retrofit measures building owners or occupants can implement, including information and tools regarding how to access funding. Methods of increasing information to consumers include benchmarking programmes, certification programmes,

building passports, mandatory disclosure, labels, educational resources, and information on utility and government programmes.

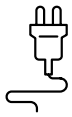
Further details regarding capacity-building activities are provided in the section "Roadmap support: Enablers".

Multiple benefits for sustainable existing buildings

Many benefits can be achieved through sustainable existing buildings, and many of these are aligned with the Sustainable Development Goals. In particular, Goal 7 (affordable and clean energy), Goal 11 (sustainable cities and communities), Goal 12 (responsible consumption and production) and Goal 13 (climate action).

Some of these benefits are described below in Table 10, although many of them require further analysis to quantify them:

Table 10 • Multiple benefits of sustainable existing buildings

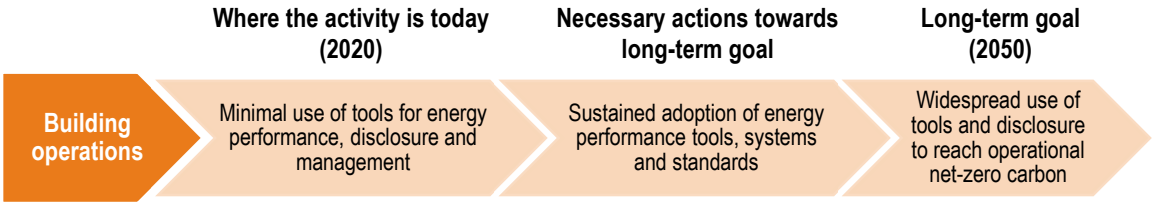
	Environment
	• **Emissions reductions –** sustainable retrofits to existing buildings can deliver GHG reductions through lowered energy consumption. • **Air quality –** sustainable retrofits to existing buildings can reduce air pollution.
	Energy
	• **Energy savings** – sustainable retrofits to existing buildings deliver energy efficiency improvements. • **Energy security** – sustainable retrofits improve the energy efficiency of existing buildings and put less strain on energy systems. • **Energy prices** – sustainable retrofits to existing buildings reduce energy demand and peak loads, lowering network infrastructure and system costs.
	Economy
	• **Economic performance** – sustainable retrofits to existing buildings create employment for sustainability services and reduce building operation costs, freeing up resources to invest in other parts of the economy. • **Productivity** – sustainable retrofits to existing buildings increase the productivity of students and employees through improved thermal comfort, lighting and noise. • **Employment** – sustainable retrofits to existing buildings boost employment through new design and construction services for increased sustainability, including quality assurance and commissioning. • **Asset value** – sustainable retrofits to existing buildings make buildings more durable with lower O&M costs.
	Society
	• **Poverty alleviation** – sustainable retrofits to existing buildings reduce building operation costs. • **Health and well-being** – sustainable retrofits to existing buildings can deliver increased thermal comfort, light, noise and indoor air quality, improving physical and mental health and well-being. • **Safety and security** – retrofits to existing buildings can include features such as building automation, sensors and lighting that can deter crime, improving safety and security.

Activity 4: Building operations

While the delivery of zero-emission, efficient and resilient new or renovated buildings is essential, it is equally important to ensure that buildings are operated efficiently. Behavioural and operational management influence the energy and emissions performance of a building.

Key actions for sustainable building operations

Figure 16 • Key actions for building operations globally



Key actions to improve energy management of buildings include:

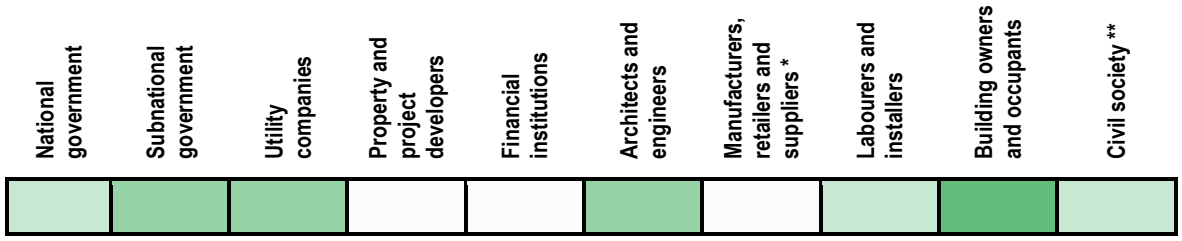
- **Rating tools and disclosure**. Develop national or subnational tools that enable the benchmarking and evaluation of a building's energy performance; develop disclosure schemes to enable comparison and incentivise improved performance. Globally, there are a number of tools being used to rate buildings, such as energy performance certificates in Europe, and expanding these programmes and strengthening their adoption and reporting will provide a basis from which to improve performance.
- **Energy audits**. Promote the use of regular energy audits to identify inefficiencies in building operations and systems. Globally, audits are used widely in advanced economies and will provide a meaningful process for regular checking of system performance, particularly among large energy-using sectors.
- **Energy management systems**. Provide tools and training for energy management systems and use energy management processes in all buildings, particularly non-residential buildings.
- **Smart controls**. The use of digital sensors and controls can enable better managing of building operations, such as temperature, lighting and ventilation system controls. Installing energy metering and links with building and energy management systems will also enable better management. Encourage the correct adoption of smart sensors and intelligent building energy management systems. Work with industry to enable demand-side response solutions.
- **Building passports**. Developing and supporting a system for regular information collection related to building system operations and energy use will support the availability and access to building information to current and subsequent owners and those who work with the building.

Stakeholders for sustainable building operations

Globally, the key stakeholders for existing building operations include those who can influence existing buildings and those who can deliver the results of zero-emission, efficient and resilient buildings through operations. Additional stakeholders include those who can support the process through research, funding, training and making technologies available.

These stakeholders are mapped in Table 11, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 11 • Stakeholder mapping for building operations globally



* of appliances and materials. Includes product testers and certifiers.

** including academia, NGOs, research institutions, social networks and community associations.

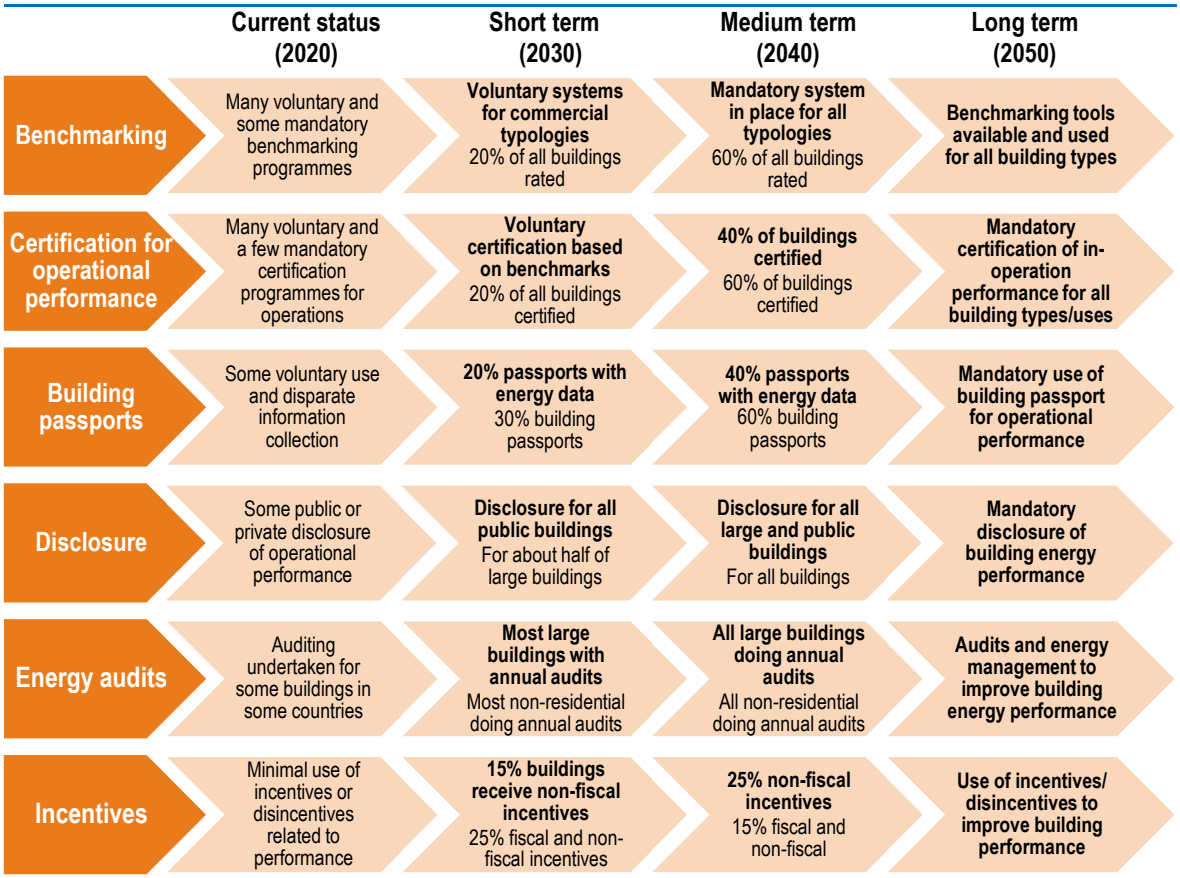
Notes: *How to read*: The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for sustainable building operations

Policies can be developed to promote highly efficient building operations.

Within the targets for sustainable building operations, the following policy sub-targets and timelines offer more details:

Figure 17 • Policy timelines for building operations globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the policy targets for building operations are outlined below.

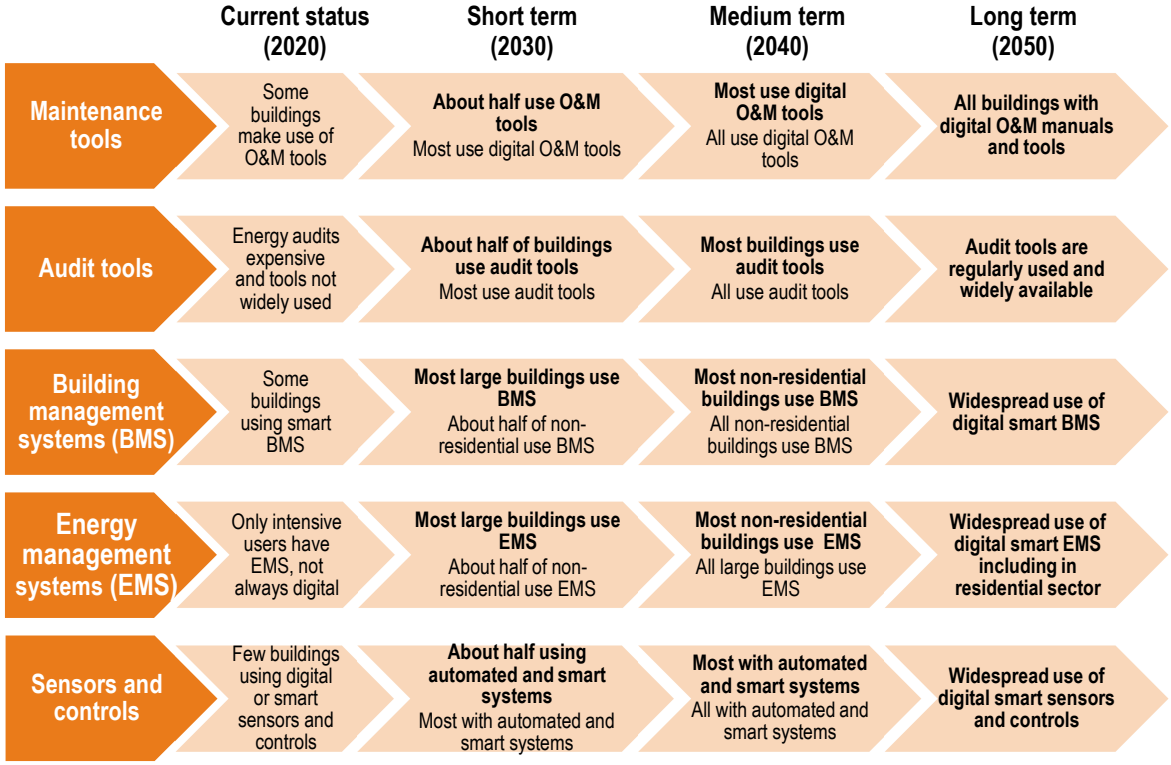
- **Benchmarking**: By tracking performance and comparing that performance with other buildings, sustainability managers can make educated investment decisions to improve the overall performance of the building operations. Benchmarking can also support energy disclosure, certification and building passport goals.

- **Certification for operational performance**: Building energy or sustainability certification and labelling can be used to disclose performance of the existing building and enforce performance requirements. The certification may be linked to benchmarking tools. The certificate or label can enable increased information sharing and documentation for consumers and financial decisions. The certification of operational performance can also allow the development of green lease agreements, where there is a binding agreement between the landlord and the tenant to enable the landlord to operate the building in accordance with its potential.
- **Building passports**: Building passports can be used to track information about the building, materials, systems, energy use, renovations and other relevant information to improve decision-making processes with improved data that are tracked and stored.
- **Disclosure**: Mandatory disclosure of energy performance, certificates and/or benchmark rating of buildings can support improved data collection, decision making and competition.
- **Energy audits**: Regular energy audits are powerful tools to assess opportunities for energy-saving measures, and should be performed regularly, particularly in buildings with high energy consumption.
- **Incentives**: Non-financial incentives, such as expedited permits or increased floor area allowances, can encourage sustainable buildings operation. Financial incentives should be used to support the very best performing buildings. Both should be linked to building certification or disclosure policies.

Technology for sustainable building operations

Specific targets and timelines for the sustainable building operation technologies are outlined below:

Figure 18 • Technology timelines for building operations globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the policy targets for building operations are outlined below.

- **Maintenance tools**: Operation and maintenance manuals can support timely and active maintenance of the building with the schedules of specific periodic maintenance actions (e.g. cleaning or replacement of air intake filters). O&M manuals should increasingly be provided at the handover of a system after a retrofit or new installation and be actively used by building managers or operators. Active fault detection is a digital method for identifying maintenance needs and can increasingly be included in system installations and in BMS.
- **Audit tools**: Building energy and/or sustainability audits provide an opportunity to systematically check the optimisation of system configurations and to identify priority retrofit measures. Audit tools (e.g. software, sensors and thermal cameras) can reduce the cost to conduct an audit and improve the rate of annual building audits.
- **BMS**: BMS can range from full-scale building software to simple controls that manage individual technologies within a building. Increasingly, digital tools are connecting multiple systems within a building with learning and fault detection to improve the overall management of the building system controls.
- **EMS**: EMS enable monitoring of energy consumption of systems, components, and/or the building as a whole to identify anomalies and understand energy consumption trends. A network of digital energy meters or sensors, or a simple smart meter can form the basis of an EMS.

- **Sensors and controls**: Sensors and controls are fundamental to smart maintenance, audit, energy management and building management. Control systems can range from fully centralised systems to simpler systems such as programmable thermostats. Sensors and controls are increasingly starting to incorporate machine learning to understand occupant preferences and optimise system settings based on internal and external conditions.

Finance for sustainable building operations

Finance can enable increased action toward zero-emission, efficient and resilient building operations.

Finance tools relevant to building operations may include:

- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, such as sustainable buildings or development projects.
- **Risk-sharing loan/loan guarantee**: Large organisations, such as a government, international bank or aid organisation, covering the risk of payment default to allow banks to fund a project with lower costs and better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding associated with sustainable projects.
- **Preferential tax**: Direct funding from the government to reduce or eliminate the tax for sustainable products and services.
- **Grants and rebates**: Direct funding provided by the government, organisation or programme during or after the purchase of a sustainable product or service.
- **Energy performance/energy service contracts**: Contracts for services or delivered savings that typically are delivered by an ESCO and can include a range of energy efficiency services and products.
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy-efficient products on a rental basis to reduce a capital expenditure.
- **On-bill/tax repayment**: An approach where any recurring bill, such as utility bills, insurance bills or home improvement store bills, can collect small amounts of money over a long period of time to pay for energy efficiency purchases in smaller payments. An offshoot of on-bill finance, tax repayment is where the tax authority uses recurring tax payments as a means for collecting money over time. The most common of these is PACE finance, which is able to use low-interest-loan repayments on the property tax bill until the purchase is full paid.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Capacity building for sustainable building operations

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver sustainable building operations.

The types of capacity-building activities relevant to building operations are mapped in Table 12, where the darker the colour, the higher the impact that capacity-building type has for this activity.

Table 12 • Capacity building for building operations globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most critical capacity building activities are explained below:

- **Training of professionals**: Provide training programmes for service and product providers of buildings operations (facilities managers, contractors, etc.) regarding how to undertake the most cost-effective operational measures in buildings, and how to comply with policies for new or existing buildings, programmes or incentives for the retrofit or efficient operation of buildings. Develop educational programmes including primary, secondary, vocational, university and adult education, to enable increased knowledge of how to efficiently operate buildings. Provide certification or accreditation for professionals in the sector.
- **Training of general public**: Develop information and awareness campaigns regarding the cost-effective operational measures building owners or occupants can implement, including information and tools regarding how to access funding. Methods of increasing information to consumers include benchmarking programmes, certification programmes, building passports, mandatory disclosure, labels, educational resources, and information on utility and government programmes.

Further details regarding capacity building activities are provided in the section “Roadmap support: Enablers”.

Multiple benefits of sustainable building operations

Many benefits can be achieved through sustainable building operations. Many of them are aligned with the Sustainable Development Goals, in particular with Goal 7 (affordable and clean energy), and Goal 13 (climate action).

Some of these benefits are described below, although many of them require further analysis to quantify them:

Table 13 • Multiple benefits of sustainable building operations

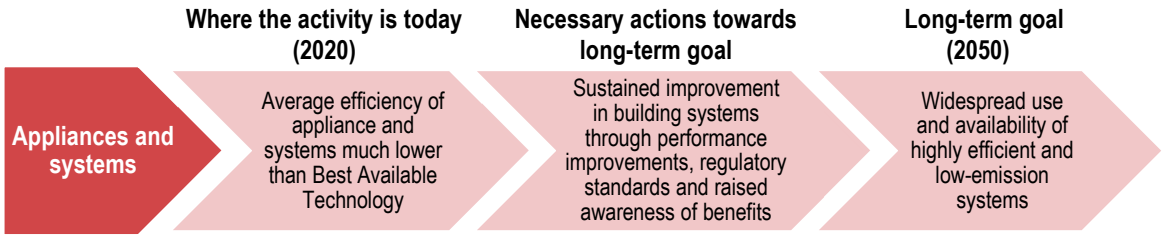
	Environment
	• **Emissions reductions** – more sustainable building operations deliver GHG reductions through lowered energy consumption. • **Air quality** – sustainable building operations reduce air pollution.
	Energy
	• **Energy savings** – sustainable building operations result in the more efficient use of building systems. • **Energy security** – sustainable building operations deliver reductions in energy use and put less strain on energy systems. • **Energy prices** – sustainable building operations reduce energy demand and peak loads, lowering network infrastructure and system costs.
	Economy
	• **Economic performance** – sustainable building operations reduce operating costs, freeing up resources to invest in other parts of the economy. • **Productivity** – sustainable building operations can enable increased thermal, light and acoustic comfort which can result in improved productivity of occupants. • **Employment** – sustainable building operations can grow employment through operational services for increased sustainability.
	Society
	• **Poverty alleviation** – sustainable building operations result in lower costs. • **Health and well-being** – sustainable building operations can deliver increased physical and mental health through retro-commissioning and building management that increases thermal, light and acoustic comfort. • **Safety and security** – sustainble building operations can contribute to improved building management, operation and maintenance, avoiding for example, system failure.

Activity 5: Appliances and systems

Energy-consuming lighting, appliances and equipment systems commonly have a shorter lifetime than the buildings themselves and offer significant opportunity to reduce emissions in new and existing buildings. Aside from increasing appliances' efficiency, human behavioural factors must also be considered: the manner in which users utilise appliances (e.g. operating air conditioners at temperature set points that are lower than required).

Key actions for sustainable appliances and systems

Figure 19 • Key actions for appliances and systems globally



Key actions to enable increased sustainability of systems in buildings include:

- **MEPS**. Further develop, enforce and strengthen standards that set product quality and performance requirements. Expand and update MEPS to cover all major appliances and major systems and set energy performance requirements for networked devices. The harmonisation of MEPS and labelling programmes across regions may facilitate implementation.
- **Enable investment in clean systems**. Enable increasing use of sustainable products by increasing access to and use of finance to enable private investment. The global rate of investment in building energy efficiency needs to grow at a rate of 3% to meet the efficiency levels needed to support sustainable development.
- **Governments lead by example**. Develop policies that ensure all government buildings invest in low-emission and efficient systems. Globally, governments own and operate a large share of the building stock, and through government action, the use of MEPS, labelling programs and investment in energy efficiency systems will help foster a strong market for energy efficiency in buildings.
- **Adopting efficient systems**. Following building fabric, making use of efficient systems makes the biggest impact on energy demand in a building. Global levels of investment in building construction means adopting more high-performance systems for space heating and cooling, water heating, ventilation, and lighting is a great opportunity and possible through MEPS and with the support of government and industry.

Stakeholders for sustainable appliances and systems

Globally, the key stakeholders for sustainable systems include those that can influence technologies and those that can deliver the results of zero-emission, efficient and resilient buildings through the adoption of sustainable appliances and systems. Additional stakeholders include those that can support the process through research, funding and training.

These stakeholders are mapped in Table 14, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 14 • Stakeholder mapping for appliances and systems globally

National government	Subnational government	Utility companies	Property and project developers	Financial institutions	Architects and engineers	Manufacturers, retailers, suppliers*	Labourers and installers	Building owners and occupants	Civil society **

* of appliances and materials (includes product testers and certifiers).

** including academia, NGOs, research institutions, social networks, and community associations.

Notes: *How to read*: The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for sustainable appliances and systems

Appliances and systems policy can support zero-emission, efficient and resilient buildings goals by enabling market transformation that increases the availability of sustainable products. Within the targets for sustainable systems, the following sub-targets and timelines offer more details:

Figure 20 • Policy timelines for sustainable appliances and systems globally

	Current status (2020)	Short term (2030)	Medium term (2040)	Long term (2050)
Minimum performance standards	Most countries have at least one minimum performance standard	**Many appliances with mandatory MEPS** All appliances with mandatory MEPS	**All appliances with mandatory progressive MEPS** MEPS 50% more stringent than in 2030	**Complete mandatory progressive MEPS**
Labels	Medium consumer awareness of labels, many appliances with mandatory labels	**All main appliances with mandatory labels** All appliances with mandatory labels	**All appliances with mandatory labels with intuitive information for consumer**	**Full use of labels for energy performance of appliances**
Research and development (R&D)	Very low levels of investment in energy efficiency of building systems	**40% more investment** 60% more investment	**50% more investment** 75% more investment	**Doubling or more of investment in R&D**
Procurement	Low use of green procurement in the purchasing of appliances or systems	**40% "green" procurement** Most public procurement is "green"	**60% "green" procurement** Most public procurement is "green"	**Widespread use of green procurement for building systems**
Incentives	Leading jurisdictions provide incentives for the purchase of efficient systems	**Financial and non-financial incentives for top-rated products becoming widespread**	**Financial and non-financial incentives for top-rated products widespread**	**Widespread use of incentives for purchase or manufacture of efficient systems**

Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the policy targets for building appliances and systems are outlined below.

- **Minimum performance standards**: Lighting, appliance and equipment products commonly have standards in many countries. These standards need to be expanded to all countries and strengthened for higher performance requirements. Testing protocols and enforcement of MEPS are essential for the standards to work effectively, and harmonisation of protocols or

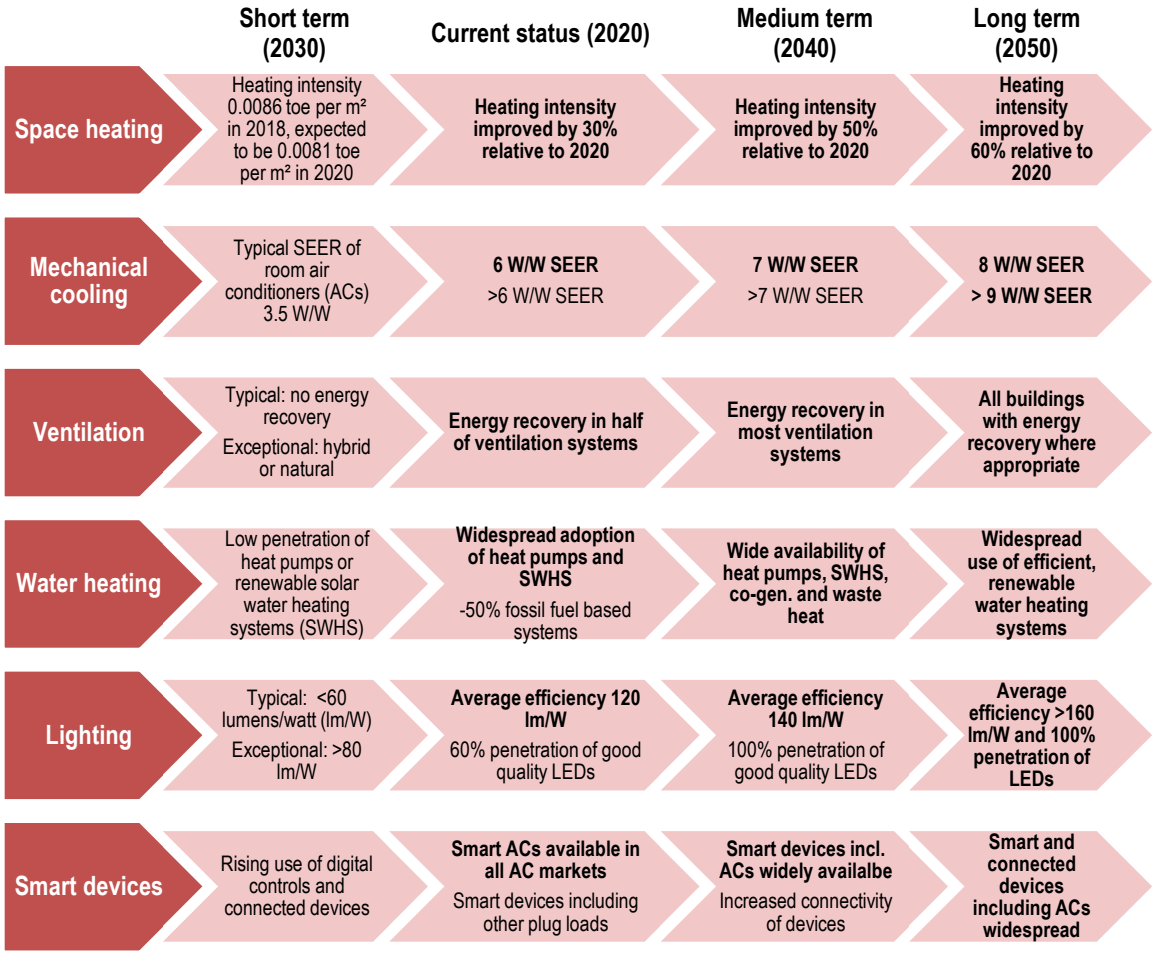
MEPS across regions may facilitate this. MEPS should also be in terms of the most adequate performance metric – for example, seasonal energy efficiency ratio (SEER) is a more appropriate metric than the Energy Efficiency Ratio (EER) as it is more reflective of the appliance's actual consumption over the cooling season. Minimum performance standards should also include limits regarding global warming potential of refrigerants and emissions of indoor air pollutants.

- **Labels**: Product labels on systems and appliances can provide information on the performance of the products including their embodied carbon and their life-cycle energy and carbon performance. This kind of information enables consumers to make choices on a life-cycle basis, but also facilitates the implementation of incentives, MEPS and phase-out programmes.
- **R&D**: Increasing research funding can enable the invention of new products and services while also increasing the ability to get improved technologies to the market cost-effectively.
- **Procurement**: Public and private entities can purchase sustainable products and services to support the effort to phase out the use of unsustainable products and services. This effort should be done by both public and private entities and can include bulk procurement or minimum performance specifications for procurement rules. The target in the timeline above refers to increasing shares of "green" procurement which is procurement based on minimum specifications such as minimum energy efficeincy and/or other environmental standards.
- **Incentives**: Non-financial incentives, such as expedited product approvals, should be the priority to encourage sustainable systems. Financial incentives should be used to enable the market development or purchasing of the very best sustainable systems, while finance support, such as loan guarantees, should enable private investment in sustainable systems.

Technology for sustainable appliances and systems

Specific targets and timelines for the sustainable system technologies are outlined below:

Figure 21 • Technology timelines for sustainable appliances and systems globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the technology targets for building appliances and systems are outlined below.

- **Space heating systems**: Heating technology can enable more efficient delivery of space comfort through improved system efficiency. Heating systems also offer an opportunity for decarbonisation in the transition from fossil fuel heating systems to electricity or renewable energy heating systems. Key technologies to achieve these reductions are heat pumps, modern biomass stoves and boilers, the phasing out of traditional biomass, and the use of waste heat or co-generation.[5]
- **Mechanical cooling systems**: While cooling is the fastest-growing end use in buildings globally, cooling technology can enable more efficient delivery of thermal comfort through improved peak demand efficiency (energy efficiency ratio) and SEER. Alongside appropriate design strategies that minimise the need for cooling, adoption of hybrid cooling methods, such as evaporative cooling, ventilate cooling, and other "free cooling" that uses ground or water

[5] *Co-generation* refers to the combined production of heat and power.

temperatures, can support the increased overall efficiency. Overall system efficiency will also increase with the use of variable speed drives and improved thermal distribution efficiency.

- **Ventilation**: To improve indoor air quality, controllable ventilation is essential. The three primary ventilation types include mechanical, natural and hybrid. To increase both the ventilation efficiency and energy retention efficiency, buildings can shift increasingly to hybrid ventilation, which uses natural ventilation when feasible and mechanical ventilation when natural ventilation is not effective. To further improve the efficiency, when in mechanical ventilation mode the system should include energy recovery ventilation technology to enable air exchange with minimal heat and humidity transfer. Energy recovery ventilation efficiency will also need to improve from low-efficiency systems near 50% efficiency to high efficiency in the 80-90% range.

- **Water heating systems**: Available heating technologies can enable more sustainable and efficient delivery of hot water through the use of modern renewable energy sources and improved system efficiency. Efficient heat pumps, solar thermal water heaters, efficient modern biomass boilers and the use of waste heat and co-generation offer effective solutions for decarbonising water heating.

- **Lighting**: Lighting technology can enable more efficient delivery of visual comfort through improved lumens per watt efficiency. Lighting technology developments in more efficient solid-state lighting is improving the quality of light, efficiency, maintenance and reducing costs. Daylight harvesting systems with intelligent controls, sensors and shading devices can also support the target for increased lumens per watt.

- **Smart devices**: Ongoing digitalisation of electric appliances is unveiling new opportunities to improve resource efficiency and flexibility, and allow consumers to manage their consumption through demand-side response. Appliances such as air conditioners and other devices should increasingly be equipped with the capacity for smart or connected control.

Beyond the items above with specific targets, the following system technologies can also support increased sustainability in buildings.

- **Appliances**: Large and small appliances both have opportunities for increased sustainability. Development in appliance efficiency is needed to counter the surge in appliance usage from rising wealth and ownership. The most significant gains have been in refrigerators, with specific targets noted above, where increased efficiency continues through variable speed compressors, improved insulation and heat pump technologies. Other appliances such as dishwashers, clothes washers and dryers, televisions, and digital appliances will need to become more efficient and reduce standby losses and connectivity energy use through the use of sensors, controls and automation to enable low-power modes, load balancing, demand response and remote programming.

- **Energy storage**: Thermal energy storage for heating or cooling can enable load shifting, optimised heat transfer efficiency and integration with renewable energy, which will become ever more important with growing electrification and pressure on peak demand. Thermal energy storage systems can take the form of highly insulated water or refrigerant tanks, thermal mass, or phase-change materials. Current research is focused on reducing the costs, reliability and lifetime of high-density storage. Electrical storage in the form of batteries may also become important with the rise of decentralised renewable electricity generation and the interconnectivity of electric vehicles and buildings.

Finance for sustainable appliances and systems

Finance can enable increased action towards zero-emission, efficient and resilient buildings through sustainable systems.

Financial tools particularly relevant to building systems include:

- **Green bonds**: Bonds that can be used to bundle funding associated with sustainable projects.
- **Preferential tax**: Direct funding from the government to reduce or eliminate the tax for sustainable products and services.
- **Grants and rebates**: Direct funding provided by the government, organisation or programme during or after the purchase of a sustainable product or service.
- **Energy performance/energy service contracts**: Contracts for services or delivered savings that typically are delivered by an ESCO and can include a range of energy efficiency services and products.
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy efficient products on a rental basis to reduce a capital expenditure.
- **On-bill/tax repayment**: An approach where any recurring bill, such as utility bills, insurance bills or home improvement store bills, can collect small amounts of money over a long period of time to pay for energy efficiency purchases in smaller payments. An off-shoot of on-bill finance, tax repayment is where tax authority uses recurring tax payments as a means for collecting money over time. The most common of these is PACE finance, which is able to use low-interest-loan repayments on the property tax bill until the purchase is full paid.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Capacity building for sustainable appliances and systems

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver sustainable systems.

The types of capacity-building activities relevant to appliances and systems are mapped in Table 15, where the darker the colour, the higher the impact that capacity-building type has for this activity.

Table 15 • Capacity building for appliances and systems globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most critical capacity-building activities are explained below:

- **Training within government**: Provide training to central and local government regarding the implementation of MEPS and labelling systems, the development of testing protocols, training on how to co-ordinate with other government stakeholders and industry and obtain their buy-in, and training as to how to monitor and evaluate the success of policies.

- **Training of product and material manufacturers**: Provide training to industry on how to comply with MEPS and labelling policies, including support for leveraging the benefits of producing more efficient equipment.
- **Training of general public**: Develop information and awareness campaigns regarding the benefits of more efficient and more sustainable appliances, including information and tools regarding how to access funding. Raise awareness regarding the human behavioural factors influencing the consumption of appliances and air conditioning. Methods of increasing information to consumers include benchmarking programmes, certification programmes, labels, educational resources, and information on utility and government programmes.

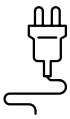
Further details regarding capacity building activities are provided in the section "Roadmap support: Enablers".

Multiple benefits of sustainable appliances and systems

Many benefits can be achieved through sustainable systems. Many of them are aligned with the Sustainable Development Goals, in particular Goal 7 (affordable and clean energy), and Goal 13 (climate action).

Some of these benefits are described below, although many of them require further analysis to quantify them:

Table 16 • Multiple benefits of sustainable appliances and systems

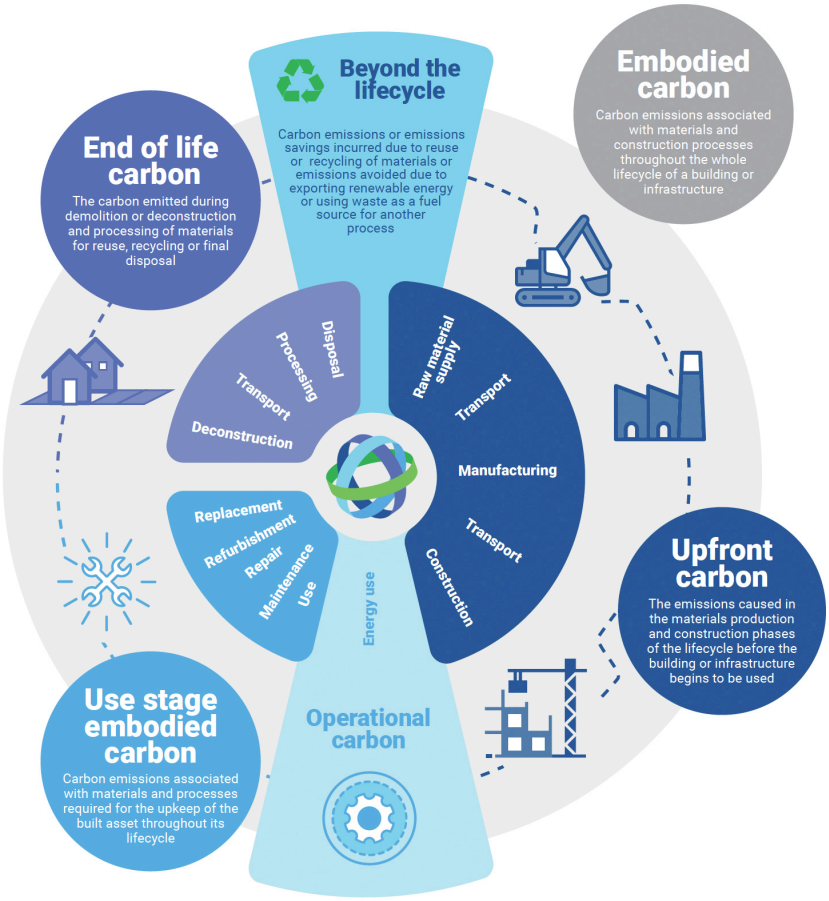
Environment	
	• **Emissions reductions** – sustainable appliances and systems deliver GHG reductions through lowered energy consumption. • **Air quality – sustainable appliances and systems** reduce air pollution through lower on-site emissions and lowered energy consumption.
Energy	
	• **Energy savings** – sustainable appliances and systems are more energy efficient. • **Energy security** – sustainable appliances and systems use less energy and put less strain on energy systems. • **Energy prices** – sustainable appliances and systems reduce energy demand and peak loads, which can lower network infrastructure and system costs.
Economy	
	• **Productivity** – sustainable appliances and systems can increase the productivity of students and employees through improved thermal comfort, lighting and noise. • **Asset value** – sustainable appliances and systems can improve the asset value of buildings.
Society	
	• **Poverty alleviation** – sustainable appliances and systems reduce building operation costs. • **Health and well-being** – sustainable appliances and systems deliver increased thermal comfort, light, noise and indoor air quality, improving physical and mental health and well-being. • **Safety and security** – sustainable appliances and systems can include features such as building automation, sensors and lighting, as well as features to improve and facilitate maintenance wich can prevent system failure.

Activity 6: Materials

Construction activity in the buildings sector generates a major flow of materials in every country. The construction and demolition of buildings accounts for around one-third of global material consumption and waste generation. GHG emissions or energy consumption are linked to every phase of the life cycle of materials, from extraction or harvesting to manufacture, transport, construction, use and demolition. For instance, steel, cement bricks and non-certified wood (deforestation issue) are some of the major building product emitters of CO_2.

Embodied carbon is the sum impact of all the carbon emissions attributed to the materials throughout their life cycle (extracting from the ground, manufacturing, construction, maintenance and end of life/disposal), as shown in Figure 22.

Figure 22 • The WorldGBC's scope and definition of the building life cycle



Source: World Green Building Council (2019), "Bringing embodied carbon upfront – Coordinated action for the building and construction sector to tackle embodied carbon".

Currently the carbon emissions associated with the extraction, manufacturing and construction of materials for buildings represents close to 11% of all global emissions. These emissions include the energy- and process-related emissions associated with these processes (GlobalABC/IEA/UNEP, 2019).

The factors that influence embodied carbon include the construction technique, material demand, durability, origin (recycled versus virgin and location), composition, manufacturing processes, and reusability or recyclability.

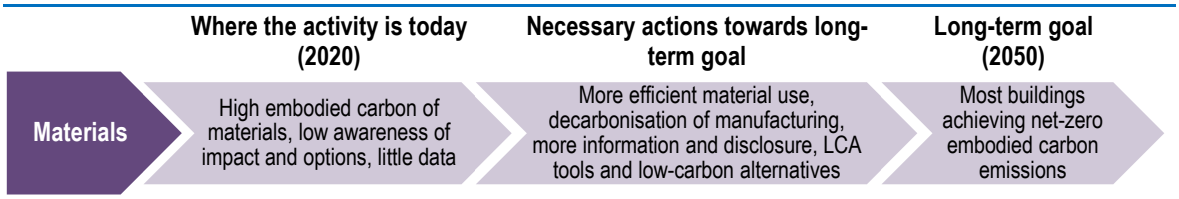
Globally, cement and steel are two of the largest sources of building material-related CO_2 emissions. Total cement production is responsible for around 7% of global CO_2 emissions, with steel contributing 7-9% of the global total, of which around half can be attributed to buildings and construction (WorldGBC, 2019).

Reaching net-zero embodied carbon for major building components such as cement and steel is highly challenging as these sectors are among the hardest to decarbonise. It will require concerted action along multiple dimensions: from lowering the demand of material and promoting switches to low-carbon materials, to maximising energy efficiency in manufacturing and switching away from carbon-intensive sources of energy (Energy Transitions Commission, 2018). There are also significant opportunities in developing systems to enable the reuse and recycling of construction materials.

Actions include engaging all stakeholders along the value chain, the provision of clear information and robust data on embodied carbon, promoting the implementation of EMS in industry, revision of building standards and codes, use of building certification systems, green public procurement and virgin material taxation, developing and enforcing regulations on embodied carbon levels, ensuring embodied carbon is considered in policy and planning instruments, and decarbonisation of the energy system (IRP, 2020).

Key actions for sustainable materials

Figure 23 • Key actions for sustainable materials globally



Key actions to enable increased sustainability of materials in buildings and buildings products include:

- **Collect data on embodied carbon** of building and construction materials; develop a database that can be accessed by all relevant stakeholders and that allows comparisons and calculations. Develop guidance on the use of methodologies and standards for making calculations and assessments.
- **Provide information and raise awareness**. Promote capacity on low-carbon materials and technologies (e.g. wood and earth constructions, innovative concrete) among professionals involved in the building design and construction process. Provide tools, training and capacity building; conduct or commission research into low-carbon materials and approaches. Carry out or commission case studies to convey the benefits of use of low-carbon materials and raise awareness.
- **Integrate considerations of embodied carbon in planning and building regulations,** require disclosure for all new construction and for large renovation projects, initiate low-carbon materials pilot projects, provide incentives to property and project developers.
- **Accelerate energy efficiency in manufacturing**. Develop measures to effectively speed up the implementation of energy efficiency in industries that manufacture building and construction materials. Promote energy management, develop best practice guides, and support the adoption of BATs. Include building material manufacturing industries as part of demand-side management efforts.
- **Stimulate markets for low-carbon products and materials**. Implement policies that enable improved design and purchasing decisions based on embodied carbon and energy. This could be achieved combining push levers, such as carbon pricing, tax incentives, subsidies and regulations on production of materials, with pull levers, such as public procurement and regulations on the construction sector. Develop policies that ensure all government buildings invest in low-carbon and efficient materials based on LCAs.
- **Require embodied carbon assessments** or LCAs to be undertaken on all new major and public investments, disclose portfolio- and/or asset-level embodied carbon emissions, provide financial

products to incentivise low-carbon projects and business models, provide preferential loans or mortgages to stimulate a market for low-carbon materials.

- **Reduce demand**. Develop approaches for lowering the demand for building and construction materials through design briefs and construction approaches that reduce the need for added materials. This in turn will help to **reduce extraction** of key natural resources, e.g. sand for building materials.
- **Reuse and recycle**. Develop strategies for repurposing of buildings when appropriate. Mandate plans and systems for collection and reuse/recycling of construction and demolition waste. Improve deconstruction processes including via the development of guidelines or protocols for deconstruction and selective sorting of waste.
- **Support the development of material reuse and recycling processes** for products and materials that can reduce the lifecycle embodied energy and emissions and **increase the use of repurposed materials** in product manufacturing and in building and construction projects.
- **Promote circular economy**. Develop cradle to cradle lifecycle approaches in the building sector to enable a systemic, material-neutral and performance-based approach and business models. Integrate whole lifecycle carbon thinking into planning and design processes
- **Support research, development and innovation**. Develop measures to enable and support basic and applied research into low carbon materials and solutions, provide support to demonstration projects.
- **Decarbonise energy**. Shift investments towards renewable energy on an energy system level as well as on a manufacturing plant level.

Stakeholders for sustainable materials

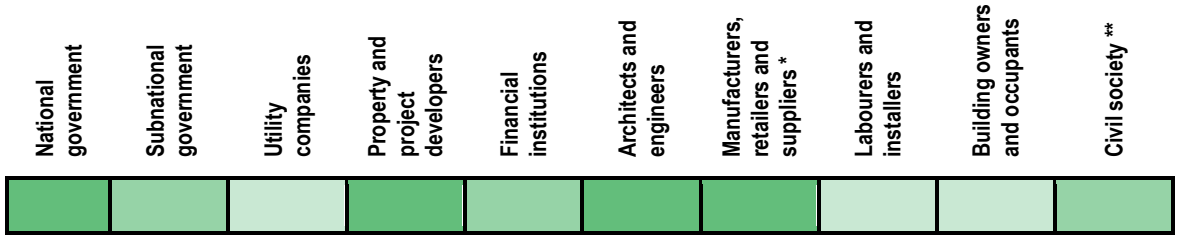
Globally, the key stakeholders for sustainable materials include those that can influence materials and those that can deliver the results of zero-emission, efficient and resilient buildings through the use of sustainable materials.

Additional stakeholders include those that can support the process through research, funding and training.

While policies play a central role in accelerating a transition to zero embodied carbon, a range of different stakeholders can play an active part in the process. For instance, project and property developers can request disclosure on embodied carbon from material suppliers, and financial institutions can provide preferential financial products to projects that can demonstrate low embodied carbon. Manufacturing companies can start to voluntarily disclose information on embodied carbon of their products, and civil society organisations can play an important role in developing knowledge, raising awareness and providing capacity building.

These stakeholders are mapped in Table 17, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 17 • Stakeholder mapping for materials globally



* of appliances and materials. Includes product testers and certifiers.

** including academia, NGOs, research institutions, social networks and community associations.

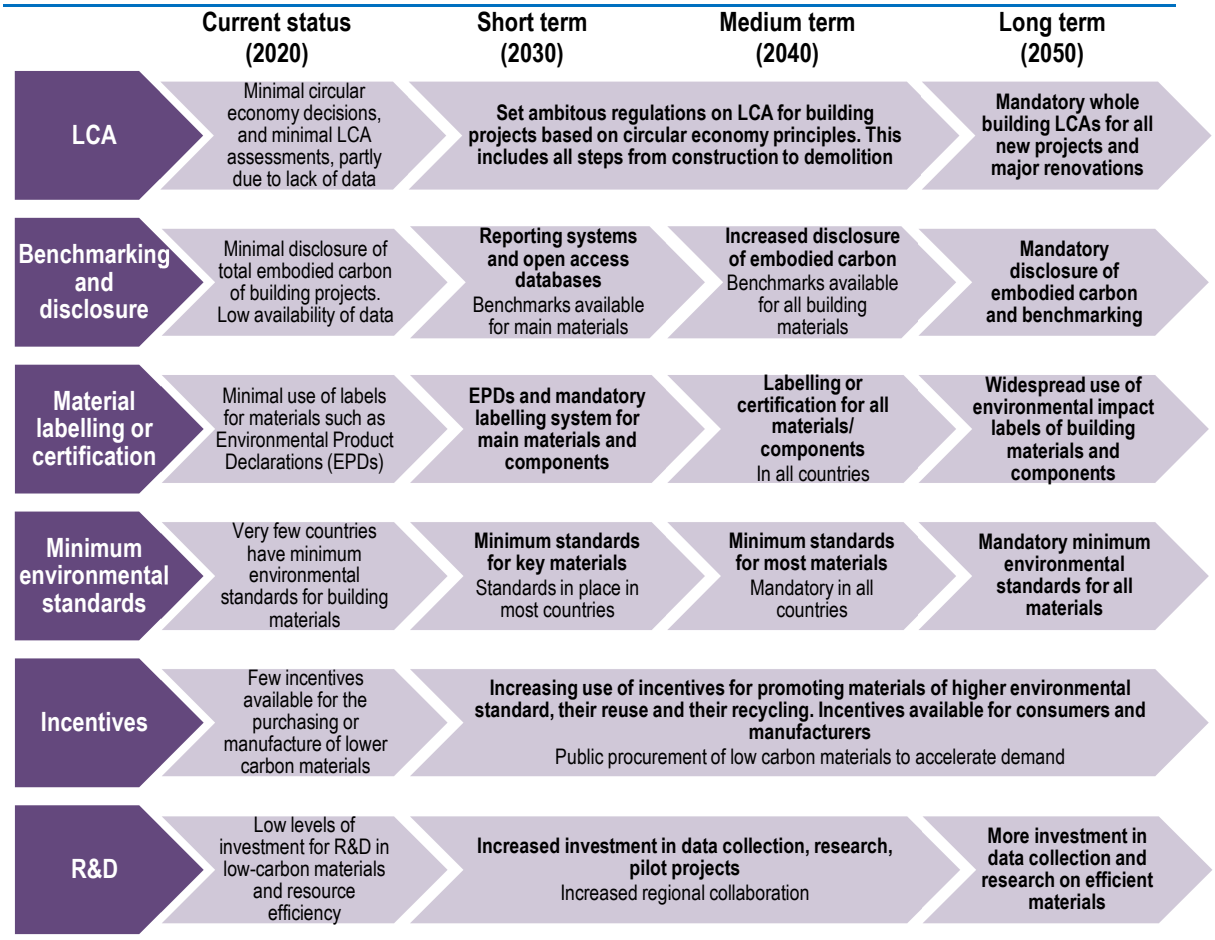
Notes: *How to read:* The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for sustainable materials

National, state and local governments are well positioned to spark action towards net-zero embodied carbon as they have the greatest powers to set standards and targets, implement legislation on materials and planning policies, invest in R&D, and deploy financial and fiscal measures that can shift the market.

In particular, national governments may have the widest reach to facilitate value chain collaboration, stimulate market demand and integrate new holistic approaches such as circular principles in buildings and infrastructure.

Figure 24 • Policy timelines for materials globally



Notes:- in **bold** is the **proposed global target**. Below that is the proposed accelerated target.

Details of the policy targets for building materials are outlined below:

- **LCA**: LCAs seek to quantify environmental impacts from material extraction and product manufacturing through to end of life. Decisions regarding the building use, design and choice of materials should consider the entire lifetime of the building and its components. National, regional, or international databases containing information on the embodied energy and carbon of construction materials will be necessary to undertake comprehensive life-cycle impact analysis of design choices. All plans and designs should focus on lowering life-cycle impact. This means that all stages of projects should be considered and planned, from construction to demolition. In particular, plans on how waste will be reduced and managed should be established as early as possible in projects. A waste management plan

reduces the construction and demolition waste that is usually disposed in landfills or incinerated by providing options to recover, reuse or recycle the materials.

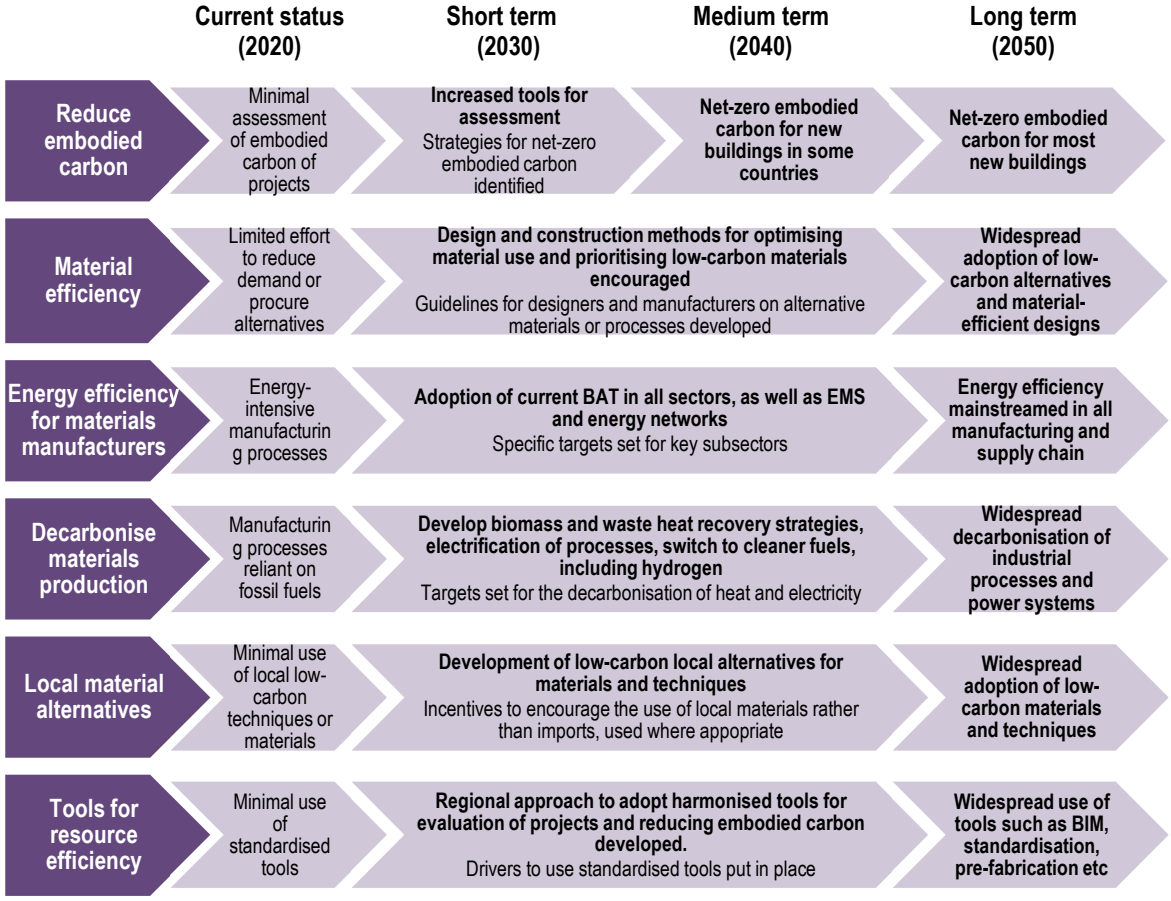
- **Benchmark and disclosure**: In order to monitor progress, understand best practices and to facilitate better decisions at the design stage and in policy-making, benchmarking coupled with data disclosure will be of importance. Data disclosure requirements could build on experiences with material passports[6] and other initiatives such as the CDP.[7] Disclosure of the environmental impacts and efficiency levels of building projects should be developed in order to ensure a better enforcement of regulations.
- **Material labelling**: Product labels on materials and components can provide information on the sustainability of the products, including their embodied energy and carbon, in ways that can be used in a life-cycle carbon assessment. EPDs and Health Product Declaration (HPDs) are some of the different voluntary labelling systems available currently supporting the information roll-out with educational efforts to increase the capacity for people to make better design, purchase and operational decisions. The creation of EPDs for building and construction materials and products and their use in design is voluntary in most regions and countries. Some European countries, such as Finland, France and the Netherlands, are moving towards legislative adoption of LCA requirements for the construction industry, which is expected to be a catalyst for wider market penetration of EPDs (WorldGBC, 2019).
- **Minimum environmental standards**: The successive development and expansion of voluntary schemes towards mandatory minimum environmental standards for materials would effectively create markets for low-emission products. Testing protocols and standards for materials (including new materials) will have to be developed. Building codes, where in place, should include minimum environmental performance standards for materials to be used or, via performance requirements, encourage use of low-carbon materials. Stringency should be increased over time to continue to drive the market further towards low-carbon solutions.
- **Incentives**: Financial incentives should be used to drive markets towards sustainable materials, while financial support, such as loan guarantees, should enable private investment in sustainable materials. Incentives should therefore address both sides: consumers and manufacturers of sustainable materials. These incentives will drive but also rely on procurement strategies: purchasing sustainable products and services should be done by both public and private entities and can include bulk procurement or minimum performance specifications for procurement rules. Public procurement should also include requirements for minimum recycled content and reusability or recyclability. Financial incentives should also be used to support new construction techniques that lower embodied carbon.
- **R&D**: Increasing research funding can enable the development of local materials production and supply chains, improved processes, practices and services while also increasing their economic competitiveness and their diffusion. Collective R&D efforts fostering co-operation and collaboration instead of competition can enable better allocation of resources, and a faster uptake of innovation as research outcomes are shared across the different countries.

[6] Material passports include data on all the materials that are included in a construction and provide information on characteristics and highlight the potential for reuse and recycling.
[7] Formerly known as the Carbon Disclosure Project, the CDP is a voluntary global system for investors, companies, cities, states and regions to manage their environmental impacts.

Technology and strategy for low-carbon materials

Specific technology targets and timelines for sustainable materials are outlined below:

Figure 25 • Technology timelines for materials globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the technology targets for building materials are outlined below:

- **Reduce embodied carbon**: Set targets for overall embodied carbon of building projects. This strategy will need to rely on comprehensive data collection efforts and the development or adaptation of standardised tools, EPDs and benchmarks to assess embodied carbon and set performance targets of reduction over baseline over time. Specific targets should be set for material efficiency, energy efficiency of production and decarbonisation technologies in all subsectors and in particular for the major materials used such as cement and steel, while promoting low-carbon and nature-based solutions for building materials.
- **Material efficiency**: Reducing primary material demand through optimised design, optimised building techniques, the more intensive use of existing materials and the reuse of scrap material offers cost-effective measures to reduce embodied carbon of materials. In addition, low-carbon alternative materials already exist for several processes and usages, (such as clinker substitutes for cement production or timber instead of steel in construction) and should be strongly encouraged and incentivised. Other examples include promoting concrete-steel composite construction, reducing cement content in concrete and lower clinker-to-cement ratio. Precautionary steps would have to be taken in order to prevent

negative effects (e.g. promoting the use of timber might increase demand for wood that will have to be met by sustainable harvesting).

- **Energy efficiency in material production**: Indicators to monitor specific energy use for the production and processing of material and components should be established, tracked and compared with BATs. This will allow the setting of targets for manufacturers and set minimum standards. Current BATs should be promoted across all sectors. Further measures to improve energy efficiency include making EMS (such as the ISO 50001) compulsory, promoting industry networks (to share best practices, identify energy efficiency potentials, set targets, etc.), and promoting access to and uptake of sustainable manufacturing technologies.
- **Decarbonising materials production**: The extensive use of renewable energy can be challenging in various industrial processes. However, by tracking the embodied carbon of materials, manufacturers will be encouraged to shift towards cleaner energy mixes (e.g. gas instead of coal, electrification of processes, use of hydrogen) and develop innovative solutions to maximise the use of waste heat and alternative sources of energy, or even waste material as fuel. These areas show great potential in sectors such as the cement and steel industries. There are currently few pilots to explore ways to decarbonise the heavy industry.[8] With the rate of increase in demand for materials in India, for instance, there could be an opportunity to develop a new industry based on the most advanced technology.
- **Locally produced materials**: Embodied carbon can be reduced by promoting the development of local low-carbon industry for the production of building materials where appropriate as determined by LCAs. This should be paired with new building methods, demonstration projects and case studies. Mapping of material flows and inventories of embodied carbon could support such a development.
- **Tools for resource efficiency**: Measures should be taken to reduce manufacturing waste, develop materials and products that require less resources, and develop projects that require fewer material inputs. At the design stage, reducing over-sizing and encouraging structural optimisation (such as lightweighting, drywalls, etc.) may enable using fewer materials to provide the same service, as could, for instance, the use of precast concrete material, the development of 3D printing, prefabrication, BIM and modularity of buildings.

Finance for sustainable materials

Financial tools particularly relevant to sustainable materials may include:

- **Infrastructure funds**: Dedicated funding for infrastructure projects, which can prioritise sustainable infrastructure projects.
- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, which can prioritise sustainable buildings, construction or development projects. Dedicated credit lines to national or local governments can also be used to establish a revolving loan fund, which collects repaid loans for energy efficiency projects and reinvests them in additional energy efficiency projects.
- **Preferential tax**: Direct funding from the government to reduce or eliminate taxes for sustainable products and services.

[8] The Swedish initiative HYBRIT for steel manufacturing and the Norwegian project in Brevik for cement are to be noted as examples of pilots across the world trying to reach net-zero carbon emission manufacturing.

- **Carbon pricing**: In order to facilitate the uptake of materials with low embodied carbon, a carbon price, could be implemented. This would be particularly relevant for cement and steel. It would encourage materials efficiency, reuse and recycling; promote R&D for alternative solutions; and promote the decarbonisation of materials.
- **Grants and rebates**: Direct funding to overcome upfront cost barriers, provided by a government, organisation or programme either through a competitive process (grants) or during or after the purchase of a sustainable product or service (rebates).
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy-efficient products on a rental basis to overcome high upfront costs or capital intensive investments.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Capacity building for sustainable materials

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver sustainable materials.

The types of capacity-building activities relevant to materials are mapped in Table 18, where the darker the colour, the higher the impact that capacity building type has for this activity.

Table 18 • Capacity building for materials globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of the general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most critical capacity building activities are explained below:

- **Training within government**: Provide training to governments about collecting data on embodied carbon of materials and building projects, training on the development of an integrated policy portfolio towards zero-embodied-carbon buildings and construction, and training on how to develop information and assessment tools for project developers, designers and consumers such as embodied carbon disclosure, LCA, labelling and EPDs. These tools enable awareness among the building community and consumers, enabling them to make improved choices and promote lower-carbon design.
- **Training of professionals**: Provide training programmes for service and product providers of buildings and construction (architects, engineers, contractors, etc.) regarding how to design buildings with lower embodied life-cycle carbon in their materials, including how to assess embodied carbon, how to use EPDs, how to perform LCAs, how to adapt design and construction techniques to lower embodied carbon in construction, how to correctly plan for end of life, and other circular design principles. This will require data collection and analysis to enable the creation of databases and resource platforms. Provide training on how to comply with policies such as labelling, EPDs, disclosure and LCA. Develop educational programmes including primary, secondary, vocational, university and adult education, to

enable increased knowledge of sustainable building materials. Provide certification or accreditation for professionals in the sustainable construction sector.

- **Training of product and material manufacturers**: Provide training to industry regarding how to decrease the embodied carbon of materials and building, increase efficiency in manufacturing and construction processes, enhance the use of local materials, plan for end of life, increase recycling and reuse, and other circular design principles. Provide training on how to comply with policies regarding labelling, EPDs and disclosure.

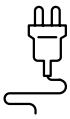
Further details regarding capacity building activities are provided in the section "Roadmap support: Enablers".

Multiple benefits of sustainable materials

Many benefits can be achieved through sustainable materials measures. Many of them are aligned with the Sustainable Development Goals, in particular with Goal 7 (affordable and clean energy), and Goal 13 (climate action).

Some of these benefits are described below in Table 19 although many of them require further analysis to quantify them:

Table 19 • Multiple benefits of sustainable materials

	Environment
	• **Emissions reductions –** sustainable materials reduce embodied carbon emissions in building and construction through lowered energy consumption in manufacturing. • **Air quality –** sustainable materials can improve indoor air quality because of lower pollutants, and can improve outdoor air quality through lowered combustion and cleaner manufacturing processes. • **Resource efficiency –** sustainable materials improve the resource efficiency of the manufacturing and construction of buildings through increased resource recovery, reuse and recycling across the supply chain.
	Energy
	• **Energy savings –** sustainable materials can deliver energy savings in both the manufacturing process and in the operation of buildings.
	Economy
	• **Economic performance –** sustainable materials can boost economic performance as the circular economy turns waste streams into new resource streams.
	Society
	• **Poverty alleviation –** producing materials locally and training local populations can boost local economies. • **Health and well-being –** sustainable materials can be more natural, and less toxic.

Activity 7: Resilience

The concept of resilience has emerged in recent years as a crucial lens to look at the built environment. It promotes a holistic view of urban systems, embracing the interconnected and complex nature of cities' spatial configuration, physical assets, socio-economic functions and organisational structures. Resilience provides an overarching framework to classify the types of urban risks. Key factors influencing urban resilience include the "range and severity of hazards; the risk to lives and property; the vulnerability and exposure of human, social and environmental systems, and; the degree of preparedness of both physical and governance systems to any shock or stress" (United Nations Task Team on Habitat III, 2015). As recognised by Article 7 of the Paris Agreement, resilience is linked to both mitigation and adaptation.

Through the Sendai Framework for Disaster Risk Reduction, countries are engaged in taking measures to reduce disaster risks through seven global targets aimed at reducing mortality; reducing risks to livelihoods, economic assets and infrastructure; and strengthening governance and local capacity to develop disaster risk reduction strategies, multi-hazard early warning systems and disaster risk information (UNISDR, 2015).

Climate and climate change affect construction in two principal ways: 1) as the climate changes, buildings' and building materials' design standards will have to change in order to withstand new weather conditions; and 2) as the pattern of natural disasters changes, a change in the demand for rebuilding and repair will occur. Therefore, the objective is to upgrade the durability and resilience of all buildings by gradually addressing the most critical infrastructures (e.g. those with social and economic relevance, such as hospitals, emergency facilities, schools, power plants, hazardous material facilities), followed by the most vulnerable buildings (e.g. in vulnerable communities, and in regions prone to natural disasters and extreme weather) and the building stock as a whole. Despite its importance for globally, only 10% of NDCs include resilience targets. Box 2 provides further information on the definition of a resilient city.

Box 2 • What is a resilient city?

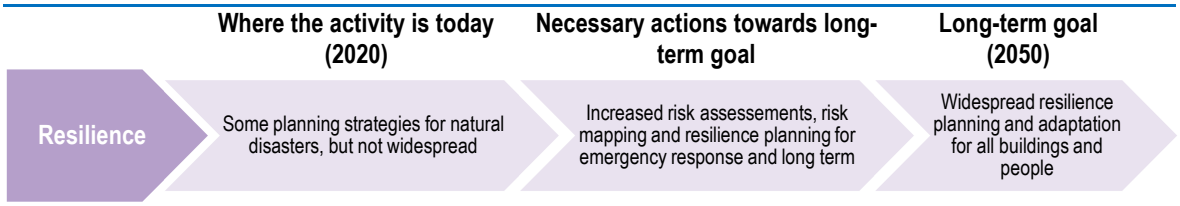
The Sendai Framework for Disaster Risk Reduction 2015-2010 defines resilience as "The ability of a city exposed to hazards to resist, absorb, accommodate to, and recover from, the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR, 2015).

The discontinued 100 Resilient Cities Initiative of the Rockefeller Foundation lays out a City Resilience Framework: "The capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience".

In the context of cities, resilience has helped to bridge the gap between disaster risk reduction and climate change adaptation.

Key actions for resilience

Figure 26 • Key actions for resilience globally



Key actions to enable increased resilience of buildings include:

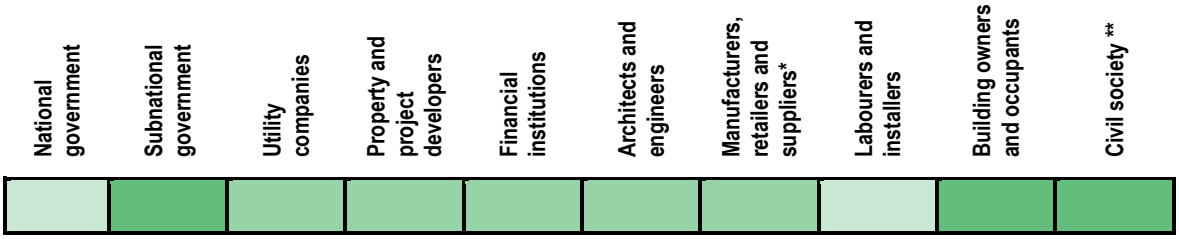
- **Urban planning risk zoning**. Use data and information to document the potential risk exposure by location to enable improved decision-making during the building and infrastructure design process.
- **Wind and seismic resistant construction**. Implement policies and encourage best practice design and construction processes to enable buildings to be resistant to extreme weather events.
- **Storm-water management**. Require improved retention of storm water within properties to reduce the negative impact of water flowing to other properties and to surging waterways.
- **Thermal-resistant construction**. Implement policies and use best practice design techniques to increase the resistance of buildings to extreme temperatures and moisture.
- **Develop integrated assessment**. Work across governments and stakeholders to develop assessment plans that help to ensure resilience plans are holistic across jurisdiction and agencies.

Stakeholders for resilience

Globally, the key stakeholders for resilience include those who can influence the ability to make technologies and design approaches available to increase resilience of buildings and those who can deliver resilient buildings. Additional stakeholders include those who can support the process through research, funding and training, as well as: emergency planners; ministries in charge of disaster recovery and resilience; state agencies with data, GIS or planning responsibilities; and energy and water planning offices.

These stakeholders are mapped in Table 20, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 20 • Stakeholder mapping for resilience globally



* of appliances and materials. Includes product testers and certifiers.

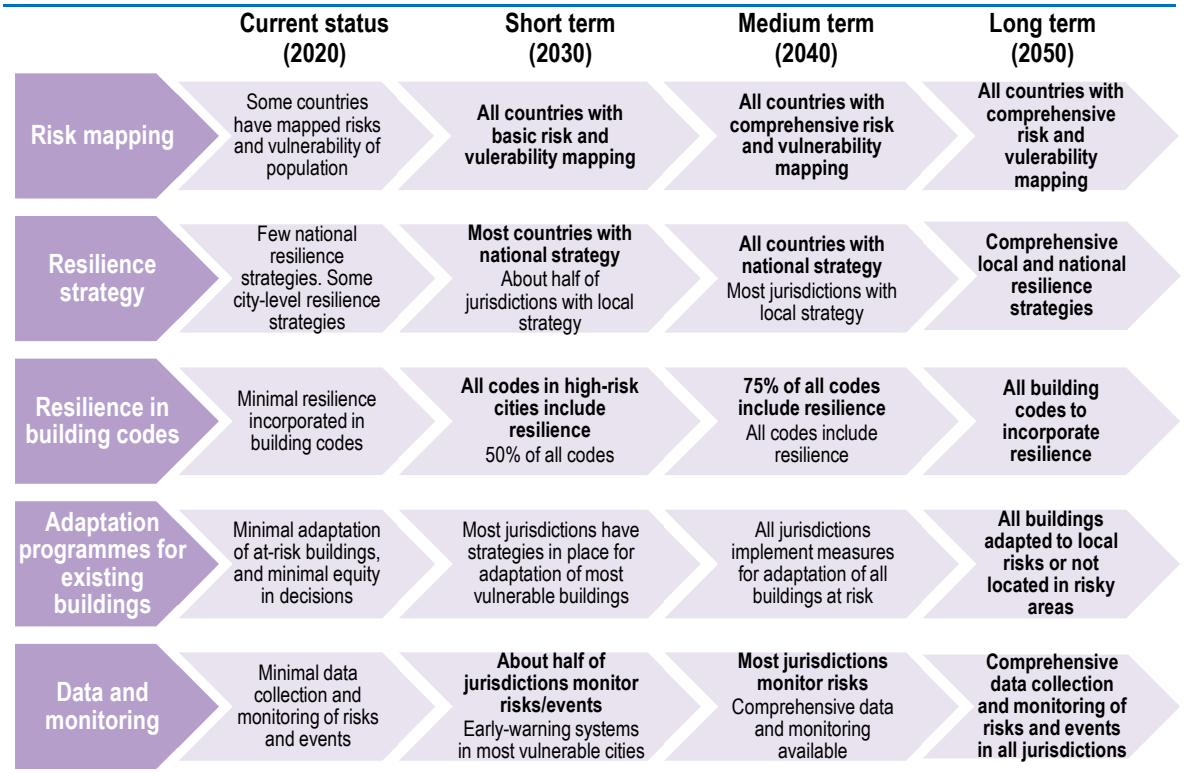
** including academia, NGOs, research institutions, social networks and community associations.

Notes: *How to read:* The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for resilience

Within the targets for sustainable building resilience, the following sub-targets and timelines offer more details:

Figure 27 • Policy timelines for resilience globally



Notes: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details of the policy targets for building resilience are outlined below:

- **Risk mapping**: Gather and document data related to: land-use plans incorporating natural hazards (e.g. landslides, earthquakes) and climate-related risks (e.g. flooding, heatwaves), emergency plans, existing community plans, ordinances and codes, maps and data on geographic location of critical infrastructure systems or facilities, community utility needs (e.g. energy, water, and fuel use and generation), and climate preparedness plans.
- **Resilience strategy**: Develop a resilience strategy that identifies the list of policies and measures that can support increased resilience and addresses the potential for relocation and crisis plans for high-risk settlements. All countries should develop national resilience strategies, and all jurisdictions should develop local resilience strategies. Resilience strategies should include planning for critical infrastructure (hospitals, schools, water supply, energy supply, etc.). Resilience strategies should also include requirements for "building back better" during reconstruction after a disaster. An example of the types of measures to be included within a resilience strategy in a low-lying coastal area would be coastline retreat management.
- **Resilience in building codes**: Incorporate measures in building codes to increase structural and thermal resilience, including passive measures that enable occupants to use buildings when energy services are not available in an extreme weather event or natural disaster. This

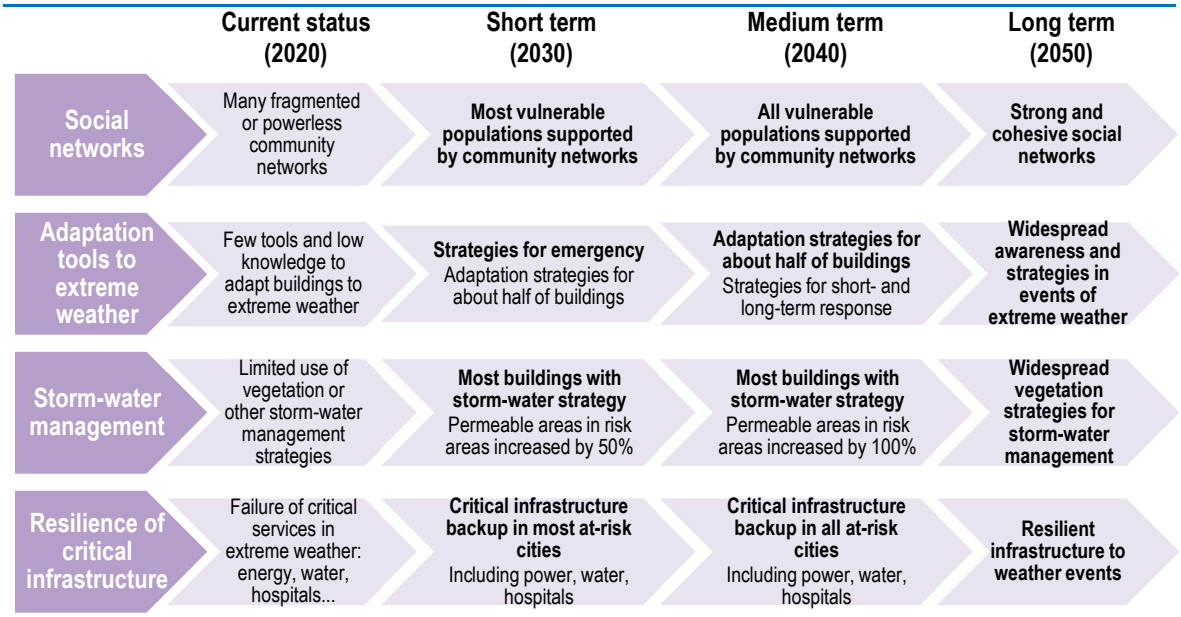
includes insulating, shading, load-bearing roofs, wind- and seismic-proof walls, and water drainage and storage systems.

- **Adaptation programmes for existing buildings**: In many cities, existing buildings in informal settlements are located on sites at high risk from floods or landslides or from other risks (for instance on unstable landfills). Upgrading informal settlements is particularly challenging because of the high degree of informality, and in order to change communities as a whole, rather than isolated projects, commitment from national and local governments is particularly important. Community members should be involved in the planning and implementation of resilience urban upgrading schemes to enhance their understanding of risks and harness their knowledge of the environment in which they live.
- **Data and monitoring**: The Sendai Framework includes a specific target dedicated to "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030" (UNISDR, 2015). Several initiatives, often led by grassroots organisations, use a combination of satellite imagery and community-led surveys to map and analyse the profile of specific neighbourhoods and informal settlements. Settlements are mapped using plane table methods that show plot boundaries. Spatial and socio-economic data are then entered into a GIS database. Using this information, municipal governments and communities are able to prepare upgrading and resilience plans by widening roads, installing flood protection and building new infrastructure.

Technology for resilience

The life-cycle energy and emissions for buildings are influenced by the resilience of the building and its components. Specific targets and timelines for resilience are outlined below:

Figure 28 • Technology timelines for resilience globally



Note: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Details on the technology targets for building operations are outlined below:

- **Social networks**: The promotion of cohesive and engaged communities is one of the drivers of urban resilience with the most robust empirical evidence (Therrien et al., 2018). As a result, many grassroots groups and local government authorities are actively promoting urban resilience by building tightly knit community networks, in particular in informal neighbourhoods. When community residents and neighbours form close relationships, they can better understand and respond to the changing needs of others, in particular the most vulnerable, the elderly and children.

- **Adaptation tools to extreme weather**: Each year, tens of thousands of people die from extreme heat and extreme cold. Heatwaves are estimated to cause 12 000 deaths annually across the world. The World Health Organization forecasts that by 2030 there will be almost 92 000 deaths per year from heatwaves, with that figure expected to rise in 2050 to 255 000 deaths annually unless national and local governments adapt to heat-related risks (WHO, 2014). Building envelope efficiency and thermal comfort systems can reduce the impact of extreme climatic conditions. This includes achieving the targets for envelope thermal performance, air sealing, heating, cooling and ventilation in other roadmap activities. Furthermore, strategies for improved resilience to heavy rain, wind, land movements or any other hazards should be developed for relevant risk zones.

- **Storm-water management**: In the wake of Hurricane Sandy and the increase in frequency and severity of climate impacts in urban areas, the paradigm of Design with Nature first conceptualised by Ian McHarg has generated new thinking and momentum. Impervious surfaces in urban areas such as asphalt and concrete constrain natural drainage, exacerbating peak flows and flood risks. In many coastal cities, wetlands are turned into hard surfaces and mangroves are cleared to make space for construction, removing important buffers against floods and storms. By safeguarding natural buffers to enhance ecosystems' protective functions and designing parks and green features (e.g. bioswales), urban planning and landscape design interventions can optimise rain-capture potential and enhance protection from extreme rains (Aponte, 2019).

- **Resilience of critical infrastructure**: Every city should have a resilient power strategy to ensure that critical public and private facilities can keep operating, the communication systems function, and emergency services remain functional in the event of a power disruption. Resilient power technologies such as solar plus battery storage to protect critical facilities from power outages now enable this function (NREL, 2018). Embedded microgrids, which include renewable energy distributed generation combined with energy storage, load management and smart systems, can disconnect from the main grid through "adaptive islanding" in the event of major disruptions. These microgrid solutions are emerging as a key element of urban energy systems resilience (Ostefeld, Whitmeyer and Von Meier, 2018). Resilience strategies are also required for water supply in areas subject to drought, including water efficiency among consumers, rainwater harvesting and water reuse.

Finance for resilience

Finance can enable increased and accelerated action towards improving the resilience of the built environment. Financial tools particularly relevant to funding resilience in buildings may include:

- **Insurance**: More intense or frequent extreme weather events will affect property insurance. Insurance providers can encourage action to reduce risk exposure by giving resilience ratings to buildings, which could lead to lower premiums (CISL, 2014). Insurance products can also

be tailored specifically to clean technologies and emissions reduction activities (e.g. parametric climate insurance).

- **Urban development funds**: Dedicated funding for urban development projects, which can be directed towards sustainable urban development projects.
- **Infrastructure funds**: Dedicated funding for infrastructure projects, which can be directed towards sustainable infrastructure projects.
- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, which can prioritise sustainable buildings, construction or development projects. Dedicated credit lines to national or local governments can also be used to establish a revolving loan fund, which collects repaid loans for energy efficiency or resilience projects and re-invests them in additional projects.
- **Risk-sharing loan/loan guarantee/concessional loan**: Large organisations (such as a government, international bank or aid organisation) covering the risk of payment default, offering below-market interest rates, or offering longer grace periods for repayment to enable banks to fund projects with lower costs and therefore better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding for projects with climate or environmental benefits.
- **Grants and rebates**: Direct funding to overcome upfront cost barriers, provided by a government, organisation or programme either through a competitive process (grants) or during or after the purchase of a sustainable product or service (rebates).
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy-efficient products on a rental basis to reduce a capital expenditure.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Capacity building for resilience

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver resilient buildings.

The types of capacity-building activities relevant to materials are mapped in Table 21, where the darker the colour, the higher the impact that capacity building type has for this activity.

Table 21 • Capacity building for resilience globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most critical capacity-building activities are explained below:

- **Training within government**: Provide training to central and local governments about assessing climate risks, developing vulnerability maps and collaborating across

multi-stakeholders regarding the development of integrated policies aimed at enhancing resilience in the built environment. Provide training regarding how to communicate the risks and the benefits associated with improved resilience. This will require data collection and analysis to enable the creation of databases, resource platforms and information campaigns.

- **Training of professionals**: Provide training programmes for service and product providers of buildings and construction (architects, engineers, contractors, installers etc.) regarding how to design buildings with increased resilience to climate risks. Provide training on how to comply with policies such as resilience requirements in building codes or urban plans. Develop educational programmes including primary, secondary, vocational, university and adult education, to enable increased knowledge of resilience.
- **Training of general public**: Provide training for the general public on how to monitor climate risks and respective adaptation strategies. In particular, provide access to information on measures and available resources (programmes, finance) to improve the resilience of living and working environments.

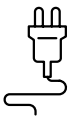
Further details regarding capacity building activities are provided in the section "Roadmap support: Enablers".

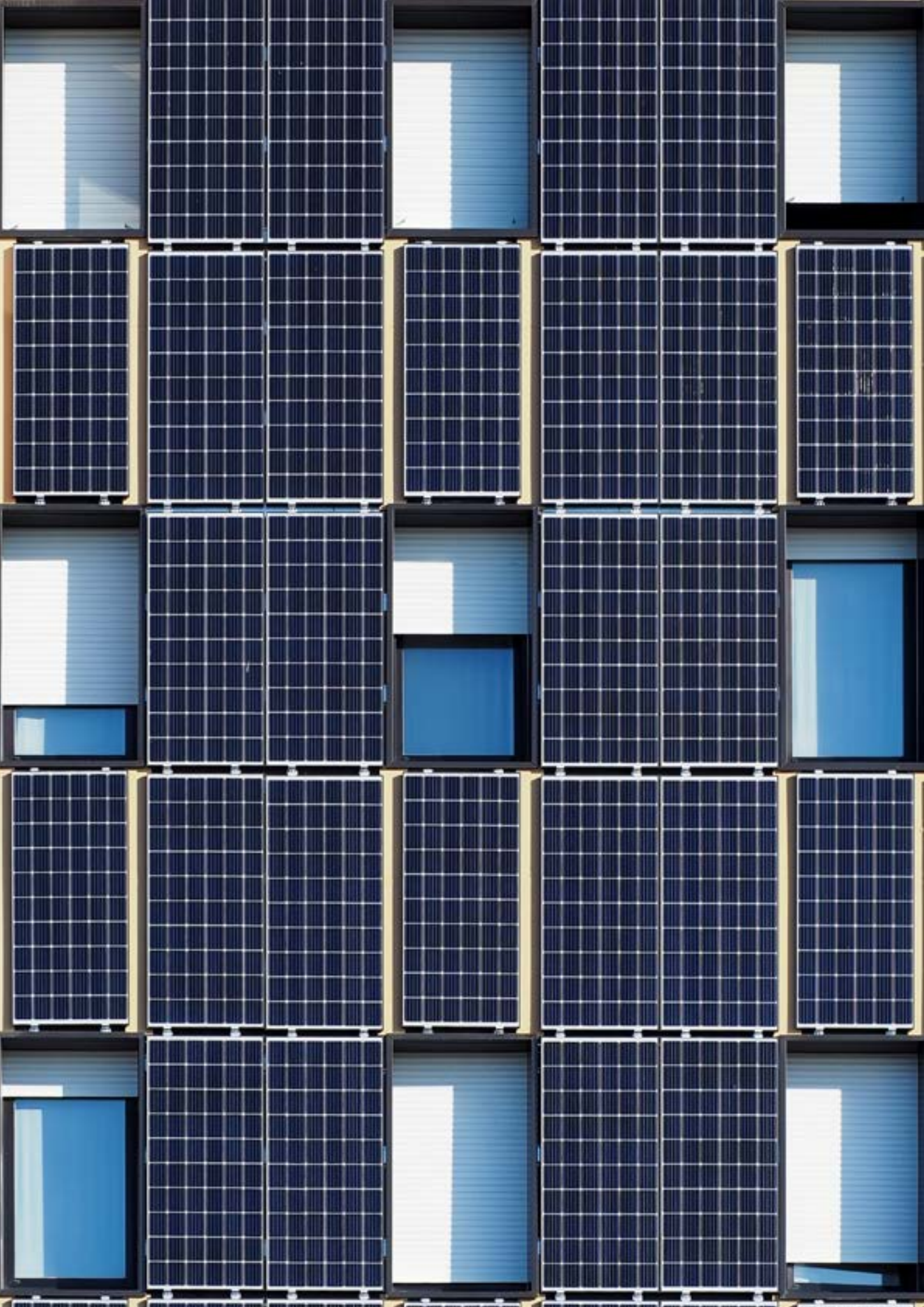
Multiple benefits of resilience

Many benefits can be achieved through resilient buildings. Many of them are aligned with the Sustainable Development Goals, including Goal 7 (affordable and clean energy), Goal 11 (sustainable cities and communities), Goal 12 (responsible consumption and production) and Goal 13 (climate action).

Some of these benefits are described below in Table 22, although many of them require further analysis to quantify them:

Table 22 • Multiple benefits of resilience

Environment	
	• **Resource efficiency** – resilient buildings have a longer useful life.
Energy	
	• **Energy savings** – buildings designed to withstand extreme heat and cold are more energy efficient; buildings resilient to natural disasters have a longer useful life.
Economy	
	• **Productivity –** resilience reduces operational disruption to cities and services. • **Asset value –** resilient buildings have lower risk of damage due to extreme weather events or natural disasters, improving property values and reducing insurance costs.
Society	
	• **Poverty alleviation –** resilient buildings can better withstand extreme weather events or natural disasters, reducing loss of homes and infrastructure. • **Health and well-being** – resilient, durable buildings can withstand extreme weather events or natural disasters, delivering improved physical and mental health and well-being.

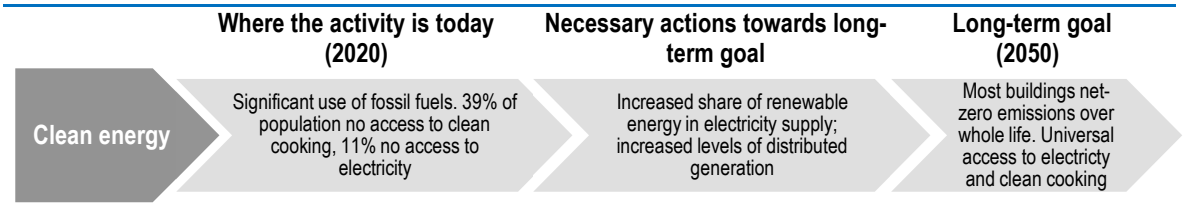


Activity 8: Clean energy

Buildings account for 36% of global final energy consumption, and good management of their energy supply and demand will be key to enabling a transition to clean energy. Shifting to clean energy sources allows for reduced fossil fuel dependency, greater energy autonomy, reduced environmental impacts, reduced GHG emissions and climate change mitigation, as well as provide employment opportunities. Energy service companies can help overcome high upfront costs for renewable and energy efficiency companies, making their diffusion broader, while demand-response and energy storage can play an important role in enabling a greater penetration of variable renewables in the energy mix.

Key actions for clean energy

Figure 29 • Key actions for clean energy globally



Key actions to enable the clean energy transition for buildings include:

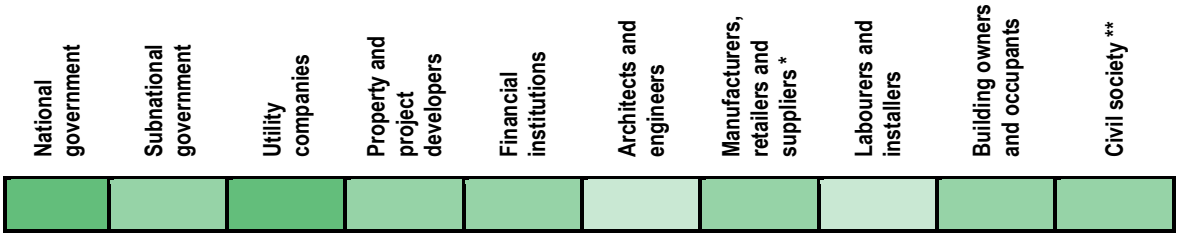
- **Integration of on-site renewable energy**. Adoption of on-site renewable distributed generation will support a significant reduction in building carbon emissions. National and local governments and the private sector can support emissions reductions by adopting building-level technologies such as solar PV, solar thermal, geothermal, micro-wind and advanced biofuels.
- **Accelerate access to universal access to clean cooking and to electricity**. Continue progress on electrification, still lacking in remote areas and overburdened cities. Closing this gap will require private-sector financing, robust policy-planning frameworks, distributed renewables, and extension and strengthening of electricity grids. In order to reach access to clean cooking by 2030 for the almost 3 billion still lacking, solutions will include liquefied petroleum gas (LPG) in cities, and improved biomass or solar thermal in rural areas, with electric devices emerging as possible cost-effective solutions.
- **Clear regulatory frameworks**. Regulations play an important role in accelerating the adoption of distributed generation as they define operational rules, remuneration schemes, incentives allocation, integration mechanisms and goals at national and local levels. Stable regulatory frameworks are key to provide investors with the long term visibility needed for renewable investments.
- **Provide adequate financial incentives**. The construction of distributed generation for new and existing buildings generally depends on the economic viability of the projects. Financial incentives either diminish upfront costs or reduce payback periods, making the systems more financially attractive. Actions in this regard are taken by national and local authorities and include options as feed-in tariffs, value-added tax exemptions, and near-zero or zero-interest loans rates, among various others.
- **Green power procurement**. Where local distributed generation is not feasible or is insufficient to meet the local energy demand, the use of green electricity procurement can further reduce building-related emissions. Buildings can widely support renewable utility-scale projects through power purchase agreements (PPAs).
- **Zero-carbon policies**. Governments can undertake zero-carbon strategies as part of their green agenda. The plans usually include targets at national and local levels, and mandatory standards and norms related to new construction, retrofits and materials.
- **District energy systems**. District energy systems can replace fossil-based peak power plants, while diversifying the electricity production matrix at the same time. New technologies such as battery energy storage systems (BESS) can also contribute to this transition.

Stakeholders for clean energy

Globally, key stakeholders are those who either influence the availability of clean energy technologies and services or facilitate clean energy supply in buildings. Additional relevant actors include those who can support the process through research, funding and training and are essential to deliver the roadmap targets.

These stakeholders are mapped in Table 23, where the darker the colour, the higher the impact that stakeholder group has on the activity and the more essential it is to delivering the roadmap targets.

Table 23 • Stakeholder mapping for clean energy globally



* of appliances and materials. Includes product testers and certifiers.

** including academia, NGOs, research institutions, social networks and community associations.

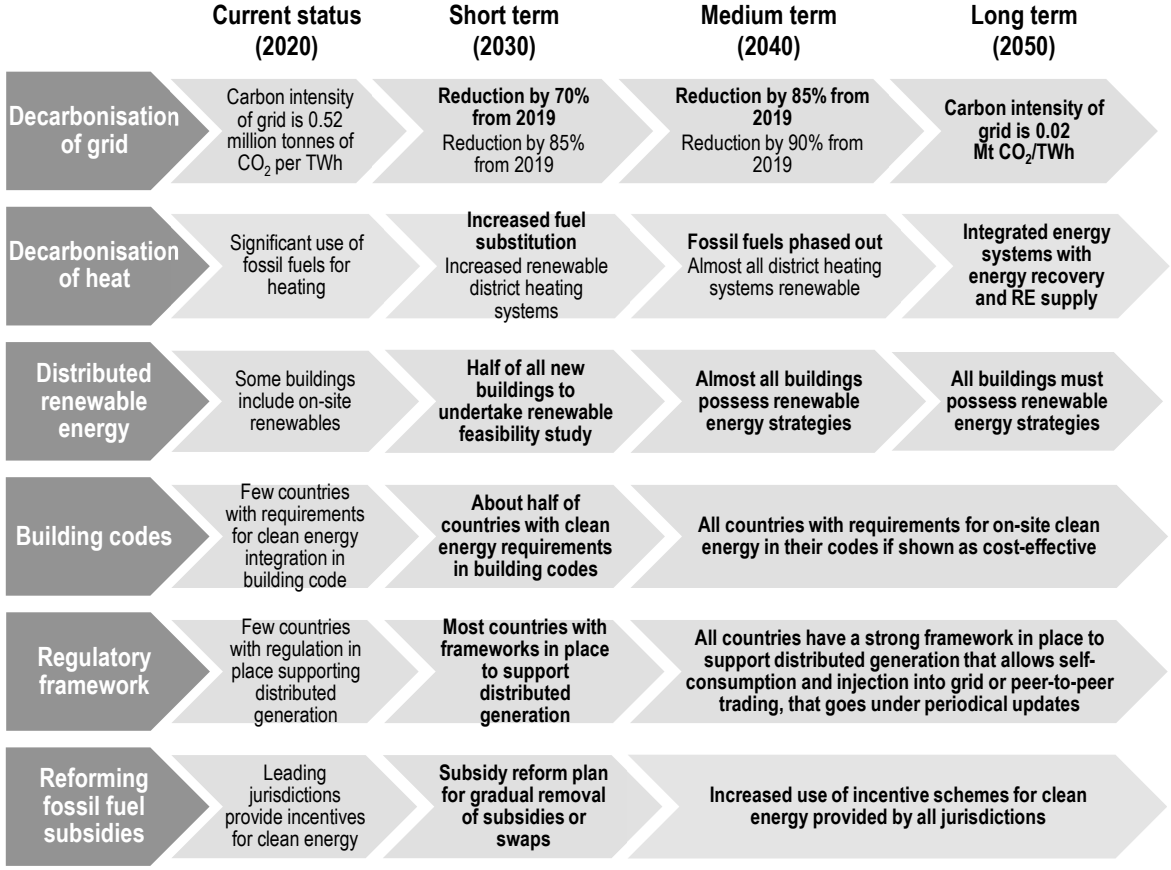
Notes: *How to read:* The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Policy for clean energy

Clean energy policy supports zero-emission, efficient and resilient buildings by enabling the decarbonisation of the energy used in buildings and in the production of construction materials.

Within the targets for clean energy, the following sub-targets and timelines offer more details:

Figure 30 • Policy timelines for clean energy globally



Note: The **proposed global target** is in **bold**. Below that is the proposed accelerated target.

Policy for clean energy target details:

- **Decarbonisation of electricity**: The wide integration of distributed power generation, mainly in consumption centres, represents a valuable opportunity for countries to the extent that it allows cleaning the energy mix at efficient cost (this highly depends on the regulation in place for remuneration schemes). Moreover, since production and consumption of electricity can be made on-site, further benefits from no electrical losses in the grid (which are high-carbon-intensive as well) can be taken into account.
- **Decarbonisation of heat**: The decarbonisation of heat will be enabled by an increased penetration of renewable electricity systems, fuel subsitutions away from fossil fuels, heat recovery and renewable district heating systems, among others. These subsitutions can be enabled by strong policy to phase out fossil fuels in space heating systems. Heating systems should aim to be fully integrated with the wider energy system, using heat and cold storage as flexibility mechanisms for the system.

- **Distributed renewable energy**: At the building level, on-site renewable generation is one of the possible strategies to achieve net-zero energy and net-zero carbon standards. Buildings may fully or partially meet their energy needs with local heat and electricity generation systems (solar PV, solar thermal, biogas and geothermal, among others). Local production of renewable heat and electricity to displace fossil fuel consumption offers multiple benefits, including not only lower environmental impacts (e.g. GHG emissions, particulate emissions, etc.) but also energy diversification resulting in greater energy security and lower energy dependency for import countries, and greater possibilities of local energy governance at community level. The widespread adoption of distributed energy generation can be further encouraged through feasibility studies for the installation of on-site generation projects in new and existing buildings.

- **Building codes**: The incorporation of measures such as readiness for demand-side response measures, obligations for renewable energy systems or provisions for their future installation (e.g. structural integrity requirements) can be stipulated in building codes. The codes should be developed jointly among national authorities, builders and other stakeholders so appropriate technologies are considered and mandatory requirements are applicable, enforceable, and well-designed. Building codes also must include requirements in structural integrity or other requirements which will enable the safe inclusion of on-site renewable energy systems.

- **Regulatory framework**: Regulatory frameworks define operating rules, connection permits, the use of networks for distributed resources, goals, incentives, market conditions, prices for surpluses and other factors that allow an easy adoption of on-site generation. In this sense, a clear, simple, well-designed, updated and consistent regulation framework can facilitate widespread adoption. Frameworks covering technical regulations and administrative provisions for multi-dwelling PV or solar thermal installations can also help increase uptake in dense urban environments.

- **Reforming fossil fuel subsidies**: The environmental and health costs of fossil fuel usage must be accounted for when comparing the costs of fossil fuels to those of renewable energy sources. This would mean phasing out fossil fuel subsidies and setting appopriate taxation wherever applicable. Rolling back subsidies may be complemented with more targeted social welfare measures, to mitigate the socio-economic impacts on the population, in particularly the most vulnerable. For example, in developing Asia,[9] subsidies for kerosene, generally used for lighting, cost USD 10.2 billion per year (Evan, 2017). Subsidy reforms could enable replacements such as solar lighting distribution instead. Similarly, incentives can be used to promote renewable energy. These incentives can be non-financial, like expedited product approvals and permits, or financial. The former offers appropriate enabling conditions for the development of renewable energy technology, while the latter can substantially accelerate its deployment by encouraging private investment.

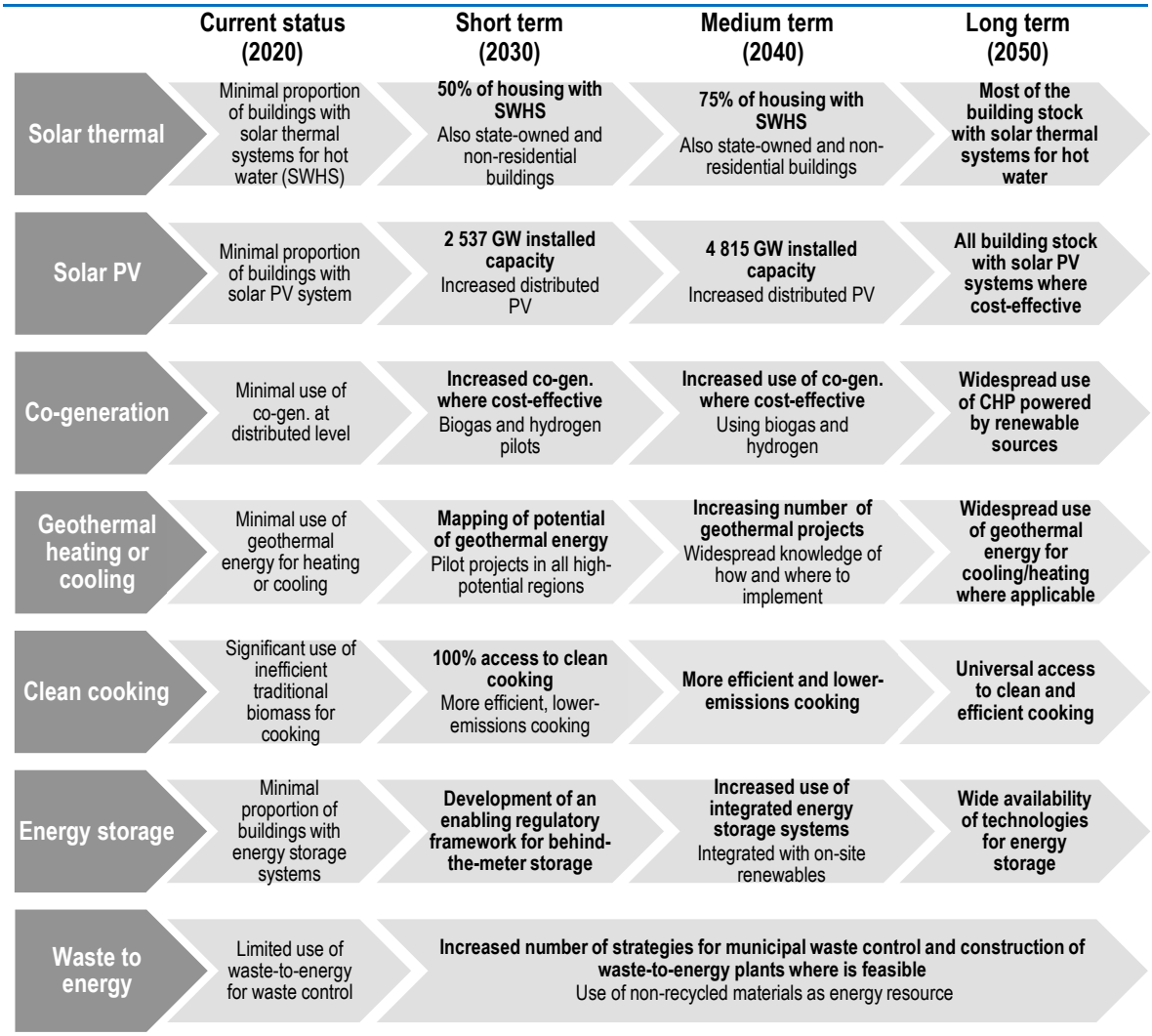
[9] Developing Asia based on the International Monetary Fund (IMF) definition refers to Bangladesh, Cambodia, Lao People's Democratic Republic, Mongolia, Myanmar, Nepal and Sri Lanka.

Technology for clean energy

The life-cycle energy and emissions for buildings are influenced by the energy used in buildings.

Specific targets and timelines for clean energy are outlined below:

Figure 31 • Technology timelines for clean energy globally



Notes: The **proposed global target** is in **bold** . Below that is the proposed accelerated target.

Clean energy technology target details include:

- **Solar thermal**: On-site solar thermal collectors produce hot water in a renewable way and should be encouraged in areas of high solar radiation. Solar thermal systems have significant potential to displace electricity consumption from electric residential hot water production at a competitive prive.
- **Solar PV**: On-site building integrated or roof-mounted PV can enable the generation of electricity for self-consumption. According to the size of the installed system, buildings could partially or totally cover their electricity needs on an annual basis. Coupling with BESS can provide off-grid buildings with the required flexibility to meet their electricity demand at times of no generation (e.g. at night). Surpluses can also be delivered to the power grid using bidirectional metering. Low-voltage direct current home solar systems also offer significant

potential for increasing access to electricity. The targets outlined above are based on the global capacity of solar PV in the IEA's SDS (IEA, 2019a).

- **Co-generation**: Co-generation can provide significant gains in terms of energy efficiency and reduction of CO_2 emissions in buildings by recovering waste heat from electricity production and using it for water and space heating. Co-generation can use a variety of fuels, from fossil fuels to biogas, biomass and even hydrogen. Co-generation systems can be expanded using tri-generation (combined cooling, heat and power) to also produce chilled water for space cooling.

- **Geothermal heating or cooling**: Geothermal systems exploit the earth or bodies of water as a heat sink, to provide heating or cooling. They can be used in combination with a heat pump, or where temperatures allow, in a direct circulation loop. Policy support in the form of risk guarantees or investment grants can help mitigate investment risks associated with high upfront costs and uncertain drilling operation outcomes.

- **Clean cooking**: The use of traditional biomass for cooking is responsible for significant air pollution, deforestation and missed development opportunities. The benefits from switching from traditional biomass to clean energy for cooking are therefore multiple. In the IEA's SDS, a 95% reduction of traditional biomass makes it possible to reduce particle matter emissions by 97% by 2040 compared to 2018 (IEA, 2019a). There is no single solution and universal clean cooking can be achieved through a combination of switching to gas and electric cookers, efficient stoves and modern biomass, taking into account local circumstaces and cultral acceptability.

- **Energy storage**: With increasing shares of variable and non-pilotable renewable energy in the energy supply, energy storage becomes an important element for balancing supply with demand. Thermal energy storage can be implemented at the building or district scale, with higher cost-effectiveness at the latter. Coupled with solar thermal systems, heat storage tanks can ensure continued supply of hot water. Coupled with electric boilers or heat pumps, heat, chilled water or ice storage make it possible to avoid curtailment during periods of excess electricity production from variable renewable sources, and shift load to off-peak hours to lower the strain on the grid. BESS can store electricity for delayed uses, providing flexibility to off-grid buildings equipped with distributed variable renewable energy technologies, such as distributed PV. Time of use (ToU) tariffs for electricity can incentivise the deployment of behind-the-meter BESS in connected buildings, as these BESS allow consumers to reduce grid-electricity consumption at peak hours and even potentially to sell electric surpluses to the grid, using bidirectional metering at the most profitable time. However, unless all BESS include bidirectional metering, on-grid storage offers a more economical and energy efficient solution than behind-the-meter storage from a system perspective, due to (i) economies of scale (ii) the smoothening effect from both demand and supply aggregation, which reduces the overall storage capacity needs, and the intensity of its use.

- **Waste to energy**: Waste from buildings and construction that could not be avoided or recycled can be used as additional fuel input to municipal waste-to-energy plants. Although variability in the physical and chemical properties of waste makes it a less profitable combustible, waste-to-energy can provide a waste management alternative to landfill disposal. Landfill taxation and gate fees can help encourage the development of waste-to-energy.

Other clean energy technologies that do not have specific targets above include:

- **Small-scale hydro**: Historically, small-scale hydro was an important energy source for industrial buildings that were located near rivers. Currently, most small scale hydro is directly fed into the power grid and not used on-site. It is common that these types of projects do not have storage capacity or water reservoirs, in contrast to large dammed hydroelectric plants.

Finance for clean energy

Finance can enable increased penetration of clean energy for buildings. Financial tools particularly relevant to financing clean energy for buildings may include:

- **Green power procurement**: Depending on the regulatory framework, large electricity consumers can go to the competitive market to procure electricity directly from renewable energy projects or green-electricity retailers. In this way, large buildings, districts or municipalities can use their aggregated market power to support renewable utility- or distributed-scale projects. Green power procurement is a common practice in some cities around the world, where municipalities decide to meet the electricity demand of public buildings through PPAs linked to renewable projects.
- **Urban development funds**: Dedicated funding for urban development projects, which can be directed towards renewable energy projects.
- **Infrastructure funds**: Dedicated funding for infrastructure projects, which can be directed towards sustainable renewable infrastructure projects.
- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, which can prioritise sustainable buildings, construction or development projects. Dedicated credit lines to national or local governments can also be used to establish a revolving loan fund, which collects repaid loans from renewable energy projects and re-invests them in additional energy efficiency or renewable energy projects.
- **Risk-sharing loan/loan guarantee**: Large organisations, such as a government, international bank or aid organisation, covering the risk of payment default to allow banks to fund a project with lower costs and better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding associated with sustainable projects, including renewable energy projects.
- **Preferential tax**: Direct funding from the government to reduce or eliminate the tax for sustainable products and services, including renewable energy projects.
- **Grants and rebates**: Direct funding to overcome up-front cost barriers, provided by a government, organisation or programme either through a competitive process (grants) or during or after the purchase of a sustainable product or service (rebates).
- **Energy performance/energy service contracts**: Contracts for services or delivered savings that typically are delivered by an ESCO and can include a range of energy efficiency or renewable energy services and products.
- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy efficient products or renewable energy technologies on a rental basis to overcome high upfront capital expenditure.
- **On-bill/tax repayment**: An approach where any recurring bill, such as utility bills, insurance bills or home improvement store bills, can collect small amounts of money over a long period

of time to pay for energy efficiency purchases in smaller payments. An offshoot of on-bill finance, tax repayment is where the tax authority uses recurring tax payments as a means for collecting money over time. The most common of these is PACE finance, which is able to use low-interest-loan repayments on the property tax bill until the purchase is full paid.

- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.
- **Energy prices**: Cost-reflective pricing and subsidies are powerful influencers of how people consume energy. Pricing strategies should consider decarbonisation goals. Time of use and location based pricing are other mechanisms by which pricing can influence consumption for a more robust integration of renewable energy.

Capacity building for clean energy

Information combined with capacity-building activities can increase overall awareness, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment can enable increased resources and capacity to deliver clean energy.

The types of capacity-building activities relevant to urban planning are mapped below, where the darker the colour, the higher the impact that capacity-building type has for this activity.

Table 24 • Capacity building for clean energy globally

Training within government	Training of professionals	Training of product and material manufacturers	Training of financiers and developers	Training of general public

Note: The darker the colour, the higher the impact that capacity building type has for this activity.

Details regarding the most relevant capacity-building activities are explained below:

- **Training within government**: Build capacity and awareness in all levels of government on the benefits of clean energy production to the energy system, as well as broader benefits to infrastructure, public health and well-being, and the environment. Provide training on the integration of clean energy in all relevant aspects of policy planning, design and implementation, including in integrated resource planning, investment decisions, and urban planning and buildings sector policies among others. Strengthen capacity in co-ordination among relevant government and non-government organisations to enable improved policy coherence.
- **Training of financiers and developers**: Provide training to financiers and developers in identifying, assessing and financing clean energy projects, both at utility scale and distributed generation. Also build capacity in creating and nurturing stakeholder networks among policy makers, developers and financiers to build more project pipelines.

Further details regarding capacity building activities are provided in the section “Roadmap support: Enablers”.

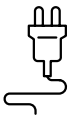
Multiple benefits of clean energy

Many benefits can be achieved through the clean energy transition. Many are aligned with the Sustainable Development Goals, including Goals 7 (affordable and clean energy), Goal 11

(sustainable cities and communities), Goal 12 (responsible consumption and production) and Goal 13 (climate action).

Some of these benefits are described below in Table 25, although many of them require further analysis to quantify them:

Table 25 • Multiple benefits of clean energy

	Environment
	• **Emissions reductions –** clean energy reduces GHG emissions. • **Air quality –** many forms of clean energy produce no air pollution, improving air quality.
	Energy
	• **Energy security –** local clean energy solutions improve energy security by reducing reliance on fuel imports. • **Energy prices –** cost-competitive clean energy can reduce energy prices as generation profiles often have a strong overlap with peak demand profiles.
	Economy
	• **Economic performance –** clean energy delivers energy productivity improvements. • **Employment –** clean energy creates local jobs during the manufacturing, installation, and O&M of renewable energy systems.
	Society
	• **Poverty alleviation –** increasing access to reliable electricity and to clean forms of cooking can bring significant economic opportunity benefits to households. • **Health and well-being –** reducing indoor air pollution caused by the use of solid fuels, and by reducing time spent on energy collection or cooking activities increases both health and well-being.

Roadmap support: Enablers

Across all eight activity areas, a set of actions are key to enabling their successful implementation: capacity building, financing and multi-stakeholder engagement. **Capacity building** enables people to understand and act on information that can support the achievement of zero-emission, efficient and resilient buildings. **Financing** is critical to turning policy and project ideas into reality. **Multi-stakeholder engagement** incorporates feedback from implementers and those affected, builds trust, and creates strong community buy-in to maintain momentum through leadership transitions.

Key actions for enablers

Figure 32 • Key actions for enablers globally

Key actions for capacity building and finance include:

- **Data collection and analysis**: More efforts are needed to collect and centralise data management, understand how best to use it, and balance data privacy and transparency. Data sharing can be made obligatory or can be incentivised it if it is voluntary.
- **Educational and professional training**: There is low availability of green building curriculum in universities. Workforce training programmes are more common, especially for the construction workforce on topics such as green building materials and energy efficiency.
- **Awareness**: More awareness is needed of integrated approaches with urban development and connections with air pollution and public health.
- **Institutional co-ordination across multiple stakeholders**. Co-ordination is critical in several dimensions:
    - across government institutions, especially to avoid duplication of initiatives
    - across organisations supporting governments, especially to improve ease of government participation in initiatives
    - between public, private and civil society sectors to enable continuity and access to centralised information.
- **Encourage the formation of global and regional green building communities**. For example, regional and national Green Building Councils and National Alliances are examples of communities with convening power capable of bringing together actors across the fragmented value chain.
- **Financing**: Financing options are available, but access is often difficult due to lack of information, awareness, and standardisation. Increased awareness can enable incentives to raise industry ambition and interest.
- **Policies** in general need to address the decision-making processes in building design and construction in a way that **addresses whole life-cycle carbon**, stimulating full decarbonisation of the sector.

Capacity building

Capacity building is used to increase awareness, access and analysis of data and information. This includes data and tools to assess building emissions and energy consumption, information about co-ordination across institutions in the public sector or across sectors, and awareness of green buildings in education and training curricula. Capacity-building activities can increase overall awareness across all relevant stakeholder groups, improve the decision-making process and encourage more sustainable choices. Training for professionals working directly with the built environment is important to increase resources and capacity to deliver zero-emission, efficient and resilient buildings.

Capacity building target details include:

- **Training within government**: Increased technical, financial and human resources in the public sector can improve the implementation and enforcement of policies. Increasing awareness is also crucial within government institutions on the benefits of green buildings and construction such as economic impacts, public health and well-being, and benefits to the energy sector and the environment. Shared goals and co-ordination within and among relevant government institutions and with NGOs can enable improved policy coherence. For example, national policy can create an enabling environment for local governments to accelerate action towards green buildings, and local policy is required for strong implementation.
- **Training of professionals**: Training programmes for service and product providers for buildings and construction (architects, developers, contractors, vendors, etc.) and building owners increase awareness of green building and construction policies, programmes or incentives for sustainable buildings and construction. This increases professionals' ability and willingness to implement these programmes.
- **Educational training**: Educational programmes including primary, secondary, vocational, university and adult education enable increased knowledge of green buildings. Certification or accreditation for professionals in the buildings sector can motivate more people to undertake educational training programmes, and increase awareness of who is trained to support green buildings and construction.
- **Training of product and material manufacturers**: This includes training for industry on how to comply with product and building standards as well as capacity building to enable the development and deployment of low-carbon solutions, such as increasing efficiency in manufacturing and construction processes and design, employing circular design principles and strategies to increase recycling and reuse.
- **Training of financiers and developers**: Training and access to tools for financiers and developers to better identify, assess and finance investment opportunities in the zero-carbon, efficient and resilient buildings sector. Particularly important is a better understanding and assessment of the benefits of zero-carbon, efficient and resilient buildings within the broader context of climate risk exposure of buildings as assets. Moreover, capacity building is necessary to create stakeholder networks among policy makers, developers and financiers to set up project pipelines.
- **Training of the general public**: Information tools to increase awareness, improve decision-making and promote more sustainable choices by the general public. Methods of increasing information to consumers include benchmarking programmes, certification programmes, building passports, mandatory disclosure, labels, educational resources, and information on utility and government programmes.
- **Data collection and analysis**: Baseline data on building stock and typologies, energy consumption, and emissions is a critical first step to understanding the starting point and therefore how to improve towards zero-emission buildings and calculate the multiple benefits there are to gain from the decarbonisation of buildings.

These elements of capacity building have differing relevance across the eight activity areas. A general indication of the relevance of each is mapped out in Table 26.

Table 26 • Summary table of capacity-building actions

	Training within government	Training of professionals	Training of product and materials manufacturers	Training financiers and developers	Training of the general public (incl. owners and occupants)
Urban planning					
New buildings					
Existing buildings					
Building operations					
Appliances and systems					
Materials					
Resilience					
Clean energy					

Finance

Zero-emission, resilient and efficient buildings and construction often face barriers to finance because they require upfront investments for benefits that develop over several years. Incentives and financing encourage building and construction stakeholders to make decisions in support of green buildings.

Financial tools particularly relevant to financing clean energy for buildings may include:

- **Urban development funds**: Dedicated funding for urban development projects, which can be directed towards sustainable urban development projects.
- **Infrastructure funds**: Dedicated funding for infrastructure projects, which can be directed towards sustainable infrastructure projects.
- **Dedicated credit lines**: Funding delivered through banks for a specific purpose, such as sustainable buildings or development projects.
- **Risk-sharing loan/loan guarantee**: Large organisations, such as a government, international bank or aid organisation, covering the risk of payment default to allow banks to fund a project with lower costs and better loan terms.
- **Green bonds**: Bonds that can be used to bundle funding associated with sustainable projects.
- **Preferential tax**: Direct funding from the government to reduce or eliminate the tax for sustainable products and services.
- **Grants and rebates**: Direct funding provided by the government, organisation or programme during or after the purchase of a sustainable product or service.
- **Energy performance/energy service contracts**: Contracts for services or delivered savings that typically are delivered by an ESCO and can include a range of energy efficiency services and products.

- **Procurement purchase and lease**: The purchase or lease of sustainable products and services. Leasing enables the ability to use energy-efficient products on a rental basis to reduce a capital expenditure.
- **On-bill/tax repayment**: An approach where any recurring bill, such as utility bills, insurance bills or home improvement store bills, can collect small amounts of money over a long period of time to pay for energy efficiency purchases in smaller payments. An offshoot of on-bill finance, tax repayment is where the tax authority uses recurring tax payments as a means for collecting money over time. The most common of these is PACE finance, which is able to use low-interest-loan repayments on the property tax bill until the purchase is full paid.
- **Community finance and crowdfunding**: Collective funding from a large number of people connected either locally or through a call for funding.

Engagement across multiple stakeholders

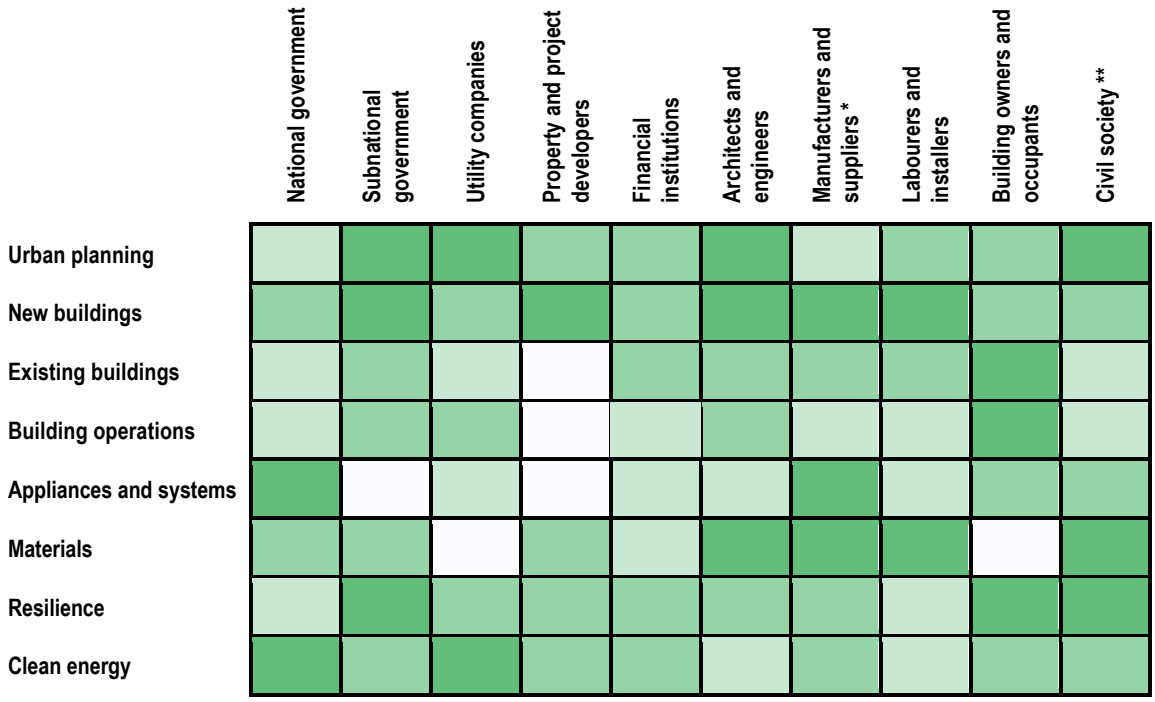
Engagement with stakeholders across sectors offers the opportunity to gain feedback from a variety of perspectives, especially those that will support implementation of the roadmap (especially across the private sector) and those who will be affected by the policies. Multi-stakeholder engagement also creates strong community buy-in to maintain momentum through leadership transitions.

Stakeholders to be engaged are listed below, and it must be noted that some of these cover different sectors that may not efficiently co-ordinate or collaborate:

- **National government**: National governments design and implement policies that enable or disable the uptake of sustainable building and construction. National governments act as regulators and can play an important role in facilitating partnerships among other stakeholders.
- **Subnational government**: Subnational governments play a critical role in developing, implementing, and enforcing policy. In addition to their regulatory role, cities and states can convene actors across sectors, and can take action as owners of public buildings.
- **Utility companies**: Utilities have significant building data and valuable relationships with owners and tenants that already includes payment and financing. In some cases, utilities also have to comply with legislation to reduce their emissions. Utilities can therefore be either a significant barrier or enabler to action on sustainable buildings and construction.
- **Property and project developers**: Developers make decisions about how property will be used, including cost-benefit assessments for different building and construction approaches. These early decisions can have far-reaching impacts into what options are considered in a building or construction project.
- **Financial institutions**: Financiers provide mechanisms to make the necessary up-front investments for sustainable buildings and construction, with repayment often coming from the energy saving benefits that develop over several years.
- **Architects and engineers**: Professionals who lead on technical project design determine what is possible within the parameters set by developers. Professional and educational training provides these experts with the knowledge they need to develop sustainable building and construction designs.

- **Manufacturers and suppliers**: Companies that make equipment and systems determine what products are available on the market, and whether building upgrade solutions are sold with a systems-view or more piecemeal replacements over time.
- **Labourers and installers**: Construction professionals must interpret project designs and bring them to life, and there are many risks for real-life installations to fall short of the sustainability envisioned in the designs on paper. Professional training is critical for labourers and installers to achieve sustainable buildings and construction projects with the required level of quality.
- **Building owners and occupants**: Owners and occupants are responsible for the buildings energy service consumption, for paying for any building upgrades, paying for energy bills, and get the benefit of improved energy services.
- **Civil society**: Civil society organisations, such as consumer and environmental advocates, or social service providers, can provide analytical capacity and grounded expertise to inform all stakeholders and improve government decision making. Civil society can represent the perspectives of communities and buildings occupants and users that may otherwise be absent from buildings and construction dialogues.

Table 27 • Summary mapping of stakeholders



* of appliances and materials

** including academia, NGOs, research institutions, social networks and community associations.

Notes: *How to read:* The darker the colour, the higher the impact that stakeholder group has on the activity and the more essential they are to delivering the roadmap targets.

Multiple stakeholder engagement processes, involving civil society and users before and during policy design processes, enable government decision-makers to explore and assess the relevance and feasibility of different approaches, taking into consideration various needs and perspectives. Stakeholder engagement can also build relationships with key players, driving policy acceptance and improving participation and compliance.

Several approaches can facilitate stakeholder engagement. For instance, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis can be facilitated collaboratively with stakeholders to better understand what will drive success of policy for sustainable buildings and construction and what threats to be aware of. PIE (Progress, Impact, Effort) multi-matrix (such as the Assessment Tool for Building Efficiency Policies [Becqué et al. 2016]) can seed stakeholder discussion to prioritise policies for action. Stakeholders can collaboratively use a responsibility matrix such as RACI (Responsible, Accountable, Consulted, Informed) to clearly identify which roles are appropriate for each stakeholder throughout policy roadmap development and implementation.

Box 3 • Examples of mechanisms to facilitate institutional co-ordination

The "green building" community has a powerful part to play in convening the relevant stakeholders and actors including academia, the private sector and civil society; providing training; and generally raising awareness of the benefits of green buildings. Green building communities are present and growing in many of the countries across the region. Two examples of these types of communities are described below:

Green building councils

Green building councils (GBCs) facilitate institutional co-ordination of public, private and civil society by advocating for a more sustainable built environment, developing the capacity of the industry to build better buildings and raising awareness of the benefits of green buildings. The global GBC network is developing tools, programmes and resources to accelerate uptake of net-zero carbon buildings towards sector decarbonisation goals.

National alliances

The GlobalABC helps promote national alliances that bring together key public, private and civil society stakeholders, to overcome the fragmented value chain and jointly work towards a zero-emission, efficient, and resilient buildings and construction sector.

National alliances offer recommendations for policy makers and actively work to enhance economic activity. Typical pursuits range from awareness raising, training sessions and project assistance to legislative lobbying.

National alliances have been successfully established in France, Germany, Mexico, Morocco and Tunisia, in many cases inspired by GlobalABC.

Conclusions and outlook

Buildings have a dominant role to play in the clean energy transition and towards reaching the sustainable development goals. Yet the *2019 Global Status Report* highlights that this sector is not on track, as energy efficiency improvements are outpaced by rapidly expanding floor area and growth in demand for energy-consuming services. To counteract these trends, the global average building energy intensity per unit of floor area needs to be at least 30% lower than current levels by 2050 (IEA, 2019c). Furthermore, full decarbonisation of the sector requires a life-cycle approach, ensuring circularity in building materials and reducing their embodied carbon, adequate urban planning and development, and adopting adaptation and resilience measures.

Along with the three regional roadmaps, this Global Roadmap can serve as a tool for countries to include ambitious and effective buildings and construction sector actions when undertaking the 2020-25 NDC revision, and supporting the monitoring, reporting and verification process for NDCs. It can also support organisations in determining their buildings investment strategies by identifying goals and milestones, supporting detailed national or local buildings and construction roadmaps. By creating a common vision for the whole sector, these documents aim to facilitate co-operation among the entire value chain in the buildings and construction sector, and also between countries and regions. The global key actions across these activities set out the ingredients for policy makers to include in their strategies and the elements needed to transition towards a zero-emission, efficient and resilient building stock.

These documents provide targets and timelines for establishing both a proposed pathway of improvement in the planning, development, operation, servicing and resilience of the global building stock, along with ambitious or “stretch” targets that allow countries and subnational entities to push further faster. It is the expectation that these documents, the themes, checklists, guides, recommendations, stakeholder mapping, examples and key actions can help guide policy-making, raise awareness, help build the evidence-base for more ambitious buildings and construction policies and effecive market signals.

Although this Global Roadmap is the product of extensive consultation and expert input, there are activities and action areas that need more data to ensure appropriate target setting and prioritisation. There remains the need across the sector to build the evidence base and develop tools for the adoption of low-carbon materials, and of improving the understanding of the systems and processes that can improve their resilience. There is also the need to raise the level of ambition across all eight activities for which all stakeholders along the building value chain need to play their part.

Global effort in support of buildings and construction sector decarbonisation

Governments and stakeholders across the world are starting to take action towards buildings sector decarbonisation.

The GlobalABC was launched at COP21 as a voluntary partnership of national and local governments, intergovernmental organisations, businesses, associations, networks and think tanks committed to a common vision: a zero-emission, efficient and resilient buildings and construction sector. The GlobalABC functions as a meta-platform that brings together initiatives and actors focusing on the buildings and construction sector.

Box 4 • The GlobalABC

By working with buildings and construction experts through a series of workshops, meetings, events and interactive dialogues, the GlobalABC with the IEA developed this roadmap that sets out actions towards decarbonising the sector through a comprehensive approach to buildings and construction. This document guides the GlobalABC in its efforts to raise ambition to meet the Paris climate goals and mobilise all actors along the buildings and construction value chain. Such efforts include:

- Keeping track of the sector through an annual buildings and construction global status report.
- Raising ambition levels by supporting countries in including ambitious, concrete buildings and construction climate actions into their NDCs (i.e. *A Guide for Incorporating Buildings Sector Actions in NDCs*).
- Shaping the global agenda: showcasing the potential of the buildings and construction sector for mitigation and adaption by giving the buildings and construction sector a voice in the global climate change debate.
- Forging regional pathways towards zero-emission, efficient, and resilient buildings and construction through stakeholder-driven regional roadmaps, based on our Global Roadmap.
- Promoting national alliances: supporting national governments to overcome the fragmentation in the buildings and construction sector and ramp up the level of action. The GlobalABC so far has sparked three national alliances in Mexico, Morocco and Tunisia.
- Working with the GlobalABC-catalysed Programme for Energy Efficiency in Buildings (PEEB) and its first five partner countries Mexico, Morocco, Senegal, Tunisia and Viet Nam towards implementing actions towards decarbonising the buildings sector.

The GlobalABC, through these activities, aims to mobilise all actors along the value chain, identifying priorities and goals towards decarbonising the built environment, while fostering transparency, inclusion and co-operation. The Global Roadmap is a key step in this process

As part of the 2018 Clean Energy Ministerial, six GlobalABC member countries (Argentina, France, Germany, Mexico, Morocco and Switzerland) signed the Global Call for Low-Carbon, Energy-Efficient and Resilient Buildings to develop national strategies for buildings and construction in line with the Paris Agreement goals. Furthermore, multiple businesses, cities, and regions have signed up to the Net Zero Carbon Buildings Commitment, which challenges companies, cities, states and regions to reach net-zero operating emissions in their portfolios by 2030, and to advocate for all buildings to be net-zero in operation by 2050. And countries, the private sector and financial institutions have signed up to the Zero Carbon Buildings for All initiative as part of the UN Secretary-General's Climate Summit in 2019.

While this Global Roadmap promotes a common language and vision, to accelerate progress, the approach of developing key actions and setting of targets across the buildings and construction sector illustrated by this roadmap can be cascaded to the regional, subregional, national and subnational levels to create locally owned and adopted roadmaps. To this end, the GlobalABC has developed a series of Regional Roadmaps for Africa, Asia and Latin America, to serve as guidelines for regional and subregional action.

References

100 Resilient Cities (2016). *100 Resilient Cities*. Retrieved from Porto Alegre, Brazil: https://www.100resilientcities.org/wp-content/uploads/2017/07/PortoAlegre_Strategy_Portuguese_PDF.pdf

ACEEE (American Council for an Energy-Efficient Economy) (2019). *The 2019 City Clean Energy Scorecard.* Retrieved from https://aceee.org/research-report/u1904

Aponte, G. (2019). *The Nature of Cities*. Retrieved from Towards Innovative Design of Stormwater Management, with Landscape at the Center: https://www.thenatureofcities.com/2019/09/30/towards-innovative-design-of-stormwater-management-with-landscape-at-the-center/

Ashwill M., Flora, C. and Flora, J. (2011). *Building Community Resilience to Climate Change: Testing the Adaptation Coalition Framework in Latin America.* The International Bank for Reconstruction and Development/ The World Bank. Retrieved from http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1232059926563/5747581-1239131985528/Adaptation-Coalition-Framework-Latin-America_web.pdf

Becqué, R. et al. (2016). "Assessment tool for building efficiency policies", Annex 2 in *Accelerating Building Efficiency: Eight Actions for Urban Leaders*, World Resources Institute, Ross Center for Sustainable Cities, https://www.wrirosscities.org/sites/default/files/16_REP_Accelerating_Building_Efficiency.pdf

Braungardt, S. and Göthner, K.-C. (2017). *Harmonisation of MEPS and energy labelling in Latin America and the Caribbean - opportunities and challenges.* ECEEE. Retrieved from https://www.researchgate.net/publication/335574325_Harmonisation_of_MEPS_and_Energy_Labelling_in_Latin_America_and_the_Caribbean_-Opportunities_and_Challenges

Carrizosa, M. et al. (2019). *Facing Risk. New Urban Resilience Practices in Latin America.* Retrieved from http://scioteca.caf.com/handle/123456789/1431

CISL (Cambridge Institute for Sustainability Leadership) (2014). *Climate Change: Implication for Buildings.* Cambridge. Retrieved from https://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/pdfs/briefings/IPCC_AR5__Implications_for_Buildings__Briefing__WEB_EN.pdf

Ecofys (2017). *GABC - Global Roadmap towards low-GHG and resilient buildings.* Berlin: BMWi. Retrieved from https://www.dena.de/fileadmin/dena/Dokumente/Themen_und_Projekte/Gebaeude/Rahmenvertrag_BMWi/Fachliche_Begleitung_Global_Alliance_Buildings_Construction.pdf

Encyclopaedia Britannica (2019). *Urban Planning*. Retrieved from Encyclopaedia Britannica: https://www.britannica.com/topic/urban-planning

Energy Transitions Commission (2018). *Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century.* Retrieved from http://www.energy-transitions.org/mission-possible

EPA (Environmental Protection Agency) (2019). *Heat Island Effect*. Retrieved from EPA: https://www.epa.gov/heat-islands

EPA (2011). *Location Efficiency and Housing Type. Boiling it down to BTUs.* Retrieved from https://www.epa.gov/sites/production/files/2014-03/documents/location_efficiency_btu.pdf

Evan, M. (2017). *Global Kerosene Subsidies: An Obstacle to Energy Efficiency and Development.* Retrieved from https://doi.org/10.1016/j.worlddev.2017.05.036

Fundación IDEA (2017). *Urban Resilience in Latin America: a Brief Guide for City Policymakers.* Retrieved from https://website-c230-consultores.nyc3.digitaloceanspaces.com/IDEA/files/UrbanResilience_PolicyBrief_170407_English_1536704685.pdf

GlobalABC/IEA/UNEP (2019). *2019 Global Status Report for Buildings and Construction.* Retrieved from https://webstore.iea.org/download/direct/2930?fileName=2019_Global_Status_Report_for_Buildings_and_Construction.pdf

GlobalABC/IEA/UNEP (2018). *2018 Global Status Report for Buildings and Construction.* Paris. Retrieved from https://www.iea.org/reports/2018-global-status-report

GlobalABC/IEA/UNEP (2016). *Global Roadmap: Towards low-GHG, efficient and resilient buildings.* Retrieved from https://globalabc.org/uploads/media/default/0001/02/9ab4984b5d2e006ad533bca08257a43bdf974fa9.pdf

Government of Mexico (2016). *Guía de Resiliencia Urbana [Urban Resilience Guide].* Retrieved from https://www.gob.mx/cms/uploads/attachment/file/179708/Guia_de_Resiliencia_Urbana_2016.pdf

IEA (International Energy Agency) (2020). *World Energy Statistics and Balances* (database), www.iea.org/statistics

IEA (2019a). *World Energy Outlook 2019.* Retrieved from https://www.iea.org/reports/world-energy-outlook-2019

IEA (2019b). *Tracking Buildings.* Retrieved from https://www.iea.org/reports/tracking-buildings

IEA (2019c). *The Critical Role of Buildings.* Retrieved from https://www.iea.org/reports/the-critical-role-of-buildings

IEA (2018). *Renewables 2018.* Paris: IEA. Retrieved from https://www.iea.org/reports/renewables-2018

IEA (2017). *Energy Technology Perspectives 2017 – Catalysing Energy Technology Transformations*, Retrieved from https://webstore.iea.org/energy-technology-perspectives-2017 .

IEA (2016). *Energy Technology Perspectives 2016 - Towards Sustainable Urban Energy Systems.* Paris: OECD/IEA. Retrieved from https://www.iea.org/reports/energy-technology-perspectives-2016

IEA (2013). *Policy Pathway - Modernising Building Energy Codes.* OECD. Retrieved from https://webstore.iea.org/policy-pathway-modernising-building-energy-codes-2013

IEA/KCEP (Kigali Cooling Efficiency Programme) (2019). *Kigali Tracker.* Retrieved from https://www.iea.org/reports/tracking-buildings/cooling

IFC (International Finance Corporation) (2019). *Green Buildings: a Finance and Policy Blueprint for Emerging Markets.* Washington D.C. Retrieved from https://www.ifc.org/wps/wcm/connect/a6e06449-0819-4814-8e75-903d4f564731/59988-IFC-GreenBuildings-report_FINAL_1-30-20.pdf?MOD=AJPERES&CVID=m.TZbMU

Infonavit (2015). *Infonavit on reshaping Mexico's mortgage market*. Retrieved from World Finance: https://www.worldfinance.com/inward-investment/infonavit-on-reshaping-mexicos-mortgage-market

IPCC (International Panel on Climate Change). (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Retrieved from https://www.ipcc.ch/sr15/

Irazábal, C. (2009), *Revisiting Urban Planning in Latin America and the Caribbean*. Retrieved from https://www.researchgate.net/publication/265579292_Revisiting_Urban_Planning_in_Latin_America_and_the_Caribbean

IRENA (International Renewable Energy Agency) (2017). *Biogas for Domestic Cooking.* Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Dec/IRENA_Biogas_for_domestic_cooking_2017.pdf

IRP (International Resource Panel) (2020). *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future*. Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N., A report of the International Resource Panel, UNEP, Nairobi, Kenya, https://www.resourcepanel.org/reports/resource-efficiency-and-climate-change

IRP (2018). *The Weight of Cities: Resource Requirements of Future Urbanization*. Swilling, M., Hajer, M., Baynes, T., Bergesen, J., Labbé, F., Musango, J.K., Ramaswami, A., Robinson, B., Salat, S., Suh, S., Currie, P., Fang, A., Hanson, A. Kruit, K., Reiner, M., Smit, S., Tabory, S. A Report by the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya. Retrieved from https://www.resourcepanel.org/reports/weight-cities

NREL (National Renewable Energy Laboratory)(2018). *Resilience Roadmap: A Collaborative Approach to Multi-Jurisdictional Resilience Planning.* Retrieved from https://www.nrel.gov/docs/fy19osti/73509.pdf

OECD/IPEEC (Organisation for Economic Co-operation and Development/International Partnership for Energy Efficiency Cooperation) (2018). *Zero Energy Building Definitions and Policy Activity: An International Review.* Retrieved from https://ipeec.org/upload/publication_related_language/pdf/766.pdf

Ostefeld, M., Whitmeyer, M. and Von Meier, A. (2018). *Block-Level Microgrids for Power System Resilience: Scaling and Impacts.* Retrieved from http://www.cired.net/publications/workshop2018/pdfs/Submission%200322%20-%20Paper%20(ID-21011).pdf

The McHarg Center (n.d.). *What Does it Mean to Design with Nature now?* Retrieved from The McHarg Center: https://mcharg.upenn.edu/conversations/what-does-it-mean-design-nature-now

The World Bank (2017). *The Cities of the Future in Latin America: Fewer Cars, Fewer Youth*. Retrieved from The World Bank: https://www.worldbank.org/en/news/feature/2017/10/05/ciudades-del-futuro-en-america-latina

Therrien, M.-C. et al. (2018). *Towards Urban Resilience: Synthesizing the Strategies that Enable and Factors that Impede.* Retrieved from http://cite-id.com/documents/synth%C3%A8se-de-connaissances/Scoping-review-Final-version-siteweb.pdf

UN (United Nations). (2017). *New Urban Agenda*, UN Habitat III Secretariat, http://habitat3.org/wp-content/uploads/NUA-English.pdf" http://habitat3.org/wp-content/uploads/NUA-English.pdf

UN DESA (United Nations Department of Economic and Social Affairs)(2019). *World Population Prospects 2019.* Retrieved from https://population.un.org/wpp

UN Habitat (2015). *Sustainable Urban Development in Latin America.* Retrieved from http://www.housingfinance.org/uploads/IUHF%20Congress%202015/7_Elkin_Velasquez.pdf

UNEP (2019). *Emissions Gap Report 2019* (website). Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/30797/EGR2019.pdf?sequence=1&isAllowed=y

UNEP (2018). *A Guide for Incorporating Buildings Actions in NDCs.* Retrieved from https://globalabc.org/uploads/media/default/0001/02/67fea075bbb7a9dc8dd08f2ddb3ebc0f41df8a97.pdf

UN Task Team on Habitat III. (2015). *Urban Resilience.* New York: UN Habitat. Retrieved from http://habitat3.org/wp-content/uploads/Habitat-III-Issue-Paper-15_Urban-Resilience-2.0.pdf

UNISDR (United Nations Office for Disaster Risk Reduction) (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030.* New York: United Nations. Retrieved from https://www.preventionweb.net/files/resolutions/N1516716.pdf

Warah, R. (2003). *The Challenge of Slums: Global Report on Human Settlements 2003.* Retrieved from https://www.globalpolicy.org/component/content/article/211-development/44579.html

WHO (World Health Organization) (2014). *Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s.* Retrieved from https://apps.who.int/iris/bitstream/handle/10665/134014/9789241507691_eng.pdf

World Green Building Council (2019). *Bringing Embodied Carbon Upfront - Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon.* Retrieved from https://worldgbc.org/news-media/bringing-embodied-carbon-upfront

Additional resources

The following are freely available resources that could be useful in developing a roadmap. Some of these resources have a broad view of the buildings sector while others include roadmaps for specific activities within the buildings sector, such as a roadmap for building codes or a roadmap for building renovation.

Key resources:

- Global Roadmap Towards Low-GhG and Resilient Buildings, Global Alliance for Buildings and Construction, 2016
- Recommendation for a classification of measures and policies related to local conditions, Ecofys Germany GmbH, 2017
- Science-based Targets for Buildings, A framework for carbon emissions management along the building and construction value chain, WBCSD, 2018
- Capturing the Multiple Benefits of Energy Efficiency, International Energy Agency, 2014

Additional resources:

- Policy Pathway: Energy Performance Certification of Buildings, International Energy Agency, 2010
- Policy Pathway: Modernising Building Energy Codes, International Energy Agency, 2013
- Technology Roadmap: A Guide to Development and Implementation, International Energy Agency, 2014
- Technology Roadmap: Energy-efficient Buildings Heating and Cooling Equipment, International Energy Agency, 2011
- Technology Roadmap: Energy Efficient Building Envelopes, International Energy Agency, 2013 Transition to Sustainable Buildings, International Energy Agency, 2013
- 25 Energy Efficiency Policy Recommendations, International Energy Agency, 2011
- Energy Efficiency Policy Recommendations: Arab-Southern and Eastern Mediterranean, International Energy Agency, 2014
- Energy Efficiency Policy Recommendations: Latin American and Caribbean, International Energy Agency, 2015
- Energy Efficiency Policy Recommendations: South East Asia Region, International Energy Agency, 2014

Additional roadmap projects that can be built on or used for inspiration:

- Roadmap for Implementation of Energy Efficiency in Public Buildings of Kyrgyz Republic, World Bank, 2019
- Super Low Energy Building Technology Roadmap, Singapore BCA, 2018 Nearly (Net) Zero Energy Building Roadmap, APEC, 2018
- A Carbon Positive Roadmap for the built environment, Green Building Council Australia, 2018
- Roadmap for Healthy Buildings – 1st step: Harmonisation of Health Criteria for Construction Products, German Environment Agency, 2018
- Roadmap to Healthy Low-Carbon Lifestyles, Cities and Buildings, Science Council of Japan, 2018

- A Roadmap for Retrofits in Canada: A detailed roadmap for reducing greenhouse gas emissions from large buildings, Canada Green Building Council, 2017
- Zero Energy Building Pathway to 2035, National Grid, 2016
- Policy Roadmap to 50% Energy Reduction in Chinese Buildings by 2050, LBNL, RMI and ERI, 2016
- Roadmap to Resilient, Net-Zero Buildings in the Pacific Northwest, Pacific Northwest Economic Region, 2015
- Washington State Energy Code Roadmap, NBI, 2015
- Buildings modernisation strategy: Roadmap 2050, Poland and BPIE, 2015
- Roadmap to Zero Emissions, Architecture 2030, 2014
- NASA Net Zero Energy Buildings Roadmap, NREL, 2014
- A Guide to Developing Strategies for Building Energy Renovations, BPIE, 2013
- Strategy Roadmap for Net Zero Energy Buildings in India, USAID, 2011
- Roadmap to Green Government Buildings, USGBC, 2011
- Measurement Science Roadmap for Net-Zero Energy Buildings, NIST, 2010
- Roadmap for a Transformation of Energy Use in Buildings, WBCSD, 2009
- Going the distance: the low-carbon buildings roadmap, CBI, 2009
- Roadmap for positive-energy and low-carbon buildings and building clusters, ADEME
- Better Buildings Through Energy Efficiency: A Roadmap for Europe, Eurima, 2006
- High-performance Commercial Buildings: A Technology Roadmap, US DOE, 2000
- Model Regulation Guidelines: Energy Efficiency and Functional Performance Requirements based on International Standards, U4E, 2019

Acronyms, abbreviations, and units of measure

Acronyms and abbreviations

ASEAN	Association of Southeast Asian Nations
BAT	best available technology
BESS	battery energy storage system
BIM	building information modelling
BMS	building management systems
BMWi	German Federal Ministry of Economic Affairs and Energy (Bundesministeriums für Wirtschaft und Energie)
CO_2	carbon dioxide
COP	coefficient of performance
COP21	21st Conference of the Parties
EMS	energy management systems
EPD	Environmental Product Declaration
ESCO	energy services companyHPD Health Product Declaration
G7	Group of 7
GIS	geographic information system
GHG	greenhouse gas
GlobalABC	Global Alliance for Buildings and Construction
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
LCA	life-cycle assessment
LED	light-emitting diode
low-e	low-emissivity
LPG	liquefied petroleum gas
MEF	Material Efficiency variant Scenario
MEPS	minimum energy performance standards
NDC	Nationally Determined Contribution
NGO	non-governmental organisation
OTTV	overall thermal transfer value
O&M	operations and maintenance
PACE	property-assessed clean energy
PEEB	Programme for Energy Efficiency in Buildings

PV	photovoltaic
R&D	research and development
RTS	Reference Technology Scenario
SDS	Sustainable Development Scenario
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SWHS	solar water heating systems
TOD	transit-oriented design
UHI	urban heat island
UNFCCC	United Nations Framework Convention on Climate Change
UN	United Nations
UNEP	United Nations Environment Programme
WRI	World Resources Institute

Units of measure

EJ	exajoule
Gt CO_2	gigatonne of carbon dioxide
lm/W	lumens per watt
m^2	square metre
Mt CO_2/TWh	million tonnes of carbon dioxide per terawatt hour
W/W	watt per watt