COMPENDIUM ON GREENHOUSE GAS BASELINES AND MONITORING

BUILDING AND CONSTRUCTION SECTOR

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COMPENDIUM ON GREENHOUSE GAS BASELINES AND MONITORING

BUILDING AND CONSTRUCTION SECTOR

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FOREWORD

At COP26 in Glasgow, Parties —or, to say it more candidly, the representatives of nearly every country in the world— built a bridge between good intentions and measurable actions to lower emissions, increase resilience and provide much-needed finance. The final package, while not perfect, nevertheless represented the most significant progress achieved since the adoption of the Paris Agreement. Key to this fruitful outcome, following six years of negotiations, was the finalization of guidelines for the full implementation of the Paris Agreement.

The consensus reflected in the Glasgow Climate Pact must be followed by decisive action, commensurate with the climate challenges the world faces. Despite the positive results from COP26, we are still far off the trajectory of stabilizing global temperature rise at 1.5-degrees. An enormous task lies ahead. Our work and the work of Parties must continue with the greatest resolve towards COP27.

At the heart of this work are the NDCs. I encourage all countries to explore areas of opportunity to strengthen and accelerate climate action. This requires developing and implementing more robust and ambitious national climate plans. The recent iterations of the UN NDC Synthesis Report make this point forcefully: what we currently have is not enough to bend the climate curve. Moreover, an increase in ambition must be accompanied by a *significant* increase in support for climate action in developing countries, thereby fulfilling a key element of the Paris Agreement. Turning the commitments expressed in NDCs into action will require that developing country Parties have at their disposal appropriate tools and receive the necessary support to put in place policies and programs that allow their societies to prosper in a way that is sustainable. Lowering greenhouse gas emissions must be a priority for all moving forward.

It is my sincere hope that this compendium will be a source of knowledge and support for developing-country policymakers and national experts as they take the next crucial steps to enhance their mitigation strategies and programs in the building and construction sector. On a more technical level, I also trust that this will help the sector strengthen its reporting in accordance with the Convention and the enhanced transparency framework under the Paris Agreement.

If we are to succeed in addressing climate change, every sector needs to make their distinct, individual contribution to achieve our collective climate goals. I have no doubt that the building and construction sector will be a key ally in these efforts. I look forward to working with this vital element of every economy as we build a cleaner, greener and more resilient future.

Patricia Espinosa C

Patricia Espinosa
Executive Secretary
United Nations Convention on Climate Change
Bonn, Germany, December 2021

PREFACE

The building and construction sector play a critical role in both national economies and greenhouse gas emissions. With the expected future population growth and improved living standards, this role is expected to expand further. The building and construction sector will therefore become increasingly important to achieving the global UN Sustainable Development Goals and the goals of the Paris Agreement.

As outlined in the Paris Agreement, all signatory nations are required to periodically prepare or update their national determined contributions (NDCs) outlining their ambitious climate targets. In developing these NDCs, it is essential that policymakers and technical experts obtain an understanding of the different sectoral drivers and sources of greenhouse gas emissions, and how to set sectoral mitigation targets that contribute to the overall national climate action plans.

Over the next few years, countries will also start implementing the enhanced transparency framework for action and support (ETF) under the Paris Agreement which builds on and enhances the current measurement, verification and reporting requirements under the Convention. The ETF specifies how Parties to the Paris Agreement must report on the state of their greenhouse gas emissions and removals, progress in implementing and achieving NDCs, adaptation measures and support provided or received. It also provides for international procedures for the review of the submitted reports. The information gathered through the ETF will feed into the Global stocktake – a process under the Paris Agreement o periodically take stock of the implementation of the Agreement to assess the collective progress towards achieving its purpose and long-term climate goals.

This is the third volume of the Compendium Series on GHG Baselines and Monitoring. It follows previous volumes on: The National Level Mitigation Actions; and, The Passenger and Freight Transport. This volume on the building and construction sector provides an overview of the different sources of GHG emissions from the building and construction sector, as well as methodologies for quantifying these emissions to feed into the preparation and reporting of national GHG inventories. By better understanding the sources of emissions over the whole life cycle of buildings, it thus provides guidance on the most appropriate and effective mitigation strategies and policies for decarbonizing the building and construction sector based on national circumstances. We are optimistic that the guidance contained in this volume will be of some help to developing country Parties to make informed choices when setting building and construction sector emission reduction targets; implementing climate change mitigation actions and reporting on them in their national communications, biennial update reports and in future, biennial transparency reports.

Donald Cooper
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Bonn, Germany, December 2021

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GLOSSARY

Term	Definition
Barrier	Any factor or consideration that would discourage mitigation activity
Base year	A specific year of historical data against which greenhouse gas emissions are compared over time
Baseline scenario	Projection of greenhouse gas emissions and their key drivers as they might evolve in a future in which no explicit actions are taken to reduce greenhouse gas emissions
‘Business as usual’ scenario	A reference case that represents future events or conditions that are most likely to occur without implementation of mitigation policies or projects. It is sometimes used as an alternative term for “baseline scenario”
Clean development mechanism	A mechanism to assist Parties not included in Annex I to the Convention in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation or reduction commitments
Carbon dioxide equivalent	The universal unit of measurement to indicate the global warming potential value of each greenhouse gas, expressed in terms of the equivalent global warming potential of 1 unit of carbon dioxide
Combined heat and power	An energy conversion process in which more than one useful product, typically electricity and heat or steam, is generated from the same energy input stream. Also referred to as cogeneration systems
Cumulative emissions	A sum of emissions over a defined period of time
Double counting	The counting of the same transferable greenhouse gas emission unit towards the mitigation goal of more than one jurisdiction. Similarly: double claiming, double selling and double issuance of units
Emissions lock-in	Where suboptimal mitigation actions are taken, rendering subsequent improvement impractical or uneconomic, resulting in higher greenhouse gas emissions than could have been economically achieved
Direct emissions	Emissions from burning fossil fuels to supply energy (often heat) within buildings
Indirect emissions	Emissions resulting from the energy supplied into buildings from electricity grid and from district heating and cooling plants. Also, embedded emissions in building material products and emissions from the supply chain of buildings (e.g. construction process and end of life demolition).
Energy performance contract	Agreement between two or more parties where payment is based on achieving specified results, such as reductions in energy costs or payback of investment within a stated period
Energy efficiency	The improvement in the service provided per unit of energy supplied, for example, project activities which increase unit output of electricity, heat, light (or fuel) per unit of energy input

Term	Definition
Energy end use	Application of energy for a specific purpose, such as ventilation, lighting, heating, cooling, domestic hot water, motive power, etc.
Energy savings	Value, in energy units, of energy consumption or demand reduction determined by comparing measured energy values before and after implementation of an energy efficiency measure, making suitable adjustments for changes in conditions
Emission factor	A carbon intensity factor that converts activity data into greenhouse gas emission data
Estimated value	Parameters used in saving calculations determined through methods other than conducting measurements in situ. The methods used to estimate values may range from arbitrary assumptions and benchmarking to engineering estimates derived from manufacturer ratings of equipment performance
Greenfield	Site for construction of a new building or other facility where previously none existed
Model	A calculation used to represent the operation, characteristics and impacts of a process. In the context of mitigation actions in buildings, a model is often created using building analysis software
Nationally Determined Contribution	Each Party to the Paris Agreement shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.
Nationally appropriate mitigation action	Any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative
Nearly Zero Energy Building	A building that has a very high energy performance, requiring a very low amount of energy that is ideally supplied from renewable sources
Reference year	A year against which commitments are made and measured, typically in the form of emission abatement. Most frequently it is a year in the past, for example 1990 for the commitments under the Kyoto Protocol. It can also to be an average of a number of years
Small-scale clean development mechanism project	A clean development mechanism project below a certain size threshold for which procedures have been simplified: Type I: Renewable energy projects up to 15 MW (or an appropriate equivalent); Type II: Energy efficiency projects with a maximum output of 60 GWh per year (or an appropriate equivalent); and Type III: Other projects that result in emission reductions of less than or equal to 60ktCO_2 eq annually
Scenario	The evolution of key variables (e.g. greenhouse gas emissions, energy consumption) over time under a specific set of assumptions
Tri-generation	Simultaneous generation of electrical energy and thermal energy in the form of cooling and heating in one process or one plant
Verification	A periodic independent review and determination of the net greenhouse gas emission reduction achieved as a result of a project

ABBREVIATIONS

AFOLU	agriculture, forestry and other land use
BEA	Building Efficiency Accelerator
BPIE	Buildings Performance Institute Europe
BREEAM	Building Research Establishment Environmental Assessment Method
CaaS	Cooling as a Service
CDM	clean development mechanism
CO_2 eq	carbon dioxide equivalent (a unit of measurement)
ECOWAS	Economic Community of West African States
EJ	exajoules. 1 exajoule is equal to 10^{18} joules, or 277.8 TWh
EPBD	European Union Energy Performance of Buildings Directive
ESCO	energy service company
ESI	energy savings insurance
EU	European Union
GCF	Green Climate Fund
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German International Development Cooperation)
Gt	Gigatonne
GW	Gigawatt
GWh	gigawatt hours
HVAC	heating, ventilation and air conditioning
ICT	information and communication technology
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kW	Kilowatt
kWh	kilowatt hour
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
M	Million
MRV	measurement, reporting and verification
MW	megawatt = 1000 kW
MWh	megawatt hour = 1000 kWh
NDC	nationally determined contribution
NECP	national energy and climate plan
PV	Photovoltaic
SMEs	small and medium-sized enterprises
TWh	terawatt hour = 1 million MWh
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar

1. INTRODUCTION

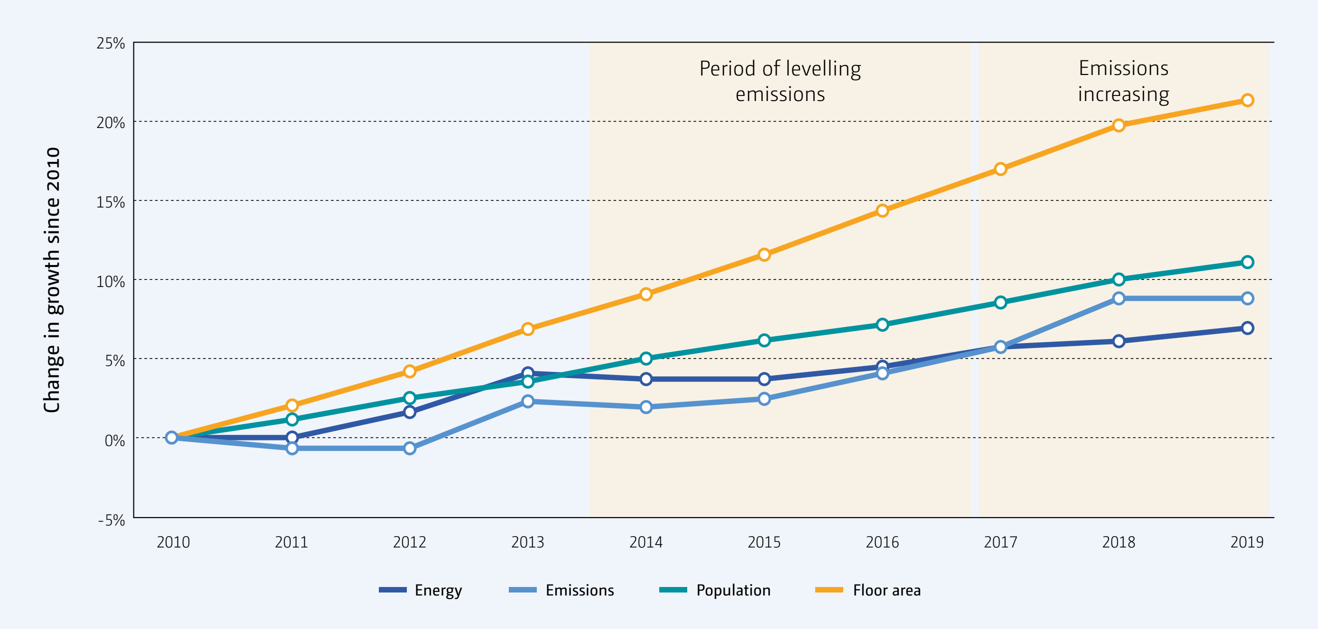
1.1 Buildings – their role in our lives and impact on the environment

Buildings represent one of the most basic human needs, the need for shelter, safety and security. Our homes are places where we can relax and live our lives. Different types of buildings provide a myriad of functions, from educational and health buildings to shops, places of work, leisure facilities and many more. The building and construction sector is also important to national and global economies. For instance, in 2018, the global investment in building construction and renovation amounted to USD 4.5 trillion, over 5 per cent of global gross domestic product (GDP)[1].

However, the critical role played by the sector in our daily lives and our economies comes with a significant energy cost and environmental burden. In 2019, the collective stock of existing buildings and the construction of new ones together accounted for over one third (35%) of global final energy use, making the sector the largest energy consumer, ahead of industry (31%) and transport (28%). It also accounts for the largest share of energy-related carbon dioxide (CO_2) emissions, at 38% (Global ABC 2020). Furthermore, the sector is growing as a result of ongoing construction activities to meet the demand caused by rising populations and improving living standards, particularly in developing countries (IPCC 2014). In the absence of effective mitigation policies and actions, this will lead to higher levels of greenhouse gas (GHG) emissions in future see figure 1 below. In addition to creating pressure on natural resources, this growth also has an impact on land use, with most new construction taking place on greenfield sites, including on land that was previously given over to agriculture.

A new indicator, developed by the Global Alliance for Buildings and Construction, is the Buildings Climate Tracker (GlobalABC 2020). The Tracker monitors

Figure 1
Change in global drivers of trends in buildings energy and emissions (2010-2019)



Source: IEA, Energy Technology Perspectives, 2020.

1 Global GDP in 2018 was USD 84.9 trillion. www.statista.com/statistics/268750/global-gross-domestic-product-gdp

progress on decarbonisation in the building and construction sector across the world, using seven global indicators. In 2020, the first published results from the Tracker revealed that progress towards decarbonisation is slowing down, rather than accelerating as required to achieve the full decarbonisation of the building and construction sector globally by 2050. A five-fold increase in decarbonisation activity is required to get back on track.

Everyone contributes in some way to the emission of GHGs caused by the use of buildings through our daily demands for heating and cooling, hot water, lighting, cooking, use of the internet and miscellaneous other power loads, although per capita emissions vary greatly from country to country. This dispersed nature of emissions from the building and construction sector presents a challenge, in that policies and mitigation actions need to engage with very large numbers of people, businesses, governments and organisations in order to be effective.

Another challenge, from the perspective of GHG baseline development, monitoring and reporting, is that the building and construction sector includes both direct emissions, from the burning of fossil fuels to supply heat and or energy within buildings, and indirect emissions, such as embedded emissions in building materials and the supply chain of materials and fuels. The latter arise from the GHG emissions resulting from the energy supplied into buildings from the electricity grid and from district heating and cooling plants. In fact, over half (55%) of global electricity production is consumed in buildings (GlobalABC 2020), illustrating the importance of the sector in driving demand for power stations. Collectively, the level of these indirect emissions is approximately double that of the direct emissions arising from fossil fuel use in buildings. As described in this volume of the compendium series, mitigation actions need to target both direct and indirect emissions if the sector is to contribute meaningfully to international efforts to address climate change.

Because of the very long lifespans of buildings and retrofits, the risk of “emissions lock-in” is higher than in other sectors. Once a building has been constructed especially if it is without adequate building design and energy-saving concepts, the specific energy demand for cooling, heating or lighting of the building will very likely remain for many decades until the building undergoes a substantial refurbishment or is demolished to be replaced by a new structure. This phenomenon is particularly important in rapidly expanding developing countries with high rates of new building construction. Furthermore, driven by the global population growth and rising incomes, the global demand for cooling is predicted to triple between 2016 and 2050 (IEA 2018), not only in warm or tropical regions but also in more temperate zones, where summer peak temperatures are already resulting in increased numbers and use of air-conditioning plants. Clearly then, the building and construction sector has a key role to play in national and global efforts to substantially reduce the risks and effects of climate change.

1.2 An overview

The UNFCCC secretariat has already published two volumes as part of the Compendium Series on GHG Baselines and Monitoring. The published volumes are: The National Level Mitigation Actions[2]; and, The Passenger and Freight Transport[3]. The Compendium series on GHG Baselines and Monitoring will, with time, cover different and critical economic sectors to support developing countries to establish GHG baselines and emissions monitoring from respective national-level mitigation actions. This building and construction sector volume is the third publication in the series.

The aim of this volume is to provide an overview of the depth and extent of the **sources of GHG emissions** in the building and construction sector and, thereafter, to present methods and instruments for quantifying these GHG emissions. This is important as effective national **strategies and measures to reduce GHG emissions** can only be developed based on a holistic understanding of the extensive sources of emissions over the entire **building life cycle**, from the production of building materials, to the construction, operation and, finally, the demolition of a building at the end of its lifetime. Based on this approach, national mitigation impacts of the buildings and construction sector can be fed into national GHG inventories and be incorporated into the relevant UNFCCC reporting processes.

This volume is split into two parts. Part I comprises of chapters 2 and 3, and provides an overview of the building and construction sector, together with the GHG emissions associated with the different stages in a building's lifecycle. **Chapter 2** firstly discusses the international context for monitoring and reporting GHG emissions, before setting out the sources of emissions associated with the sector, their relative importance and the mitigation potential. **Chapter 3** provides methods of quantifying the GHG emissions at various stages of the building lifecycle. The procedures, data requirements and boundary conditions to be followed in the estimation of the GHG emissions of the sector are highlighted.

Part II comprises of chapters 4 and 5, and introduces strategies, policies and mitigation actions for the reduction of buildings sector related GHG emissions. **Chapter 4** provides guidance for practitioners on a range of mitigation actions designed to reduce sector GHG emissions. **Chapter 5** is geared primarily towards policy-makers. It provides guidance on policies, plans, programmes and strategies that can provide a framework that is conducive to the implementation of mitigation actions described in **chapter 4**, together with a discussion on financing mitigation actions.

An annex is also included. Annex 1 presents an overview of existing clean development mechanism (CDM) and other methodologies of relevance to the sector.

2 https://unfccc.int/files/national_reports/non-annex_i_natcom/cge/application/pdf/final-compendium-mitigation-actions.pdf
3 https://unfccc.int/sites/default/files/resource/Transport_0.pdf

PART I

CONTRIBUTION OF THE BUILDING AND CONSTRUCTION SECTOR TO GLOBAL GREENHOUSE GAS EMISSIONS

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2. ENERGY USE AND GREENHOUSE GAS EMISSIONS OF THE BULDING AND CONSTRUCTION SECTOR

This chapter aims to assist national governments, policy-makers and stakeholders to understand the sources and extent of GHG emissions generated by buildings, including in their construction operation and demolition, and puts them into context compared with emissions from other sectors of the global economy. To begin with, the international context for monitoring and reporting GHG emissions is introduced.

2.1 United Nations Framework Convention on Climate Change

In 1992, in response to the growing recognition of the global threat posed by climate change, countries around the world collaborated in the establishment of an international treaty – the United Nations Framework Convention on Climate Change (UNFCCC). By 1997, agreement was reached on the first legally binding targets for developed countries to reduce emissions under the Kyoto Protocol. The 2015 Paris Agreement marks the latest step in the evolution of the Convention. It seeks to accelerate and intensify the actions and investment needed for a sustainable low-carbon future. The central goal of the Paris Agreement is to strengthen the global response to the threat of climate change by holding the increase in global average temperature this century to well below 2 degrees Celsius (°C) above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 °C (see box 1 below). The calculation of GHG emissions by country and by sector, and the implementation of strategies to significantly reduce emissions play an important part in meeting this objective.

The Paris Agreement also provides for enhanced clarity of action and support through a more robust enhanced transparency framework. Thus, countries are obliged to calculate their GHG emissions from all sectors and sources and regularly report the evolution of emissions over time to the UNFCCC.

Box 1
Article 2 of the Paris Agreement

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

   (a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

   (b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and

   (c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

2. This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

In 2018, the Intergovernmental Panel on Climate Change (IPCC) published a special report (IPCC 2018) on the impacts of global warming of 1.5 °C above pre-industrial levels. Among its conclusions, the report found that pathways limiting global warming to 1.5°C would require rapid and far-reaching transitions in energy, land, urban infrastructure (including transport and buildings) and industrial systems. Doing so would have a greater benefit in terms of sustainable development, eradication of poverty and reducing inequalities than if global warming were limited to 2°C, and there would be a reduced need for global adaptation.

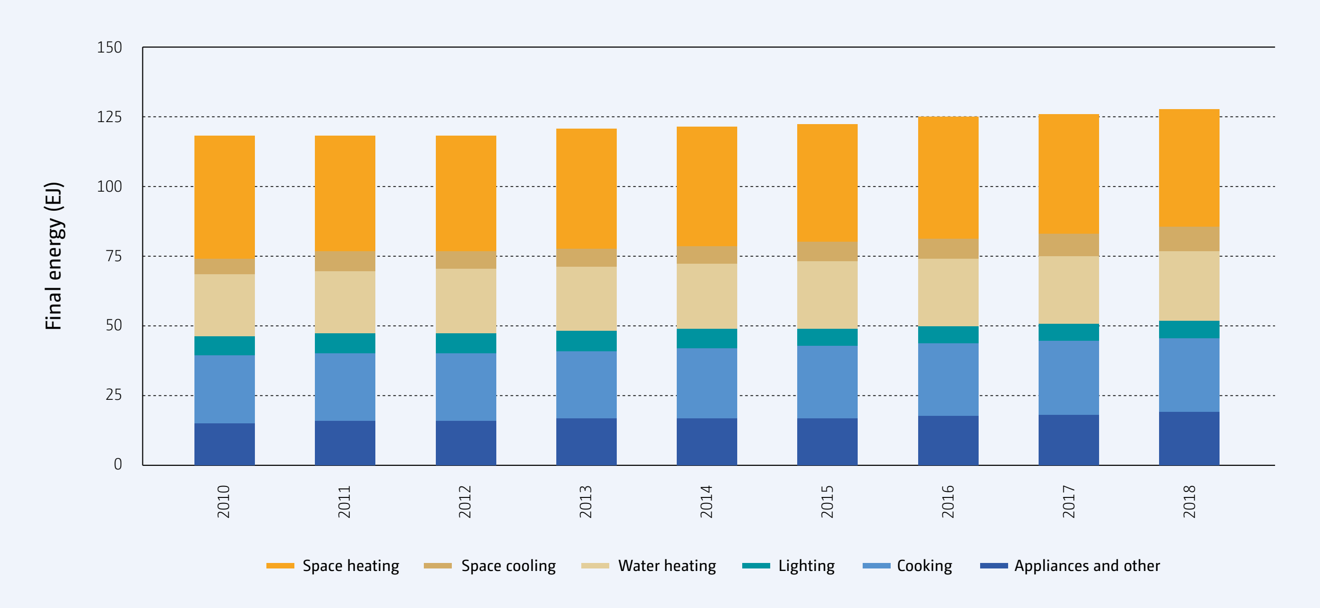
2.2 Energy use in buildings and the associated greenhouse gas emissions

Energy has a wide variety of end uses in buildings. Space heating currently represents the largest share, followed by water heating and cooking, as illustrated in figure 2. While these three end-uses currently dominate demand for energy, most of the growth in demand over the last decade has been in space cooling and appliances (e.g. refrigerators, washing machines and televisions). This growth is set to continue, particularly for space cooling. According to the International Energy Agency (IEA), energy needs for space cooling are predicted to triple between 2016 and 2050 (IEA 2018). It predicts that nearly 70% of the increase will come from residential buildings, mostly in developing countries located in hot or tropical climates.

Figure 3 shows the different sources of the energy supplied to buildings. A significant proportion comes from the direct use of fossil fuels – coal, oil and natural gas. Traditional biomass (e.g. wood) is a significant source of energy, particularly in rural communities in emerging economies. In global terms, biomass is roughly as important a source of energy as natural gas, used mainly in developed countries. Direct use of renewable energy currently accounts for only a small proportion of the total. However, the largest share of energy supplied to buildings is electricity – generated for the most part in power stations burning fossil fuels.

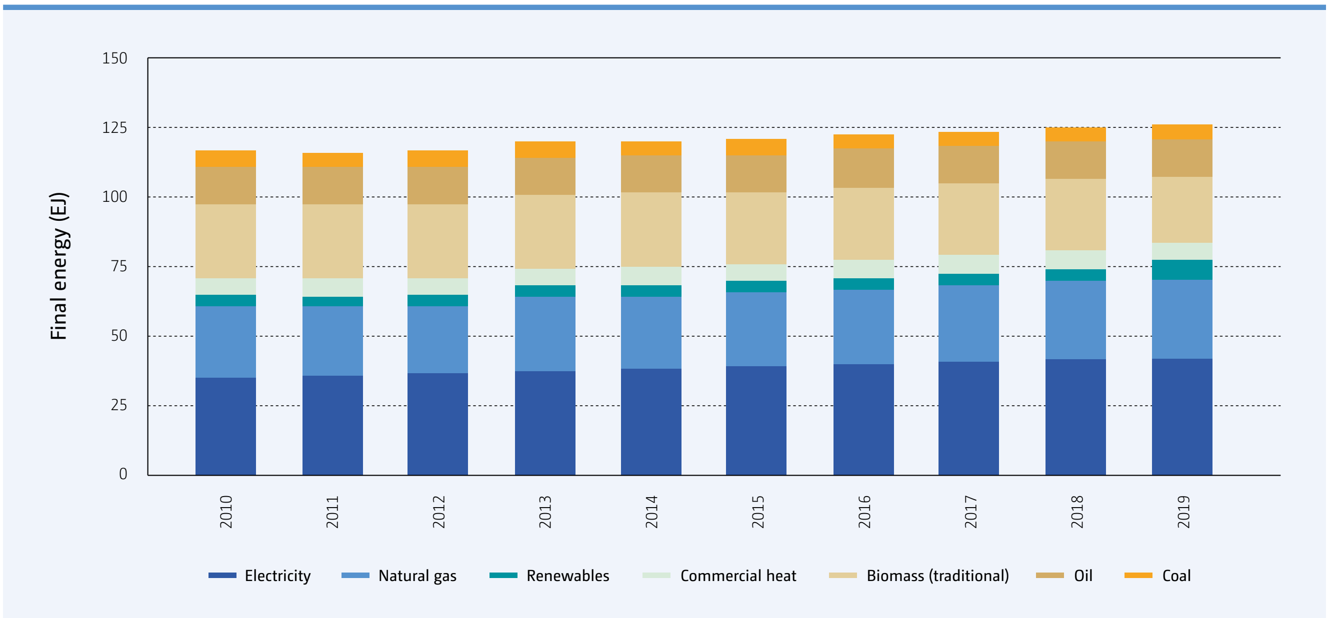
In addition to energy use within buildings, significant energy consumption, and consequent GHG emissions, occurs in the construction of new buildings. When considering the total impact of the sector, the

Figure 2
Building sector energy consumption by end use (2010–2018)



Source: Global ABC 2019.

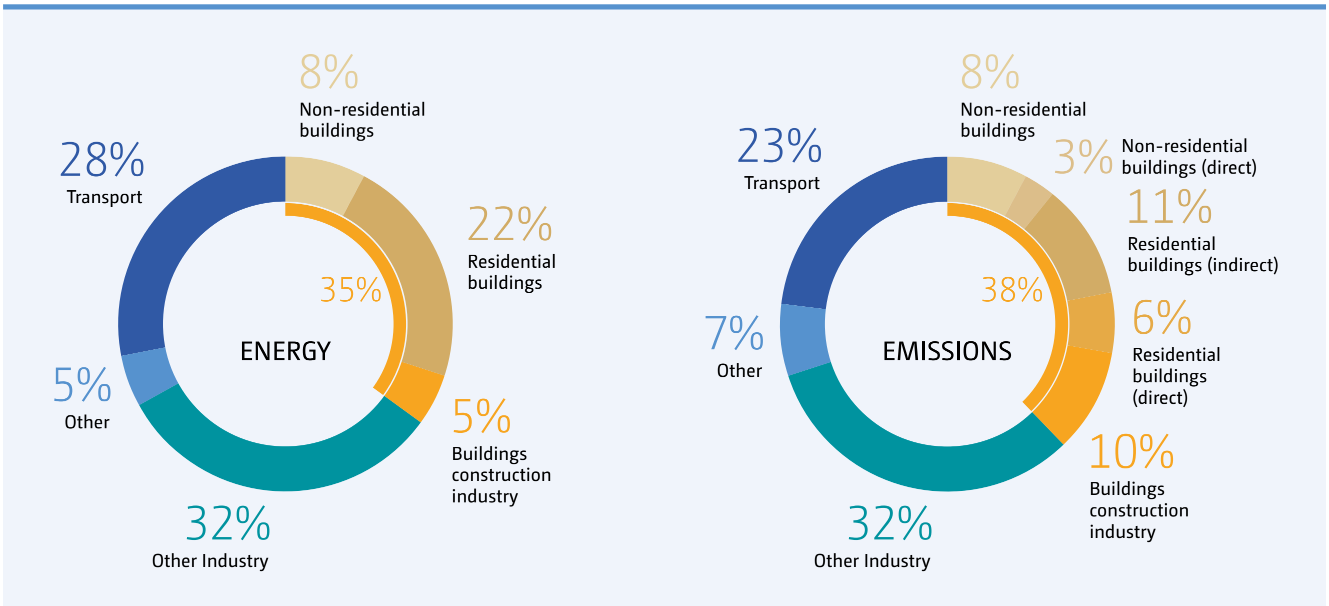
Figure 3
Final energy supplied to buildings by fuel type (2010–2019)



Source: Global ABC 2020.

construction and operation of buildings worldwide accounted for 35% of global final energy use and 38% of energy-related CO_2 emissions (Global ABC 2019). This makes the building sector, including the construction of new buildings, the largest consumer of energy and greatest contributor to emissions (figure 4).

Figure 4
Global share of buildings and construction final energy and emissions, 2019



Source: Global ABC 2020.

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

Within this global picture, there are significant regional differences. At one end of the spectrum, annual energy consumption per person in the residential sector was 10.2 MWh in North America in 2010, while for Latin America and South Asia, it was less than 2 MWh (IPCC 2014). For sub-Saharan Africa, the figure was 3.8 MWh. However, with rapid population growth, greater urbanization and increasing living standards, energy demand and consumption is increasing towards much higher levels in many developing countries.

Across Africa, buildings are responsible for a much higher share, 61%, of all energy consumption. However, since three quarters of this energy comes from biomass, net carbon emissions are only 32% of the continent's total (GlobalABC, 2020, Africa Roadmap). A major downside of burning biomass for cooking is the indoor air pollution which leads to premature deaths, while collecting wood is a time-consuming activity mainly undertaken by women, with consequent depletion of forests and degradation of ecosystems.

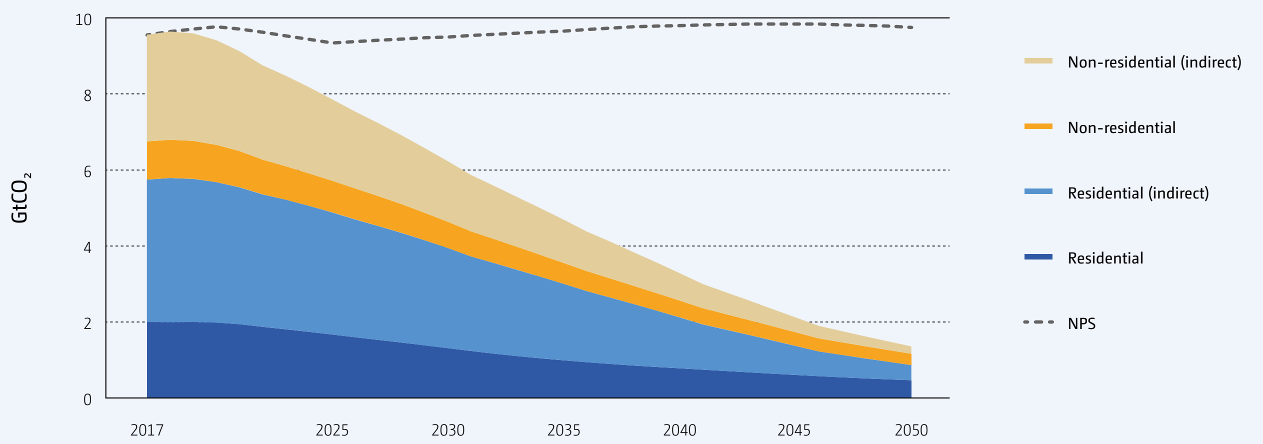
2.3 Greenhouse gas mitigation potential

The vast majority of today's building stock has a significant potential to mitigate GHG emissions. Furthermore, most buildings which are being constructed today still fall short of what is technically and economically viable to reduce GHG emissions and energy consumption. Subsequent retrofitting to improve building energy performance is often technically difficult, economically unattractive and disruptive to occupants, so these higher-than-optimal emissions are locked in, possibly for the life of the building or until a major renovation occurs.

The IEA, in its 2019 report *Perspectives for the Clean Energy Transition: The Critical Role of Buildings*, modelled a number of scenarios to consider the trajectory of building and construction sector emissions. Under the New Policies Scenario (NPS), which essentially reflects current policies, including those set out in countries' nationally determined contributions (NDCs), emissions hardly change over the period to 2050.

By comparison, under a more ambitious policy framework described in the IEA's Faster Transition Scenario, the global building sector could reduce emissions by up to 87% (fig. 5). This could be achieved by major improvements in energy efficiency, particularly of walls, roofs, windows and other building fabric elements, and a shift to high-

Figure 5
Building sector mitigation potential up to 2050



Source: IEA, 2019. Figure 2.10, p.43.

Note: Indirect CO_2 emissions result from upstream generation of electricity and heat used in buildings. NPS (dotted line) = New Policies Scenario. Shaded areas correspond to the Faster Transition Scenario.

performance, low-carbon technical systems such as heat pumps, coupled with much greater deployment of renewable energy technologies. In this way, direct emissions from fossil fuels could be cut by 75%. The remaining reduction to 87% would be achieved by decarbonizing indirect emissions, primarily electricity supplied to buildings.

Figure 5 also illustrates two other important aspects. Firstly, most of the current emissions are in the residential sector (in blue). While the emissions arising in an individual dwelling in a developing country are modest, it is the sheer number of homes, of all shapes and sizes, that adds up to a large emission burden. The implication is that the implementation of policies needs to reach ordinary households, as well as the non-residential commercial and public buildings, if the mitigation potential is to be achieved.

Secondly, the graph shows that the majority of emissions, in both the residential and the non-residential sector, are indirect. This has significant implications for the reporting of emissions, as discussed in the next chapter.

The IEA report draws some important conclusions regarding the need for urgent action to curb building and construction sector CO_2 emissions while also highlighting the economic benefits of doing so:

- The current pace and scale of the global clean energy transition is not in line with climate targets. Energy-related CO_2 emissions rose again in 2018 by 1.7% for the second consecutive year, suggesting a change in the trend from 2013 to 2016, when emissions had been levelling off;
- Since 2000, the rate of electricity demand in buildings increased five times faster than improvements in the carbon intensity of the power sector;
- CO_2 emissions need to peak around 2020 and enter a steep decline thereafter;
- Technology can reduce CO_2 emissions from buildings while improving comfort and services;
- A surge in clean energy investment will ultimately bring savings across the global economy and halve the proportion of household income spent on energy;
- Government effort is critical to make sustainable buildings a reality. Immediate action is needed to expand and strengthen mandatory energy policies everywhere, and governments can work together to transfer knowledge and share best practices;
- Delaying assertive policy action has major economic implications. Waiting another 10 years to act on high-performance buildings construction and renovations would result in more than 2 Gt additional CO_2 emissions to 2050, increasing global spending on heating and cooling by USD 2.5 trillion.

Chapter summary

This chapter highlighted the contribution of building and construction sector to global GHG emissions, sources and drivers and the role the sector may play in contributing to the achievement of the Paris Agreement goals. The following are the main points highlighted:

- The international community has recognized the need to drastically reduce GHG emissions in order to avoid damaging climate change;
- Globally, buildings represent the largest source of GHG emissions;
- Building sector emissions arise directly, from onsite fossil fuel use, and indirectly, from electricity, heating and cooling supplied to buildings;
- There are significant regional variations in building stock energy consumption and construction rates.

3. QUANTIFICATION OF GREENHOUSE GAS EMISSIONS

This chapter, presents, firstly, the key emissions associated with the building and construction sector and how their relation to the sectoral categories of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). The chapter explains in which life cycle phase of a building the associated GHG emissions occur and how these emissions can be determined or estimated.

3.1 Harmonizing the reporting of greenhouse gas emissions through the use of IPCC guidelines

Source accounting

As part of international efforts to address the challenge of climate change, the IPCC, a body within the United Nations, has developed guidelines for national greenhouse gas Inventories. The above-mentioned 2006 IPCC Guidelines provides internationally agreed methodologies for national governments to estimate and report GHG emissions and removals. Readers should refer to this guidance as the official source of information on how to prepare GHG inventories and report on GHG emissions. According to the IPCC, the GHG inventory classifies emissions across five sectors:

1. Energy;
2. Industry;
3. Agriculture, Forestry and Other Land Use (AFOLU);
4. Waste;
5. Other/Cross-sectoral.

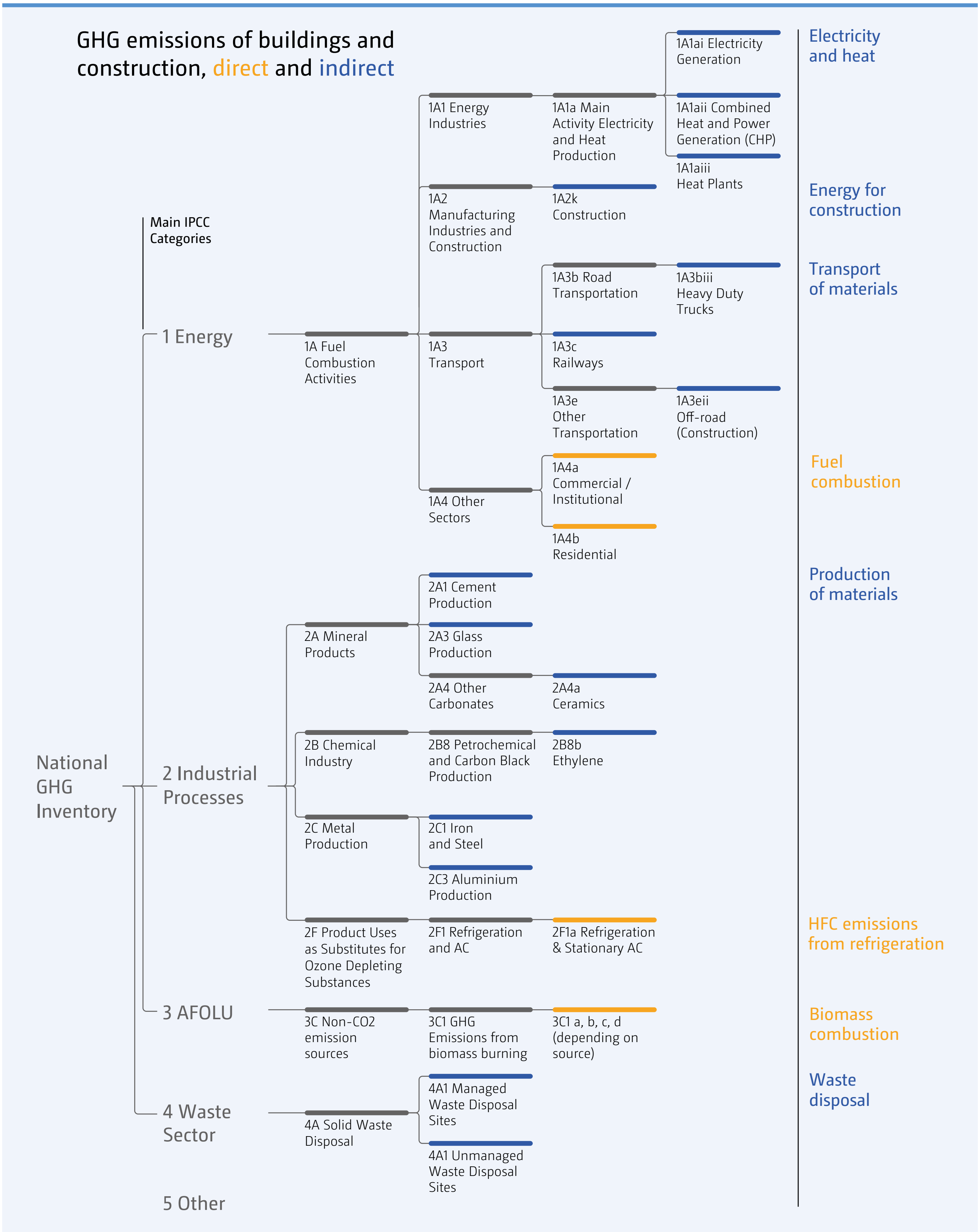
The IPCC guidelines are based on the principle of **source accounting**, namely that emissions are allocated to the activity from which they arise. In the case of buildings, this means the direct combustion of fossil fuels such as coal, oil and gas for heating, hot water, cooking and other uses. These emissions are categorized under “Fuel Combustion Activities”, “Other Sectors,” of the main energy sector (in **bold**):

1 Energy
- 1A Fuel Combustion Activities
  - 1A1 Energy Industries
  - 1A2 Manufacturing Industries and Construction
  - 1A3 Transport
  - 1A4 Other Sectors
    - **1A4a Commercial/Institutional Buildings**
    - **1A4b Residential Buildings**
    - 1A4c Agriculture/Forestry/Fishing

However, direct emissions are less than half of the total emissions associated with the building sector. The much larger proportion are the indirect emissions, which arise primarily from the electricity and thermal energy (heating and cooling) supplied from a remote source, categorized under “1A1 Energy Industries”, and also from the construction of buildings under “1A2 Manufacturing Industries and Construction”. Other indirect emissions arise in the transportation of building materials and waste disposal. The orange (direct emissions) and blue (indirect emissions) bars in figure 6 illustrate the diversity of sectors and subsectors under which different parts of the emissions associated with the building and construction sector are accounted for in the IPCC GHG emissions inventory.

In addition to direct and indirect emissions from buildings and construction, the construction of new buildings leads to emissions from land use change in certain circumstances. For example, experts estimate that global urbanization in tropical climates could be responsible for around 5% of annual GHG emissions caused by biomass losses and land use changes. While in temperate climates urban areas rarely expand into forest areas, it is estimated that in tropical climates there are high carbon

Figure 6
Building and construction sector in the national greenhouse gas inventories



Source: GIZ/*PEEB*, based on IPCC guidelines.

losses associated with deforestation for new urban expansion and the associated biomass losses[4].

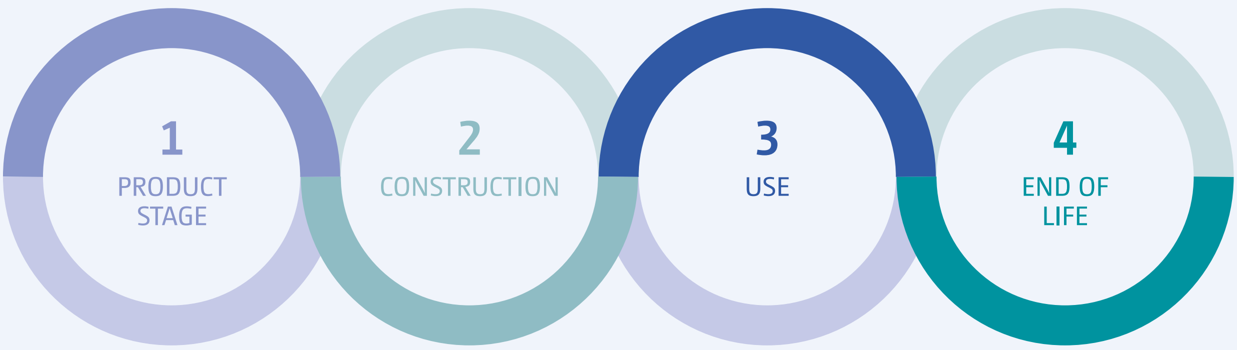
Recognizing the connection between building construction and land use change will help develop effective mitigation strategies, policies and actions such as urban planning, but these emissions are not further considered in this compendium due to the complexity involving estimates on carbon pools in urban areas such as vegetation, landfills and soils.

It is assumed that these emissions are quantified by relevant authorities in the context of the settlement category of the AFOLU sector. According to the IPCC methodology, these emissions would be classified as part of the AFOLU sector under “3B5b Land converted to settlements” and there mainly under “3B5bi Forest land converted to settlements”.

3.2 Understanding the full range of building and construction sector emissions

The main goal of this compendium is to provide an overview and methods for quantifying full range of GHG emissions[5] in the buildings and construction sector over the entire life cycle of buildings. To be able to quantify the diverse direct and indirect sources of GHG emissions that **really occur** from the operation and construction of buildings, another perspective than the methodology of the IPCC guidelines is required. A closer look at the different phases of the **lifecycle of buildings** is required. There are four main stages in a building’s lifecycle, each of which generates GHG emissions:

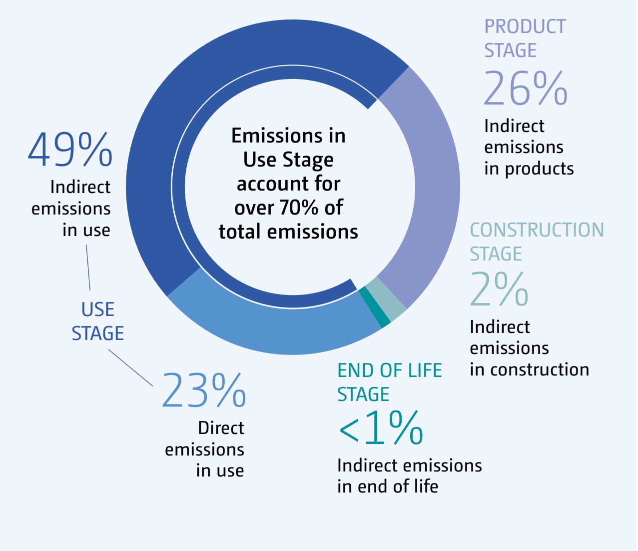
- **Stage 1: Product**
  Production and fabrication of materials and building system components required for the construction of a new building or refurbishment of an existing building;
- **Stage 2: Construction**
  The process of the construction of a building, including the transportation of raw and construction materials to site, assembly into finished structures and removal of surplus waste material;
- **Stage 3: Use**
  Use of the building by its occupants, including periodic maintenance of building elements and heating, ventilation and air conditioning (HVAC) and other systems, repair and renovation;
- **Stage 4: End of life**
  End of life, including demolition, disposal and/or reuse of reclaimed materials.



4 https://www.pnas.org/content/109/40/16083
5 www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf

Naturally, the full lifecycle of an individual building will take place over a period of many decades, or even centuries. However, when considering the building and construction sector at the national level, there will be buildings at different stages of this lifecycle. Concerning GHG emissions, it is the annual total of the emissions arising from each of buildings stages in a given time period (e.g. year) that needs to be considered and quantified. The share of emissions from each stage will vary over time and from country to country, although overall, it is the "use" stage that, globally, accounts for the majority (over 70%), as shown in figure 7. Many developing countries exhibit a high rate of new construction, and relatively low rate of in-use energy consumption, so the shares will be quite different, with a larger proportion of total emissions arising in the product and construction phases.

Figure 7
Estimated global breakdown of building and construction sector emissions by lifecycle stage



Source: Adapted from (Global ABC, 2019), with authors' estimates for construction and end of life emissions.

Cause accounting

In order to determine the full range of GHG emissions generated by the building and construction sector, the principle of **cause accounting** needs to be applied (see box 2 below). Accordingly, the three main emission categories are:

i. **Direct** emissions in stage 3 (use) stemming from combustion processes that occur in existing buildings (both residential and non-residential), for example for heating and hot water;

ii. **Indirect** emissions in stage 3 (use) stemming from energy supplied to existing buildings (e.g. electricity and thermal energy from the grid);

iii. **Indirect** emissions in stage 1 (product) arising from the production of materials that go into stage 2 (construction) of new buildings and their eventual demolition in stage 4 (end of life).

The importance of indirect emissions during the use stage is evident given that buildings consume over half (55%) of global electricity generation (GlobalABC 2020).

Box 2
Source accounting vs. Cause accounting

Source accounting should be used when reporting emissions to the UNFCCC as part of the GHG emissions inventory. These are the **direct** emissions associated with fossil fuels used in buildings.

Cause accounting should be used when developing mitigation strategies, policies and action plans. These should encompass both **direct** emissions from fossil fuels used in buildings and **indirect** emissions from secondary fuels such as electricity and heating or cooling supplied to buildings, as well as emissions arising during the construction and demolition of buildings, including the emissions embodied in building materials. Cause accounting looks at the sector holistically, thereby reflecting the full spectrum of emissions associated with the sector.

Direct emissions

Direct emissions stem from fuel combustion activities in the use stage of buildings (e.g. for space and water heating, cooking, etc.). These are included in section 1A4 of the GHG emissions inventory as “Commercial/ Institutional” and “Residential” for fossil fuels and, to a lesser extent, in section 3C1 as biogas burning (fig. 8). For developed countries, these accounted for around 11% of total national GHG emissions (without land use, land-use change and forestry) in 2016, according to the UNFCCC GHG data interface.[6] However, direct emissions represent only part of the total emissions that can be attributed to buildings. Building-related indirect emissions are generally much higher (see fig. 7).

Indirect emissions

Indirect emissions arise during all four stages of a building’s lifecycle:

1. The **product stage**, through emissions occurring in the production of building materials. This is accounted for in the category “Industrial Processes and Product Use”, notably in:
   - 2A1 – Cement Production;
   - 2A3 – Glass Production;
   - 2B – Chemical Industry;
   - 2C – Metal Industry.

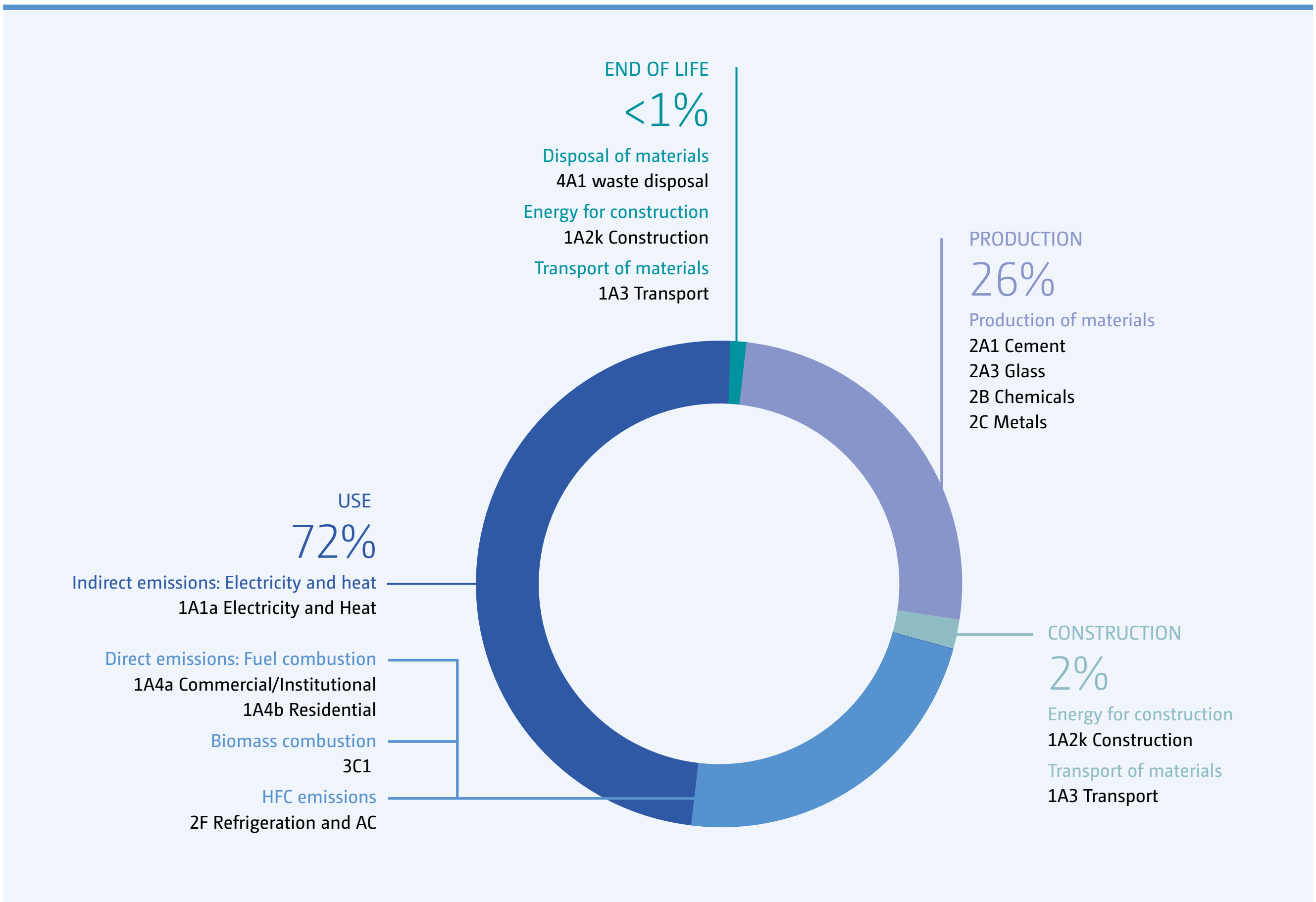
2. The **construction stage**, through emissions that are related to transportation of building products and on the construction site. There may also be emissions associated with changes in landuse, when construction occurs on greenfield sites. This is accounted for in the category “Energy”, particularly in:
   - 1A2k – Construction;
   - 1A3 – Transport.

3. The **use stage**, through consumption of electricity/ heat/cooling that was produced in power stations or in cogeneration or trigeneration plants outside of the buildings :
   - 1A1a – Power and Heat Generation.

There are also emissions associated with the ongoing maintenance, repair and renovation of buildings

6 https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/ghg-data-unfccc/ghg-data-from-unfccc

Figure 8
Emissions from the building and construction sector based on national greenhouse gas inventories



Notes:

1. Key categories in bold
2. All emissions are indirect, with the exception of 1A4a Commercial/Institutional and 1A4b Residential;
3. Emissions from maintenance, repair and renovation during the life of the building should be considered within the product and construction stages.

throughout their life. These activities essentially involve replacing building components that have a shorter life than the building itself, such as roofs, windows, heating systems and finishes. As such, they can be considered alongside the product and construction stages, together with which they comprise the lifecycle embodied emissions of the building stock. In relation to appliances (e.g. air conditioners, refrigerators, chillers), direct emissions of greenhouse gas refrigerants (e.g. Hydrochlorofluorocarbons, and hydrofluorocarbons) are controlled by the Montreal Protocol and its Kigali amendment throughout manufacturing, use and decommissioning phase. While some refrigerants are controlled exclusively by the Montreal Protocol and not to the UNFCCC processes, the hydrofluorocarbons emissions need to be reported as a part of the national inventory.

4. The end of life stage, through emissions related to the demolition and disposal of buildings:
   - 1A2k – Construction (as on-site deconstruction);
   - 1A3 – Transport;
   - 4A – Solid Waste Disposal.

In figure 8, the IPCC sectoral categories of relevance for the sector are summarized according to the four stages of the building and construction sector lifecycle.

3.3 Assessing greenhouse gas emissions across the building lifecycle

In order to quantify the emissions from the building and construction sector for the purposes of establishing a baseline and for subsequent periodic reporting, it is necessary to consider the dynamics of the sector. In a given year, there will be a large stock of existing buildings consuming energy directly, as well as indirectly through electricity and heat supply networks. In addition, there are emissions arising from the production of the materials that go into making new buildings and renovating existing ones, and in construction and demolition activities.

The different sources of GHG emissions during the four stages of building lifecycle are illustrated using an example of public housing in Lagos, Nigeria. In a lifecycle analysis of the public housing sector in Lagos, Nigeria, (Ezema IC, Opoko A P and Oluwatayo A, 2016). In-use emissions were responsible for three quarters of total lifecycle emissions. Embodied energy in the construction phase contributed 14%, while a further 10% came from ongoing maintenance (e.g. painting) and repair/replacement of building elements such as roofs, windows and fixtures and fittings (plumbing, electricals, ceiling/wall finishes, etc.). Transportation of materials and on-site emissions together accounted for only 0.6% of the total. The demolition phase was not assessed in this study.

Table 1 below, shows the breakdown of emissions for a reference building over a 50-year lifespan covering its construction, use and ongoing maintenance. This is not to be confused with the annual snapshot emissions required for IPCC GHG reporting. However, the percentages provide a useful indication of the relative importance of the different stages of activity. In this example, direct emissions comprise the majority of total emissions, unlike the global average, which has indirect emissions as the dominant share. The reason for this is the very low consumption of electricity per capita, at only 100 kWh per person per annum. It serves to illustrate the wide diversity of emission profiles that exist within different building typologies and different countries.

Emissions from the sector depend on the status of the buildings in a given year (e.g. baseline year). Some buildings will be in the process of being constructed,

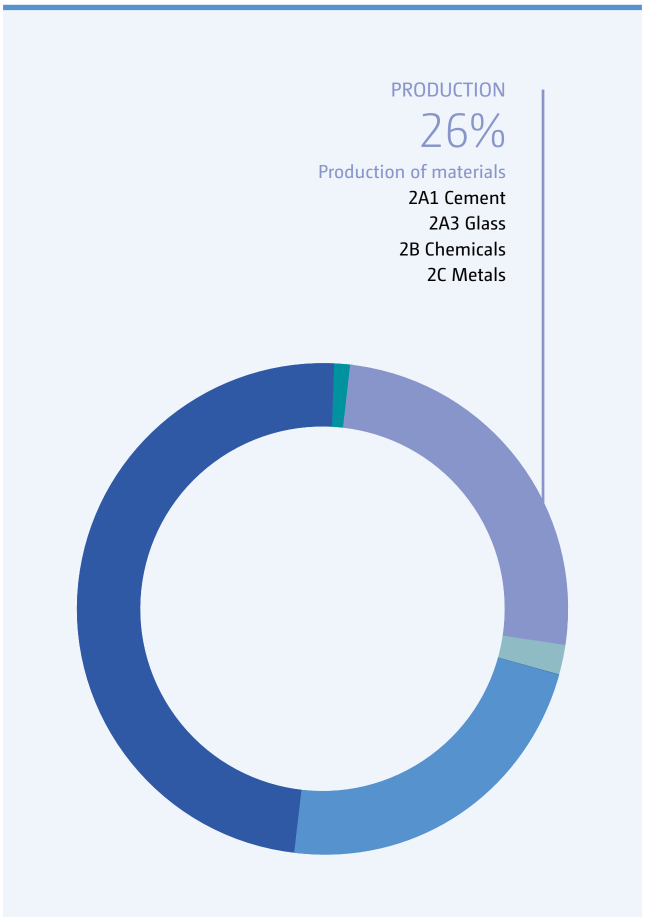
Table 1
Assessing baselines emissions – case of Nigeria

Stage	Activity	TYPE	kg CO_2	% of total	% of total
Product	Production of materials	INDIRECT embodied emissions	238 589	13.8	EMBODIED EMISSIONS **24.6**
Construction	Transportation to construction site	INDIRECT embodied emissions	7 527	0.4	
	On-site construction energy use	INDIRECT embodied emissions	3 105	0.2	
Use	Use – ongoing maintenance, repairs and periodic renovation	INDIRECT embodied emissions	174 862	10.1	
	Use – grid electricity	INDIRECT in-use emissions	158 400	9.2	IN-USE EMISSIONS **75.4**
	Use – fuel combustion	DIRECT in-use emissions	1 141 800	66.2	
	Total		**1 724 283**	**100.0**	

while others are demolished. The full range of emissions in a given year will be a mixture of the four stages. The relative importance of each stage will vary from country to country according to factors such as the level of construction activity and end use energy requirements. Emissions associated with each of the four stages are considered in the following sections.

Product stage

Extracting and processing the raw materials and producing the final products that go into the construction of buildings is frequently an energy- and carbon-intensive process. The most significant component in modern architecture is cement and cement products. Other significant materials include metals such as steel and aluminium. There is also a growing use of wood, which, assuming it is sourced from sustainable forests, is a renewable material and generally considered to have low or zero carbon emissions associated with it.

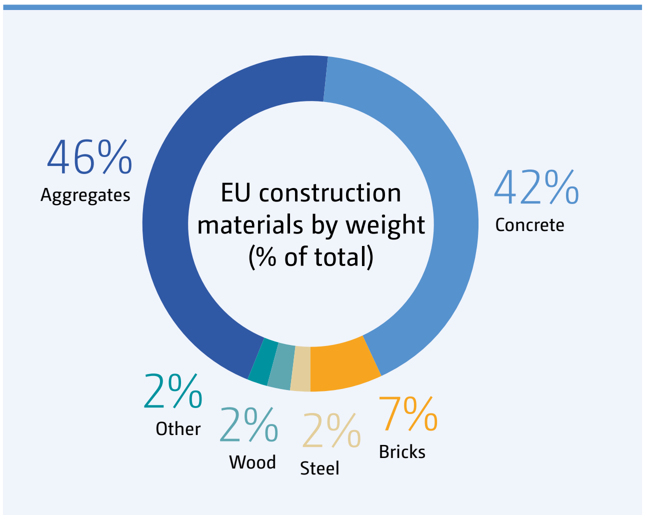


Quantities for each of the main building types can be determined from quantity surveyors/structural engineers or from national statistics offices in a given country. Such data might give, for example, the quantity in tonnes of the different materials – glass, cement, steel, etc. Ideally, this would be available as the national total.

Having established the quantity of materials going into building construction each year, these amounts need to be multiplied by the emission factor for the respective materials, which can be sourced from the IPCC Emission Factor Database.[7]

An analysis for the European Union (EU)[8]. found that the main materials used in building construction were aggregates (sand, gravel, crushed stone, etc.) and concrete, which together make up nearly 90% by weight of buildings. Other materials include bricks, wood, glass and metals (steel, aluminium and copper) (see fig. 9).

Figure 9
Material usage in building construction case of the European Union



7 https://www.ipcc-nggip.iges.or.jp/EFDB/main.php.
8 Ecorys 2014 pages 21 and 47.

While steel and aluminium together only account for less than 5% of the total by weight, they are responsible for over half (51%) of the total embodied energy in building materials. By contrast, aggregates, which make up the largest amount by weight, account for only 1% of embodied energy (fig. 10).

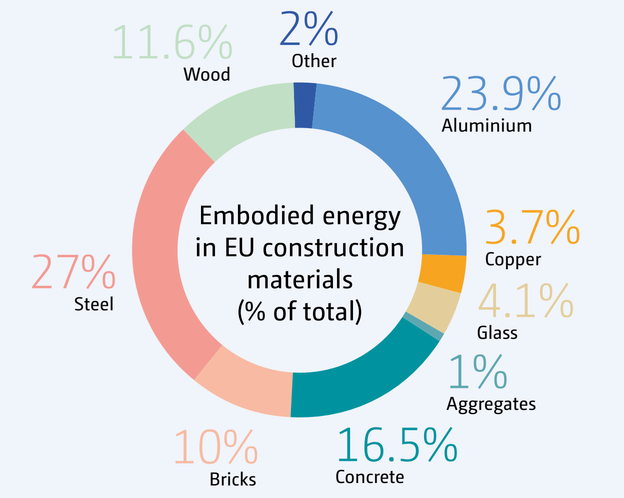
Embodied emissions in the materials used in construction and renovation can be estimated in two ways:

- **Top-down approach**
  The starting point is to determine the most significant materials in building construction (e.g. by weight, volume, value) and to determine what share of national or global production is accounted for by the sector. For example, cement and cement products are used in buildings as well as other infrastructure projects such as bridges. For many of these materials, buildings represent the largest end use. Within the EU, for example, buildings account for over 50% of the total consumption of bricks, clay, concrete, glass and aggregates. If the proportion of these materials going to the sector can be determined (e.g. from national statistics bodies[9]), this provides the share of that sector's emissions to allocate to the building and construction sector.

- **Bottom-up approach**
  Firstly, new construction needs to be split into the main typologies (e.g. single-family houses, multi-family houses, offices, retail/warehouses, other). This information would normally be available from national statistics bodies, or from trade associations representing the construction sector. The material requirements for each building type should be identified (e.g. from architects or quantity surveyors) and then grossed up according to the floor area of that building type. Emission factors for the various material inputs are then applied to the total volumes of each product.

  In the Lagos case study, emissions from the products that go into erecting a typical representative house amount to 239 t CO_2 (see table). If the annual construction of new houses is, say, 100,000, the total emissions from the production of new housing in a given year is 23.9 Mt CO_2. Similar calculations need to be done for the non-residential stock to determine the total building product emissions.

Figure 10
Embodied energy of building components case of European Union



Product carbon footprints may also be available in national databases, or from Green Building Councils.[10] If there are no established carbon footprint figures, these can be developed according to one of two recognized standards:

i. **ISO 14067:2018**, Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification developed by ISO technical committee ISO/TC 207, Environmental management, Subcommittee SC 7, Greenhouse gas management and related activities[11]. ISO 14067 provides internationally agreed principles, requirements and guidelines to quantify and report

9 For the EU, Eurostat provides a central database for all member States; available at https://ec.europa.eu/eurostat.
10 https://www.worldgbc.org
11 https://www.iso.org/obp/ui/#iso:std:71206:en

Table 2
Estimating GHG emissions from residential building – case of Nigeria

Building Component	Embodied CO_2 (tonnes)	% of total
Substructure	42.2	18%
Frame	66.5	28%
Walls	32.5	14%
Roof	8.4	4%
Doors & Windows	8.3	3%
Fixtures & Fittings	7.2	3%
Finishes	49.5	21%
Plumbing	5.5	2%
Electrics	11.3	5%
Painting	7.1	3%
TOTAL per housing unit	**239**	**100%**
Annual construction of new dwellings (indicative figure)	100,000	
Total Annual Emissions from Building Products	**23.9 M tonnes CO_2**	

the carbon footprint of a product, in a manner consistent with International Standards on life cycle assessment (LCA) (ISO 14040 and ISO 14044). It will give organizations of all kinds a means to calculate the carbon footprint of their products and provide a better understanding of ways in which they can reduce it.

ii. **The GHG Protocol Product Standard**[12], developed by the Greenhouse Gas Protocol initiative, a collaboration of the World Resources Institute and the World Business Council for Sustainable Development, through a multi-stakeholder process with participation from businesses, government agencies, non-governmental organizations and academic institutions around the world;

iii. **Publicly Available Specification 2050 (PAS 2050)**[13], *Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services*, developed by the British Standards Institution in 2008. PAS 2050 was the first consensus-based and internationally applicable standard on product carbon footprint and has been used as the basis for the development of other standards internationally. The 2011 revision to PAS 2050 was developed through extensive consultation with international stakeholders, and in particular through significant engagement with the wide PAS 2050 user community.

For further information on embodied energy, readers may wish to refer to the IEA Annex 57 programme, which is dedicated to the topic of embodied energy and CO_2 in buildings.[14]

12 https://ghgprotocol.org/standards.
13 www.bsigroup.com/PAS2050
14 www.annex57.org

Construction stage

During the construction stage, the materials from the product stage are transported to the building site and assembled to produce the building(s). The main energy uses are therefore transportation and on-site processing.

Estimating emissions from transportation can be challenging, given the wide diversity of materials going into the construction of a building from multiple suppliers and production sites – including from abroad. For this reason, it would be very difficult to use a top-down approach based on national data for quantifying emissions.

A bottom-up approach could more readily be used to estimate emissions. This could be done as follows:

Step 1 – Quantify in tonnes the material inputs required for building construction;

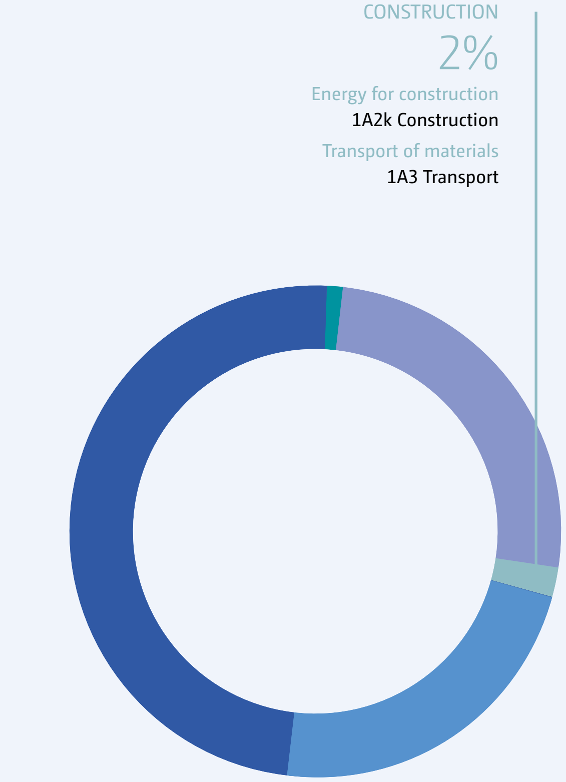
Step 2 – Determine average distance travelled from production site to construction site for each material;

Step 3 – Apply industry-based transport fuel requirements to transport a tonne of each material one kilometre, noting that lighter materials (e.g. insulation) require more loads per tonne than heavier ones (e.g. steel, aggregates) to generate a table of "litres of fuel per tonne-km" by material type and transportation mode (by road, rail or water);

Step 4 – Multiply the "litres of fuel per tonne-km" by the tonnage and distance transported to derive a total quantity of fuel requirement;

Step 5 – Apply the appropriate emission factor to the total consumption of each fuel type to derive the total GHG emissions from the transportation of materials.

Some construction companies will have assessed their own transport emissions as part of their environmental management systems or green building certification (e.g. Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), etc.), or included them in their corporate social responsibility reporting. In the absence of other data sources, these can be used to provide a figure for GHG emissions per unit of new construction floor area. National research or statistical bodies should also have information on various aspects of the construction process, including transportation of materials to site.



The other main source of emissions is on the construction site itself. Various machines and equipment, from cranes and dumper trucks to lighting and power tools, require energy in the form of electricity or diesel (for generators and vehicle fuel), as well as the energy needs for onsite offices and accommodation. There is also embodied energy in processing and supplying water to site, which is widely used in preparing concrete mixes, cleaning, etc. Construction companies should be able to quantify the on-site energy needs of each fuel type. This information can then be used to generate a normalized energy need for a given volume of

Table 3
Estimating GHG emissions construction stage – case of Nigeria

Energy/fuel type	Quantity	Emission factor	CO_2 emissions	% of total
Transportation of materials to site (diesel)	2 788 litres	2.7 kg CO_2/litre	7 528 kg	71
On-site diesel	300 litres	2.7 kg CO_2/litre	810 kg	8
On-site petrol	900 litres	2.3 kg CO_2/litre	2 070 kg	19
On-site lubricants	24 litres	2.9 kg CO_2/litre	70 kg	1
On-site grid electricity	450 kWh	0.4 kg CO_2/kWh	180 kg	2
TOTAL			10 657 kg	100
Annual construction of new dwellings (estimate): 200 000				
Total annual emissions from building products			**2.1 Mt**	

construction. Total GHG emissions associated with the construction site itself are then simply derived by multiplying the normalized energy need by the total volume of construction and applying the relevant emission factors.

In the Lagos case study, the transportation of 1,396 tonnes of building materials to site required 2,788 litres of diesel. This is multiplied by the emission factor for diesel (2.7 kg CO_2/litre), giving a figure of 7,528 kg CO_2 arising from diesel use. Similar calculations are then undertaken for the other fuels used on-site, as summarized in the table below. The construction of new dwellings led to estimated emissions of 2.1 Mt CO_2/year (100,000 X 10,657 kg CO_2). The emissions associated with non-residential construction sites need to be added to get the full picture for the entire building stock.

Interaction between the product and construction stages

While the processes involved and the associated emissions in the product and construction stages are quite different, the two are often grouped together for the purposes of determining the embodied energy of the building stock. In practice, the embodied energy is dominated by the products and materials going into the buildings, with only a relatively small proportion associated with transportation and assembly.

Clearly, some of the materials necessary in a construction project might have been produced in an earlier period and stockpiled for future use. However, it would be impractical to track back to the date of physical production when considering emissions for a baseline year. Instead, it is suggested that, for the purposes of quantifying GHG emissions for the sector, the products and materials used in construction are assumed to have been produced in the same year as the construction activity. When looking at the baselines, it is also important to consider only the embodied energy of **new buildings that were built in a given year**, not the embodied energy of the existing building stock.

Finally, it should be noted that there is a small but growing market for off-site construction, with consequently much less on-site processing. In extreme cases, virtually the only activity on-site could be the final assembly of prefabricated rooms, roofs or other structural elements. In such cases, it is important to quantify the emissions associated with the off-site construction of building products/elements.

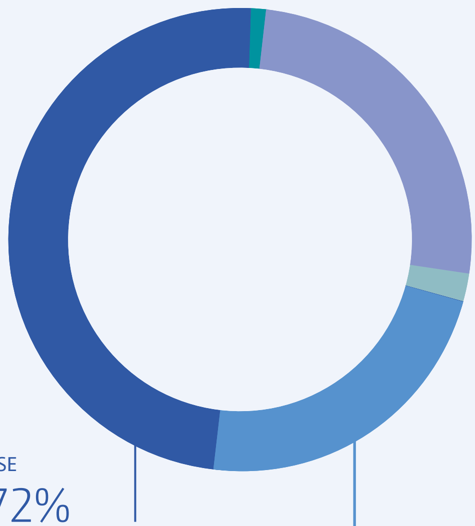
Use stage

(a) Energy usage

The largest portion of emissions from the sector arises during the use stage of existing buildings.

The two main sources of emissions relate to the combustion of fossil fuels for heating, cooking and others (direct emissions) and use of energy such as electricity or district heating from an external location (indirect emissions).

Emissions during the use stage can be estimated using either a top-down or a bottom-up approach.



Top-down approach
The top-down methodology relies on access to national-level statistics on energy consumption in the sector. These may be available from national statistics bureaux, or from building research institutes. In Europe, the EU Building Stock Observatory provides a wealth of data on the size, age, energy use and other information pertaining to the buildings in member States.[15]

Bottom-up approach
The bottom-up approach relies on good disaggregated data on the building stock by the main typologies, namely housing, offices, warehouses, etc. Data on the building stock will normally be held in national cadastres, tax offices or other records held at the local or regional level.

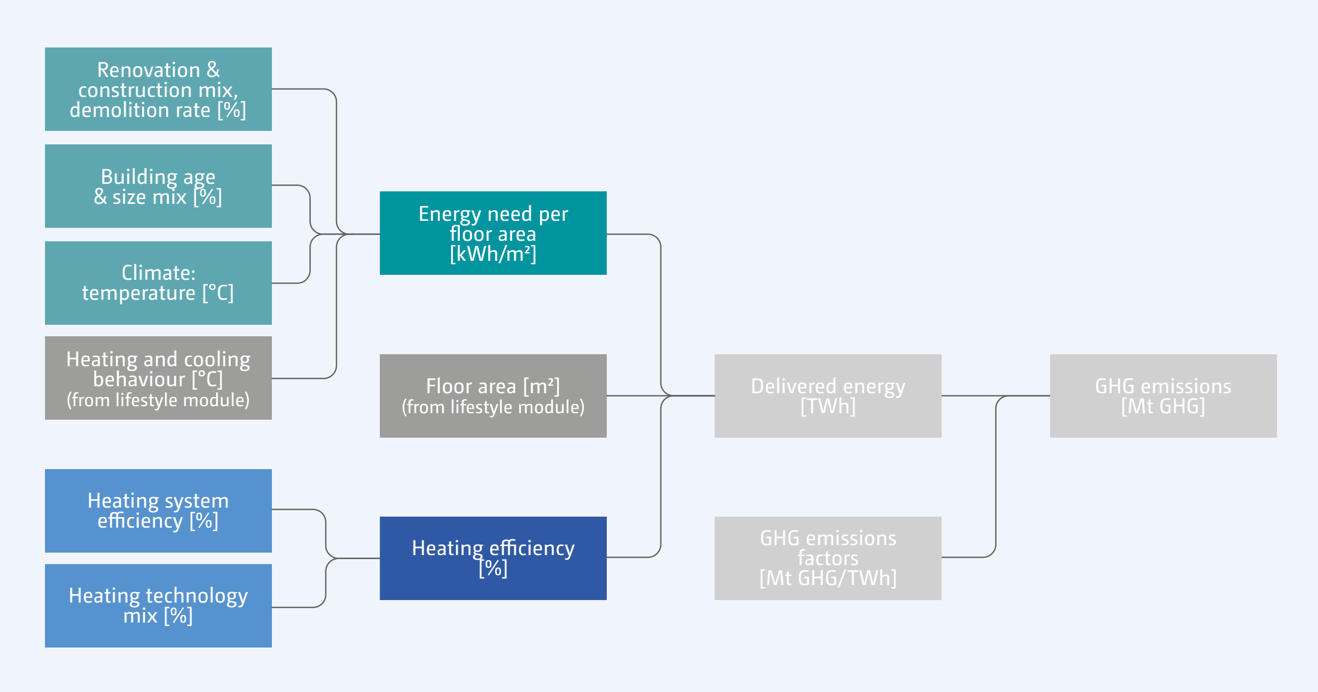
As a minimum, a breakdown by residential and non-residential building needs to be determined, since the energy needs, and associated emissions vary considerably owing to the differing usage patterns. A more detailed breakdown is preferable, where availability of data permits.

Clearly, the usage of individual buildings, even of the same typology, can be very different depending on occupants, so it is important that a representative average building is selected, based on a statistical sample of the building stock. Having determined a representative building (which could be at the regional or national level), its annual energy needs, in kWh/m^2 of floor area, need to be determined by fuel type. The GHG emissions of the representative building can be determined by multiplying the energy use of each fuel type by its emission factor, in kg CO_2 per kWh, and adding up the individual fuels used. This will give a normalized emission per unit of floor area, expressed in kg CO_2/m^2. This figure can then be grossed up according to the total floor area of the building type. The same process is repeated for each building type in order to determine the total for the entire building stock.

Hybrid approach
Depending on the availability of data from different sources, it may be possible to use a combination of top-down and bottom-up approaches. Figure 11 illustrates how the delivered energy requirement for heating

15 https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eubuildings

Figure 11
Estimating energy requirements for heating



Source: BPIE (2019), derived from EU Calculator[16].

is derived from a combination of top-down statistics such as population and floor areas, with bottom-up parameters such as energy need per person or per unit floor area. Similar calculations could be used for the other main end uses of energy (e.g. for cooling, lighting, etc.) in buildings.

The benefit of this approach is that mitigation actions can be more readily determined, since the underlying drivers of energy usage can be identified. For example, building and construction sector energy consumption in a country might be rising owing to a combination of population growth and increasing floor area per person. A valid mitigation action to improve heating technology efficiency might improve the delivered efficiency by, say, 2% per annum but if the combination of population growth and floor area per person is higher than this rate, emissions will continue to rise. In other situations, household income growth leads to higher emissions and energy consumption due to increased appliance ownership (e.g. refrigerator, air-conditioner and washing machine) and/or previously suppressed demand for heating and cooling. Similarly, the impact of improved technology efficiency will be partially offset when users increase energy consumption rather than keeping the same level of consumption at a lower cost, so-called rebound effect. By breaking down the component drivers of demand, the savings from technology improvement can be quantified and reported, even against a backdrop of rising emissions in the sector.

Whichever approach is used, the end result should be the quantification of the total annual consumption of each energy carrier used in the building stock. This should include:

- **Electricity** – for lighting, appliances, air conditioning, information and communication technology (ICT) and numerous other loads (note: we recommend distinguishing between fixed

16 www.european-calculator.eu/wp-content/uploads/2019/09/EUCalc_Building_documentation.pdf p.15.

electrical loads such as air conditioning and movable appliances such as computers and refrigeration);

- **District heating/cooling** – energy for space heating/cooling and water heating provided by a plant not on the building site;
- **Direct use of on-site fossil fuels** (oil, coal, gas) and biomass (wood, crop residues, etc.) for space and water heating, cooking, etc;
- **On-site renewables** – solar heating, photovoltaic (PV) systems, heat pumps, etc. As these are renewable fuels with zero emissions, they do not contribute to the GHG load of the sector, but it is important to quantify these for two reasons. Firstly, in the hybrid approach described above, the end calculation is a figure for delivered energy, but a proportion of this energy will be provided by on-site renewables, so this amount needs to be netted off the total. Secondly, a mitigation action that promotes uptake of on-site renewables will reduce building and construction sector emissions by displacing fossil fuels, so knowledge of the baseline position provides a metric against which to measure progress.

For electricity and district heating/cooling, the upstream energy requirements to produce the delivered energy need to be calculated based on input fuels and plant efficiencies, also taking into account losses in transmission and distribution.

Having determined both direct and indirect energy use, the final step is to apply the relevant emission factors to each fuel/energy type and then sum the total.

(b) Maintenance, repair and renovation

In addition to the carbon emissions associated with meeting the energy requirements of a building and its occupants during the building use, emissions arise from ongoing maintenance, repair and periodic renovations. Qualitatively, these emissions are similar to those in the product and construction stages, in that they relate to the manufacture, transportation and installation of products ranging from building fabric elements such as windows to technical systems such as air conditioning.

These emissions can be significant. In the case of the analysis undertaken for Lagos, they amount to 10% of the lifecycle emissions, almost as much as the embodied energy of the originally constructed building. In this case study, the authors assessed how many times particular elements (e.g. windows) are replaced over the life of the building, and then used the emissions derived during the production and construction stages for those products in order to build up the total emissions associated with the maintenance, repair and renovation of the building throughout its life.

In the Lagos case study, the annual emissions resulting from operational energy use for the representative house were calculated to be 26 t CO_2 by summing the different fuels used in buildings, together with the electricity consumption of the housing stock. This figure needs to be multiplied by the total housing stock of Nigeria of 28 million in 2006[17] to derive the annual in-use emissions of 728 Mt CO_2 (see table 4 below). Similar calculations need to be undertaken for the non-residential sector.

Table 4
Estimating GHG emissions Use Stage – case of Nigeria

Type of in-use energy	Emissions per dwelling (t CO_2/year)	Total emissions for the housing stock (Mt CO_2/year	% of total
Grid electricity (indirect)	3.2	89.6	12
Fuel combustion (direct)	22.8	638.4	88
Total	26	728.0	100

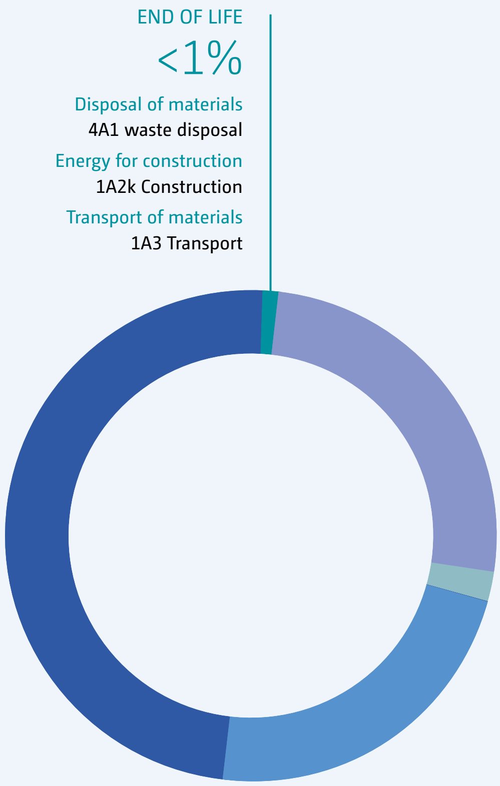
17 http://nigeria.opendataforafrica.org/ivpwkze/nigeria-distribution-of-regular-households-2006

End of life stage

While buildings are counted among the longest-lived of physical assets, there will come a stage at which they will need to be demolished, including in order to make way for new buildings. The process involves the use of construction machinery and equipment, processing and transportation of demolished products and their final disposal or reprocessing into other useful materials.

Compared with the other stages of a building's lifecycle, the end of life is relatively insignificant in terms of its GHG emissions. This is because:

- Only a small proportion of the existing building stock is demolished in a given year. For developed economies such as the EU, only 0.1% of the existing floor area of buildings is demolished annually,[18] although this rate is likely to be significantly higher in rapidly developing economies;
- Much of the demolished material is inert and is often reused in other construction (buildings or roads).



Using the Lagos case study, the total annual emissions from the residential sector is summarized in Table 5. Please note that this example uses indicative figures for the new construction rate and does not include end of life emissions or emissions from the non-residential sector. It is noteworthy that in this example, direct emissions account for the majority of the total. This is because of the very low usage of electricity.

Table 5
Estimating GHG emissions for all buildings stages – case of Nigeria

Stage	Type of emissions	Annual emissions (t CO_2)	% of total
Product	Indirect	23.9	3.2
Construction	Indirect	2.1	0.3
Use	Indirect	89.6	11.9
Use	Direct	638.4	84.7
Total		**754**	**100**

18 EU BIO Intelligence Service (2011).

The ability of countries to accurately report their emissions internationally, and to fully quantify total sectoral emissions, depends critically on access to good quality data. The Lagos case study shows that these spans a variety of topics, sourced from different places. Some may be from national statistics, while others may be from research institutes or commercial organizations.

In many cases, data may be collected at the local or regional level, although there are inadequate procedures to aggregate this at the national level.

The case study below describes South Africa's ongoing efforts to improve data management for the purposes of reporting to the UNFCCC.

Box 3

Data quality and collection – case of South Africa[19]

Up until 2015, South Africa had no formal data collection procedures in place, a lack of well-defined institutional arrangements and an absence of legal and formal procedures for the compilation of national GHG inventories. The responsibility for collecting input data for the inventories fell on the individual sector compilers. Data were sourced from many institutes, associations, companies and ministerial branches. This led to challenges in accessing data and data gaps for estimating emissions for the energy, industrial processes and product use, waste and AFOLU sectors.

To tackle data-related issues, the Department of Environmental Affairs developed the National Greenhouse Gas Inventory System in 2016. It also introduced additional legal instruments such as memorandums of understanding formalizing institutional and procedural arrangements, a dispute resolution mechanism and protection of confidential information. Data collection templates and plans were used to prepare the draft 2000–2017 GHG inventory and for periodic reporting to the UNFCCC.

19 https://unfccc.int/process-and-meetings/bodies/constituted-bodies/consultative-group-of-experts-cge/cge-toolbox-on-institutional-arrangements#eq-17.

3.4 Priority areas and system boundary for the quantification of national emissions from the building and construction sector

Having identified the various GHG emissions throughout the building lifecycle and how they relate to national GHG inventories, as a next step, the system boundary for estimating the national emissions for the sector is defined. Given the relative importance of the different stages, three levels of prioritization are proposed to quantify the national building and construction sector emissions.

PRIORITY 1 – as noted above, the emissions related to the use stage of the existing building stock represent the majority (perhaps as high as 70–90%) of the total lifecycle emissions in a given year. It is therefore recommended that, as a minimum, estimated sector emissions comprise:

1) Direct emissions due to **fuel combustion in buildings (1A4a and 1A4b)**;

2) Indirect emissions due to **power/heat generation outside of buildings (1A1a)**.

Direct emissions will be relatively easy to determine, as they are counted within their own GHG inventory sub-category (1A4). For indirect emissions, it is necessary to apportion an appropriate share of the indirect emissions associated with electricity and heat generation. This share can be derived by calculating the sector's consumption of these indirect fuels and applying the appropriate emission factors, as described above.

In countries with significant use of biogas/biomass for cooking, emissions in sub-category 3C1 should be included within priority 1.

PRIORITY 2 – as a second level of priority, the emissions that relate to the embodied energy of all main construction materials generated during the product stage should be calculated, including those arising during maintenance, repair and renovation of buildings in use. While these currently constitute a small fraction of the total, their relative importance could grow significantly over time as the trend towards lower energy consumption in buildings accelerates, driven by climate mitigation policies and increasingly stringent policies towards very low or zero energy buildings.

Renovation, repair and ongoing maintenance of buildings also have a significant emissions impact. Such emissions should be considered alongside those of the product stage rather than the use stage, since they relate to the embodied energy of the building rather than its energy consumption in use. By including these in-use emissions, a more complete picture of the true embodied energy of the building stock can be determined.

Accordingly, the following emissions should be quantified where possible:

Indirect emissions due to the production of main construction materials, including those used in renovations, repairs and ongoing maintenance – mainly **cement (2A1), glass (2A3), chemicals (2B) and metal (2C)**.

PRIORITY 3 – as a third level of priority, and for the sake of completeness, the following emissions caused during the construction and end of life stages could also be taken into account:

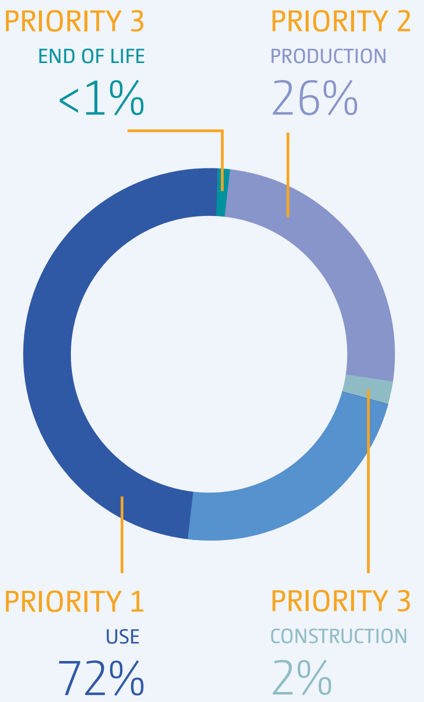
1) Indirect emissions due to **construction activities (1A2k)**;

2) Indirect emissions due to **transport of production materials (1A3)**;

3) Indirect emissions due to the end of life activities of buildings – **on-site deconstruction (1A2k), solid waste disposal (4A) and transport (1A3)**.

The recommended system boundary for the quantification of sector GHG emissions should include: in-use energy consumption (priority 1); and embodied energy of the building stock (priority 2). Together, these two areas typically cover over 90% of the full sector emissions. For completeness, the emissions in priority 3 (construction, transportation and end of life) can also be included, if adequate data can be accessed.

Figure 12
Components of the building and construction sector emissions inventory



Priority 1	Use	Emissions resulting from **fuel combustion in buildings** (direct emissions) and **power and heat generation outside of buildings** (indirect emissions) during the use of the existing building stock, representing the majority (as high as 70–90%) of the total lifecycle emissions.
Priority 2	Production	Emissions related to the **embodied energy of all main construction materials** generated during the production. These emissions currently constitute a small fraction of the total, but their relative importance could grow significantly over time as the trend towards lower energy consumption in buildings accelerates.
Priority 3	Construction End of life	Emissions resulting from the **construction, transportation and waste disposal** can also be included, if adequate data can be accessed.

Figure 12 summarizes the various emissions associated with the building and construction sector, according to the three priority areas.

3.5 Interaction between embodied energy and in-use energy

As the energy efficiency of buildings in use improves, so the proportion of in-use emissions falls. Consequently, emissions associated with the construction of a building rise as a proportion of the total. Findings show that, for a building constructed to the 2016 national energy efficiency standard in Germany, 40% of its lifecycle energy consumption will occur prior to operation. This figure rises to 60–70% for nearly zero-energy buildings, which is a requirement for all new construction across the EU from 2021[20]. Furthermore, it is possible to construct “energy positive” buildings which generate more energy from on-site renewables than the building consumes.

However, most buildings that are currently in use were not built to today’s energy efficiency standards, so the proportion of emissions prior to occupation (i.e. the embodied energy of a building) is much lower, at around 20% or less. Also, when considering the entirety of existing buildings and new construction in a given year, the floor area of existing building stock far exceeds that of new building activity. In developed countries, new construction adds only around 1% of floor area annually, although this figure is typically much higher in rapidly developing countries. For example, China is currently experiencing a

20 https://transfermagazin.steinbeis.de/?p=5653&lang=en

significant increase of new buildings, representing over 2 billion m^2 every year. Between 1995 and 2005, China's building stock nearly tripled, and it is expected to nearly triple again by 2030.[21] In other words, most of the building stock that will exist by mid-century is yet to be built.

Chapter summary

This chapter discussed the IPCC Guidelines on Harmonised Reporting of GHG Emissions, which account for GHG emissions according to the source of emissions under the five main IPCC categories – Energy; Industry; Agriculture, Forestry & Other Land Use (AFOLU); Waste; and Other/Cross-sectoral.

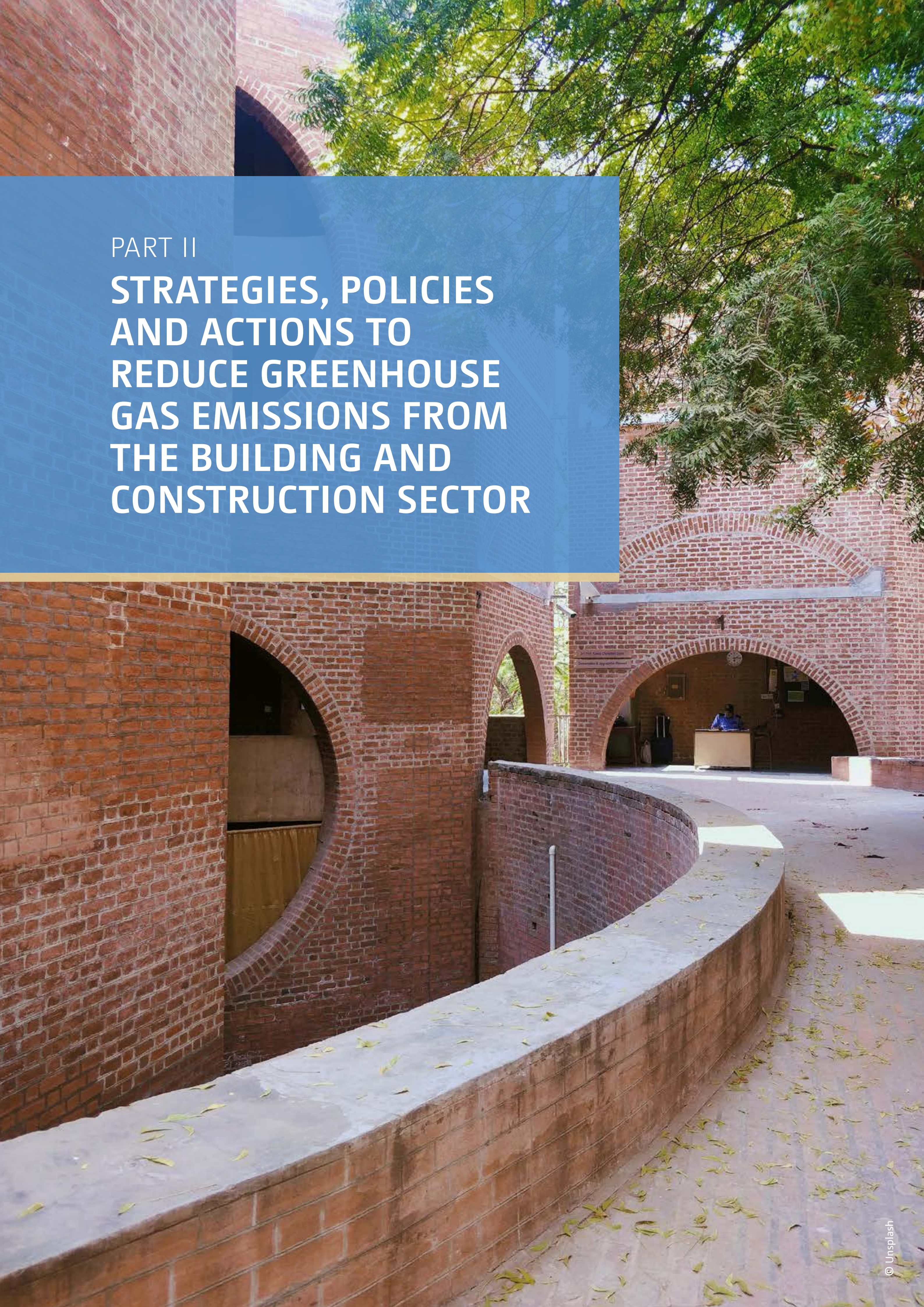
The following are the main highlights:

- Direct emissions from fossil fuel use in buildings are categorized within the energy sector. However, most building emissions are indirect;
- In order to quantify the full GHG impact of buildings, there is need to use the **cause** accounting methodology;
- GHG emissions arise in all four stages of the building lifecycle: (1) Production of materials; (2) Construction; (3) Use of the building; (4) End of life demolition;
- The share of emissions in each stage varies considerably, with the majority arising in stages 1 and 3, so these should be prioritized when considering mitigation actions and policies;
- The importance of different stages also depends on the rate of new construction, which is typically much higher in developing economies than in developed ones.

21 https://www.gbpn.org/activities/china

PART II

STRATEGIES, POLICIES AND ACTIONS TO REDUCE GREENHOUSE GAS EMISSIONS FROM THE BUILDING AND CONSTRUCTION SECTOR



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The aim of Part II is to provide information and guidance to reduce building and construction sector GHG emissions. In chapter 4, the range of mitigation actions that might be taken up are introduced. Examples of actions that countries have successfully used are presented, including several that form part of their national energy and climate plans (NECPs) and NDCs. NDCs are very relevant to the building and construction sector, with many countries identifying the sector as an important source of GHG emissions and an area for action in their NDCs. In 2019, existing policies and NDCs addressed just over 50% of global buildings-related CO_2 emissions, though most NDCs are still lacking specific targets and actions. Coverage would rise to over 60% if committed NDCs become policy (GlobalABC, 2019). Chapter 5 describes ways that provide a more conducive environment for mitigation with examples of policies, measures and other initiatives that are already effectively operating in many countries around the world.

4. MITIGATION ACTIONS – GUIDANCE FOR PRACTITIONERS

This chapter provides an overview of the most common categories of mitigation action that can be taken in the building and construction sector. We start by exploring mitigation strategies and then describe six key types of mitigation actions.

4.1 Mitigation strategies

To effectively contribute to achieving the Paris Agreement objectives, a country's mitigation strategies for the entire building and construction sector need to focus on the greatest possible energy-saving and GHG emission mitigation impact potential. In new construction, through the adoption of ambitious building codes and shifting towards net zero energy buildings, energy demand can be reduced by 50-90%. In existing buildings, energy-efficient retrofits can reduce the energy demand by 50–75%[22], although many examples now go beyond this level and can achieve net zero energy demand.

In addition to building design and technologies, the way in which occupants use energy can have a major impact. In many countries, behavioural and lifestyle changes such as reducing heating/cooling could reduce the energy demand by up to 20% in the short term and 50% by 2050[23], or moderate the growth of energy consumption.

The IPCC Fifth Assessment Report identified the following major strategies with high GHG mitigation potential for the sector[24]:

- **Carbon efficiency** (on-site): fuel switching to low-carbon fuels, use of biomass, renewables (e.g. solar thermal or PV);
- **Technology efficiency:** increasing the energy efficiency of technologies, appliances and devices, which also impacts on indirect emissions from power consumption;
- **System efficiency:** increasing the energy efficiency of the building through improved systemic solutions (e.g. district heating/cooling, high-efficiency energy distribution systems);
- **Energy service demand reduction:** behavioural changes of the users and occupants of buildings.

22 IPCC (2014) page 690.
23 IPCC (2014) page 695.
24 IPCC (2014) page 676.

Table 6
Key strategies for mitigation in the building and construction sector

Strategies	Mitigation options	GHG mitigation potentials
Carbon efficiency	Solar domestic hot water system	20%
	Solar electricity generation through roof-top PV installations	15–58%
	Biomass use for stoves	30–60%
	Reduction of embodied carbon of construction materials	5–40+%*
Technology efficiency	High-performance thermal envelope with efficient heating, ventilation and air conditioning	10–68%
	Efficient appliances	45–75%
	Efficient lighting	<50%
System efficiency	District heating/cooling	30–70%
	Building automation and control systems for space heating, water heating and cooling/ventilation or for lighting	25–37%
	Passive House standard	30–70%
	High-efficiency energy distribution systems, co-generation, trigeneration	30–70%
Energy service demand reduction	Behaviour and lifestyle changes of users Smart metering	20–40%

Source: Elaboration based on IPCC (2014), tables 9.1, 9.4 and 9.6, and GlobalABC (2018).

Note: *The vision of the World Green Building Council (2019) is that, by 2030, all new buildings, infrastructure and renovations will have at least 40% less embodied carbon and be net zero embodied carbon by 2050.

Table 6 illustrates the GHG mitigation potential of different strategies as identified by the IPCC, the Global Alliance for Building and Construction and other sources.

4.2 Baselines

To quantify mitigation impacts, GHG emissions from a proposed mitigation action has to be compared against a baseline. For mitigation actions targeting CDM projects, the CDM Methodology Handbook (UNFCCC 2019), outlines different methodologies which are useful in estimating standard baselines. The “*Methodological Tool 31: Determination of Standardized Baselines for Energy Efficiency Measures in Residential, Commercial and Institutional Buildings*”.[25] is one example of the baseline methodologies. The tool sets out how to benchmark the specific CO_2 emissions (i.e. the CO_2 emissions per unit of floor area – kg CO_2/m^2) of different building types based on using the top 20% of best-performing

25 https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-31-v1.pdf

buildings of that type that are located in the same geographical/climatic area. This can be achieved either by undertaking a survey of similar buildings, or by using data from official national data repositories, where available.

Three examples of approaches to developing standardized baselines are provided in the boxes 4, 5 and 6. The first example comes from Malawi and relates to domestic cookstoves, the second concerns the Mexican housing sector, and the third covers residential building in Republic of Korea.

Box 4

Developing standardized baseline for household cookstoves – case of Malawi

The Malawi Biomass Energy Strategy, developed by the Government of Malawi in 2009, specifies average per capita firewood (fuelwood) and charcoal consumption values in rural and urban areas[26]. The total consumption was divided by the population. A key source of data was a survey of the energy consumption habits of 851 rural households in 22 districts. The household survey included a questionnaire and an assessment of fuel consumption based on direct weighting. Then, per capita consumption values were estimated taking into account the major consumers. Total consumption was divided by share of population that use firewood or charcoal, based on the information on the penetration rate (i.e. the source of fuels used for cooking in urban and rural areas) from the Integrated Household Survey 2010–2011 carried out by the National Statistical Office of Malawi. The resulting standardized baseline values of per capita annual consumption to be used in the calculation of savings in CDM projects are:

Firewood:
rural users = 0.63 tonnes; urban users = 0.70 tonnes;

Charcoal:
rural users = 1.40 tonnes; urban users = 0.94 tonnes.

Box 5

Developing baseline for housing nationally appropriate mitigation action – case of Mexico

For the calculation of the baseline of the housing nationally appropriate mitigation action (NAMA) in Mexico[27], two methodologies have been applied: top-down and bottom-up.

The **top-down** methodology is based on energy consumption data for 2014 and 2015. GHG emissions based on final energy consumption by type of fuel for the residential sector are estimated, differentiating between CO_2, CH_4 and N_2O. The conversion factors for energy into GHG emissions are based on the standard IPCC GHG emission factors, while for electricity, the conversion factor published by the Environment Ministry is used. The 'business as usual' scenario also takes into account the projected growth in number of apartments.

For the **bottom-up** approach, the most common housing prototypes were analysed for each housing typology (individual, semi-detached and multi-family buildings) and for each major climate zone, taking into consideration the most common social housing construction methods. For each of these prototypes, energy demand simulations have been carried out for 34 cities using a special simulation tool developed for the Mexican housing sector. The results of the simulations provided the input data for further calculating the GHG mitigation potential.

26 https://cdm.unfccc.int/methodologies/standard_base/2015/sb107.html
27 https://energypedia.info/wiki/File:Housing_NAMA_Mexico-Annex_2.pdf.

Box 6

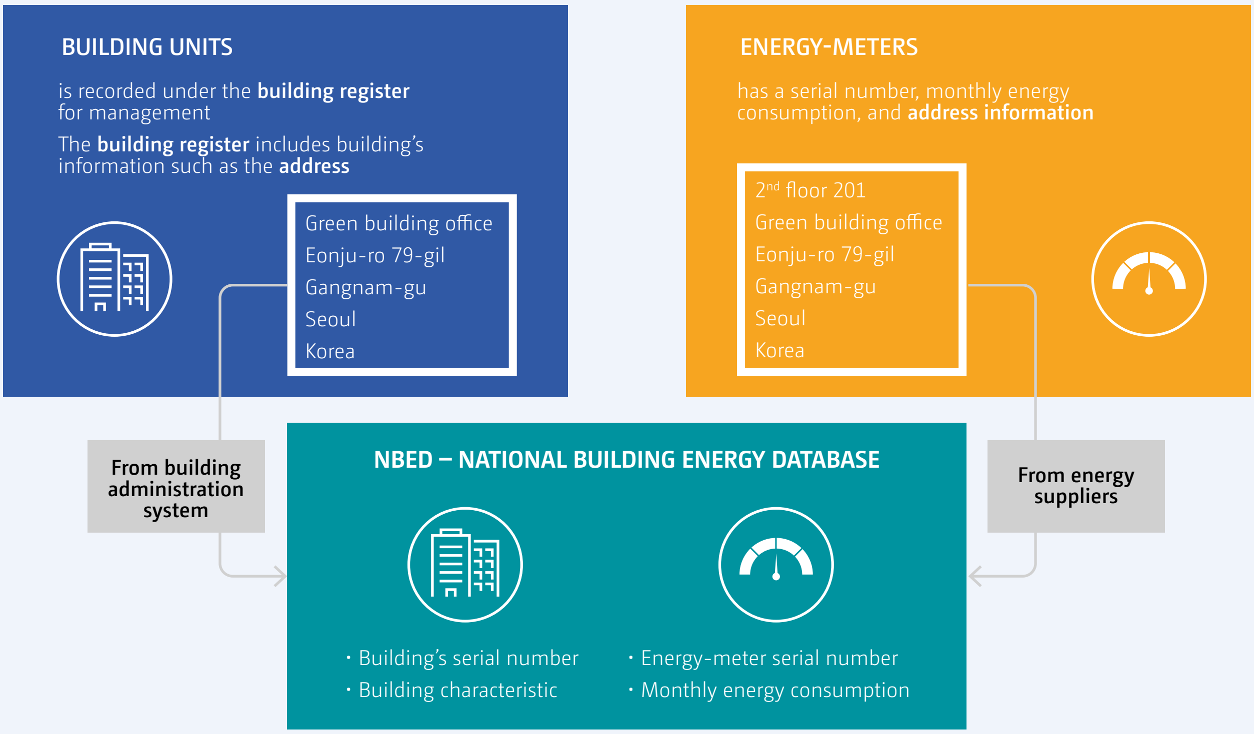
Developing baseline for residential buildings – case of Republic of Korea

Republic of Korea was the first to develop a standardized baseline for the residential buildings (emission intensity values in tCO_{2e}/m^2)[28] by applying the "TOOL31: Determination of Standardized Baselines for Energy Efficiency Measures in Residential, Commercial and Institutional Buildings" (TOOL31)[29].

Target buildings for the standardised baseline development were prioritised based on the emission reduction potential and data availability. Residential Apartments that receive electricity from grid and that are not connected to district heating units were selected (non-residential buildings and single-family housing units were excluded). A key source of data was National Building Energy Database (NBED) which contains information on different building characteristics (such as location, type of building, year of construction, gross floor area, height, number of stories) and energy consumed (electricity, gas and district heating). Building characteristics data from 7.2 million building units and monthly energy consumption data from 57 million meters aggregating to more than 4.4 billion data points were collected.

Figure 13

Integration principle of the NBED



Source: *"Development of Korean Standardized baselines in the building sector"*, presentation made by Korea Appraisal Board (KAB) and Ecoeye at the workshop *"CDM standards and tools for GHG Emissions in the building sector"*, held at the 81st meeting of the CDM Methodologies Panel on 17/02/2020.

28 https://cdm.unfccc.int/methodologies/standard_base/2015/sb151.html
29 https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-31-v1.pdf/history_view

Box 6 (continued)

Developing baseline for residential buildings – case of Republic of Korea

Initially 120 categories of data/parameters were identified for new and existing buildings considering the factors that affect energy consumption and emission reduction, data coverage under the NBED and the requirements of the TOOL 31. These variables included climatic zones (i.e. Southern, Central and Jeju), administrative provinces (e.g. Daegu City, Daejeon City, Gwangju City, Seoul and Ulsan City) and gross floor area based on the 'Building Act of the Republic of Korea'(i.e. A60[30], B85[31] and C85[32]). A data filtering process was applied to remove outliers, such as buildings with gross floor area below 5 m^2, building units with zero energy consumed in any month. Then, the data was statistically assessed to identify most useful criteria. As a result, the number of standardized baseline values decreased from 120 to 18 (9 for new buildings and 9 for existing buildings).

The specific CO_2 emissions of building units were calculated based on the procedures and equations provided by the TOOL31 (the electricity and gas consumption multiplied by respective emission factor divided by the gross floor area of the building unit). The results were separated for each building criteria (e.g. new A60 building units located in the Southern region) and sorted from the lowest specific CO_2 emissions to the highest specific CO_2 emissions. The average of the top 20% buildings by performance was set as the standardized baseline value for those building unit types. The selected levels are almost always above Building Energy Efficiency Certification (BEEC) level 1+ which means mitigation projects should aim for 60 ~ 90 kWh/m2 year or higher level. Such a robust level of baseline values is expected to trigger ambitious climate action encompassing construction projects but also supply chain of building materials to achieve transformative changes in the sector consistent with the national and international climate goals.

Figure 14

Criteria applied to determine the number of standardized baseline values

AGE	2	NEW (less than 5 years)	EXISTING (more than 5 years)	
CLIMATIC REGION	3	CENTRAL	SOUTHERN	JEJU
AREA OF HOUSEHOLD	3	Less than 60 m^2	60 m^2 to 85 m^2	More than 85 m^2

For a more comprehensive discussion on baselines, please refer to the Guidance for assessing the GHG Impacts of buildings, published by Initiative for Climate Action Transparency (ICAT 2018).

4.3 Mitigation actions

This chapter introduces specific mitigation actions for each of the priority areas identified in chapter 3 according to the four stages of the building lifecycle.

30 Gross floor area < 60 m^2

31 Gross floor area > 60 m^2 and < 85 m^2

32 Gross floor area > 85 m^2

PRIORITY 1 – mitigation actions in the use stage

1. Design and construct **new buildings to be net zero carbon** through a combination of bioclimatic and passive building design, high levels of thermal insulation, and utilization of highly energy-efficient products and available renewable energy resources. Ultimately, new buildings need to shift towards being carbon sinks by producing more energy from low-carbon renewable sources (e.g. PV electricity) than is required by the building itself.

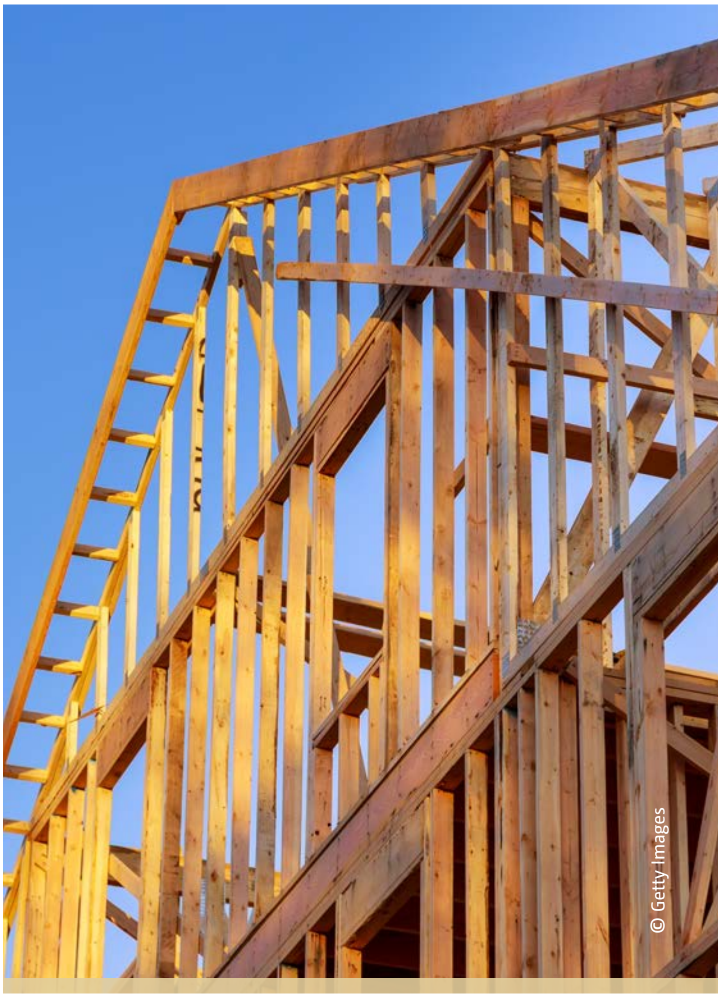
2. Improve the **thermal performance of existing buildings** through better insulation, solar shading, maximized natural light and improved airtightness, including through the setting of minimum energy performance standards. This will minimize the energy requirements of the building.

3. Improve the **technical systems of existing buildings** such as HVAC, lighting systems, appliances and controls (e.g. occupancy and daylight sensors, building automation systems), including through the setting of minimum energy performance standards and the use of no or low GWP refrigerant in appliances (e.g. refrigerator, air-conditioner, chiller). This will ensure that the energy needs of the building are met as efficiently as possible.

4. Switch to **lower-carbon fuels** and maximize the potential for renewable energy generation. This will minimize the carbon emissions associated with the energy requirements of existing and new buildings. In combination with priorities 1 and 2 above, the aim should be to approach or achieve net zero emissions from the existing building stock by 2050.

PRIORITY 2 – mitigation actions in the product stage

5. Plan and use **low-carbon, renewable, reused and recycled materials** in construction and renovation processes. This will minimize the embodied carbon locked up in the structure of the building.



PRIORITY 3 – mitigation actions in the construction and end-of-life stages

6. Ensure **efficient processes** in construction and demolition that are geared towards minimizing the carbon impact.

This chapter describes each of the six actions and provides case study examples, most of which are selected from actual projects submitted and approved under the CDM. Further details of these and other projects can be found on the UNFCCC website.[33] Each project is developed according to one of the approved methodologies. A summary of CDM-approved methodologies applicable to the building and construction sector is provided in annex 1.

33 https://cdm.unfccc.int/Projects/projsearch.html

PRIORITY 1 – mitigation actions in the use stage

Description of some of the mitigation actions in the use stage are highlighted and described in the Tables 7 to 10 below.

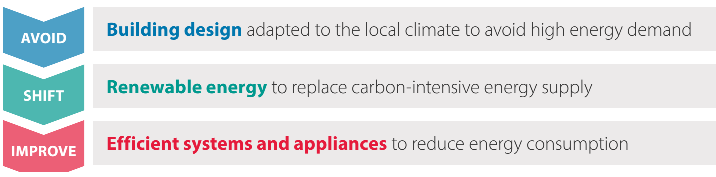
Table 7
Examples of mitigation actions on towards zero net carbon new buildings

Description	In many parts of the world, particularly developing countries, the construction of new buildings is a major activity leading to increased carbon emissions. Given the long lifetime of buildings, it is vital to move swiftly to minimize, eliminate and ultimately reverse the carbon burden that this new construction currently generates. Achieving very low or zero carbon emissions requires careful consideration of all aspects of the building's energy profile, and an integrated design process. Heat losses and gains through the fabric need to be minimized through climate-adapted building design with an optimized building envelope, adequate insulation and use of high-performance components such as windows. Technical systems need to be highly efficient, with good controls (e.g. inverter heat pumps), while available renewable technologies, both passive and active, need to be deployed to the extent possible.

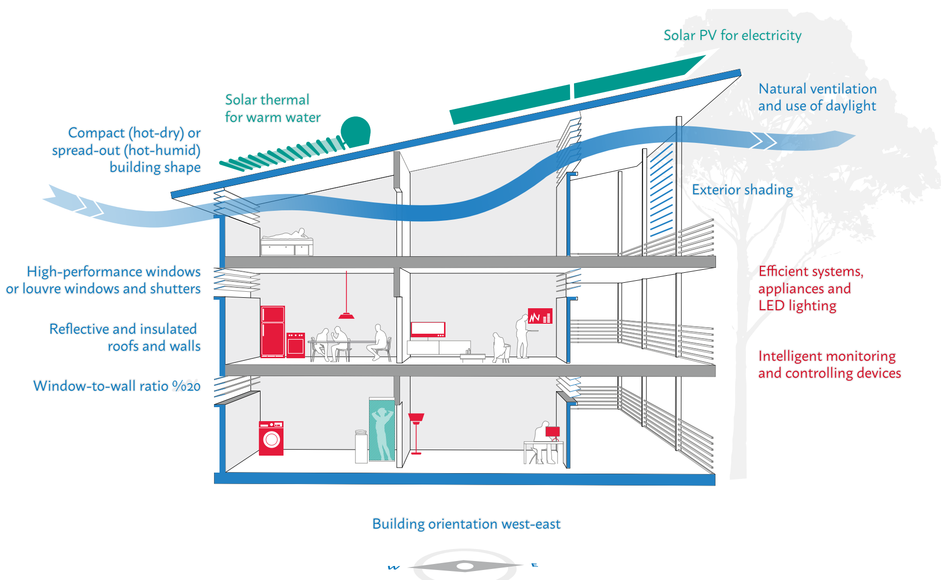
Key measures

Foster the construction of new buildings with climate-adapted passive building design, use of climate-friendly and renewable energy and apply highly efficient systems and appliances. Apply the hierarchic three steps: avoid, shift and improve (see illustrative example below).

Three steps can make buildings energy-efficient:



Source: Programme for Energy Efficiency in Buildings (PEEB). (2020); cf. Cool Coalition; Dalkmann & Sakamoto (2011).



** whenever possible in the respective local socio-economic context*

Source: Programme for Energy Efficiency in Buildings (PEEB). (2020).

Table 7 (continued)

Examples of mitigation actions on towards zero net carbon new buildings

Mitigation strategies	Carbon efficiency; technology efficiency; system efficiency; energy service demand reduction.
Example	LEED building certification (i) India[34] Construction of a new green building in Delhi, India, was designed to meet the LEED platinum building standard. By incorporating various green design features throughout the project, including installing an integrated building management system, reducing lighting load by increasing natural lighting and utilizing waste heat, savings of 5,944 t CO_2 eq/year were achieved. (ii) Kenya[35] The Garden City Mall is a mixed-use building (with residences, a retail park, offices and a hotel) in Nairobi, Kenya. The building was the first mixed-use building in East Africa to obtain LEED certification. The project is also the first in Kenya to adopt the Green Star SA-Kenya rating system, which is overseen by Green Building Council South Africa, in collaboration with green building councils throughout Africa. By implementing energy efficiency measures and through the process of securing Green Star SA-Kenya and LEED certification, the Garden City Mall project resulted in an annual reduction in emissions of 750 t CO_2 and it generates 1,256 MWh solar energy a year.
Selected CDM-approved methodology[36]	AMS-II.E: Energy efficiency and fuel switching measures for buildings[37].

Table 8

Examples of mitigation actions on thermal performance of existing buildings

Description	Existing building stocks are responsible for most of the sector emissions. The majority of these buildings will continue to be used for many decades to come, so reducing their energy consumption is vital. This is particularly so in developed countries, where the rate of new building is quite low. This measure involves reducing the heat transfer (both heating and cooling) between an existing building and its surroundings by improving the thermal performance.
Key measures	Active measures: retrofit insulation, replacement of windows and doors, removal of thermal bridges; Passive measures: solar shading, reflective coatings on roofs and facades.
Mitigation strategies	Technology efficiency; system efficiency.

34 https://cdm.unfccc.int/Projects/DB/RWTUV1340716484.37/view.
35 www.edgebuildings.com/wp-content/uploads/2017/09/Kenya-Green-Building-Market-Intelligence-EXPORT.pdf.
36 For a fuller description of CDM methodologies, please refer to annex 2.
37 https://cdm.unfccc.int/methodologies/DB/P4PO65N66CEQGPE2RJU15FIVB7AX4A

Table 8 (continued)

Examples of mitigation actions on thermal performance of existing buildings

Example	The Moldova Energy Conservation and Greenhouse Gases Emissions Reductions project is a good example of energy savings achieved in public sector buildings. The CDM methodology selected for the project is AMS-II.E: Energy efficiency and fuel switching measures for buildings. According to the methodology, the baseline for the project is determined by the energy use of the equipment being replaced in the case of a retrofit, and by the energy use of the equipment that would be selected if not for the project in the case of new builds. The emissions baseline is then multiplied by an emissions coefficient depending on the energy source (electricity, fossil fuels, etc.). The project focused on public buildings in the Republic of Moldova (schools, hospitals, police stations, etc.) and involved both fuel switching and energy efficiency improvements to achieve energy savings, including window replacements and additional insulation. Overall, the project achieved annual savings of 11,567 tCO_2 eq.[38]
Selected CDM-approved methodologies	Verified Carbon Standard: Weatherization of Single Family and Multi-Family Buildings.[39] The Gold Standard: Thermal performance improvements in low-income dwelling structures.[40]

Table 9

Examples of mitigation actions on improve technical systems and equipment in existing buildings

Description	Technical systems relate to the technologies and equipment that supply energy to a building such as lighting and space conditioning (temperature, air quality, humidity, etc.). They are key to the ongoing operational energy consumption of all buildings, so the most efficient products should always be selected. Efficient operation of technical systems should be achieved through a combination of automation and user-enabled manual control to meet internal comfort conditions.
Key measures	<u>Space conditioning</u> Generally referred to as heating, ventilation and air conditioning, or HVAC. Combined heat and power or cogeneration provides heating and electricity more efficiently than separate production, while tri-generation also provides cooling. Within HVAC, there is a range of high-efficiency products, including boilers, air conditioners, ventilation systems and heat pumps, which can operate in isolation (typically in residential properties or smaller commercial units) or as a combined system (typically in larger buildings and building complexes) in order to provide a comfortable internal environment. In cooler regions, these systems usually also supply domestic hot water. <u>Lighting and appliances</u> More efficient internal and external lighting systems, cooking equipment, stand-alone domestic hot water systems, refrigeration and various power appliances. <u>Controls</u> Temperature, air quality, light and occupancy sensors, either individually or within a building automation system, should be deployed to ensure that the energy service provision matches occupancy and prevailing external conditions.

38 https://cdm.unfccc.int/Projects/DB/DNV-CUK1134568842.81/view
39 https://verra.org/wp-content/uploads/2017/10/VM0008v1.1.pdf
40 https://www.goldstandard.org/sites/default/files/thermal-performance-final-draft-methodology.pdf

Table 9 (continued)

Examples of mitigation actions on improve technical systems and equipment in existing buildings

Mitigation strategies	Technology efficiency; energy service demand reduction.
Examples	(i) Tri-generation A tri-generation system, providing heating, cooling and electricity, was installed in a 52-storey headquarters commercial building in Jeddah, Saudi Arabia. It consisted of installing an on-site tri-generation system to supply all the required heating, cooling and electrical power to the building. The project led to annual savings of 6,515 t CO_2 eq as a result of the installation. Based on a capital investment of USD 37.2 million, annual revenues from sales of electricity, cooling and heating are USD 7.8 million, providing a pre-tax internal rate of return of 12.9% for the project.[41] (ii) Efficient biomass cookstoves Low-cost, high-efficiency biomass cookers were given to 19,000 households in the Nkhata Bay district in Malawi to replace low-efficiency ones, thereby reducing the consumption of wood and easing pressure on natural resources in the region. The cookstoves were specifically developed through extensive trials in the local communities and with Malawian conditions in mind. They are constructed from locally available materials and do not require specialist construction skills or equipment. Overall, the project led to annual savings of 32,672 t CO_2 eq.[42] (iii) Lamp replacement[43] The Pasate a LED lamp replacement programme in Buenos Aires, Argentina, promotes the installation of LED lighting. The project includes a disposal plan for the collected fluorescent lamps, whereby old lamps undergo treatment to safely dispose of the mercury. The remaining, uncontaminated parts are then reused for tile manufacturing. Owing to the success of the project so far, the current scope has been expanded with the aim of replacing up to 3 million lamps with LEDs. The plan is to reach 325,000 homes in total; as at January 2020, 162,757 homes had had lamp replacements. Current savings equal 21,367 t CO_2 eq (out of the total projected 43,000 t CO_2 eq), with total energy savings of 45.2 GWh, equivalent to the energy consumption of 13,627 homes per year. Homeowners are experiencing 14% lower energy bills, and collective savings of USD 3 million (total expected savings are projected to be as high as USD 100 million). (iv) Cooling as a Service[44] Cooling as a Service (CaaS) is a system where a customer pays for cooling as a service, rather than for the physical cooling infrastructure (e.g. HVAC system, fans, air conditioners). CaaS is a financial instrument to address the upfront investment costs of cooling equipment. It is similar to current "pay as you save" programmes and already exists for a variety of technologies such as software, photocopying services and transport (Pay as You Save for Clean Transport[45]). Under CaaS, a technology provider installs and maintains the cooling equipment, and recuperates the cost through periodic payments from the end user. The technology provider maintains ownership throughout the total equipment lifecycle, thereby shifting the investment focus from the purchase price of equipment to the lifecycle cost of the technology. The technology provider is also responsible for paying for the energy used, so is incentivized to have highly efficient equipment.

41 https://cdm.unfccc.int/Projects/DB/TUEV-SUED1370345123.67/view.

42 https://cdm.unfccc.int/Projects/DB/TUEV-SUED1397540352.85/view.

43 www.c40.org/case_studies/buenos-aires-pasate-a-led.

44 www.climatefinancelab.org/project/cooling-service.

45 https://www.climatefinancelab.org/project/pay-save-clean-transport/

Table 9 (continued)

Examples of mitigation actions on improve technical systems and equipment in existing buildings

Examples	The Global Innovation Lab for Climate Finance is working on a CaaS programme, along with the Kigali Cooling Efficiency Program and the Basel Agency of Sustainable Energy. The project is working towards implementation throughout the Dominican Republic, India, Jamaica, Mexico and South Africa. Like many developing countries, Mexico is currently experiencing increased demand for cooling. The CaaS programme estimates that the installation and operation of high-efficiency chillers over a period of seven years would lead to a reduction in emissions of nearly 18,000 t CO_2. (v) Energy-efficient cooling product distribution[46] The ECOFRIDGES project aims to provide energy-efficient and climate-friendly cooling products to the countries of the Economic Community of West African States (ECOWAS). The goal of the project is to support the distribution of 50,000 cooling products and develop plans for appliance disposal, as well as running awareness-raising campaigns (such as radio advertisements, public events and a project website). Additionally, the project will include a finance mechanism (potentially some form of on-bill financing). The project, which is funded from the Kigali Cooling Efficiency Program, is a collaboration between the United Nation's United for Efficiency initiative, the African Development Bank, the Governments of Senegal and Ghana, the ECOWAS Centre for Renewable Energy and Energy Efficiency, and the Basel Agency for Sustainable Energy.
Selected CDM-approved methodologies	AMS-II.K: Installation of co-generation or tri-generation systems supplying energy to commercial buildings.[47] AMS-II.G: Energy efficiency measures in thermal applications of non-renewable biomass[48] AMS-II.R: Energy efficiency space heating measures for residential buildings.[49] AMS-II.J: Demand-side activities for efficient lighting technologies.[50] ACM0023: Introduction of an efficiency improvement technology in a boiler.[51] AM0060: Power saving through replacement by energy-efficient chillers.[52]

Table 10

Examples of mitigation actions on switch to lower-carbon fuels

Description	This action seeks to reduce the carbon content of the energy supplied to meet a building's needs by switching from higher-carbon fuels such as coal to lower-carbon fuels such as natural gas or switching to renewable energy sources. A growing number of initiatives are paving the way for the eventual elimination of all fossil fuels for heating. For example: (i) The city of Berkeley in California, United States, banned natural gas in new buildings from 2020,[53] a policy which is being considered by numerous other cities in California; (ii) In 2019, the United Kingdom announced that, from 2025, all new homes should be heated without natural gas.

46 https://energy-base.org/projects/ecofridges-initiative-in-west-africa/.
47 https://cdm.unfccc.int/methodologies/DB/B5PBIP57SKC8VG133CZ3JG7B6J4WHY.
48 https://cdm.unfccc.int/methodologies/DB/ZI2M2X5P7ZLRGFO37YBVDYOW62UHQP.
49 https://cdm.unfccc.int/methodologies/DB/9SD9B6O4446YU1PEV624CYUO5RF3QU.
50 https://cdm.unfccc.int/methodologies/DB/GIIF3094709KR4YEEJXX72UY39L6Y4.
51 https://cdm.unfccc.int/methodologies/DB/JW18PCU5MLZGRQB5QYE6JOM2EUOUDR.
52 https://cdm.unfccc.int/methodologies/DB/YK8TH8WJAQDX52TC32G9C627X17P38/view.html.
53 https://www.npr.org/2019/08/05/745051104/give-up-your-gas-stove-to-save-the-planet-banning-gas-is-the-next-climate-push?t=1582480108366.%3E?t=1582480108366.%3E&t=1615891702897.>

Table 10 (continued)

Examples of mitigation actions on switch to lower-carbon fuels

Description	The large reductions in recent years in the costs of key renewable energy technologies, particularly solar and wind, has increased their economic attractiveness, with costs now comparable or below those of conventional fossil fuel generation in many locations, resulting in growing deployment of non-subsidized capacity. These rapid changes need to be reflected in the development of mass-market technical solutions for the deployment of building-integrated renewables, which should now be considered as not only a standard requirement for all new buildings, but also a cost-effective retrofit option for existing buildings.
Key measures	Switching from coal to natural gas. Replacing gas-fired heating systems with electric heat pumps, while bearing in mind that the emissions factor of the grid electricity affects emissions level[54]. Harnessing local renewable sources such as hydropower, wind, solar, sustainable biomass and biomass residues.
Mitigation strategies	Carbon efficiency.
Example	The Community-based Renewable Energy Development in the Northern Areas and Chitral District of Pakistan invested in micro and mini run-of-the-river hydroelectricity plants to serve remote rural communities. The project generates electricity from 90 individual plants ranging in size from 30 to 800 kW, not exceeding 15 MW of combined installed capacity, feeding into mini-grids isolated from any regional and national grids. The power they provide is used to meet community energy needs, at the same time substituting for the use of diesel fuel and reducing GHG emissions by 77,500 t CO_2 eq. The majority of beneficiaries did not previously have access to electricity from any source. Without a clean energy alternative, there would be growing penetration by diesel generators into the area and increased overharvesting of wood for cooking and heating in the region's rare alpine forests. In addition to the environmental benefits, the project has created opportunities for economic development and alleviation of poverty in the underdeveloped and remote mountain communities of northern Pakistan. Total project costs were USD 17.8 million. Without the revenue from carbon credits, the overall internal rate of return for the project would be 9.3%. Including the carbon revenues increases this to 23%.[55]
Selected CDM-approved methodologies	AMS-I.I: Biogas/biomass thermal applications for households/small users.[56] AM0036: Fuel switch from fossil fuels to biomass residues in heat generation equipment.[57] AM0094: Distribution of biomass-based stove and/or heater for household or institutional use.[58] AMS-I.K: Solar cookers for households.[59] AMS-I.J: Solar water heating systems.[60] ACM0009: Consolidated baseline and monitoring methodology for fuel switching from coal or petroleum fuel to natural gas.[61]

54 https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.pdf/history_view.
55 https://cdm.unfccc.int/Projects/DB/DNV-CUK1204739473.81/view.
56 https://cdm.unfccc.int/methodologies/DB/3WJ6C7R0JFA62VYA2Z2K6WE1RK1PXI.
57 https://cdm.unfccc.int/methodologies/DB/7P3CG1OWTTS3XX0N9XKCENFI050SH6/view.html.
58 https://cdm.unfccc.int/methodologies/DB/SN0LYZ32U7OZ29CYJF3WH6FCFKVGS0.
59 https://cdm.unfccc.int/methodologies/DB/5EUY1AEXAX0RKWNJ6INHVROP71DD8R.
60 https://cdm.unfccc.int/methodologies/DB/7FWC9VI15EMP2EOCF44OUZH9XHLL5W.
61 https://cdm.unfccc.int/methodologies/DB/2CRBYLJO5JWC9YHBSWJQWYIH2LLGMJ/view.html.

Combining thermal improvement, technical system efficiency and renewable energy in a deep energy retrofit to deliver a zero-carbon solution for existing buildings

While the mitigation action types (Improve the thermal performance of existing buildings; Improve the technical systems and equipment in existing buildings; Switch to lower-carbon fuels and maximize potential for renewable energy generation) described above are each individually important for addressing existing buildings, the ultimate goal is that they are combined as part of a holistic solution that delivers a deep renovation, ideally striving towards a net zero carbon outcome. While this is technically possible in different climate zones, economically feasible solutions have to be urgently developed. In order to explore the implications, several organizations have undertaken demonstration projects as part of the learning process. One such example is described in the Box 7, below.

Box 7

Deep energy retrofit of an existing building to net zero carbon – case of USA

The American Geophysical Union is a not-for-profit, professional scientific organization representing more than 60,000 members in 137 countries[62]. It recently renovated its existing 5,800 m^2 headquarters building, located in Washington, D.C., United States. In approaching the renovation, it devised and adopted four key principles:

Reduction – push the building's footprint as low as possible by creating a high-performing building envelope, enhancing the use of natural daylight, replacing building control systems with energy-efficient ones, new low-emissivity, low-reflective glass windows, a radiant cooling ceiling system, low-energy light-emitting diode lighting and a direct current electrified grid, among other strategies to reduce the building's need for energy.

Reclamation – by installing a green wall, indoor air that is already at the right temperature will be circulated through the plants where it will be cleaned and filtered before passing back into the building, reducing the energy need to heat or cool the air.

Absorption – utilizing energy from the city's wastewater through a municipal heat exchange system.

Generation – a large solar PV array on the roof generates enough energy to meet the remaining needs of the building.

62 https://building.agu.org/2016/03/12/the-pathway-to-net-zero/.

PRIORITY 2 – mitigation actions in the product stage, also partly at the use (refurbishment) and end of life stages

Table 11
Examples of low embodied carbon products in construction and renovation processes

Description	There is a distinction between the narrower concept of 'embodied energy' which encompasses energy-related emissions from construction activities, and 'embodied emissions' that also include emissions due to material properties, such as cement carbonation[63]. 'Embodied energy' describes the energy used in building material flows and construction activities throughout the life-cycle of a building. This includes material extraction, transport, processing, manufacturing, construction, maintenance, repair, replacement, refurbishment, deconstruction, waste processing, and disposal (EN 15978, 2011). The energy consumption for the operation of the building and its appliances is excluded. 'Embodied emissions' or 'embodied carbon' includes both the emissions from embodied energy and from inherent chemical absorption and emission properties of building materials. For example, cement is produced through a carbon dioxide (CO_2) emitting chemical reaction called carbonation, while wood offsets carbon emissions by absorbing CO_2 during growth. It is important to look at both the embodied energy-related emissions and at the inherent properties of the materials. Compared with the mature market for energy efficiency in the use stage of buildings, that related to the product stage is still in its infancy. Low-carbon and renewable products such as wood, straw and bamboo were used widely in the past, but have been almost entirely replaced in the industrial era by high-carbon products like cement, steel, glass and plastics. Now, there is growing interest in utilizing these low-carbon renewable materials again in new construction and renovations. A wide range of alternative materials exists that can drastically lower the carbon footprint of a building. To be effective and economically viable, material choices must however be context specific. In general: • Locally sourced materials lower transport emissions, • Low-processed materials consume less resources for production, • Organic materials are renewable and absorb CO_2 during growth and • Recycled materials reduce the need for raw matter and resource depletion.
Key measures	Planning stage: • Consider whether the building asset is required, or if an existing building can be reused. • Optimize building design to utilize materials with low embodied carbon, including natural products such as wood (where feasible, avoiding deforestation) and other biomass. For example, certain kinds of wood such as timber or bamboos with excellent structural properties that can replace steel and reinforced concrete at much lower CO_2 cost. • If concrete is unavoidable, use lower carbon concrete mixes by using fly ash, slag, calcined clays, or even lower-strength concrete where feasible. • Consider using reused and recycled products.

63 World Green Building Council 2019.

Table 11 (continued)

Examples of low Low embodied carbon products in construction and renovation processes

Key measures	Construction stage: • Efficient management and operation of the construction to minimize wastage of materials. Use and demolition stages: • Equally, consider using natural products or reused and recycled products, and respectively, consider reusing and recycling of demolition materials for other new buildings at the end of life stage.
Mitigation strategies	Carbon efficiency.
Initiatives	(i) Green building rating tools[64] are used to assess and recognize buildings which meet certain green requirements or standards. For the most part, these are voluntary, although some jurisdictions or local authorities might specify the certification of buildings in certain areas or under certain circumstances. The overall aim of these tools is to encourage and incentivize the adoption of sustainability practices, from the design and construction stage, including the incorporation of low embodied energy products, through to use of energy and water in the operational phase of a building. (ii) The World Green Building Council, in partnership with European Climate Foundation, Children's Investment Fund Foundation, C40 Cities and Ramboll, has launched its Bringing Embodied Carbon Upfront initiative[65] as part of the Advancing Net Zero project. The goal of the initiative is to reduce embodied carbon in new buildings by at least 40%, and to eliminate all embodied carbon by 2050. Within the project, two industry-led initiatives, the Concrete Sustainability Council and the Responsible Steel Standard, seek to address products currently responsible for over 40% of embodied carbon: cement and steel. (iii) Based at the University of Washington, United States, the Embodied Carbon Network aims to provide a forum for interested parties working towards the elimination of embodied carbon in buildings. Among the resources made available by the Network is the Embodied Carbon in Construction Calculator (EC3), a free open-access tool[66] launched in November 2019, designed to give users the information they need to make more informed decisions on embodied carbon, allowing them to enact positive change.
Selected CDM-approved methodologies	AMS-III.BH - Displacement of production of brick and cement by manufacture and installation of gypsum concrete wall panels[67]

64 https://www.worldgbc.org/rating-tools.
65 https://www.worldgbc.org/embodied-carbon.
66 http://carbonleadershipforum.org/projects/ec3.
67 https://cdm.unfccc.int/methodologies/DB/YZBSIH9BCH894GDSD4BP2FMNMI9FU6.

PRIORITY 3 – mitigation actions in the construction and end-of-life stages

Table 12
Examples of mitigation actions during construction and demolition processes

Description	The design, construction and ultimate demolition of a building needs to be undertaken with a view to the whole lifecycle of the building. Adopting circular economy principles means that both the materials used, and the processes adopted in construction are viewed with the ultimate goals of maximizing resource efficiency and minimizing carbon emissions.
Key measures	Efficient transportation, waste minimization; reuse of demolition materials.
Mitigation strategies	Carbon efficiency; technology efficiency; system efficiency.
Example	*At the time of publication, there are no CDM methodologies for low-carbon products.* (i) Off-site construction techniques The techniques are increasingly being deployed – these have numerous operational benefits and can also be effective in cutting waste and maximizing reuse of materials. Since 2013, Energiesprong[68] in the Netherlands has been a leading pioneer in the off-site construction of "whole building" zero energy renovations, which can be completed in less than 10 days by using new technologies such as prefabricated facades, insulated rooftops with solar panels, smart heating, and ventilation and cooling installations. A typical renovation is installed with no upfront payment by the building occupants. Instead, it is financed by future energy cost savings plus the savings on maintenance and repairs over the coming 30 years. It comes with a performance warranty on both the indoor climate and the energy performance for up to 40 years. The process has now been extended to include new buildings. Several other European countries are now adopting the Energiesprong approach, which is also beginning to make inroads in North America. (ii) 3D-printed building[69] A transportable 3D printer was used to construct a 650m^2 building located in Dubai, United Arab Emirates, in just two weeks. Due to the severe desert climate, in which the temperatures rise and drop significantly during the day and night, respectively, the materials used in the printing process had to be able to withstand extreme heat and cold. By printing the main structure in situ, based on a previously programmed design, there was no wastage of materials. The machine printed out the structure section by section using a gypsum-based mixture. Later, traditional construction methods were used to install the windows and roof, and rebar supports were added to reinforce the walls. The resulting building, which will house administrative offices for the Dubai Municipality, has a white facade that reflects the sun's rays to minimize heat gain during the day. 

68 https://energiesprong.org.
69 https://inhabitat.com/worlds-largest-3d-printed-building-opens-in-dubai-after-2-weeks-of-construction

Chapter summary

This chapter focussed on mitigation actions and strategies available in the building and construction sector. Examples on establishing baselines were outlined and key mitigations strategies and actions highlighted.

Taking into consideration the carbon mitigation strategies for the sector identified by the IPCC, six broad types of mitigation actions identified include:

1. Design and construct zero net carbon new buildings;
2. Improve the thermal performance of existing buildings;
3. Improve the technical systems and equipment in existing buildings;
4. Switch to lower-carbon fuels and maximize potential for renewable energy generation;
5. Use low embodied carbon products in construction and renovation processes;
6. Ensure construction and demolition processes are delivered with the lowest carbon impact.

5. POLICIES AND STRATEGIES TO DRIVE MITIGATION ACTIONS – GUIDANCE FOR POLICY-MAKERS

This chapter describes policies, plans, programmes and strategies that provide a framework to underpin and support mitigation actions in the building and construction sector. The chapter concludes with a brief description of climate finance initiatives facilitated by the UNFCCC that developing countries could use to support their mitigation efforts.

5.1 A strategic approach

To be effective, a strategy to reduce the carbon emissions from the building stock needs to encompass a holistic range of policies, plans, programmes and measures. These should work synergistically to create an environment that is conducive to large numbers of stakeholders such as individuals, organizations, public bodies, manufacturers, craftspeople, financiers, professional service providers and intermediaries taking action to reduce the carbon footprint of the building stock. The strategy should be continually reviewed and improved, and consequently the policy landscape will be dynamic in response to changing attitudes, practice, costs and technology development.

Each country has its own unique building stock, climatic conditions, challenges, issues and technical capacity. Some have put in place comprehensive road maps for decarbonizing their building stocks, while others are at an earlier stage in the journey. Whatever the current position, all countries need to ramp up their decarbonization activities by following the continual cycle of improvement illustrated in figure 15.

Figure 15
Building decarbonization outline process

Source: BPIE (2015).

It is important for policy-makers to understand the co-benefits and impacts of mitigation actions in order to coordinate policy responses to generate synergies and mitigate trade-offs. Given that GHG emissions reduction is often not the primary objective of government departments and stakeholders, clear understanding of both benefits and impacts of mitigation actions is a key to mobilize resource. Contribution to broader public policy goals as well as tangible near-term benefit for a specific stakeholder will build up support for mitigation actions. For example, building energy efficiency brings multiple benefits and costs to different stakeholders as illustrated in table 13. Active stakeholder engagement, combined with relevant institutional arrangements, will help identify common and divergent interests and build consensus for implementation.

Table 13
Multiple impacts of building energy efficiency

Impact • **Benefit** • **Cost**	**Occupant** • Energy cost ↓ • Energy poverty ↓ • Indoor comfort ↑ • Health ↑ • Labour productivity ↑	**Business** • New business ↑ • Employment ↑ • Sales/profit ↑ ↓	**Government** • Air quality ↑ • Health ↑ • GHG emissions ↓ • Water use ↓ • Fiscal balance ↑
	Owner • Property value ↑ • Initial cost ↑	**Utility** • Capacity investment ↓ • Sales ↓	**Government (Energy importer)** • Energy security ↑ • Trade balance ↑

Source: GEA (2012), IPCC (2014), IEA (2015).

5.2 Policies, programmes and action plans

This section explores broad types of policies designed to reduce energy demand in buildings from a low towards a higher level of commitment and obligation, which include the following:

- Awareness-raising, information provision and labelling;
- Capacity-building, training, technical assistance and one-stop shops;
- Benchmarking;
- Provision of financial support;
- Mandatory energy audits;
- Voluntary or mandatory energy-saving targets;
- Voluntary or mandatory energy performance standards for products and technologies;
- Banning inefficient products;
- Mandatory renovation.

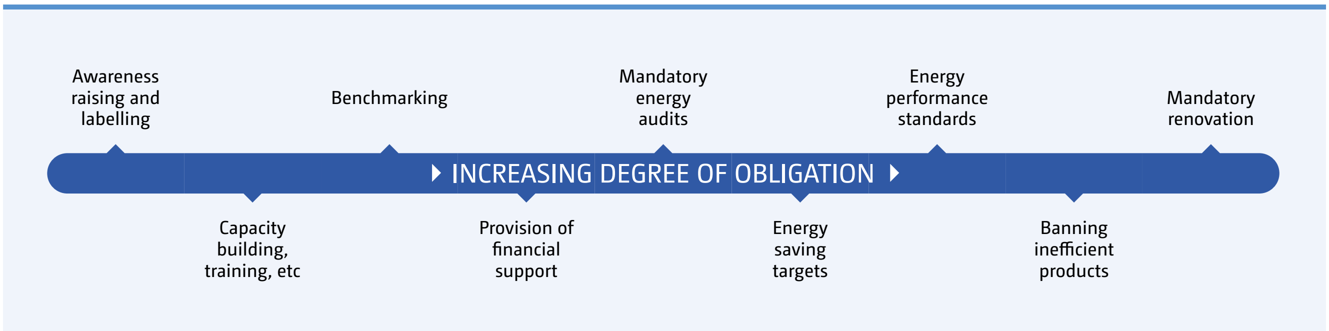
5.2.1 Types of mitigation policies in the building and construction sector

This chapter describes the different types of mitigation policies in the building and construction sector.

1. Awareness-raising, information provision and labelling

Awareness-raising programmes can combat the lack of knowledge surrounding mitigation actions and the associated benefits. There are several ways to raise awareness of the benefits of energy efficiency and energy-saving measures, including:

Figure 16
Spectrum of policy options indicating levels of obligation



- Information campaigns directed at the general public. These could include posters, social media initiatives, television commercials, etc;
- Web resources where citizens can find additional information on available material and contacts;
- Labelling and energy performance certifications for buildings and appliances. Mandating that a building standards factsheet or a "building scorecard" be included at point of sale (or upon rental) is a great way to inform the new building owner or tenant of the energy use of the building (addressing the issue of split incentives where the owner doesn't receive benefit from the investment in energy efficiency while tenants receive the benefit without incurring the investment cost).

Such awareness-raising campaigns can help to stimulate the market by providing information on possible measures and benefits. Information and labelling at point of sale, whether appliances, equipment or buildings, increases the propensity of the purchaser to choose a more efficient product – this is particularly important for a sector like energy efficiency, as most people are unfamiliar with the technical aspects of energy-saving measures. In addition to traditional energy efficiency labelling schemes, some countries (e.g. Ghana) are planning to introduce labelling schemes to show multiple benefits of clean cookstoves such as economic (financial saving from low fuel usage), health (less black smoke inhalation and eye irritation) and environment.

Box 8
Energy saving schemes – case of Denmark

The Danish Energy Agency created a website[70] where end users can find information on energy savings. The website includes information by sector (private homeowners, commercial buildings, public buildings, etc.) and provides information on subjects such as home energy labelling, selecting a heat pump and renovation advice. The website serves as a central first stop for users to find information specific to their needs and indicates where further details can be found.

"One-stop shops" is a generic term that describes a particular type of support to end consumers that combines information provision with technical assistance, or "hand-holding". The reasoning behind this type of service is that, even armed with the relevant information, the consumer may not choose the low-carbon option because it may not be familiar to them, it may be less accessible than standard products or it may be more expensive. The "hand-holding" aspect seeks to guide the consumer whether they are choosing a more efficient product or undertaking a whole building renovation, at the same time to assist the consumer in identifying and applying for any financial support that may be available.

70 www.sparenergi.dk

Box 9

Energy efficiency rating system – case of India

The Buildings Star Rating System was developed by the Bureau of Energy Efficiency[71], with the objective of promoting a market pool for energy-efficient buildings. This system is based on the actual performance of a building in terms of its specific energy usage in kWh/m²/year. The programme rates buildings on a 1–5-star scale, with 5-star labelled buildings being the most energy efficient. The rating considers operational characteristics that define building use, hours of operation, climatic zone and conditioned space. Star labels for day-use office buildings, hospitals and shopping malls have been developed. A total of 184 commercial buildings in different categories had been star rated by June 2018. The code will be made more stringent to promote the construction of even more energy-efficient/near-zero energy buildings. Design guidelines for energy-efficient multi-storey residential buildings have also been launched.

The Building Retrofitting Project, launched in 2014, focuses on lighting and air-conditioning systems. The National Building Dashboard provides information on real-time/estimated energy savings following energy efficiency intervention measures in all buildings on a pan-India basis. It also provides an annual reduction in CO_2 emissions and avoided peak demand through retrofitting energy-efficient equipment. As at October 2018, 9,740 buildings had been completed, which has led to energy savings of 79.8 GWh and reductions in emissions of 65,578 t CO_2 per year.

Box 10

National low carbon strategy – case of Maldives

The Low-Carbon Energy Island Strategies project is one of Maldives' key initiatives promoting energy-efficient practices and technologies for public buildings and the incorporation of energy efficiency measures into the building codes[72]. The government has showcased a number of energy efficiency measures, including the use of centralized air conditioning and energy-efficient air-conditioning systems for buildings and LED lights for public lighting. Government initiatives such as the "It's cool at 25°C" awareness campaign have had a positive effect throughout the country. A standard labelling programme and energy efficiency guidance for buildings being developed under the Low-Carbon Energy Island Strategies project will further enhance the proliferation of energy efficiency technologies among end users.

71 https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf page 12.

72 https://unfccc.int/sites/default/files/resource/First%20BUR%20of%20Maldives.pdf (see pp. 25 and 56)

Box 11

International rating system – EDGE certification – case of South Africa

EDGE certification[73] was developed by the International Finance Corporation as an international rating system for buildings in developing countries. EDGE provides a broad framework for evaluating and monitoring projects, and provides third party verification for green buildings, catering to different building types. The International Finance Corporation uses EDGE data, collected from the projects, to track investment opportunities in green buildings. By early 2020, over 16 million m^2 of buildings were registered for certification under the EDGE system, delivering 385,317 MWh/year in energy savings.

International Housing Solutions (IHS), a South African developer focused on low-income housing, uses the EDGE certification system for its projects. According to IHS, the cost of EDGE compliance is approximately USD 270 per housing unit (less than 1% of the construction cost), while annual utility savings equal a month's rent – providing them with a competitive advantage over non-certified developments. Owing to the benefits of building to the EDGE standard, IHS has certified nearly 7,000 units, surpassing its green construction target by 21%.

2. Capacity-building, training and technical assistance

In order to execute the main pillars of energy efficiency policies, plans and programmes, a well-trained workforce is essential. Dedicating resources to capacity-building and training activities creates an enabling environment for energy efficiency measures, which encourages adherence to building codes and allows robust climate targets to be met. Capacity-building and training initiatives focus on workers/specialists in different building areas with a view to creating a highly skilled and capable workforce, equipped to carry out energy savings and mitigation measures.

Among the types of capacity-building available is technical assistance. Many international donor programmes include technical assistance as a stand-alone measure or as a component of a wider financing package. The principle here is that the recipient country or organization may not have prior experience of running a particular initiative, so the donor organization pays for the expertise to be provided. Usually this is for a limited length of time, to enable local expertise to be developed.

Box 12

Energy efficiency labelling – case of South Africa

From 2018, retailers selling household appliances have been required, as part of their sales pitch, to explain to customers the importance and benefits of buying more energy-efficient appliances. In addition, retail online platforms are required to make customers aware of the importance of buying energy-efficient appliances as part of the online user experience. A training programme[74], was developed by the Department of Energy with funding from the United Nations Development Programme and the GEF. It comprises a 15-minute video, a learner manual, an online, cloud-based training and assessment portal and a certificate of completion of the training for appliance sales staff. The objectives of this training programme are to enable retailers to understand the reason behind the mandatory energy performance standards, the energy efficiency label and its correct utilization and the legal implications for retail appliance sales (in-store or online). This will enhance the ability of staff to sell energy-efficient appliances using the energy efficiency label as a key feature.

73 https://www.edgebuildings.com/
74 https://www.savingenergy.org.za/wp-content/uploads/2018/05/Energy-Label-Learner-Guide.pdf.

Box 13

Building Efficiency Accelerator through public-private collaboration – case of Nairobi, Kenya

The Building Efficiency Accelerator (BEA) is a global public–private collaboration[75], run by the World Resources Institute, in partnership with the United Nations Sustainable Energy for All initiative. The aim of the project is to utilize international knowledge in order to implement energy efficiency policies and programmes at the local level. The BEA acts as network to connect cities with experts as well as private sector partners.

In 2017 Nairobi joined the BEA, through which it has begun drafting green building guidelines and is establishing a pilot programme on selected building types throughout the city. The BEA supports participating cities like Nairobi by enabling access to experts who can provide location-/climate-specific guidance on policy measures and implementation, which considers existing initiatives, as well as access to tools to track and document progress.

Box 14

Federal Energy Management Program – case of USA

The U.S. Department of Energy's Federal Energy Management Program (FEMP)[76] establishes legislation as well as providing executive guidance on technology integration, funding sources, progress tracking, technical assistance and training programmes. FEMP offers live and on-demand training targeted at facility management for energy efficiency. This training corresponds with the 2010 Federal Building Personnel Training Act, which requires that federal employees working in building/facility management are able to demonstrate a certain level of competency. Therefore, the training is directly compatible with the Act's requirements. Training is available across a wide range of topics, from products and services to contracting and legal issues.

The programme includes a variety of stakeholders, including federal agencies, national laboratories, Congress and industry. FEMP oversees all the United States Government's energy management, thereby coordinating and tracking all efforts in a central location. This way, all state-led initiatives comply with national standards. According to the U.S. Department of Energy, FEMP has achieved a 49% reduction in energy intensity since 1975 and cost savings of around USD 50 billion.

Box 15

Voluntary energy efficiency programme – case of China

China continues to build an average of 2 billion m^2 new buildings every year, driven by population growth, urbanization and unprecedented economic development. Cities are therefore at the frontline of efforts to deliver on the Chinese Government's commitment to reach peak CO_2 emission levels by 2030. The C40 China Buildings Programme[77], aims to reduce emissions across multiple building types. Launched in 2018, the scheme will support participating cities in delivering ambitious climate action and sharing knowledge across China and internationally.

The China Association of Building Energy Efficiency, a non-profit association of enterprises engaged in building energy efficiency products and providing energy efficiency services, manages the China Better Buildings Challenge, which was inspired by the U.S. Department of Energy's Better Buildings initiative. It represents a comprehensive voluntary energy efficiency programme for China's building and construction sector, launched in 2016 through a partnership between the China Association of Building Energy Efficiency, Lawrence Berkeley National Laboratory and Energy Foundation. The programme encourages stakeholders to work together to identify barriers and implement energy efficiency and clean energy solutions in buildings.

75 https://buildingefficiencyaccelerator.org/.
76 www.energy.gov/eere/femp/federal-energy-management-program.
77 https://www.c40.org/researches/constructing-a-new-low-carbon-future-china

Box 16

Energy management systems – case of Vietnam

In Vietnam the energy use awareness-raising **Green Office**[78] programme focuses on behavioural changes in office buildings. To date, it has implemented 10 pilot projects in office spaces throughout the Hanoi area. The main objectives of the programme are to implement an environmental management system and train employees to monitor emissions intensity per unit of profit, emissions intensity per staff member and absolute emissions of the office.

The Green Office programme provides capacity-building, including through the provision of a toolkit for estimating GHG emissions and training of trainers to become internal experts in Green Office implementation and help to establish the management system. Participating offices have experienced a reduction in overall operating costs and seen an average reduction in absolute emissions of 6.5% (and in some cases up to 20%).

3. Benchmarking

Benchmarking provides a means to compare the energy use across a cohort of similar buildings. The information is used to derive a normalized consumption in kWh/m² for each building in order to identify the spread of performance. Those with the lowest consumption can then be identified as exemplars of good practice and serve as a means for those with the highest consumption to identify opportunities to reduce energy use.

Box 17

Building Efficiency Accelerator – case of United Arab Emirates

Operating internationally, the BEA partnership is designed to complement existing networks of cities by facilitating access to global expertise in building efficiency topics and providing a forum for engagement with private sector partners.

In the United Arab Emirates, a BEA demonstration project[79] involved benchmarking the energy and water performance of a range of public and private buildings to compare energy use. Around 10% of all hotels and shopping malls and private schools in the country were assessed, providing data to identify best practice.

78 www.c40.org/case_studies/green-office-hanoi

79 https://emiratesgbc.org/wp-content/uploads/2020/06/1901010-BEA-Report-Final-2.pdf

Box 18

National rating system – case of Australia

NABERS,[80] the National Australian Built Environment Rating System, is a scheme introduced in 1998 to measure a building's energy efficiency and carbon emissions, as well as the water consumed, and waste produced, and compare it with similar buildings. Buildings are compared against benchmarks that represent the performance of other similar buildings in the same location. It is an annual assessment, utilizing actual consumption data, adjusted and normalized according to a number of factors. This helps saving opportunities to be identified on an ongoing basis and encourages continual improvement to move up the 6-star rating scale. Different rating systems apply for different building types, from data centres and shopping centres to hospitals and apartment buildings.

Over the life of the programme, Australian businesses and workplaces have reduced emissions by around 6 Mt CO_2, cutting energy bills by 870 million Australian dollars. To date, nearly 80% of Australia's office space is rated by NABERS.

4. Provision of financial support

While reducing carbon emissions from buildings is generally a cost-effective measure owing to the energy cost savings, it often requires an upfront capital investment that may prove a barrier to implementation. Although various business models exist that overcome this barrier (PEEB 2019), many projects will need income from carbon credits or other forms of financial support. Examples of financial support instruments are shown below.

- **Grants/subsidies** can cover some or all of the costs for homeowners and companies who are not able to bear the full cost of project implementation, and specifically address the barrier of high capital costs.

Box 19

Energy grants and subsidies – case of Israel

In 2016, Israel approved the National Plan for Implementation of the Greenhouse Gas Emissions Reduction Targets and for Energy Efficiency. The plan comprises several national mitigation targets and measures for the sector, with the main target of achieving a reduction in emissions of 5.9 Mt CO_2 eq by 2030 (from a 2016 baseline). The plan provides financial support to facilitate mitigation actions, which includes:

- 500 million New Israeli Shekel (c. USD 145 million) between 2015 and 2025 for guarantees on loans for GHG reductions and energy efficiency projects;
- 300 million New Israeli Shekel (c. USD 87 million) in grants for energy efficiency measures – with a focus on SMEs and energy-poor projects.

- **Debt financing**, including loans, is another main form of financing for mitigation measures. Debt financing can come from private or public institutions and can provide funds to building owners, energy companies or businesses.
- **Tax incentives** such as rebates or exemptions can remove financial barriers to mitigation investments and make energy efficiency technologies more beneficial.
- **Green bonds** are an increasingly popular form of debt financing for carbon reductions in buildings. There are global standards for green bonds, with a specific classification for CO_2 emissions in buildings. In addition, national governments are creating their own standards for green bonds as well as guidance for issuance.
- **Energy performance contracts** – under this type of contract, an ESCO plans, constructs, finances and operates an energy-saving investment and guarantees a certain performance in return for annual payments by the user. Such contracts

80 https://www.nabers.gov.au/

enable building owners to benefit from energy savings upgrades without requiring the full capital investment upfront. Instead, repayments are made based on the energy and operational cost savings achieved.

- **On-bill financing** involves the energy utility making an energy-saving investment at the user's premises and recouping the costs over a period of years through the energy bill. These schemes are currently offered throughout the United States and Canada and are currently being piloted in the EU.

Box 20

Low Carbon Building Criteria

The Low Carbon Buildings Criteria set out what building assets are eligible for certification under the Climate Bonds Standard. The first green bond certified under the Low Carbon Buildings criteria was issued by the ANZ Bank in May 2015, with proceeds of A$600m allocated to green buildings, wind energy and solar energy loans in Australia, New Zealand and parts of Asia. As of 2020, over 80 Climate Certified Bonds linked to Low Carbon Buildings have been issued[81].

Box 21

Risk Facility – case of India

India has a growing energy service company (ESCO) market, although ESCOs still encounter issues accessing finance for their energy efficiency projects due to the perceived financial risk. In order to develop and expand the ESCO market, the Small Industries Development Bank of India has developed the Partial Risk Sharing Facility to build up a solid foundation of demonstration projects for energy efficiency lending.[82]

The Partial Risk Sharing Facility is a risk-sharing facility of USD 37 million that provides guarantees to financial institutions that lend to ESCOs, under the condition that the ESCO engages in a formal energy performance contract per project. The guarantee covers up to 75% of the total loan amount, with a minimum guarantee amount of approximately USD 15,000 and a maximum of USD 2 million and typical loan tenure of up to five years. The fund is administered by the Small Industries Development Bank of India along with the World Bank and Energy Efficiency Services Limited India. The primary funders are the Global Environment Facility (GEF) and the Clean Technology Fund.

81 https://www.climatebonds.net/standard/buildings
82 http://prsf.sidbi.in/user/pages/viewpage/h_overview

Box 22

On bill financing – case of Canada

TakeCHARGE[83] is an on-bill financing and rebate programme run with two major Canadian regional utilities: Newfoundland Power and Newfoundland and Labrador Hydro. The programme is open to both the residential and the commercial sector and can be used towards minor upgrades (lighting, electronic/programmable thermostats, etc.) or major renovations and new build construction. Additional measures include insulation materials, heat recovery ventilation systems, heat pumps and electric heating systems, service upgrades and motors. In addition to the rebate programme, the utilities have established a one-stop shop for energy efficiency upgrades and renovations and information. TakeCHARGE started in 2017 and to date has included over 300,000 participants.

- **Energy savings insurance** is designed to cover energy efficiency projects, making them more attractive to investors. Energy Savings Insurance (ESI) involves using a standardized contract between Small and Medium-sized Enterprises (SMEs) and service providers as a risk-sharing instrument, and has been used globally, with many pilot projects emerging. The insurance aims to address the perceived risk associated with the projected energy savings of implemented energy efficiency measures.

Box 23

The Global Innovation Lab for Climate Finance – case of Central & South America

The Danish Energy Agency, the Clean Technology Fund and the Inter-American Development Bank (along with local partners) have been working on several ESI projects globally, with a focus on Latin American countries. The following projects led by this consortium are currently under way:[84]

- The first ESI pilot project was launched in 2016 in **Colombia** in collaboration with a local commercial bank. A dedicated credit line was established to fund energy efficiency projects using a risk-sharing mechanism;
- In **Mexico**, a stimulus package of USD 25 million was established for the ESI project, including a guarantee fund and dedicated credit line. The programme is well regarded by financial and governmental institutions throughout the country and continues to expand, covering a variety of energy efficiency technologies, including heat pumps, light-emitting diodes (LEDs), cooling systems and boilers;
- In **El Salvador**, the programme conducted a market assessment to identify risk management instruments, including performance contracts and validation mechanisms. The assessment drew significant interest from approximately 500 firms looking to invest in energy efficiency measures and identified a potential emissions savings of nearly 37,500 t CO_2 eq/year in the country. The project was approved for USD 21.7 million in funding by the Green Climate Fund (GCF);
- In **Peru** and **Brazil** market research is currently under way with local banks to identify potential target sectors. Current focus sectors include hotels, hospitals, clinics and SMEs.

83 https://takechargenl.ca/
84 www.climatefinancelab.org/project/insurance-for-energy-savings.

5. Energy audits

Energy audits provide the means to identify the specific energy-saving opportunities in a particular building. Normally, the measures would be costed and prioritized, so that the building owner can quickly identify which measures will deliver the greatest benefit within a given budget.


© Getty Images

Box 24

Examples of programmes for subsidised energy audits in Africa

Several African nations[85], have recently undertaken measures to increase the uptake of energy audits:

- **Algeria:** co-financing has been made available for energy audits;
- **Kenya:** The Centre for Energy Efficiency and Conservation executes audits in SMEs and public institutions (so far totalling about 14 MWh of energy savings);
- **South Africa:** currently two schemes are under way – the United Nations Industrial Development Organization funded energy audits (run by the National Cleaner Production Centre) and the Private Sector Energy Efficiency initiative (funded by the United Kingdom Department for International Development);
- **Zambia:** the national Energy Efficiency Management Programme started carrying out energy audits with selected companies. The next step is to offer training and financing options to complete energy efficiency measures. Additionally, the Zambia Association of Manufacturers has conducted a series of energy audits. Many of these initiatives are heading into further phases of implementation and planning.
- **Ghana:** The Energy Commission of Ghana applied for support from the African Climate Technology Centre to improve energy efficiency in commercial and public buildings in the country. Ghana has witnessed a growing number of high-rise office buildings, hospitals, hotels and supermarkets. As a consequence, demand for electricity for air conditioning, lighting, special purpose refrigeration and operation of office equipment has increased significantly. Currently, there are no regulations and standards regarding the design and construction of energy-efficient buildings in Ghana. This poses a serious challenge to the improvement of energy efficiency in the country. To address the problem, energy audits are being undertaken in existing commercial buildings to establish the baseline situation in terms of energy consumption per square metre of floor space, the amount of energy wasted and the savings that could be made through the installation of energy efficiency technologies. This will provide the necessary inputs for the development of energy efficiency standards and regulations for commercial/public buildings.

85 https://unepdtu.org/wp-content/uploads/2015/08/african-regional-report.pdf

Box 25

The Green Buildings Programme – case of Malaysia

Malaysian Government recognizes that leading by example in the implementation of energy efficiency presents the population with a strong message.[86] Accordingly, in 2013 the government directed all its ministries and agencies to practise energy efficiency in their operations through energy audits and good practices in energy usage. Since then, annual monitoring of electricity usage of all the buildings in 25 federal ministries at Putrajaya and Kuala Lumpur has been carried out. This has led to reductions in emissions of 10 Gt CO_2 eq in 2014 and 11.8 Gt CO_2 eq in 2015.

The promotion of green buildings is intended to ensure the efficient use of resources, particularly of energy and water, leading to GHG emission reductions. Under the Eleventh Malaysia Plan, green features, designs and building materials are to be adopted for new government buildings in accordance with existing standards, such as the Malaysia Public Works Department Green Rating Scheme, or the MyCREST and Green PASS rating tools of the Construction Industry Development Board. Existing government buildings will be gradually retrofitted while industry players will be encouraged to obtain green certification such as the Green Building Index. According to Green Building Index ratings, green buildings reduced emissions by at least 111 Gt CO_2 eq in 2014 and 126 Gt CO_2 eq in 2015.

6. Energy-saving targets

Energy-saving targets lay the foundation for strong policies and programmes to support energy efficiency measures. Building performance targets provide long-term guidance on government priorities and signal stability for investors in energy efficiency projects. In addition, they help the market to benchmark ongoing initiatives and inform local policy objectives. Interim milestones should be established to track progress.

© Getty Images

86 https://unfccc.int/sites/default/files/resource/Malaysia%20NC3%20BUR2_final%20high%20res.pdf (page189)

Box 26

India National Cooling Plan

In early 2019, India introduced its national Cooling Action Plan. This is a comprehensive plan, including multiple targets in different core cooling areas. The plan establishes the following targets:

- Reduce cooling demand across all sectors by 20–25%;
- Reduce refrigerant demand by 25–30%;
- Reduce cooling energy requirements by 25–40% by the financial year 2037/2038.

The Cooling Action Plan also includes targets for space cooling in buildings and air-conditioning technology. Additionally, the programme encourages research and development in the cooling sector, as well as training and capacity-building (targeting to train 100,000 technicians by 2022/2023). The initial strategy lays out recommendations by sector, as well as overall short-term, medium-term and long-term recommendations to provide a holistic policy package to address growing cooling demand in India.

The Plan establishes core thematic areas of focus: space cooling in buildings, air-conditioning technology, cold-chain and refrigeration, transport air conditioning, the refrigeration and air-conditioning servicing sector, refrigerant demand and indigenous production, and research and development. Each of these areas has a dedicated working group comprising a mix of stakeholders, including government, industry associations and research institutes. The working groups use a reference ('business as usual') scenario and an intervention scenario to test potential future policy measures.

Energy efficiency obligations are another form of energy-saving target. These are obligations placed on energy utilities to deliver specified energy-saving targets. The origin of these schemes dates back to the 1970s in the United States, where policy-makers and regulators concluded that it was cheaper to save a unit of energy than to generate one. Applying the principle of least-cost planning, utilities were required to implement qualifying energy savings within their customer base, rather than investing in new supplies. This example of demand-side management, or integrated resource planning, went under the name of energy efficiency resource standards.[87] According to the IEA, there are around 46 obligation schemes across the globe.[88] In some countries, notably Italy and France, the obligations are underpinned by a white certificate scheme. The certificates serve as proof of achievement of a given amount of energy saving and can be traded with other obligated parties.

Box 27

National Energy Efficiency Strategy – case of South Africa

South Africa's National Energy Efficiency Strategy is intended to support the exploration of the potential for improved energy utilization through reducing the country's energy intensity.[89] The Department of Energy has established an Energy Efficiency Target Monitoring System in order to progress with the targets set out in the strategy. The strategy set an overall reduction target in energy intensity of 12% by 2030 relative to the 2015 baseline, and sectoral energy intensity improvements of 15% in both the commercial/public building and the residential sector. The strategy aims to stimulate further energy efficiency improvements through a combination of fiscal and financial incentives, a robust legal and regulatory framework and enabling measures.

87 https://link.springer.com/article/10.1007/s12053-018-9657-1
88 https://www.iea.org/reports/market-based-instruments-for-energy-efficiency
89 https://unfccc.int/sites/default/files/resource/Final%203rd%20BUR%20of%20South%20Africa%20100.pdf (page98)

7. Energy performance standards

Building codes are a voluntary or mandatory set of regulations established geographically (at the regional, national or state level), which address energy use in buildings (with similar arrangements for appliances). To be effective, building codes and other minimum energy performance standards for products and equipment should be mandatory and be effectively administered. It is possible to start the process by introducing voluntary or advisory standards, but if these prove ineffective in shifting the market, codes and standards should become mandatory and also subject to periodic review and improvement.

Building codes addressing energy performance form the bedrock of policies to influence energy consumption in buildings. They specify minimum performance requirements for building fabric components such as walls, roofs, floors, windows and doors, as well as aspects such as airtightness, solar shading and thermal bridges. The essential aspect here is to control the heat transfer through the external shell of a building, and also between occupied and unoccupied parts of the building (e.g. garages, basements). Other requirements concern the technical performance of equipment such as HVAC plant, boilers, water heating, lights and appliances.

Box 28

Energy performance of Building Directives – case of EU

The EU has established a wide range of policies that seek to deliver on its ambition to achieve carbon neutrality by the middle of this century. In the field of energy, the clean energy for all Europeans package[90] establishes a comprehensive policy framework to facilitate the transition away from fossil fuels. Within this package, the energy performance of buildings directive (EPBD)[91] drives the agenda concerning building energy performance. The EPBD was initially introduced in 2002 and revised and strengthened in 2010 and 2018. The directive sets the context for national-level policy and strategy development across 27 EU member States and the European Free Trade Association with its 4-member States and is also voluntarily adopted (in full or in part) by some non-EU countries, notably members of the Energy Community.

Among the key initiatives within the EPBD are requirements for countries to:

- Set minimum performance standards for buildings and technical systems;
- Develop national long-term renovation strategies;
- Establish and maintain certification systems for buildings;
- Implement auditing regimes for buildings;
- Implement inspection regimes for key technical equipment;
- Ensure that all new buildings are to be nearly zero-energy buildings;
- Develop financing initiatives to support the transition towards an energy-efficient, decarbonized building stock;
- Report regularly on progress.

90 https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
91 https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1529483556082&uri=CELEX:32018L0844

Some countries, particularly northern ones with colder climatic conditions, have had building codes in place for many decades. For others it is a more recent manifestation, while some countries still do not have any codes. Where such codes have been in place for a while, a notable feature is the periodic review, typically every five years or so, under which standards are often tightened.

Box 29

Improvement of Energy Consumption Performance of Buildings Act – case of Japan

Japan has implemented a wide range of energy efficiency requirements to achieve GHG emissions and energy savings targets. One primary component of its plan in 2017 was the Act on the Improvement of Energy Consumption Performance of Buildings. The Act stipulates that all buildings (new and retrofit) must adhere to mandatory certification standards and provides a comprehensive scheme for the evaluation of energy conservation compliance and building certification/inspection.

Additionally, the Act increased the stringency of the Building-Housing Energy Efficiency Labelling System (which involves third-party verification) and provided an updated methodology for energy consumption in commercial buildings.[92]


© Getty Images

Building codes are clearly vital for all new buildings going forward and should be seen as a high priority in any jurisdiction where they are currently absent. They should also be deployed for existing buildings, whenever any building component such as windows or air-conditioning plant is being replaced. In both cases, key to the achievement of the desired mitigation outcome is an effective monitoring and compliance regime.

While in some countries or territories building codes are voluntary, or cover only certain elements, they can only be truly effective if they are mandatory and comprehensive across all aspects affecting energy use in buildings. That said, Japan has a voluntary regime in place, but is commended for providing benefits for exceeding the minimum code.

A survey found that building codes (whether mandatory or voluntary) are starting to be implemented increasingly on the global level.[93] A total of 73 countries have building codes of some kind, including most of Europe, North America, China and parts of South America and Africa. However, not all building codes cover all buildings – for example, some have codes addressing only new building.

92 www.nilim.go.jp/english/hottopics/pdf/housing1.pdf
93 UNEP and GlobalABC (2020) page 31.

Box 30

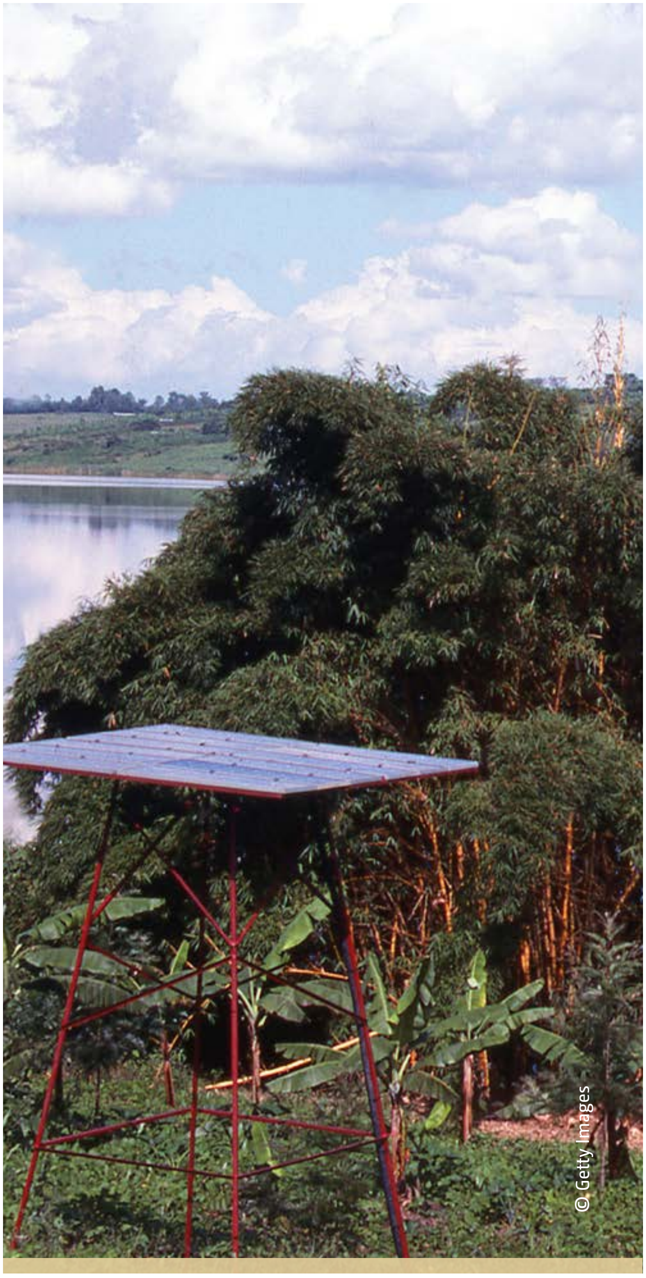
Green Buildings Minimum Compliance System – case of Rwanda

Rwanda recently established national building codes with the Green Building Minimum Compliance System. The intention is to align with the United Nations Sustainable Development Goals (in particular goals 3, 7, 8, 9, 11, 12, 13 and 15). Owing to the rapid growth and urbanization occurring in Rwanda, emphasis is on ensuring that the new building stock requirements are in line not only with international goals but also with the recently established national standards.

Rwanda has created extensive green building indicators and point allocation checklist as well as minimum compliance scoring criteria to guide the implementation process. The checklist outlines which standards are mandatory and which voluntary and sets out the required minimum score for compliance. Standards cover a range of building topics from lighting efficiency to solar hot water systems and thermal comfort. The building code compliance system also includes methodologies and detailed instructions for assessing criteria, as well as baseline values and U-values for building components. These tools serve as a useful resource to help building stakeholders to implement the new building codes.

A priority area for policy development in those countries that lack building codes for both new buildings and existing ones, where coverage of the building codes are incomplete or where level of required energy performance is low. In such cases countries can be guided by the approaches undertaken in other countries or follow the international standard for calculating the energy performance of buildings. For example, International Organization for Standardization (ISO) standards, primarily ISO 52000-1:2017, which provides a comprehensive structure for assessing the energy performance of new and existing buildings (EPB). ISO 52000-1:2017 is the overarching standard used in assessing the energy performance of buildings.

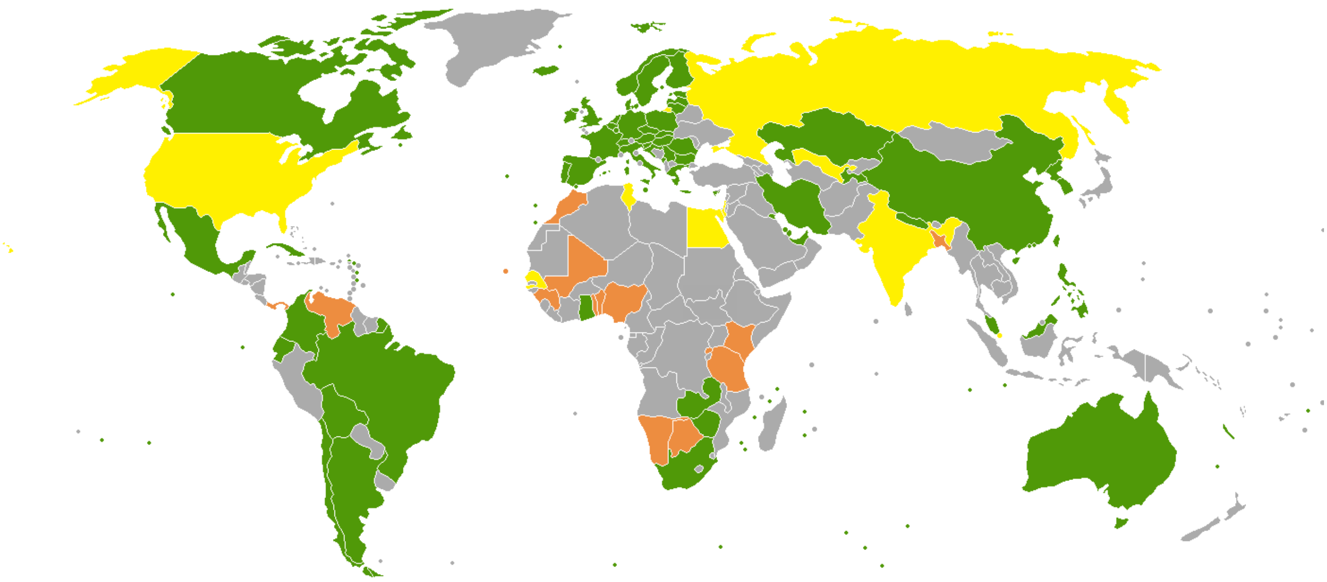
ISO 52000-1 adopts a holistic approach, taking into account overall building energy use for new and existing buildings and provides overall transparency. The standard considers the climatic conditions and building type, the energy needs of the building system and the technical building components. It includes energy performance indicators and calculation methods for heating and cooling, as well as templates for input data. The ISO standards provide a uniform procedure that can harmonize and guide different national processes.



8. Banning inefficient products (Minimum energy performance standards for appliances)

One effective way to improve the energy performance of a whole class of products is to implement a ban on inefficient ones. The best example is the ban on incandescent light bulbs implemented in many places around the world. The development of more efficient and affordable alternatives, initially compact fluorescent lamps and now LEDs, has enabled this ban to be applied successfully, leading to a significant improvement in the energy efficiency of lighting. Figure 17 shows the status of different countries with regard to a full or partial ban and countries with light bulb exchange programmes.

Figure 17
Global distribution of policies to ban inefficient lighting[94]



Full ban
Partial ban
Programmes to exchange light bulbs with more efficient types

94 https://commons.wikimedia.org/w/index.php?curid=19049409.

Box 31

Energy Efficiency Standardization – case of UAE

UAE initiated the Energy Efficiency Standardization and Labelling (EESL) Program in 2012[95]. The Program includes 3 key stages for any appliance:

- Banning Low performing products (obsolete) by setting a minimum efficiency target.
- Setting Performance Rating (1 to 5-star rating) for eligible products by comparing input and output performance measurement of the appliance.
- Provision of financial Incentive for higher performing appliances in term of fee reduction alongside by a display of information using unique National Label.

EESL program has prioritized products/appliances according to the energy consumption, magnitude of products in the market and product efficiency potential. As a result, the program is covering the following product categories: (2013) Clothes washing machines and dryers, (2014) Non-ducted Room Air-conditioners, (2014) Household refrigerators and freezers, (2016) Dishwashers, (2017) Television sets/panels, (2017) electric ovens, (2017) elevators, (2017) Vacuum cleaner.

9. Mandatory renovation

There are various examples of so-called "mandatory" renovation which requires building owners to improve their properties at certain trigger points or within a certain time frame. Analysis by the Buildings Performance Institute Europe identified a range of trigger points[96] in operation in Europe, North America and Oceania.

95 United Arab Emirates 2019 revised 4th National Communication, page 85. Available at https://unfccc.int/documents/192549

96 http://bpie.eu/publication/renovation-in-practice

Table 14
Examples of mandatory building renovation in different countries

Mandatory renovation within a specific time frame	In **Germany**, retrofitting obligations under the Energy Saving Ordinance must be fulfilled by building owners within a specific time frame. All such obligations, some of which have been in force for over 10 years, are also subject to the precondition of cost-effectiveness. They cover insulation, the replacement of old boilers and the installation of renewable energy systems when replacing a heating system in an existing building.
Progressive improvement	In **Brussels, Belgium**, owners of non-residential buildings must develop an action plan to reduce primary energy consumption and implement cost-effective measures. This process is repeated every five years. **France** has introduced a requirement for owners of non-residential buildings to progressively reduce energy consumption: 40% by 2030, 50% by 204 and 60% by 2050.
Improvement of energy performance on the occasion of other works	The **French** Law on Energy Transition for Green Growth includes requirements for upgrading the energy performance of a building on the occasion of other works, such as renovating a facade, re-roofing or undertaking a loft conversion.
Minimum energy performance standards	Since 2018 In the **United Kingdom**, residential and non-residential properties must achieve an Energy Performance Certificate rating of at least energy class E before they may be let by private landlords. France has introduced a similar requirement for all residential buildings from 2022. The **Flemish region of Belgium** has similar requirements for non-residential buildings, while in the **Netherlands** it applies to office buildings.
Mandatory emission intensity limits	**New York City, United States**, has proposed maximum emission levels for residential and non-residential buildings. It will be introduced progressively, starting with the largest buildings and eventually covering 75% of all buildings. Large-building owners must report energy and water consumption annually. If a building exceeds the emission limit for that property type, the owner must pay a fee based on the actual emission level.
Requirements in the case of change of building use	**Denmark** has established minimum energy requirements for building components in the case of change of building use, including the conversion of an outbuilding or usable roof space to accommodation.
Mandatory renewable energy supply when a boiler needs replacement	The Renewable Heat Act is a state law applying in **Baden-Württemberg** in southern **Germany**. Since January 2010, state authorities have required building owners to cover a minimum of 10% of their heat energy demand with renewable energy when replacing a boiler. The new version of the law came into force in July 2015, raising the threshold to 15%. A similar rule applies for the region of **Bolzano, Italy**. When a heat generator is replaced or renewed, renewable energy sources must provide at least 25% of overall primary energy demand and 60% of energy demand for water heating.
Green Leases	**Australia** has imposed a requirement for tenants and owners to mutually agree energy efficiency targets for leased government buildings. It is monitored by yearly reporting of energy consumption, by fuel type.
Healthy Homes	The Healthy Homes Standard became law in **New Zealand** in 2019, whereby all rental accommodation must meet certain minimum levels of heating provision, insulation level and ventilation performance
Mandatory requirements in the case of building extension	Various regions and cities in **Italy** have introduced mandatory building performance upgrades in the case of building extension.

5.2.2 Assessing the impact of policies

Policy-makers and stakeholders interested in estimating the impact of a policy may wish to refer to *Buildings Efficiency Guidance* (Initiative for Climate Action Transparency 2018), which deals comprehensively with the topic of impact assessment. According to this guidance, the main reasons for undertaking impact assessments are as follows:

- To improve policy selection, design and implementation;
- To inform goal setting by assessing the potential contribution of policies to national goals and targets, such as NDCs;
- To assess policy effectiveness by determining whether policies are delivering the intended results;
- To inform future policy design;
- To learn from experience and share best practices about the policy impacts;
- To track progress towards national goals and targets such as NDCs and understand the contribution of policies towards achieving them;
- To report, domestically or internationally, including under the Paris Agreement's enhanced transparency framework, on the impacts of policies achieved to date;
- To meet funder requirements to report on the GHG emissions impacts of policies.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Mitigation actions create multiple impacts (economic, social and environmental) over different timeframes (near-term and long-term), geography (national, local and individual level) and stakeholders. A comprehensive assessment of multiple costs and benefits may require too heavy burdens for practitioners; nevertheless, efforts to more explicitly analyse the multiple impacts, even if not their magnitude, contribute to linking mitigation actions with other policy objectives such as the Sustainable Development Goals. The Initiative for Climate Transparency's "Sustainable Development Methodology"[97] offers general guidance to conduct assessment of sustainable development impact.

5.3 Climate finance

It is important for policy-makers to consider the mobilization of climate finance from both within the country and internationally to support initiatives and strategies to reduce GHG emissions in the building and construction sector. Under the UNFCCC and the Paris Agreement, developed countries provide financial support to developing countries through the Financial Mechanism. The operation of the Financial Mechanism is entrusted to the GEF and the GCF. Decisions on climate change policies, programme priorities and eligibility criteria for funding are determined by the Conference of the Parties, to which the Financial Mechanism is accountable.

97 https://climateactiontransparency.org/wp-content/uploads/2020/04/Sustainable-Development-Assessment-Guide.pdf

Green Climate Fund[98]

The GCF is the largest international fund dedicated exclusively to helping developing countries to deal with climate change. The GCF has a multi-layered approach to mobilizing climate finance, working directly with the public and private sectors. It is important to note that developing countries are in the driving seat of GCF targeting and disbursement of climate finance. National designated authorities serve as the interface between developing countries and the GCF and are involved closely in all of GCF's funding processes.

Box 32

Reducing emissions from Bosnia and Herzegovina's public buildings

Bosnia and Herzegovina have a large stock of ageing buildings with high energy consumption that are heated by high-emission fossil fuels. This is a consequence of neglect and under-investment during and after the Bosnian War (1992-1995), leaving buildings in urgent need of upgrade. Energy efficiency retrofits and substituting coal and fuel oil with biomass will significantly reduce emissions from public buildings. This GCF project[99], will affect 7-8% of stock, some 360 public buildings. Technical assistance will also help to address non-financial barriers and create supportive policies, regulations and capacities to support the transformation and encourage replication. The project has an estimated lifespan of 20 years. Approved funding of USD 17.3 million is set to leverage an additional USD 105 million of co-finance from a range of sources, such as environmental funds, entity and municipal budgets, and international organizations (United Nations Development Programme, GEF, World Bank, Swedish International Development Cooperation Agency), by addressing country- and sector-specific investment risks.

Global Environment Facility[100]

The GEF provides funding to developing countries and countries with economies in transition for projects across a range of environmental topics, including climate mitigation in the building and construction sector. The funding comes in the form of grants and concessional funding and covers the incremental or additional costs associated with transforming a project with national benefits into one with global environmental benefits.

Box 33

Promoting low-cost energy-efficient wooden buildings – case of Turkey

The objective of this project[101], under the GEF is to promote the use of innovative wood-based technologies as low-carbon construction materials in Turkey as a means of reducing the embedded carbon content of construction material and enhancing carbon sequestration over the building's lifetime. This could lead to an additional 1.5 million m^2 new construction in wood by 2026.

In 2014, it was estimated that 151 million m^2 new buildings were constructed in Turkey, corresponding to over 50,000 new buildings. Only 290,000 m^2 (0.13%) used wooden frames and wooden materials. With the support of this project it is estimated that an additional 1% of all new buildings will be constructed from wood. GHG emissions from construction will be reduced by 197,716 t CO_2 eq per annum. The Project secured USD3.8 Million in GEF funding, with leveraged co-financing from third parties estimated at USD34 Million.

98 https://www.greenclimate.fund/
99 https://www.greenclimate.fund/document/scaling-investment-low-carbon-public-buildings
100 http://www.thegef.org./
101 https://www.thegef.org/sites/default/files/web-documents/10090_PIF.pdf

Chapter summary

This chapter focussed on policies and strategies that may enhance mitigation actions in the building and construction sector. The chapter emphasised on the need for policy makers to understand the benefits and impacts of mitigations actions. Key points to consider are:

- To be effective, a strategy to reduce the carbon emissions from the building stock needs to encompass a holistic range of policies, plans, programmes and measures;
- It is important to consider the examples in this chapter of the broad types of policies designed to reduce energy demand in buildings from a low towards a higher level of commitment and obligation;
- Policy-makers and stakeholders interested in estimating the impact of a policy may wish to refer to Buildings Efficiency Guidance (Initiative for Climate Action Transparency, 2018), which deals comprehensively with the topic of impact assessment;
- It is important for policy-makers to consider the mobilization of climate finance from both within the country and internationally to support initiatives and strategies to reduce GHG emissions in the building and construction sector.

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ANNEX 1 – OVERVIEW OF EXISTING METHODOLOGIES RELATED TO BUILDINGS

Technology	Methodology
Lighting	CDM-AMS-II.J Demand-side activities for efficient lighting technologies
	CDM-AM0046 Distribution of efficient light bulbs to households
	CDM-AM0113 Distribution of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps to households
	CDM-AMS-II.N Demand-side energy efficiency activities for installation of energy-efficient lighting and/or controls in buildings
	CDM-AMS-III.AR Substituting fossil fuel based lighting with LED/CFL lighting systems
	CDM-AMS-II.L Demand-side activities for efficient outdoor and street lighting technologies
Cooking	CDM-AMS-I.K Solar cookers for households
	GS Thermal energy from plant oil for the user of cooking stoves
	CDM-AM0094 Distribution of biomass based stove and/or heater for household or institutional use
	CDM-AMS-II.G Energy efficiency measures in thermal applications of non-renewable biomass
	GS Simplified methodology for efficient cookstoves
	GS Methodology for Improved Cook-stoves and Kitchen Regimes
Appliances	CDM-AMS-II.O Dissemination of energy efficient household appliances
	CDM-AMS-II.C Demand-side energy efficiency activities for specific technologies
Insulation	VCS-VM0008 Weatherization of Single Family and Multi-Family Buildings
	GS Thermal performance improvements in low-income dwelling structures
Heating	CDM-ACM0023 Introduction of an efficiency improvement technology in a boiler
	CDM-AMS-II.R Energy efficiency space heating measures for residential buildings
	CDM-AM0056 Efficiency improvement by boiler replacement or rehabilitation and optional fuel switch in fossil fuel-fired steam boiler systems
Cooling	CDM-AM0060 Power saving through replacement by energy efficient chillers
Water heating	CDM-AMS-I.J Solar water heating systems
Electricity generation	CDM-AMS-I.A Electricity generation by the user
	CDM-AMS-I.L Electrification of rural communities using renewable energy

Technology	Methodology
Fuel switching	CDM-AMS-II.E Energy efficiency and fuel switching measures for buildings GS Ecologically sound fuel switch to biomass with reduced energy requirement CDM-AM0036 Fuel switch from fossil fuels to biomass residues in heat generation equipment CDM-AMS-III.B Switching fossil fuels CDM-AM0091 Energy efficiency technologies and fuel switching in new and existing buildings CDM-AMS-III.AH Shift from high carbon intensive fuel mix ratio to low carbon intensive fuel mix ratio CDM-AMS-III.AG Switching from high carbon intensive grid electricity to low carbon intensive fossil fuel GS Fuel switch from fossil fuels to biomass residues in boilers for heat generation CDM-AMS-I.I Biogas/biomass thermal applications for households/small users CDM-AMS-I.E Switch from non-renewable biomass for thermal applications by the user
New building	CDM-AMS-III.AE Energy efficiency and renewable energy measures in new residential buildings
Commercial buildings	CDM-AMS-II.Q Energy efficiency and/or energy supply projects in commercial buildings
Data Centres	CDM-AM0105 Energy efficiency in data centres through dynamic power management
Campuses	VCS-VM0025 Campus Clean Energy and Energy Efficiency VCS-VMD0038, Campus-Wide Module
Certification	VCS-VMD0039 LEED-Certified Buildings Module
Refrigeration	CDM-AMS-III.X Energy Efficiency and HFC-134a Recovery in Residential Refrigerators CDM-AMS-III.AB.: Avoidance of HFC emissions in Standalone Commercial Refrigeration Cabinets
Construction	AMS-III.BH Displacement of production of brick and cement by manufacture and installation of gypsum concrete wall panels

United Nations
Framework Convention on
Climate Change