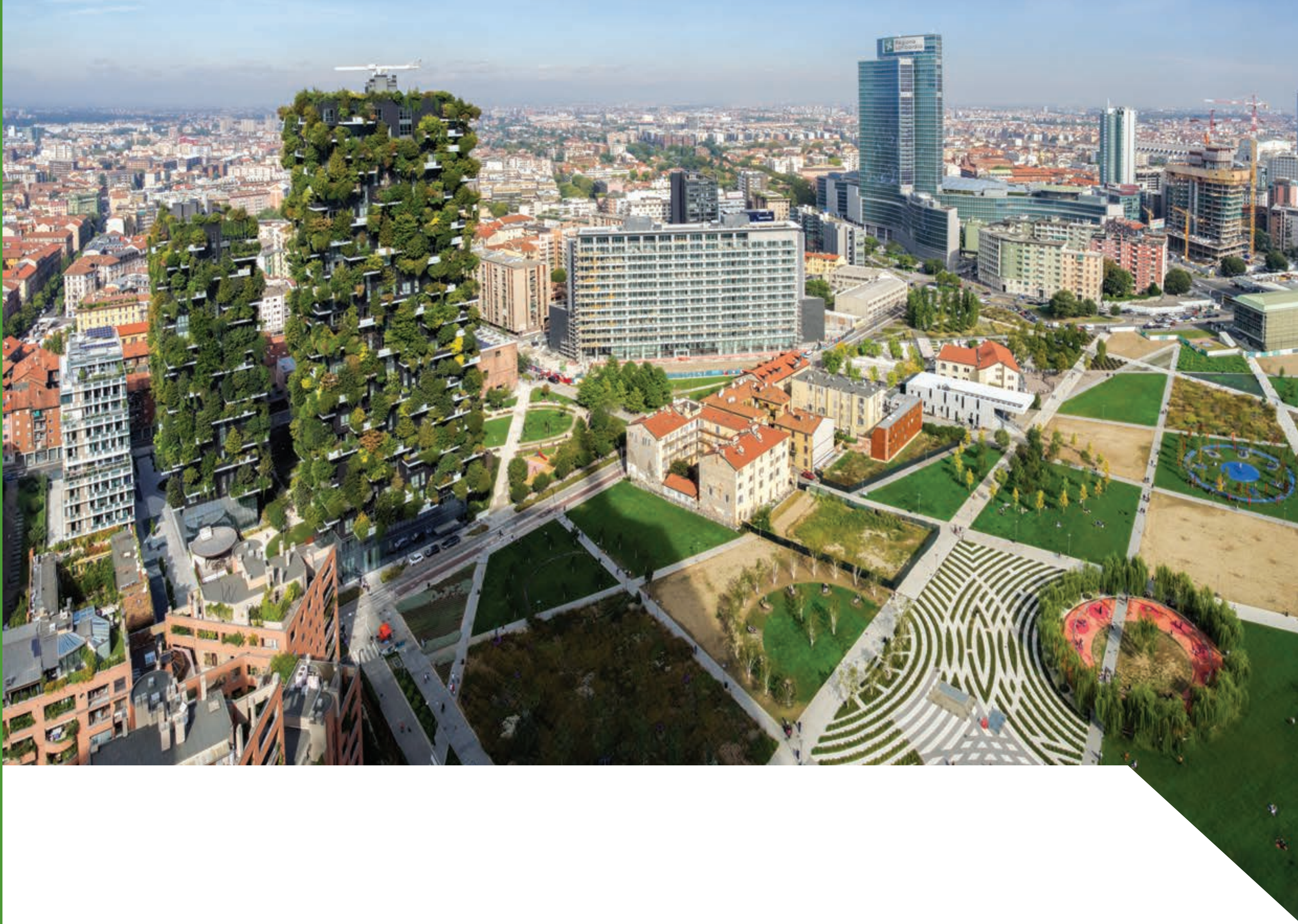

BUILDING CODE CHECKLIST FOR GREEN BUILDINGS

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Global Facility for Disaster Reduction and Recovery

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Singapore. Photo: © Miki Fernández

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List of Acronyms

AAC	Autoclaved Aerated Concrete (type of masonry block)
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BEM	Building Energy Modelling (software)
BMS	Building Management System
BRCA	Building Regulatory Capacity Assessment
BREEAM	Building Research Establishment Environmental Assessment Method
BRR	Building Regulation for Resilience
BRTS	Bus Rapid Transit System
CO_2	Carbon dioxide
DGU	Double Glazed Unit
DRM	Disaster Risk Management
DtS	Deemed-to-Satisfy
EDGE	Excellence in Design for Greater Efficiencies
EIA	Environmental Impact Assessment
EPI	Energy Performance Index
ETP	Effluent Treatment Plant
EUI	Energy Use Intensity
GFDRR	Global Facility for Disaster Reduction and Recovery
GGBS	Ground Granulated Blast Furnace Slag
GHG	Green House Gases
GRIHA	Green Rating for Integrated Habitat Assessment
HSA	Horizontal Shading Angle
HVAC	Heating, Ventilation and Air Conditioning
IBQC	International Building Quality Centre

ICC	International Code Council
IES	Integrated Environmental Solutions
IGBC	Indian Green Building Council
IgCC	International Green Construction Code
IPTU	Imposto Predial e Territorial Urbano (Property and Urban Land Tax)
LEED	Leadership in Energy and Environmental Design
MLIT	Ministry of Land, Infrastructure, Transport and Tourism in Japan
NDC	Nationally Determined Contributions
NZE	Net Zero Energy
OTTV	Overall Thermal Transfer Value
PFC	Power Factor Correctors
PPC	Pozzolanic Portland Cement
PUF	Poly-urethane Foam
PV	Photovoltaic
RCC	Reinforced Cement Concrete
RE	Renewable Energy
SDG	Sustainable Development Goal
SHGC	Solar Heat Gain Coefficient
STP	Sewage Treatment Plant
SWH	Solar Water Heaters
USGBC	United States Green Building Council
VM	Verification Method
VOC	Volatile Organic Compound
VSA	Vertical Shading Angle
WWR	Window to Wall Ratio

1.Overview

Rapid urbanization and population growth are driving the construction of new buildings, with global building stocks expected to double in the next 15 to 20 years.[1] While such trends will represent significant development advances and offer economic growth opportunities, concern remains regarding the resilience and safety of new and aging building stocks, increases in energy and water consumption, and accessibility of the existing and evolving built environment and infrastructure that support the living environment and lifestyle. Furthermore, new developments will increase exposure to climate and disaster risks because of the evolving impact of climate change depending on location and governing standards to be followed. Additional vulnerability can be compounded in unregulated and informal settlements where buildings are constructed in a high-density manner on, risky sites using substandard building materials and lack of safe design and construction practices. The combination of urbanization and climate change poses significant challenges for countries and cities to form a comprehensive set of regulatory and policy instruments to guide a resilient, sustainable, and accessible built environment.

The World Bank's Disaster Risk Management (DRM) portfolio support countries to design and implement diversified investments for risk reduction and preparedness. Among various approaches, improving the building regulatory framework and implementation capacity proves to be one of the most cost-effective means of reducing underlying climate and disaster risks[2] in combination with investments for physical structural improvements/retrofits. In this context, the Global Facility for Disaster Reduction and Recovery (GFDRR)'s global line of work (BRR) aims to promote resilient, green, healthy, and inclusive built environments through enhanced regulatory frameworks and implementation capacities.

The BRR offers technical support and advisory services for governments by analyzing the existing regulatory framework and capacity of target countries utilizing the Building Regulatory Capacity Assessment (BRCA) methodology, which identifies key issues and targeted recommendations for countries for priority actions, potentially as part of the DRM investments financed by the World Bank or any other financial sources.

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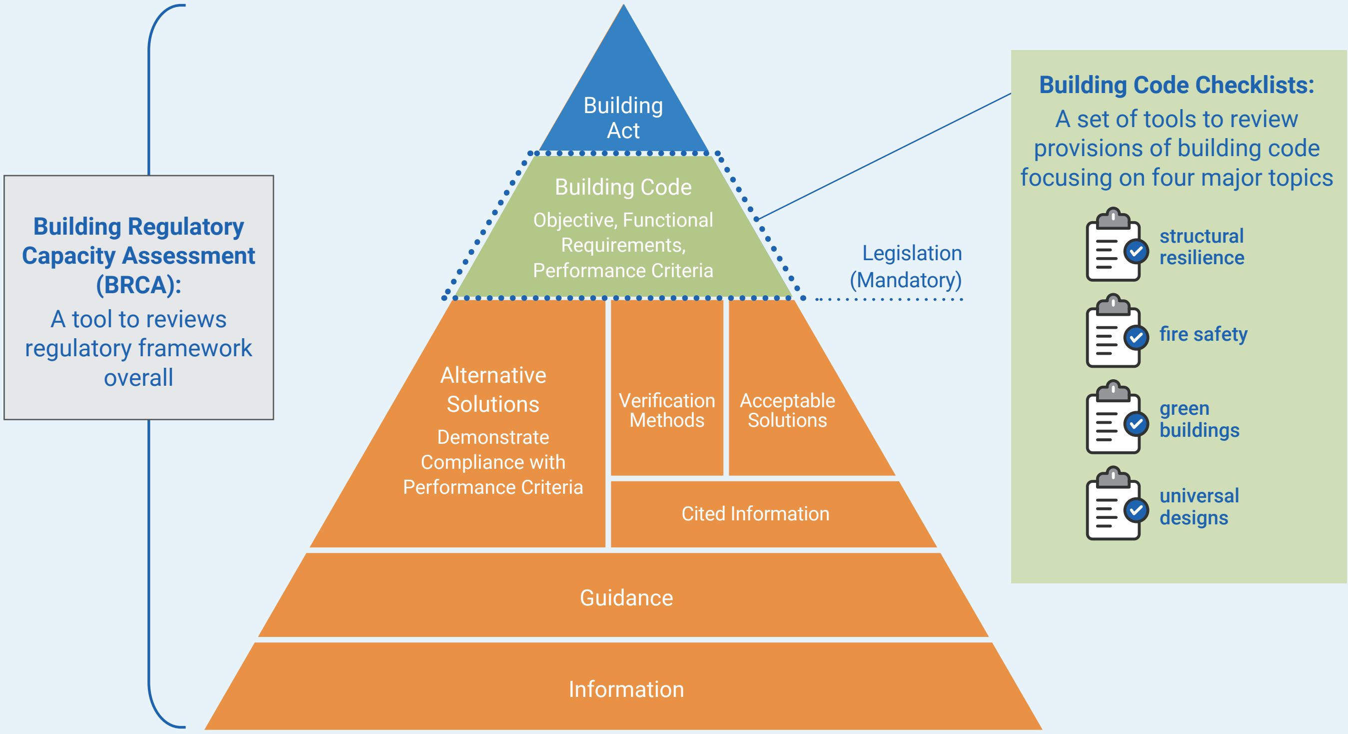
[1] Global Alliance for Buildings and Construction. 2022. "Global Status Report for Buildings and Construction." https://globalabc.org/sites/default/files/2023-03/2022%20Global%20Status%20Report%20for%20Buildings%20and%20Construction_1.pdf.

[2] Global Facility for Disaster Reduction and Recovery. 2016. "Building Regulation for Resilience: Managing Risks for Safer Cities." https://www.gfdrr.org/en/publication/building-regulation-resilience-0.

As the BRR expands, demand has grown for technical advice on details of building codes based on global knowledge and practice. Responding to such requests, the BRR has developed a set of checklists that support countries in assessing the comprehensiveness and depth of their building code provisions, focusing on four major elements: structural resilience, fire safety, green buildings, and universal accessibility. This will help countries (or professionals commissioned by governments) assess their own codes against consolidated checklists referring to global good examples. The methodology has been developed for subject matter experts in each discipline with basic engineering and architectural backgrounds. Although each document presents a methodology, users can contact the Global Facility for Disaster Reduction and Recovery for worksheets for convenient use. This document presents a checklist for **green buildings**.

Figure 1. Objectives of different BRR tools



Source: Figure adapted and modified from the original figure by Building and maintaining New Zealand's homes and buildings.

2. Introduction

Rapid urbanization in developing countries, with Africa and Asia expected to account for 90% of the projected urban population growth by 2050, will increase demand for buildings and spur construction in those countries. An estimated 1 billion new dwelling units will be constructed in low- and middle-income countries by 2050, which is expected to double the building stock over the next 15 to 20 years. Although these trends represent significant development advances and offer economic growth opportunities in developing countries, there is concern regarding increased energy and water consumption in the evolving urban spaces, including the built environment and infrastructure that support living environments and lifestyles. New developments may also create a more resource-intensive built environment if they are designed without using energy- and water-efficiency approaches.

Globally, buildings account for 37% of energy and process-related carbon dioxide (CO_2) emissions (Figure 2).[3] With increasing urbanization and population growth, demand for energy will continue to increase faster than the supply of renewable energy. This means that increasing the efficiency of current energy use is critical to climate change mitigation efforts while also meeting the development requirement of growing economies. Regulations that can increase the energy efficiency of buildings and reduce the carbon footprint of buildings are thus vital to reducing greenhouse gas (GHG) emissions and to achieving the Paris Agreement's goal of keeping the increase in average global temperature below 2°C.

Building regulations cover a broad set of disciplines, including structural safety; fire safety; electrical and plumbing design; and

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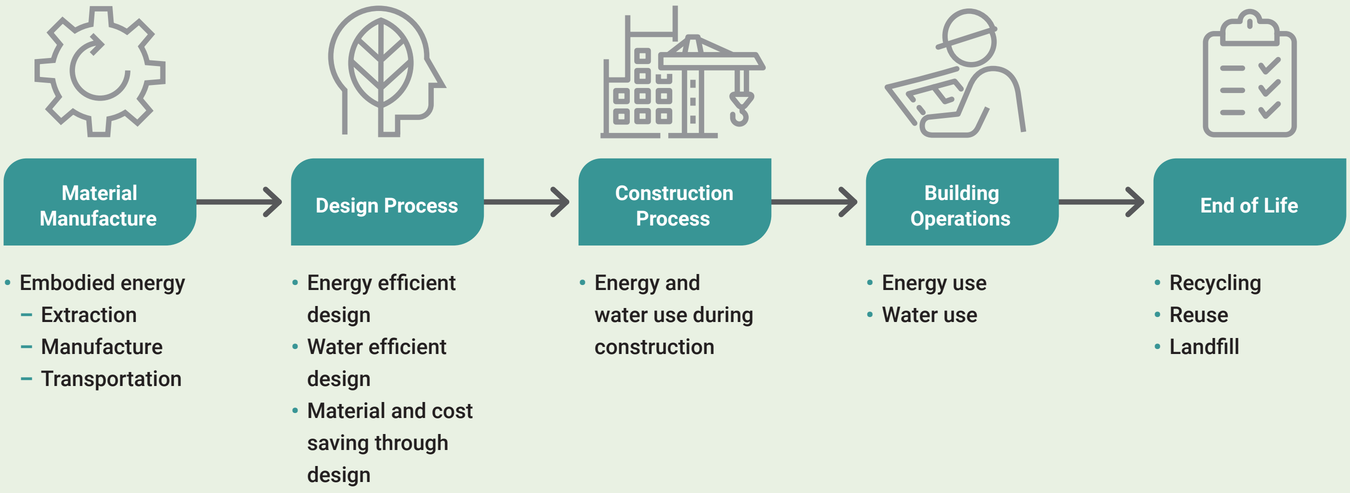
[3] UN Environment Programme and Global Alliance for Buildings and Construction. 2022 Global Status Report for Buildings and Construction (https://globalabc.org/our-work/tracking-progress-global-status-report).

more recently, sustainable or green building regulations. Resource efficiency of the built environment is a relatively new concept for emerging markets, where the clear benefits of green buildings are not widely shared and acknowledged. Green building regulations are an important part of climate resilience and sustainability of the built environment. The aim of a green building is to consume as few resources as possible while providing comfort for occupants. Decreasing resource consumption will reduce GHG emissions caused due to building construction and use.

The definition of green buildings can vary, but the World Green Building Council defines them as buildings that reduce or eliminate negative impacts on the climate and natural environment during their design, construction, and operation while also creating positive impacts and that help preserve natural resources and improve quality of life. The council identifies several features that can make a building green, including efficient use of energy, water, and other resources; use of renewable energy sources such as solar; use of measures to reduce pollution and waste and enable re-use and recycling; good indoor air quality; consideration of occupants' quality of life during design, construction, and operation; use of nontoxic, ethical, sustainable materials; consideration of the environment during design, construction, and operation; and a design that enables adaptation to a changing environment. Residential, office, educational, health care, institutional, or any other type of structure can be a green building, provided it includes these features.

Figure 2. Resource Use throughout Building Lifetime



Built Environment Sector as Green House Gas (GHG) Emitter

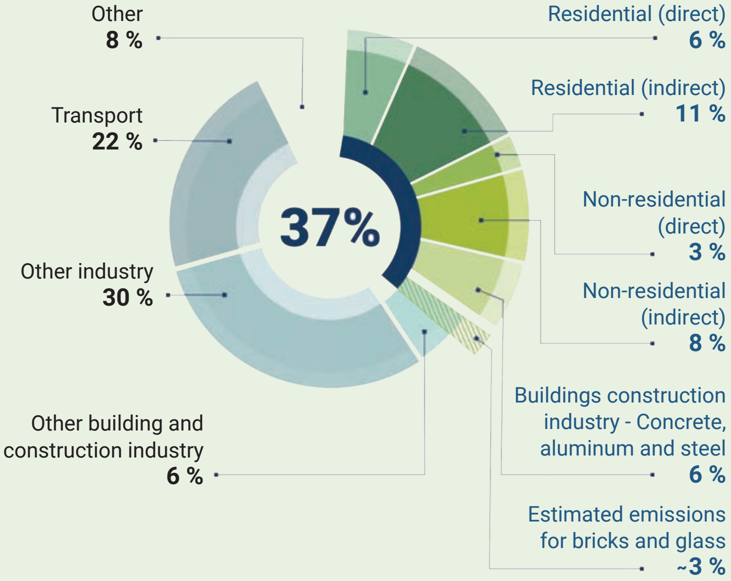
Buildings use energy and are GHG emitters throughout their lifecycle. The energy use of buildings includes the manufacture of the materials used during construction, building design, the construction process, how the building is operated, and its end of life and how it is disposed of (Figure 3). Consumption of energy in buildings depends on each of these, and various factors, such as design quality and human comfort (e.g., temperature, lighting, and water availability), can affect it.

It is useful to divide GHG emissions from the building lifecycle into two categories: (i) embodied energy of building materials and (ii) energy use in buildings during their operational lifetime. Embodied energy refers to the energy used for raw material extraction, manufacturing, processing, and transportation. Regulations and green building rating systems encourage or mandate use of low-embodied-energy materials. Energy use in buildings is primarily for space cooling and heating, lighting, pumps, fans, and other equipment. Most of a building's energy use occurs during its operational lifetime, so the benefits of green buildings are best realized when the total cost of construction, operation, and maintenance is analyzed, not construction costs alone. A building that does not incorporate green building principles in its design will remain resource inefficient throughout its minimum 50-year lifespan. With global warming, cooling loads on buildings will continue to increase, which will increase energy use.

Global Commitments for Greening the Built Environment

Green buildings also play an important role in achieving global development commitments, including the Sustainable Development Goals

Figure 3. Global Share of Buildings and Construction Operational and Process CO_2 Emissions, 2021

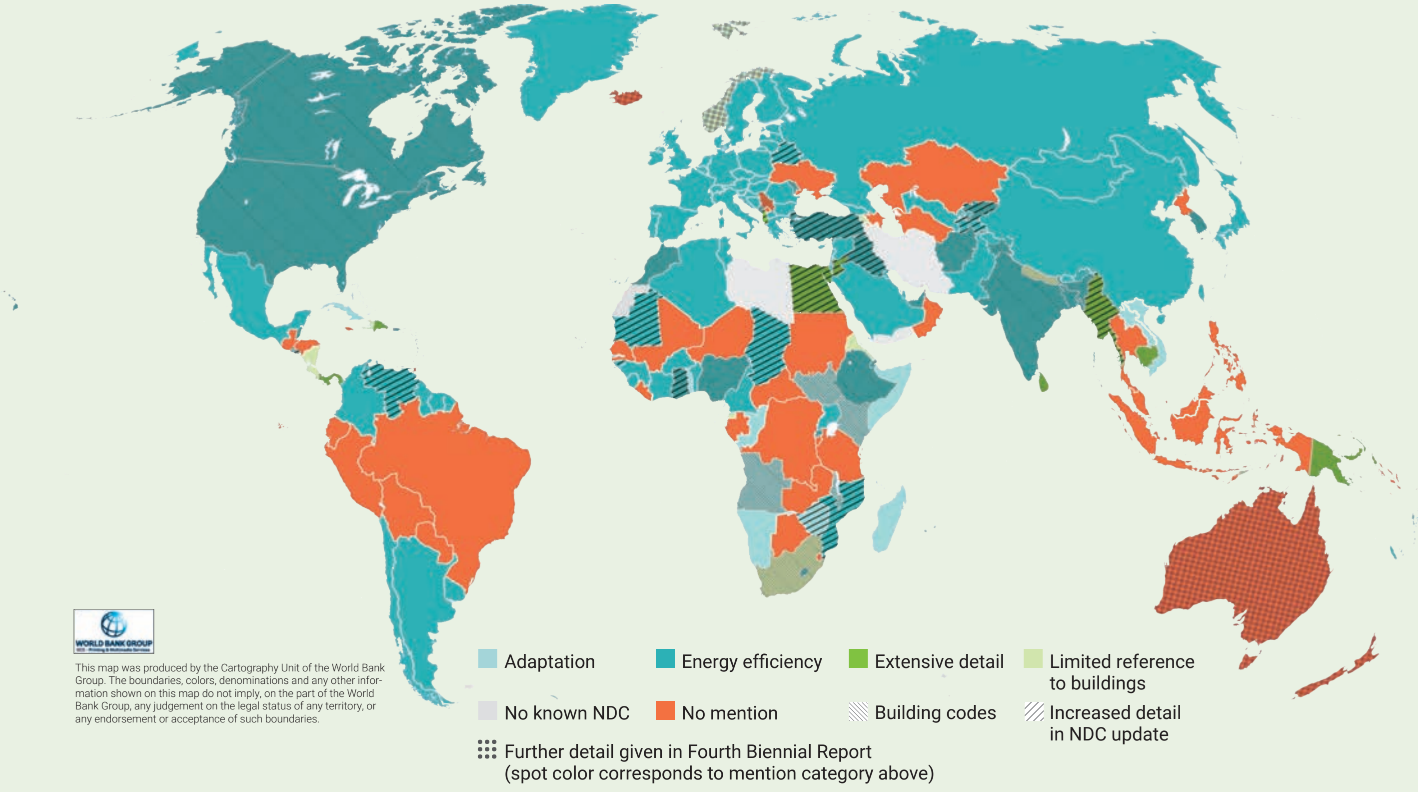


(*Source:* UN Environment Programme and Global Alliance for Buildings and Construction. 2022 Global Status Report for Buildings and Construction)

(SDGs)[4] established by the United Nations. For example, promoting good health and well-being (SDG3), providing affordable and clean energy (SDG7), supporting decent work and economic growth (SDG8), fostering industrial innovation and infrastructure (SDG9), creating sustainable cities and communities (SDG11), encouraging responsible consumption and production (SDG12), taking climate action (SDG13), promoting life on land (SDG15), and fostering partnerships to achieve these goals (SDG17).

Many countries have included specific actions with respect to buildings in their Nationally Determined Contributions (NDCs), which are national plans with targets for GHG emissions.[5] According to the 2022 Global Status Report for Buildings and Construction,[6] 158 countries included buildings in their NDCs in 2021, which is a large increase from the 88 countries that did so in 2015, highlighting the growing importance of this sector in climate change mitigation efforts; 118 countries also incorporated energy efficiency of buildings as a component of their strategy for reducing emissions. Map 1 shows the countries that have included this sector in their NDCs and those that have yet to do so.

Map 1. Countries with Mention of Buildings in Their Nationally Determined Contributions



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Source: Adapted from original image by United Nations Environment Program. 2022. 2022 Global Status Report for Buildings and Construction.

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[4] https://sdgs.un.org/goals

[5] An NDC is a national plan that is not legally binding that outlines measures to mitigate climate change, including targets for reducing GHG emissions.

[6] https://www.unep.org/resources/publication/2022-global-status-report-buildings-and-construction

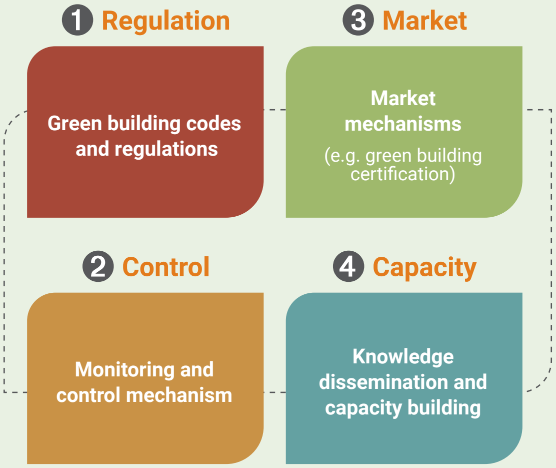
Despite growing recognition in NDCs of the importance of buildings, implementation of building energy codes must accompany the level of ambition in these targets. This report emphasizes the need for national and subnational governments to create compulsory building energy codes and establish a timeline for building codes and standards to attain net-zero status so that the Paris Agreement targets can be met.

GHG Reductions in the Built Environment

GHG reductions from the building sector can be achieved primarily through two methods: (i) building new structures using green building principles, and (ii) systematically retrofitting existing buildings. As shown above, many countries are promoting green buildings as part of their long-term decarbonization plans to meet their NDCs. These countries must simultaneously build new buildings with low GHG footprints and retrofit existing building stock to be able to meet their emission targets. It is expected that existing building stock will account for approximately two-thirds of total building stock in 2050,[7] making it vital to retrofit these buildings to reduce their carbon footprint. Similarly, all new construction must have net-zero emissions. The International Energy Agency's (IEA) report, Net Zero by 2050—A Roadmap for the Global Energy Sector,[8] recommends that more than 85% of buildings comply with zero-carbon-ready building energy codes by 2050, which can be done by establishing mandatory zero-carbon-ready building energy codes for all new buildings introduced in all regions by 2030, and that most existing buildings be retrofitted by 2050.

Four fundamental components work in tandem to create an enabling environment for a green built environment: (1) green building codes and regulations under a legislative framework; (2) monitoring and control mechanism of the regulatory implementation; (3) market mechanisms to invest in a green built environment, including green building certification; and (4) knowledge dissemination and capacity building for industry professionals (Figure 4).

Figure 4. Factors that Contribute to a Green Built Environment



Green building codes are sets of mandatory regulations and voluntary provisions that establish minimum standards for energy efficiency, water conservation, and other sustainability measures in new construction and major renovations. National and local

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[7] Climate Bonds Initiative. "Aligning Buildings with the Paris Climate Agreement: Insights and Developments from the Green Bond Market."

[8] https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.

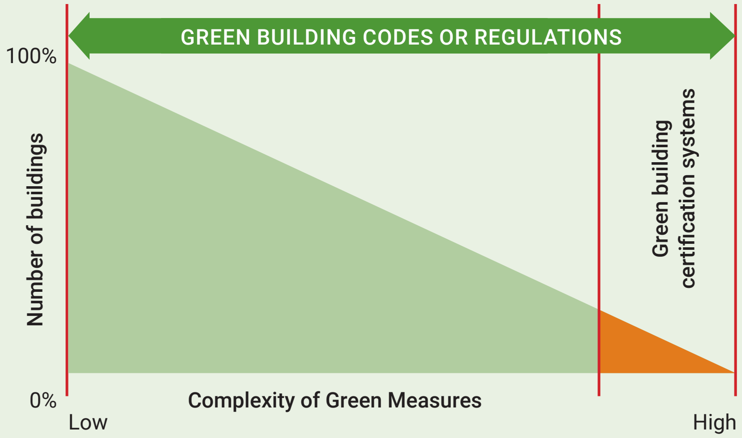
governments develop these codes, which are designed to ensure that all new buildings meet a minimum level of environmental performance. Green building regulations are designed to cover most buildings and most types of buildings, ensuring a significant impact on energy and water efficiency.

A monitoring and control mechanism of implementation of the legislative framework is usually considered to be an accountability mechanism to facilitate compliance. To support functioning control mechanism, a building asset database and a methodology and mechanism of building energy audits play important roles in recording a building's performance on water and energy efficiency.

To connect the regulatory framework and investments in green buildings, there are green building labeling systems and green building certification systems. In some countries, these are part of a regulatory system that the government manages; in other countries, it is a voluntary program that the private sector leads that provides third-party verification of sustainability features. Green building certification programs such as Leadership in Energy and Environmental Design (LEED)[9] and Building Research Establishment Environmental Assessment Methodology (BREEAM)[10] provide rating systems that assess a building's performance in areas such as energy efficiency, water conservation, and indoor air quality. These certification systems are often aimed at the upper end of the market and incorporate cutting-edge practices to demonstrate exemplary cases. Green building certification is usually voluntary and provides additional recognition for buildings that exceed minimum standards. Despite being voluntary, green building certification can encourage a green built environment by stimulating the market to promote green buildings and demonstrate best practices.

Green building codes and green building labeling and certification mechanisms work in tandem. Although codes and regulations set minimum standards and have a greater influence on emissions reductions for the overall built environment as a bottom-up approach, green building labeling and certification stimulate top-tier investors and building owners in investing more in green buildings. Figure 5 shows how these two mechanisms work together for different segments of the market.

Figure 5. Green Building Market - Roles of Green Building Regulations and Green Building Certification Systems



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[9] https://www.usgbc.org/leed

[10] https://bregroup.com/products/breeam/

Capacity building is also critical in transforming markets by disseminating knowledge and foster capacity to design buildings with green building solutions. Training programs must be provided for professionals involved in the building industry (e.g., architects, engineers, energy auditors, developers) to keep them up to date on global best practices.

Encouraging Investment in Green Buildings

In addition to regulatory framework, green buildings are also being promoted using incentive policies. These incentives may include:

- Expedited approvals: Government agencies may offer a fast-track process for obtaining building permits for green-rated projects, which would allow construction to start more quickly.
- Financial incentives: Governments may provide tax reductions and grants or subsidies.
    - Tax reductions: Governments may provide property tax rebates for a period of time after a property is occupied or rebates on stamp duties when transferring ownership of such properties.
    - Grants and subsidies: Governments can provide grants or subsidies to offset costs associated with green building projects. These can cover expenses related to energy-efficient equipment, renewable energy installations, or sustainable design and construction.
- Higher floor space index: Authorities may permit a higher floor space index, which allows a greater allowable built-up area for a given plot of land.
- Lower interest rates: Banks may offer lower mortgage rates, which allows property owners to save money or increase their budget.

Examples of incentives for green building include one used in Pune, India, where the municipal corporation provides a 5% to 15% rebate on property tax for Indian Green Building Code/Green Rating for Integrated Habitat Assessment–certified buildings and a 10% to 50% rebate on building license application fees, and one in Salvador, Brazil, where a discount of up to 10% on the property and urban land tax is given for buildings that install solar photovoltaic panels. Depending on the country context, other mechanisms may be developed to encourage adoption of sustainable building practices.

3. Objective

The Building Code Checklist for Green Buildings is designed to assist subject matter experts in the detailed review of green building provisions and other regulations.

This checklist facilitates a robust approach to reviewing green building provisions in building regulations by providing a list of fundamental green building components of building regulations, a systematic approach to reviewing green building provisions in regulations, and examples of how green building provisions are addressed within a range of exemplary building regulatory systems. Although this checklist can be applied without expertise and experience in green building regulations or design, such expertise and experience are valuable in navigating some of the complexities of codifying green building provisions.

The scope of green building provisions can be broad, including aspects of site and context, energy efficiency, water efficiency, building materials, construction measures, occupant health and comfort, and solid waste management. How these aspects are addressed can vary widely; they may all be contained in one regulation (e.g., the building regulation) or spread across multiple regulations (e.g., building and urban planning regulations). The regulatory provisions may be highly detailed specifications (prescriptive) that are largely self-contained in the building regulation, or they may be function based, with high-level objectives in the building regulation along with reference to standards and guidelines to be followed for detailed design. In some cases, the regulations may reflect a combination of prescriptive and function-based approaches.

Although green building codes and regulations are an important step in reducing a country's GHG emissions, in many developing countries, they are at a nascent stage, and there is a need to help countries create effective green building regulations. A critical step in aiding agencies involved in this sphere is providing a reference list of essential elements for a green building code. This list could be a reference for authorities developing regulations or a lens through which to analyze green building codes that have been implemented or are in the draft stage.

The aims of this tool are twofold: (i) to understand current green building code scope and contents and identify opportunities for enhancement; and (ii) to provide a reference for critical contents of a green building code or regulation based on global examples. The tool is designed for building professionals with green building specialization who are tasked with analyzing the green building code to use and can be used as a checklist for those who are developing green building codes for specific countries or comparing a code with other global examples.

4. Guidance:

How to Use the Building Code Checklist for Green Building

When reviewing regulations for green building components, it is helpful to follow a systematic approach that considers the regulatory provisions in a stepwise manner. The review should account for the regulatory and market capacity of the jurisdiction under review. Ultimately, it requires a combination of a robust building regulatory system and adequate regulatory and market capacity for the regulatory system to be most effective. Figure 6 illustrates steps to take as part of a systematic review.

How and Where Green Building Components Are Incorporated into Regulations

Although robust building regulations incorporate the green building components identified above, there is not typically a one-to-one relationship between the defined components and the provisions within the regulations because the structure of building regulation derives from national legislation and regulatory models, meaning that building regulations will be unique to the country for which they are developed, the provisions may be split between different regulations, and different terminology may be used in different countries.

Factors for consideration when initiating a review include government structure (e.g., centralized national system, federal system), the government ministry(ies) or department(s) with responsibility for green building legislation and regulations, the legislative structure, and the model used for development of the green building (if any). Specific questions include:

- Are building regulations and green building regulations under the purview of the same ministry?
- Do building regulations address all green building components of buildings, or are some provisions addressed under other regulations?

- Does other legislation or regulation contain requirements relevant to green building provisions in buildings (e.g., electricity infrastructure, water infrastructure, planning and zoning, hazardous materials regulation) and electrical and mechanical installations in buildings?
- Is the building regulatory framework (approach) functional (performance based) or prescriptive?
- If the regulatory framework is functional or performance based, are associated compliance standards clearly outlined to achieve functional or performance goals?
- Are building (and green building) regulations applied uniformly across the country (a national system), by state or territory (a federal system), or another way?
- What is (are) the source(s) of reference standards for such things as materials and system design and installation (e.g., national Bureau of Standards, International Organization for Standardization)?

Depending on the answers, a comprehensive review of green building components in regulations may require a review of documents associated with several government ministries, agencies, and private sector entities (especially for standards).

Almere, The Netherlands. Photo: © DutchScenery

Figure 6. Steps to Take as Part of a Systematic Review

①

Understand overall regulatory framework

Identify relevant ministries, legislation, and regulations with bearing on green building, including planning and zoning, water infrastructure, electrical and gas utilities, building and construction, and fire.

②

Identify green building–related regulations and chapters

Identify which regulations (e.g., planning; building; electrical; plumbing; heating, ventilation, and air conditioning) contain relevant chapters or sections on the seven fundamental green building components and subcomponents (Figure 8) for buildings and where these chapters or sections are located.

- Green building provisions may have their own chapter but are more typically dispersed across electrical, mechanical, plumbing, structural, and building services chapters or sections.
- Building use and occupancy classifications may be located with structural provisions, in their own chapter or section, or both.

③

Undertake a systematic review

Look for provisions that address each fundamental green building component and subcomponent according to the checklist (see Chapter 6), and assess the adequacy of the regulatory language, including the level of detail provided, to ensure proper interpretation and execution of the regulatory requirement and to refer to standards or guidelines that provide the necessary level of detail.

- Provisions may be written in functional language, as prescriptive-based requirements, or a combination.
- The adequacy of the regulatory language will depend on several factors, including: i) the level of detail provided and the clarity of the stated provisions; ii) the extent to which reference standards are cited; iii) the uniformity of and compatibility between the reference standards; iv) the extent to which nonmandatory guidance is included and cited, and v) the uniformity of and compatibility between the guidance.

④

Assess provisions in a country context

Consider the regulatory and market capacity required to interpret and act upon the regulatory provisions in a manner that can be expected to achieve the green building objectives for buildings that comply with the regulations.

- Consideration may be given to the market's capacity to work with a regulatory document that is significantly function based and lacks adequate, consistent reference to accepted standards and guidance: Who will be using regulations? What are their educational backgrounds?
- Consideration may also be given to the testing, approval, and accreditation systems for materials, products, and systems.

⑤

Assess interface between green building regulations and other regulations

Review the interface between green building-related and other sections of building and relevant regulations (e.g., planning and zoning, structural, mechanical, electrical, plumbing) as necessary and appropriate.

- Coordination with mechanical, electrical, plumbing, and urban planning is often required.
- Coordination with structural may be needed

⑥

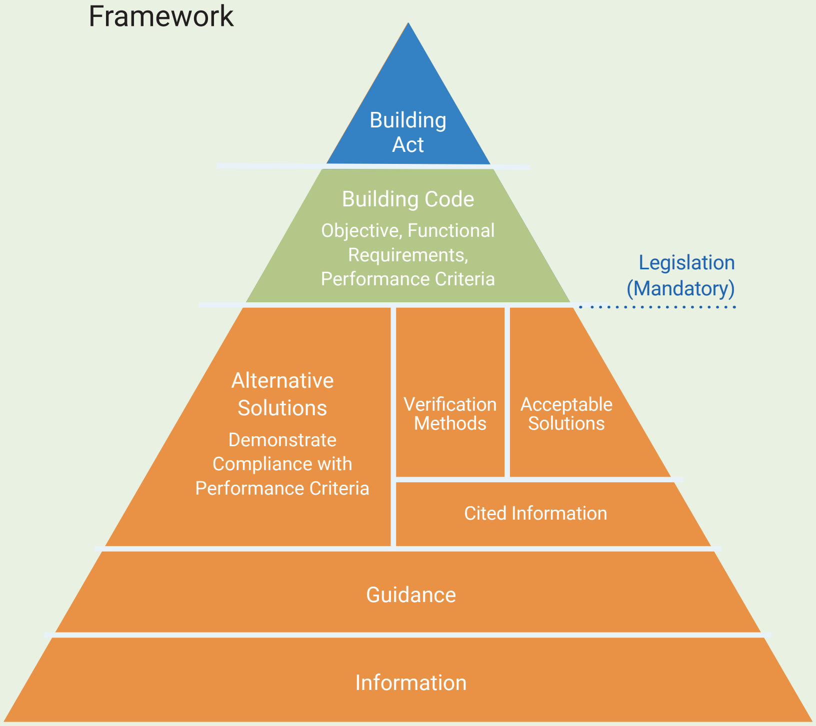
Complete checklist and reporting

Summarize findings based on completed checklist. The summary should be presented to highlight identified challenges, opportunities for enhancement, and key recommendations.

Structure of Building Regulatory Framework

A stylized structure of a building regulatory framework is shown in Figure 7, although every regulatory framework and building regulation system will be structured slightly differently. The structure will largely depend on the legislative structure used in a country and the model used to develop the building regulation (if any). Accordingly, it is difficult to pre-identify precisely where to look in any building regulation, green building regulation, or set of building and other regulations to find references to green building provisions.

Figure 7. Typical Structure of Building Regulatory Framework



Source: Figure adapted and modified from the original figure by Building and maintaining New Zealand's homes and buildings.

In all regulatory structures, it is essential that the standards be cited as uniformly and consistently as possible to help ensure that:

- Potential inconsistencies that may arise from mixing incompatible standards are minimized.
- Potential inconsistencies that may arise from lack of providing a reference standard for each regulated area (e.g., energy efficiency, water efficiency, building materials, construction measures, occupational health and comfort, solid waste management) are minimized. Failing to provide standards leaves all decisions to the market, which could result in wide-ranging variation. (For example, failing to cite a standard for installation of air conditioners or water faucets could create problems for local authorities regarding enforcement and lead to inconsistency in energy or water efficiency in buildings.)
- Reference standards are aligned with all aspects of building regulatory system capacity, including product testing, approval, and market surveillance. (For example, it would create challenges if a U.S. test standard were cited, but there were no test facilities that could test to that standard, or materials that comply with the standard were unavailable in the market.)

Chapter 5 provides basic knowledge on seven fundamental green building components for the built environment. **Users of this tool who are green building experts and already familiar with key concepts in green building components in building regulations can skip the following section 'Key Concepts in Green Building Components in Building Regulations' and proceed to 'Checklist for the Review of Green Building Provisions in Building Regulations'.**

5. Key Green Building Components in Building Regulations

The tool builds on seven fundamental green building components in building (and other) regulations, along with a more detailed set of subcomponents (Figure 8). These seven fundamental components were distilled from a comparative review of green building codes of 11 countries conducted as part of this tool development (Appendix A). This review found that building regulations (and sometimes green building regulations or a combination of both) in most countries include provisions and requirements associated with the following seven fundamental green building components.

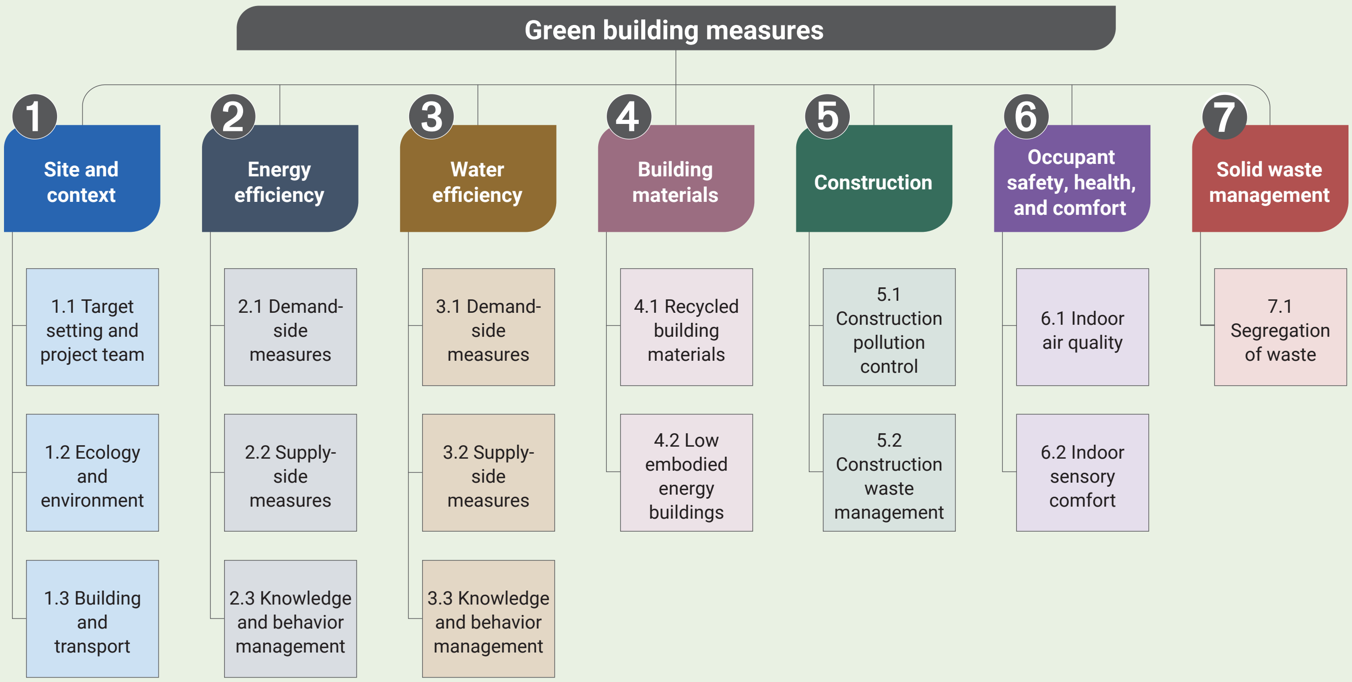
- **Site and context:** The context of the building, its surroundings, and the effect that the building has on its surroundings are the starting points for implementing sustainability measures.
- **Energy-efficiency:** Because building energy use directly affects GHG emissions, this is a critical area of intervention. A building must be designed to use the least amount of energy, for example by maximizing the availability of natural light. This is an example of a passive measure. Active measures, such as lighting; heating, ventilation, and air conditioning systems; and elevators, must also be considered. Energy-efficient technology is available that consumes less energy but provides the same performance.
- **Water-efficiency:** Water is a necessary resource for the survival of all lifeforms. Water efficiency starts with reducing demand for water by increasing the efficiency of equipment. Supply must also be addressed, such as maximizing rainwater harvesting and using recycled and treated water.
- **Building materials:** Building material production is another major source of energy use. The energy used to produce building materials is called embodied energy. The goal is to use building materials

that have low embodied energy. Using recycled materials is another way to reduce the energy footprint of building materials.

- **Construction:** Controlling air, water, and noise pollution arising during construction and managing and disposing of construction-related debris are crucial for the environment.
- **Occupant health and comfort:** The health and comfort of occupants are intrinsically connected to building design.
- **Solid waste management:** Solid waste management must be addressed during design and operation of the building.

Although there are many green building guidance documents that address the concepts embodied in these components (e.g., International Code Council 2012 International Green Construction Code (IgCC),; American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/U.S. Green Building Council ()/ Integrated Environmental Solutions (IES) Standard 189.1-2011: Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings; International Code Council 700-2012: 2012 National Green Building Standard (ICC 700); and U.S. Green

Figure 8. Fundamental Green Building Components and Subcomponents



Building Council Leadership in Energy and Environmental Design (LEED®), none of these align specifically with the typical structure of building regulations. Moreover, the terminology and definitions differ between these documents. As such, although these are useful guidance documents for green building analysis and design, they do not provide guidance for a review of regulatory provisions.

Reviewing regulations can be a complex task because green building–related items may be regulated in multiple places. For example, regulations for electrical installations, electric utilities, water supply services, planning, the environment, and occupational health and safety may be housed in different departments.

A robust, comprehensive building (and other) regulatory framework should address each of the seven fundamental components, but the extent to which they are implemented will depend on the building profile, energy and water efficiency objectives, and the jurisdiction's regulatory capacity. Any or all of these factors, along with consideration of risk-benefit-cost balancing, may influence the extent of implementation of each of these components. In other words, there may be trade-offs associated with various considerations, including area, height, construction materials used for most buildings availability of sunlight, capacity of the design community, and cost of implementation.

6. Building Code Checklist for Green Building

Table 1 is a checklist to help review green building provisions in building regulations based on the green building components overviewed above. Specific guidance for assessing regulatory provisions is not possible because all regulatory provisions are contextual to the regulatory and legislative structures and regulatory capacity of a country, and in many cases, there is more than a single approach to meeting green building objectives in a building regulation. The reviewer is expected to have sufficient knowledge to apply the following guidance to undertake an appropriate review. The primary components and major subcomponents are color-coded to align with Figure 8. Fundamental Green Building Components and Subcomponents.

Although Table 1 is extensive, it is not necessarily exhaustive. Also, as noted previously, not all principles, features, and systems may be required or appropriate in the country of focus. Some of the details associated with the green building principles, features, and systems may be located in mandatory or voluntary guidance or referenced standards.

In addition to technical contents covered in Table 1, there are some related factors that may not fit simply into the category of green building component (e.g., building use, occupancy groups), are coordination issues, or are in related legislation (e.g., utilities). Various items of concern such as these are overviewed in Table 2. If a user is new to a country of study, Table 2 could be a good starting point to understanding the country context before reviewing a code using Table 1.

Table 1. Checklist for for Review of Green Building Provisions in Building Regulations

Topic	Relevance	Diagnostic questions
1. SITE AND CONTEXT	Buildings are integral to the site on which they are built. A building affects its surroundings, such as the flora and fauna, the manner in which rainwater is absorbed into the ground, and the microclimate around it. Factors such as public transport connectivity will also affect the carbon footprint of its occupants.	
1.1 Target setting and project team	Target setting can be useful in determining a measurable objective for green building activity; availability of qualified personnel on the project team would streamline achieving green building goals.	
1.1.1 Preliminary setting of sustainability targets	Some codes set basic sustainability targets for projects. These may be in the form of total carbon dioxide (CO_2) emissions per square meter or overall thermal transfer value (OTTV) of the building or in the form of an Energy Performance Index (EPI).	• Do the regulations require that sustainability targets be set for new development projects?
1.1.2 Appointment of green building professional	Some codes require that a green building professional be on the building design team. Green building professionals include individuals with relevant education or professionals with international certifications such as LEED GA, LEED AP, EDGE Expert.	• Do the building regulations recommend that at least one Green Building Professional be appointed to the project design team?
1.2 Ecology and environment	Buildings are an integral part of the ecosystem and the environment. Care must be taken to ensure that adverse effects of the buildings are minimized.	
1.2.1 Environmental impact assessment (EIA)	An EIA determines the environmental impact of the project and mitigation measures. EIAs are usually mandatory for projects larger than a certain size in terms of built-up area. For example, in India, projects with a site area of more than 50 hectares or a built-up area of 150,000 square meters must obtain an environmental clearance by submitting an EIA to the state EIA authority. EIAs usually contain sections on such areas as air quality, water quality, noise, soil resources, traffic management, and socioeconomic impact. In certain countries, projects larger than a certain area may require an EIA. In some cases, an EIA is mandatory if the project is in an environmentally sensitive zone or there will be effluents that require special treatment.	• Do the building regulations recommend that an EIA be conducted (during project design)? • Do projects need EIAs? • Are EIA teams required to have accredited consultants? • If yes, which accreditation is required? • What are the aspects of the environment impact that an EIA must cover? – Landform – Natural resources – Ambient air – Soil – Ecology – Worker health, sanitation, and safety – Solid waste disposal – Occupational health – Public health and safety – Traffic movement
1.2.2 Integration of project's with local ecosystem	This assesses if the design of building or property respond appropriately to ecological factors such as flora, fauna, presence of water bodes (lakes, rivers, sea). For example: Leaving adequate buffer zones near water bodies to ensure that the water bodies' catch basins are not harmed. Ensuring that only native tree and shrub species are grown so that local fauna habitats are not damaged.	• Are specific protection or buffer zones set aside for water bodies, forests, etc.? If yes, please indicate: – For water bodies [enter linear distance] – For forests or nature reserves [enter linear distance] – Other, please indicate – Do the building regulations address on-site tree cutting? – Do the building regulations require native landscaping? – Do the building regulations specify a certain amount of open space allocation in the project?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
1. SITE AND CONTEXT (cont.)		
1.2.3 Exterior light pollution and controls	Nighttime light pollution from excessive lighting (especially in urban areas) affects the biological and circadian rhythms of birds, animals, and plants. This can be mitigated by ensuring that all exterior light fittings around and on buildings have shades on top so that light is directed down to the pathways as required for human way finding.	• Do the building regulations address flood lighting? • Do the building regulations address light emission from external light fixtures?
1.2.4 Storm water attenuation	Storm water must be attenuated so that as much rainwater as possible is retained within the boundaries of the property. This has two effects. It primarily reduces chances of downstream flooding outside the property. It improves the level of water table of the property.	• Do the building regulations address storm water attenuation? If yes, which measures are specified?
1.2.5 Microclimate and outdoor comfort	Buildings near each other can alter the microclimate of the outdoor spaces between them, which could result in such things as inadequate solar access and wind tunnels. For example, if a new building is built too close to an existing building, it can cast shadows that will limit daylight in the existing building. In addition, buildings close together may create a "tunnel effect," increasing wind speed and causing discomfort for people using the space between the buildings.	• Do the building regulations address minimum distance from neighboring buildings or abutting streets? If yes, please specify: – Between buildings – Between building and streets • Do the building regulations prescribe minimum distances between buildings? For example, certain codes stipulate that the distance between two buildings may be 1/2 or 1/3 of the height of the taller of the two buildings.
1.3 Building and transport	Location of buildings in the larger surroundings of urban areas plays an important role in determining the carbon footprint of its users.	
1.3.1 Proximity to public transportation	Access to the property in terms of public transport connectivity is an important aspect of site selection. It will reduce the carbon footprint of those who use or visit the building. Ideally, public transport systems such as bus, metro, and light rail will be within walking distance of the proposed development, which will reduce private vehicle use to access the building.	• Do the building regulations address maximum distance between the project and public transportation transit points such as bus stops, bus rapid transit system stops, and metro or railway stations? • Do the building regulations stipulate that a development may proceed only if there is some form of public transportation available near the proposed project?
1.3.2 Preferential parking for electric vehicles	Electric vehicles reduce vehicular pollution. Preferential parking for electric vehicles makes it easier for drivers of electric vehicles to use the building. An example of a preferential provision may be that parking spots for electric vehicles are closest to the building entrance.	• Do the building regulations require electric charging stations in the parking area? • Do the building regulations require preferential parking for electric vehicles?
1.3.3 Bicycle storage and changing rooms	Encouraging building users to use bicycles instead of cars reduces vehicular congestion and pollution. Cyclists need changing rooms to change into and out of official workwear and secure storage facilities for their bicycles.	• Do the building regulations require a minimum number of bicycle parking spots? • Do the building regulations require designated bicycle storage? • Do the building regulations require changing rooms and shower facilities for bicycle commuters?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY	Energy efficiency is a key aspect of green buildings. Because climate varies from one region to another, buildings must be built for local climatic conditions. By understanding the local building stock, architects and designers can analyze the performance of existing buildings in terms of energy consumption, thermal comfort, and natural ventilation. This knowledge can inform the design of new green buildings, incorporating passive design strategies that leverage local climate conditions such as solar orientation, shading, natural ventilation, and insulation.	
2.1 Demand-side measures (increasing energy efficiency):	Demand side accounts for the amount of energy that the building will need for optimal functioning. The aim of a code must be to reduce the energy demand of the building.	
2.1.0 Methods to achieve energy efficiency	Typically, there are two methods of estimating the energy use of a new building. The **performance method** simulates building design using building energy modeling (BEM) software and ensures that energy use intensity and the energy performance index are within prescribed limits mandated by the code. A BEM software can be used to calculate the energy performance index (EPI) (measured in kWh/m3 per year) of the proposed building, which will be limited to certain agreed-upon standards. This can be expensive because it requires trained resources and personnel to perform the building energy modeling. With the **prescriptive method**, building energy modeling software is not needed. Hence most codes also contain measures that must be followed in a prescriptive manner. The code could recommend a third method to follow the green building code: **Green building certification** can be received from a recognized third-party such as LEED, BREAAM, Green Star, EDGE or any of globally recognized green building rating systems.	• Does the code specify how the energy efficiency is to be measured? • Do the building regulations mention any route to achieve energy efficiency? • Do the building regulations mention an energy performance index or energy use intensity for different types of buildings? • Do the building regulations formally recognize buildings certified through 3rd party Green Building Rating Certification Systems as green buildings? If yes, list the recognized systems and the certification marking required (gold/platinum or a star rating).
2.1.1 Passive design measures	Passive design includes features that are integral to the construction of the building, for example types of walls, windows, and roof. Energy demand is first reduced by ensuring that the building is designed to reduce the need for occupants to rely on artificial means of achieving human comfort (e.g., air conditioning, ceiling fans).	
2.1.1.1 Building orientation	Building orientation affects building heating and cooling loads. Orienting a building optimally considering geographic location and local climate can reduce cooling load in warm climates and heating load in cold climates. For example, in warm climates, it is desirable for the long facades of a building to face north or south, which reduces incident solar radiation. This is a difficult provision to make compulsory, but guidance can be provided on orientation.	• Do the building regulations address or prescribe building orientation? • Do the building regulations specify orientation for different types of buildings?
2.1.1.2 Window-to-wall ratio (WWR)	Windows and structural glazing provide light and ventilation, but in warm climates, they also bring in unwanted heat, increasing the load on air conditioning systems and thus increasing energy use. Having the optimum window-to-wall ratio (WWR) helps balance the two opposing requirements.	• Do the building regulations address a minimum or maximum WWR? • Do the building regulations prescribe different WWR for differently oriented walls? • Does the code provide the formula for calculating WWR?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY (cont.)		
2.1.1.3 Thermal bridging	Thermal bridges are elements of a building that leak heat between the outdoors and indoors, possibly because of poorly insulated joints (e.g., exposed floor slabs, uninsulated window frames or glazing).	• Do the building regulations provide guidance on avoiding thermal bridges? • Do the building regulations provide guidance on the type of window/glazing sections that can be used for thermal bridges?
2.1.1.4 Shading	Horizontal shading reduces solar radiation on windows and glazing when the sun is high in the sky. Vertical shading reduces solar radiation on windows and glazing when the sun is low in the sky. A combination of vertical and horizontal shading is usually recommended to reduce solar radiation from various sun angles.	• Do the building regulations provide guidance on various types of shading implements? • Are there instructions on how the shading must be designed? • Do the building regulations specify shading implements for different orientations? • Are there instructions on which orientation of walls must be provided with horizontal, vertical, or combined shading? • Do the building regulations specify formulas for shading? • Do the building regulations specify the Vertical Shading Angle (VSA)? • Do the building regulations specify the Horizontal Shading Angle (HSA)? • Do the building regulations provide an illustrative cross-section drawing to explain VSA & HSA?
2.1.1.5 Thermal transmittance of glass (U-value)	Thermal transmittance is the amount of heat that a material transfers from outdoors to indoors to raise the temperature by 1°Kelvin. This is also called U-value. The lower the U-value, the greater the insulating properties of the material. The SI Unit of U-value is Watts per Square meter Kelvin (W/SqM. K)The inverse of U-value is R-value, which is the measure of how well an insulation resists the flow of heat.	• Do the building regulations specify U-value requirements for glass? • Do the building regulations outline different U-value requirements for different orientations?
2.1.1.6 Glass solar heat gain coefficient (SHGC)	SHGC is the amount of heat that glass admits from direct solar radiation incident on the surface of the glass. It is expressed as a fraction or a percentage (e.g., 0.1=10%, 0.65=65%). Shading the window reduces the SHGC, as does tinting the glass.	• Do the building regulations specify SHGC requirements for glass? • Do the building regulations outline different SHGC requirements for different orientations? • Do the building regulations have provisions for adjusted SHGC by combining this measure with shading?
2.1.1.7 Combined glazing assembly properties	Combined glazing properties include the SHGC and the U-value of the glass and the frame. Some codes require that the opening properties be seen holistically with U-values, SHGC, shading, and orientation.	• Do the building regulations provide guidance on combined glazing assembly properties?
2.1.1.8 Air infiltration	Air infiltration is the phenomenon of air leaking from one space to another, reducing cooling or heating effectiveness of the space. A well-sealed door or window will minimize air infiltration. Joints of pipes and ducts entering the walls must also be effectively sealed, which may be done by caulking, skirting, or architraves at various joints.	• Do the building regulations outline measures for preventing air infiltration? • What measures to prevent air infiltration are included in the code? • Do the building regulations prescribe specific joints for mitigating air infiltration? • Are there specific joints mentioned in the code, for example, between the window frame and the jamb? • Do the building regulations provide construction details in the form of figures or sketches as guidance?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY (cont.)		
2.1.1.9 Daylighting	Abundant daylight in a building reduces the need for artificial lighting, reducing energy use during the daytime. Most codes will suggest that adequate daylight be available in buildings. In the general building code, daylighting values will be specified in lux.	• Do the building regulations specify daylighting requirements, for example that a certain percentage of habitable building area must be adequately lit through daylight for a certain percentage of the day? If yes, has a formula or an explanatory diagram been provided to define adequate daylighting for a given space?
2.1.1.10 Natural ventilation	Natural ventilation occurs in a building without use of artificial systems such as fans and air conditioning, reducing reliance on artificial ventilation. Most codes suggest that adequate natural ventilation be available within a building when the ambient temperature is within the comfort range. Usually there is a standard that stipulates that the openable portion of a window must be at least 5% (or similar figure) of the usable floor area of the space.	• Do the building regulations specify openable window, glazing, or perforation area with respect to the room's usable floor area?
2.1.1.11 Thermal transmittance of walls (U-value)	A low U-value for a wall helps keep the building cool or warm. This can be achieved by choosing the right wall assembly material or insulating the wall surface. The SI Unit of U-value is Watts per Square meter Kelvin (W/SqM. K). The inverse of U-value is R-value, which is the measure of how well something resists the flow of heat.	• Do the building regulations specify U-value requirements for the walls? • Do the building regulations prescribe different U-value requirements for different orientations? If yes, have guidance U-values been provided for the most common masonry assemblies used in the country?
2.1.1.12 Wall reflectivity	Heating/Cooling of a wall through direct solar radiation is a function of its color and texture. Using walls with high reflectivity in warm climates reduces the heat gain of the building. The higher the solar reflectance index (SRI), the greater the reflectivity of the surface.	Do the building regulations specify a SRI for walls?
2.1.1.13 Thermal transmittance of roof (U-value)	A roof with a low U-value helps keep a building cool or warm. This can be achieved by choosing the right roof material or insulating the roof surface. The SI Unit of U-value is Watts per Square meter Kelvin (W/SqM. K). The inverse of U-value is R-value, which is the measure of how well something resists the flow of heat.	• Do the building regulations specify U-value requirements for the roof? If yes, have guidance U-values been provided for the most common roof assemblies used in the country?
2.1.1.14 Thermal transmittance of floor (U-value)	Floors with a low U-value that touch the earth or are exposed to the outside (e.g., stilted floors) helps keep the building cool or warm. This can be achieved by choosing the right floor material or insulating the floor surface. The SI Unit of U-value is Watts per Square meter Kelvin (W/SqM. K). The inverse of U-value is R-value, which is the measure of how well something resists the flow of heat.	• Do the building regulations specify U-value requirements for the floor? If yes, have guidance U-values been provided for the most common floor assemblies used in the country?
2.1.1.15 Roof reflectivity	Heating/Cooling of the roof through direct solar radiation is a function of its color and texture. Using roofs with high reflectivity in warm climates reduces heat gain. Reflectivity is measured according to a solar reflectance index. The higher the index, the greater the reflectivity of the surface.	• Do the building regulations stipulate a certain SRI solar reflectance index for the roof.

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY (cont.)		
2.1.1.16 Overall thermal transfer value (OTTV)	OTTV is the total average heat that a building envelope absorbs. Heat gain happens through all surfaces of a building that form a barrier between the external and internal environments. OTTV is calculated using various building physics equations. OTTV is specified in warm climates to ensure that the building envelope absorbs as little heat as possible, minimizing the use of air conditioning in the building. Variants of OTTV are RTTV (Roof thermal transfer value), and RETV (residential envelope transfer value). The principles of heat transfer remain the same. The unit of measure is usually watts per Square Meter of the Building Area (w/sq.m).	• Do the building regulations specify an OTTV for various types of buildings? If yes, note the standards described.
2.1.1.17 Green roofs	Green roofs have vegetation on them, along with structural and waterproofing safeguards, reducing the transfer of heat into and out of the building. Green roofs also increase biodiversity in densely built urban environments and are becoming increasingly popular.	• Do the building regulations require construction of green roofs? Is there a minimum standard for such roofs in terms of area covered by vegetation?
2.1.2. Lighting	Artificial lighting consumes a significant portion of the energy used in a building. Energy-efficient lighting reduces the amount of energy required for lighting.	
2.1.2.1 Lamps	Lighting efficiency can be measured in two ways: Light power density is defined as the total power that all lighting in a building consumes divided by the total area of the building. It indicates the energy efficiency of lighting. The unit is w/sq.m. Luminous efficacy refers to the amount of light output per watt of electricity used in a particular lamp. The unit is lumens per watt. Lighting technology has advanced so that light-emitting diode (LED) lighting is at least six times as efficient as incandescent lighting and at least twice as efficient as linear and compact fluorescent lighting. LEDs are also available in all colors and for most types of lighting applications.	• Do the building regulations specify light power density for various types of buildings? • Do the building regulations specify a minimum level of lumens per watt for lighting fixtures?
2.1.2.2 Daylight sensors	Daylight sensors are used on light fixtures that are close to windows. In large-occupancy spaces, they switch off lights when sufficient daylight is available, reducing energy use. They are usually found in large, open-plan offices, classrooms, and lecture halls, where workstations near windows receive adequate daylight.	• Do the building regulations specify daylight sensors? • Do the building regulations provide measurements for the depth (perpendicular to the window opening) up to which the spaces should be fitted with daylight sensors? • Are daylight sensors available in the local market?
2.1.2.3 Occupancy sensors	Occupancy sensors switch lights that are not used regularly off and on and can be used in spaces such as corridors and office areas where low levels of light are sufficient for one to enter the space. When someone enters the space, the remaining lights switch on for full functionality. The extra lights then switch off after the occupant exits the space.	• Do the building regulations specify occupancy sensors? • Do the building regulations prescribe minimum lighting levels for different types of spaces? • Are occupancy sensors available in the local market?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY (cont.)		
2.1.2.4 Automatic exterior lighting controls	Daylight sensors can be fitted to exterior lights (e.g., street lights, garden lights) to switch them on at dusk and off at dawn. They may be based on photoelectric sensors or timers.	• Do the building regulations specify external lighting controls? • Do the building regulations prescribe minimum lighting levels for different types of spaces? Are automatic exterior lighting controls available in the local market?
2.1.2.5 Occupancy sensors for garage lighting	Occupancy sensors connected to lighting switch off or on lights that are not used regularly and can be used in spaces like parking areas where low levels of lighting are sufficient for one to enter the space. When someone enters the space, the remaining lights switch on for full functionality. The extra lights then switch off after the occupant exits the space.	• Do the building regulations specify occupancy sensors for car parks ? • Are occupancy sensors available in the local market?
2.1.3 Heating, ventilation, and air conditioning (HVAC) systems	In a fully air-conditioned building in a warm climate, an HVAC system can account for 60 to 70% of energy use. Many components of HVAC systems can be made more efficient to decrease this energy use.	
2.1.3.1 Ceiling fans	In climates where cooling is required, ceiling fans are the most energy-efficient of the various active cooling systems.	• Do the building regulations address the use of ceiling fans? • Do the building regulations stipulate that ceiling fans are a prerequisite for installing an air-conditioning system?
2.1.3.2 Air economizers	Air economizers are installed in air conditioning equipment to let fresh air into the system when the outdoor temperature matches the desired indoor temperature. They also shut off the chiller operation, saving energy. They are an add-on feature to an HVAC air handling unit that draws in outdoor air and mixes it with return air from indoors. This is useful when the ambient temperature is within the human comfort range on many days in the year.	• Do the building regulations prescribe air economizers?
2.1.3.3 Coefficient of performance (COP) for air conditioning	The COP is the ratio of the amount of cooling or heating achieved to the amount of energy used. It can also be expressed as energy efficiency ratio (EER), seasonal energy efficiency ratio (SEER) &, or integrated energy efficiency ratio (IEER). All manufacturers include one of these values in their technical data sheet.	• Do the building regulations address minimum COP or other efficiency ratios like EER, IEER or SEER for air conditioning systems?
2.1.3.4 COP for heating equipment	The COP is the ratio of the amount of cooling or heating achieved to the amount of energy used. It can also be expressed as energy efficiency ratio (EER), seasonal energy efficiency ratio (SEER) &, or integrated energy efficiency ratio (IEER). All manufacturers include one of these values in their technical data sheet.	• Do the building regulations address minimum COP or other efficiency ratios?
2.1.3.5 Variable-frequency drives (VFDs) for air handling units (AHUs)	VFDs in AHUs help control fan speed and hence energy use based on occupancy of the space.	• Do the building regulations address VFDs for AHUs?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY (cont.)		
2.1.3.6 Variable-speed drives (VSDs) for chillers	VSD's for chillers reduce the load on compressors in the chiller based on the cooling load required.	• Do the building regulations address VSDs for chillers?
2.1.3.7 Variable-speed drives for pumps	VSD's for pumps in HVAC systems reduce the load based on cooling load required.	• Do the building regulations address VSDs for chillers?
2.1.3.8 Heat recovery from return air	Heat recovery units (HRUs) or Wheels in HVAC systems ensure that cooling and heating energy is transferred from the exhaust air to the fresh air, reducing the load on the chiller or heating unit. These are usually used in warm, humid climates.	• Do the building regulations address heat recovery units?
2.1.3.9 Geothermal cooling and heating	Unlike the surface of the earth, the temperature from about 6 meters below the earth and down is usually stable year-round. Depending on location, the temperature remains between 10°C to 25°C. Heat pumps can extract this energy and use it for cooling in hot climates and heating in cold climates. Such technologies can complement or replace conventional HVAC technology.	• Do the building regulations specify use of geothermal energy?
2.1.3.10 Carbon monoxide (CO) sensors for garages	Enclosed garages usually have exhaust systems that run continuously to prevent concentration of CO from vehicle exhaust. A CO sensor ensures that the fans switch on only when CO concentrations exceed the prescribed limit.	• Do the building regulations require CO sensors for enclosed garages? • Do the building regulations address fresh air requirements for enclosed car parking spaces?
2.1.3.11 Natural ventilation for garages	It is best that garages be naturally ventilated, which will ensure that CO concentrations do not exceed prescribed limits. This is not addressed because the most feasible location for parking is often underground.	• Do the building regulations require that the car parks be naturally ventilated?
2.1.3.12 Pipe and duct insulation	Pipes and ducts transport water or air at temperatures higher or lower than the ambient temperature. An insulated pipe or duct will ensure that heat loss or gain is minimized, reducing the load on the heating or cooling system. Most with HVAC system manufacturer have made it mandatory to insulate pipes and ducts to increase energy efficiency, even in the absence of regulation.	• Do the building regulations require insulation of pipes and ducts? • Is there another provision that addresses insulation of HVAC pipes and ducts?
2.1.4 Other: Elevators, pumps, motors, and generator sets	Many pieces of equipment have more-efficient versions. For example, elevators come with an option for regenerative brakes that convert the heat generated during braking into electrical energy that another elevator or any equipment in the building can use.	
2.1.4.1 Calculation of energy efficiency index	Most countries mandate that all equipment that uses energy adheres to the minimum efficiency prescribed in national or international standards. These are usually found in the electrical code.	• Do the building regulations prescribe minimum energy efficiency standards for equipment such as pumps and motors.
2.1.4.2 Elevator and escalator efficiency	Most countries require that elevators and escalators adhere to minimum efficiency prescribed in national or international standards. These are usually found in the electrical code.	• Do the building regulations prescribe minimum energy efficiency standards for elevators and escalators? • Do the building regulations address use of elevators with regenerative brakes?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
2. ENERGY EFFICIENCY (cont.)		
2.1.4.3 Power factor correctors (PFC)	Power quality is essential for efficient equipment operation, and power factor, which is the measure of how efficiently incoming power is used in an electrical installation, contributes to this. PFCs are electronic circuits that can increase the efficiency of equipment.	• Do the building regulations address power factor correctors?
2.1.4.4 Heat recovery from wastewater	In cold climates, heat can be extracted from wastewater through heat exchange which can then be reused for water/space heating.	• Do the building regulations address heat recovery from wastewater?
2.2 Supply-side measures (augmenting supply with renewable energy)	Renewable energy technologies such as solar photovoltaic and wind turbines enable building owners to generate their own energy, reducing reliance on fossil fuel–based energy sources.	
2.2.1 Renewable energy	Solar power or wind can be used to generate electricity on site by installing a renewable energy power plant or connecting to a grid that provides off-site renewable energy.	• Do the building regulations address renewable energy?
2.2.2 Solar water heaters	Heating water for bathing, cooking, and other purposes uses considerable energy. Solar water heaters (SWH) use freely available solar energy.	• Do the building regulations require use of solar water heaters (SWH)? • Do the building regulations specify a certain percentage of hot water that must be heated using solar water heaters?
2.2.3 Net-zero and net-positive buildings	A net-zero building produces all the energy that it uses. A net-positive building produces more energy than it needs.	• Do the building regulations provide guidance for achieving net-zero or net-positive energy consumption?
2.2.4 Thermostat management	Energy can be conserved by programming thermostats to slightly higher temperatures in warm climates or lower temperatures in cold climates. Even a 1° difference can make significant changes in the energy consumption of the HVAC system.	• Do the building regulations address set temperatures for various types of buildings?
2.3 Knowledge and behavior management	Knowledge of how energy is used is critical in managing behavior regarding energy use.	
2.3.1 Electricity submetering	Submetering enables the energy consumption of various components of the building to be measured, for example, lighting, pumps, and HVAC systems. Submetering provides data that can be used to increase energy efficiency.	• Do the building regulations address submetering? • Do the building regulations specify items for submetering?
2.3.2 Use of smart systems to monitor and control energy use	Building management systems (BMS) monitor use of various resources in the building and provide data that can be used to reduce energy use.	• Do the building regulations address BMS? • Do the building regulations recommend that certain aspects of data be collected, for example, how much energy the HVAC system or the lighting consume?
2.3.3 Documentation, regulation, implementation and commissioning	This is an important step in ensuring that the components of a building run smoothly in tandem with the use case of the building and that the minimum amount of energy is used.	• Do the building regulations address commissioning?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
3. WATER EFFICIENCY	Water efficiency affects the finite water resources of a region and energy efficiency. With shifting climate patterns, access to water is becoming difficult in many regions around the world, so water efficiency is critical.	
3.1 Demand-side measures (increasing water efficiency)	Demand signifies the amount of water that building users need for optimal functioning. The aim of a code must be to reduce the water demand of buildings.	
3.1.1 Water-efficient fixtures	Water use can be reduced by using the most water-efficient fixtures available on the market that provide sufficient "wash feel" and hygiene. Water efficiency is measured according to flow rate, expressed in liters per minute.	• Do the building regulations address water-efficient fixtures? • Do the building regulations specify flow rates for each type of fitting? – Faucets – Showers – Single-flow flush toilets – Dual-flow flush toilets
3.1.2 Water-efficient irrigation system	Use of drip irrigation instead of conventional systems such as sprinklers and planting native and drought-resistant species of plants increase water efficiency.	• Do the building regulations address water-efficient landscape irrigation systems? • Do the building regulations prescribe water-saving species or native species for landscaping?
3.1.3 Swimming pool covers	Covering pools when they are not in use prevents water from evaporating.	• Do the building regulations prescribe swimming pool covers?
3.2 Supply-side measures (augmenting through alternative sources of supply)	Harvesting rainwater and using recycled water enable building owners to generate their own water supply, which reduces reliance on resources such as rivers and lakes.	
3.2.1 Condensate recovery	Condensate, water that collects and drips out of the compressor of an air conditioner, can be captured and recycled.	• Do the building regulations address condensate recovery and recycling?
3.2.2 Wastewater treatment	About 80 to 85% of water consumed in a building is ejected as wastewater that must be treated for hygiene and safety before it can be disposed of. Most cities and towns have a centralized facility or require that buildings larger than a certain size have their own sewage treatment plants (STP).	• Is all wastewater treatment centralized and provided by the city, town, or village municipal authority? If not, is wastewater treatment addressed in the code? • Do the building regulations address on-site wastewater treatment for a certain size building (in terms of gross floor area or other measure such as number of rooms in a hotel, number of dwelling units in a residential development, number of beds in hospital)?
3.2.3 Reuse of treated water for non-potable purposes	Most sewage treatment plants provide treated water that can be used for toilet flushing and landscaping. Such water usually has a biological oxygen demand of less than 10 parts per million of bacteria present in water.	• If the answer is yes to whether wastewater treatment is required, do the building regulations address reuse of filtered water for non-potable purposes?
3.2.4 Reuse of treated water for potable purposes	Wastewater can be subjected to ultra-filtration that can then be used for potable purposes.	• If the answer is yes to whether wastewater treatment is required, do the building regulations address reuse of filtered water for potable purposes?
3.2.5 Roof rainwater harvesting	Harvesting rainwater reduces dependence on piped potable water. Rainwater can be harvested by collecting it and recharging it into the ground or can be collected and filtered and used to augment or replace conventional water supply sources.	• Do the building regulations address roof rainwater harvesting? – Do the building regulations forbid roof rainwater harvesting? – Do the building regulations prescribe the proportion of roof area to be dedicated to rainwater harvesting?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
3. WATER EFFICIENCY (cont.)		
3.3 Knowledge and behavior management	Knowledge of how water is used is critical in managing behavior regarding water use.	
3.3.1 Water use submetering	Submetering enables the water consumption of various components of the building to be measured, for example, sinks, toilets, showers. Supply-side inlets such as water from the city, town, or village authority; water from rainwater harvesting; and treated water from a sewage treatment plant can also be sub metered. Submetering provides data that can be used to increase water efficiency.	• Do the building regulations address water submetering? • Do the building regulations require that specific end uses be separately metered?
4. BUILDING MATERIALS	Incorporating green building measures involves using sustainable materials with low embodied energy, along with sustainable construction practices. Understanding the local building stock helps identify materials that can be locally sourced and that are environmentally friendly and optimal for the local context, which reduces the carbon footprint associated with transportation and supports the local economy.	
4.1 Recycled Building Materials	Many buildings components, such as steel, can be recycled and reused, reducing dependence on virgin resources.	
4.1.1 Recycled building materials	Some codes require that a certain percentage of building components be of recycled raw materials. For example, Pozzolanic Portland cement (PPC) contains a significant percentage of fly ash (a by-product of coal power production) or ground granulated blast furnace slag ((GGBS) - a by-product of steel production).	• Do the building regulations specify a percentage of building materials to be made of recycled materials?
4.2 Low Embodied Energy Materials	Manufacturing building materials consumes a significant amount of energy, which is called embodied energy. For example, producing a burnt brick consumes 4 times as much energy as producing a concrete block.	
4.2.1 Building materials with low embodied energy (Energy used for building material production)	Using materials with less embodied energy reduces the carbon footprint of a building. As a thumb rule local materials have lesser embodied energy as transportation adds to the embodied energy of a material. This also has an added advantage of encouraging local economy.	• Do the building regulations prescribe use of low embodied energy materials? • Are low embodied energy materials available in the market?
4.2.2 Design buildings to optimize building material use	Buildings can be designed to optimize use of materials. For example, a cantilevered structure usually consumes more steel than a structure supported with columns at the end. Although this can be difficult to mandate, guidance can be provided to architects and structural engineers to optimize design with a view to reducing use of building materials, reducing embodied energy.	• Do the building regulations provide guidance for optimizing building material use?
5. CONSTRUCTION	The construction process creates local pollution and generates significant waste, including debris, packaging, and unused materials. Implementing construction processes that control pollution and prioritize waste management strategies such as sorting, recycling, and responsible disposal reduces waste.	
5.1 Construction pollution control	Construction process generates pollution (e.g., dust, noise, materials leeching into the water table). It is critical to control and manage the pollution.	
5.1.1 Dust	Construction dust is a huge problem, especially in fast-developing urban areas. It is possible to control it using various methods such as spraying water and ensuring that the site is well covered on the sides.	• Do the building regulations prescribe measures to mitigate pollution during construction?

Table 1. (cont.)

Topic	Relevance	Diagnostic questions
5. CONSTRUCTION (cont.)		
5.1.2 Soil retention during stormwater discharge	Excavated soil is normally heaped in piles around a construction site. When it rains, the soil can mix with runoff, clogging streets and stormwater drains. Care must be taken to cover the soil properly or dispose of it safely.	• Do the building regulations provide guidance on management of construction site water run-off?
5.2 Construction Waste Management	Waste generated from construction goes into landfills. However, with proper management it can become a resource for recycling into other uses.	
5.2.2 Construction waste management	Construction sites generate considerable waste. For example pieces of tile, cardboard, polystyrene foam, paper, all types of plastics, leftover insulation, and scraps of steel must be segregated, stored temporarily, and disposed of responsibly. Waste generated during construction goes into landfills, but with proper management, it can be recycled for other uses.	• Do the building regulations prescribe measures for construction and demolition waste? • Are there regulations on handling of construction waste?
6. OCCUPANT HEALTH, SAFETY, AND COMFORT	Occupant health, safety, and comfort (OHSC) do not directly affect GHG emissions, but there are codes mandating some of these measures.	
6.1 Indoor Air Quality	Indoor air quality is critical to the health of occupants and can be controlled with good design and selection of materials.	
6.1.1 Indoor air quality	Carcinogenic volatile organic compounds (VOCs) in paints, carpets, and adhesives used for fixing wood and wood products decrease indoor air quality. Low VOC materials are widely available.	• Do the building regulations address indoor air quality? • Do the building regulations specify measures for low VOC materials?
6.1.2 CO_2 sensors for fresh air supply	In spaces with a high concentration of people (e.g., offices, auditoriums), CO_2 concentrations can build up above safe limits. CO_2 sensors connected to the HVAC system will signal the AHU to increase fresh air intake.	• Do the building regulations address CO_2 sensors in large assembly spaces?
6.2 Indoor sensory comfort	Indoor sensory comfort includes such factors as lighting and exterior views.	
6.2.1 Indoor lighting	Adequate indoor lighting is important for physical and mental health.	• Do the building regulations outline standards for indoor lighting?
6.2.2 Nature-connected spaces and views	Spaces connected with nature (windows overlooking a garden or the city skyline) help occupants have a sense of connection with the outdoors, which improves overall well-being.	• Do the building regulations require nature-connected views?
6.2.3 Acoustical comfort and control	Urban settings have become noisy. Some codes require measures such as well-sealed windows and doors to prevent undue amounts of noise from coming inside. Prolonged exposure to loud noise is harmful to health.	• Do the building regulations have standards on allowable noise inside?
7. SOLID WASTE MANAGEMENT	Solid waste management is becoming critical in most cities globally. A building that provides for segregation of solid waste will enable its occupants to manage waste proactively and responsibly.	
7.1 Segregation of Waste	Building designs that enable the segregation of waste is the first step towards responsible handling of waste.	
7.1.1 Segregation of solid waste	Responsible solid waste management is extremely important for local ecosystems. Spaces within a building that provide for safe segregation and storage until disposal are important. Wet waste can be composted on site and used as fertilizer for landscaping.	• Do the building regulations prescribe measures for solid waste segregation and management inside the property?

Table 2. Related Review Items

Topic	Relevance	Diagnostic Questions
A1. COUNTRY CONTEXT		
A1.1 Regulatory environment	Some countries have a code that is advisory, with the regional, provincial, or city government implementing the regulations. This code covers all aspects of a building (e.g., architectural, structural, electrical, plumbing, sewerage). Some countries include green or sustainable building as a separate chapter or document in the code; others split efficiency measures into various disciplines. For example, passive design measures may be included in the architecture section, water efficiency measures in the plumbing section, cooling and heating efficiency measures in the HVAC section.	• Is there a national building code or equivalent? – Does the national building code refer to sustainable or green buildings? – Does the code include new and existing buildings? – Does the code outline building labeling standards? Are these labeling standards linked to incentives? – Which agency or ministry is responsible for the green building code? – Which agency or ministry drafted the green building code or regulation and at what level: central or federal; regional, state, or provincial; municipal? • Is there an enabling law that the legislature has passed to initiate the green building code, and at what level was this initiated: central or federal; regional, state, or provincial; municipal? • Which agency or ministry implements the green building code or regulation and at what level: central or federal; regional, state, or provincial; municipal? • What is the state of green building code or regulation implementation? • How well has the market accepted it? • Is there resistance to its implementation? If so, why? • Are industry stakeholders aware of the code or regulation? • Are there specific building types that have a higher rate of implementation than others? If so, why? • Are there specific regions or cities that have a higher rate of implementation than others? If so, why?
A2. STATE OF THE BUILDING CONSTRUCTION INDUSTRY		
A2.1 Building stock	Understanding the local building stock enables a contextualized approach to green building, accounting for the existing built environment and incorporating sustainable practices that align with the local context. Appreciation of the local building stock helps identify buildings that can be preserved and adaptively reused rather than demolished. Retrofitting and renovating existing structures can often be more sustainable than constructing new buildings because it reduces embodied energy and preserves cultural heritage. The success of green building initiatives depends on community acceptance and participation. Understanding the local building stock enables architects, designers, and developers to engage with the community effectively, allowing for a dialogue that considers the community's needs, preferences, and cultural values and fostering a sense of ownership and cooperation in adopting sustainable building practices.	• What is the makeup of the existing building stock? • What are the major building types for which green building codes may be required? • What is the energy and water consumption for each building type or category? • What is the construction growth projected for each building type? The following building types can be characterized according to gross floor area and number of buildings. – Residential—single-family units – Residential—multifamily units (apartments) – Office – Educational (kindergartens, schools, colleges, universities) – Retail – Health care – Hospitality – Industry – Other (e.g., convention centers, airports, bus stations, railway stations)

Table 2. (cont.)

Topic	Relevance	Diagnostic Questions
A2. STATE OF THE BUILDING CONSTRUCTION INDUSTRY (cont.)		
A2.2 Local market	Local markets are an important indicator of demand for technologies. Availability of materials and technology solutions in the market eases code and regulation adoption. From an analytical point of view, the success of the code or regulation will depend on the availability of the material or technology. If materials or technology needed to make buildings green is unavailable in the local market, the government must provide incentives for adoption of such materials or technology when introducing the related measures in the code.	• What is the market penetration of construction materials that aid in green and sustainable building? – Masonry (e.g., lightweight cavity blocks, autoclaved aerated concrete blocks) – Roofs and slabs (e.g., reinforced cement concrete with ground granulated blast furnace slag or fly ash, insulated sheet metal) – Windows and glazing (e.g., high-performance glass such as double-glazed units, low-e glass) – Insulation (e.g., expanded polystyrene, polyurethane foam) – Solar water heaters – Solar photovoltaic panels – High-efficiency HVAC systems – Low-flow faucets – Sewage treatment plants with recycling facilities – Rainwater harvesting technologies • What is the status of the green building movement in the country? – Are there examples of green certified buildings? – Are there organizations (public or private) or individuals that are actively promoting green building?
A2.3 Availability and organization of building industry professionals	Professional associations play a key role in driving green building implementation by convening industry experts, disseminating knowledge, setting standards, and promoting best practices. These associations typically comprise architects, engineers, contractors, and other professionals in the built environment sector and participate in furtherance and adoption of sustainable building practices through advocacy and policy influence, knowledge sharing and research, professional development and training, networking and collaboration, standards and guidelines, recognition and awards, research and development.	• Is there an accreditation or licensing system for professionals involved in the building construction industry? – Architects – Green building professionals and experts – Structural engineers – Electrical engineers – Public health engineers (plumbing, sewage) – HVAC (mechanical) engineers – Interior designers – Contractors – Developers • Are there professional associations in the following disciplines? – Architects – Green building professionals and experts – Structural engineers – Electrical engineers – Public health engineers (plumbing, sewage) – HVAC (mechanical) engineers – Interior designers – Contractors – Developers

Table 2. (cont.)

Topic	Relevance	Diagnostic Questions
A3. USE AND OCCUPANCY CLASSES		
A3.1 Building classification	Although building classification is not a green building principle or strategy for building regulation, it sets benchmark criteria for specific requirements (e.g., based on population, size, primary activity of building). In general, building classification depends on the use and climate of the site. Building use classes in the building regulations should reflect building uses of the country in question. Different building uses and occupant characteristics present different energy and water consumption patterns and therefore require different approaches. It depends on regulatory structure. When there is more than one set of building use and occupancy classifications, check that they are not in conflict.	• Are the regulations classified according to the climate of the region? • Do the building regulations contain a single set of building use or occupancy classifications that apply to all parts of the regulation? If not, is there a specific set for green buildings? • If there is more than one set of use and occupancy classifications, is there any conflict between them?
A3.2 Mixed-use buildings	When a building has multiple uses (e.g., high-rise residential on top of commercial or mercantile space), care should be taken to identify what provisions apply to the building and its parts (e.g., most restrictive for the use applies or mix based on uses). Related regulatory provisions would typically be found wherever the overall discussion of building use and occupancy classes is found in regulations. This may be in a regulation (e.g., the International Building Code in the United States) or in a reference document (e.g., Approved Document B in England).	• Do the building regulations contain special provisions for mixed use? If so, must the entire building comply with the most restrictive use? • What triggers the dominant use?

Manhattan, New York. Photo: © francois-roux

Appendix:

Methodology of Checklist Development

The tool has been developed in the following manner:

Step 1: A desk review was conducted of global examples of green building codes to study leading examples (e.g., structure of codes and standards, set of regulatory documents and their structure and depth of regulatory guidance).

- A comprehensive literature review was conducted to gather information on green building practices, standards, and regulations, providing a solid foundation of knowledge on international green building codes and initiatives.

- A detailed desk review of building codes and regulations from the selected countries was conducted. Countries with diverse geographical, climatic, and socioeconomic conditions were identified to ensure a comprehensive analysis. Countries and states from Africa (Ghana, Egypt, Rwanda, South Africa), Asia (Dubai, India, Singapore, Sri Lanka, Vietnam), South America (Colombia), North America (California), and Europe (England) were selected. The latest versions of green building codes were obtained and reviewed. Relevant information from the building codes of the selected countries was studied.

Comparative analysis of existing green building regulations

The desk review drew upon codes from a variety of countries with different geographic, climatic, and socioeconomic conditions. The countries and states analyzed for this work were:

- **Africa**
  Egypt, Ghana, Rwanda, South Africa
- **Asia**
  Dubai, India, Singapore, Sri Lanka, Vietnam
- **South America**
  Colombia
- **North America**
  California
- **Europe**
  England

Green building provisions for the following climate conditions were analyzed for:

- **Warm and humid**
  parts of Colombia, Ghana, India, Sri Lanka, Vietnam
- **Cold**
  parts of Colombia, England
- **Hot and dry**
  Dubai, Egypt

The following green building regulations were reviewed:

- **California**
  CalGreen, 2019
- **Colombia**
  Sustainable Construction Code, 2015
- **Dubai**
  United Arab Emirates—Green Building Regulations and Specifications, 2015
- **Egypt**
  Green Pyramid Rating System, 2011
- **England, UK**
  Part L1 (Dwelling), 2021
- **England, UK**
  Part L2 (Non-dwelling), 2021
- **Ghana**
  Part 37 of Ghana Building Code: Building and Construction, 2018
- **India**
  Energy Conservation Building Code, 2017 (NR 0- Non-residential)
- **Rwanda**
  Green Building Minimum Compliance System, 2019
- **Singapore**
  Green Mark (Gold Rating), 2016 R1
- **South Africa**
  SANS 10400 XA, 2021
- **Sri Lanka**—Energy Efficiency Building Code, 2020 (Draft)
- **Vietnam**—National Technical Regulation on Energy Efficient Building, 2017

High level country comparative analysis is presented in Table A.1.

Step 2: A list was created of critical provisions included in global examples, and topics were categorized.

- The checklist was developed based on the objectives identified, such as specific green building design criteria, or provisions relevant to different climates. The comparative studies distilled key topics that most countries are addressing to identify seven fundamental green building components and verify a recommended range of design values.
- The checklist was validated by seeking input from global experts in green building, sustainability, and architecture and task team leaders from the World Bank with energy and climate backgrounds. Professionals with experience in national building codes and regulations were consulted to ensure that the checklist was comprehensive and relevant.
- Feedback from these experts was incorporated, and the checklist was refined accordingly.

Table A.1. Comparative study summary

		Asia					Africa				South America	Europe		USA
		Singapore	India	Sri Lanka	Vietnam	Dubai	South Africa	Rwanda	Ghana	Egypt	Colombia	England L1	England L2	California
Code document name		Green Mark (Gold Rating)	Energy Conservation Building Code	Energy Efficiency Building Code 2020 (Draft)	National Technical Regulations on Energy Efficient Buildings	Green Building Regulations and Specifications	SANS 10400 XA	Rwanda Green Building Minimum Compliance System	Part 37 of Ghana Building Code - Building & Construction	Green Pyramid Rating System	Sustainable Construction Code	L1 – 2021 (Dwelling)	L2 – 2021 (Non Dwelling)	CalGreen
Version and issue date		2016 R1	2017 (NR)	2020	2017	2015	2021	2019	2018	2011	2015	2021	2021	2019
1. SITE AND CONTEXT														
Preliminary setting of sustainability targets	A few codes ask for basic sustainability targets be set for the project	🟩										🟩	🟩	
Appointment of green certified team	Some codes require that a certified green professional(s) are a part of the design team	🟩	🟩											
Environmental impact assessment (EIA)	EIA is a process that outlines the environmental impact of the project along with the mitigation measures 1. EIA is normally mandated by the Environment Ministry 2. There are accredited consultants who usually work on EIA 3. EIA is usually mandatory for projects above a certain size in terms of built-up area. (For e.eg. in India, projects having a site area of above 50 hectares or built up area of 150,000 sq.m have to get Environmental Clearance by way of a EIA submitted to the State Environmental Impact Assessment Authority.) 4. They will usually contain the following sections: Air Quality, Water Quality, Noise Levels, Soil Resources, Traffic Management, Socioeconomic impacts.	🟩				🟩		🟨		🟩				
Integration of project into local ecosystem	This measure means that the design of the building or property respond appropriately to ecological factors such as flora, fauna, presence of water bodes (lakes, rivers, sea). For example: 1. Leaving adequate buffer zones near water bodies to ensure that such water bodies' catch basins are not harmed. 2. Ensuring that only native species of trees and shrubs are grown so that local fauna habitats are not damaged.	🟩				🟩		🟨		🟩				

🟩 mandatory 🟨 voluntary

Table A.1. (cont.)

		Asia					Africa				South America	Europe		USA
		Singapore	India	Sri Lanka	Vietnam	Dubai	South Africa	Rwanda	Ghana	Egypt	Colombia	England L1	England L2	California
Code document name		Green Mark (Gold Rating)	Energy Conservation Building Code	Energy Efficiency Building Code 2020 (Draft)	National Technical Regulations on Energy Efficient Buildings	Green Building Regulations and Specifications	SANS 10400 XA	Rwanda Green Building Minimum Compliance System	Part 37 of Ghana Building Code - Building & Construction	Green Pyramid Rating System	Sustainable Construction Code	L1 – 2021 (Dwelling)	L2 – 2021 (Non Dwelling)	CalGreen
Version and issue date		2016 R1	2017 (NR)	2020	2017	2015	2021	2019	2018	2011	2015	2021	2021	2019
1. SITE AND CONTEXT (cont.)														
Exterior light pollution and controls	Nighttime light pollution from excessive lighting (especially in urban areas) affects the biological and circadian rhythms of birds, animals and plants. This can be mitigated by ensuring that all exterior light fittings around and on buildings have shades on top so that light is directed down to the pathways as required for human way finding.		🟩			🟩				🟩				🟩
Microclimate and outdoor comfort	Buildings near each other can alter microclimate of outdoor spaces between them, which could result in such things as inadequate solar access and wind tunnels. For example, if a building is too close to an existing building, it can cast shadows that will affect daylight in the existing building. In addition, buildings close together may create a "tunnel effect," increasing wind speed and causing discomfort for people using the space between the buildings.					🟩				🟩				
Proximity to public transportation	Access to the property in terms of public transport connectivity is an important part of site selection. It will reduce the carbon footprint of those who use or visit the building. Ideally, public transport systems such as bus, metro, and light rail will be within walking distance of the proposed development, which will reduce private vehicle use to access the building.	🟩				🟩				🟩				
Preferential parking for electric vehicles	Electric vehicles reduce vehicular pollution. Preferential parking for electric vehicles will make it easier for drivers of electric vehicles to use the building.					🟩								
Bicycle storage and changing rooms	Encouraging building users to use bicycles instead of cars reduces vehicular congestion and pollution. Bicycle owners need changing rooms to change into and out of official workwear.		🟩								🟨			

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Table A.1. (cont.)

		Asia					Africa				South America	Europe		USA
		Singapore	India	Sri Lanka	Vietnam	Dubai	South Africa	Rwanda	Ghana	Egypt	Colombia	England L1	England L2	California
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Version and issue date		2016 R1	2017 (NR)	2020	2017	2015	2021	2019	2018	2011	2015	2021	2021	2019
2. ENERGY EFFICIENCY MEASURES														
Demand-side management (increasing energy efficiency)														
Methods to achieve energy efficiency	Typically, there are two methods of estimating the energy use of a new building. **Performance method:** This simulates the building design using building energy modeling software and ensures that energy use intensity and the energy performance index are within prescribed limits mandated in the code. Building energy modeling software can be used to calculate the energy performance index (measured in kWh/m2/year) of the proposed building, which will be limited to certain agreed-upon standards. **Prescriptive Method:** The building energy modelling software required for the performance method is expensive. It also requires for the professionals to be trained in the software. Hence most codes also contain measures that must be followed in a prescriptive manner. The code could recommend a third way to follow the green building code: **Green building certification can be received from a third party** such as Leadership in Energy and Environmental Design, Building Research Establishment Environmental Assessment Methodology, Green Star, and Excellence in Design for Greater Efficiencies.	🟩	🟩			🟩		🟨				🟩	🟩	
Passive design strategies														
Building orientation	Orienting a building properly can reduce the cooling load in warm climates and heating load in cold climates. For example, in warm climates, it is desirable for the long facades to face north or south, which reduces incident solar radiation.						🟩				🟨			
Window-to-wall ratio	Windows and structural glazing provide light and ventilation, but in warm climates, they also bring in unwanted heat, increasing the load on air conditioning systems and thus increasing energy use. Having the optimum window-to-wall ratio helps balance the two opposing requirements.		🟩	🟩	🟩	🟩	🟩	🟨	🟩		🟩	🟩		🟩

🟩 mandatory 🟨 voluntary

Table A.1. (cont.)

		Asia					Africa				South America	Europe		USA
		Singapore	India	Sri Lanka	Vietnam	Dubai	South Africa	Rwanda	Ghana	Egypt	Colombia	England L1	England L2	California
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Version and issue date		2016 R1	2017 (NR)	2020	2017	2015	2021	2019	2018	2011	2015	2021	2021	2019
2. ENERGY EFFICIENCY MEASURES (cont.)														
Demand-side management (increasing energy efficiency) (cont.)														
Thermal bridging	Thermal bridges are elements of a building that leak heat between the outdoors and indoors, possibly because of poorly insulated joints (e.g., exposed floor slabs, uninsulated window frames).					🟩						🟩	🟩	
Horizontal shading	Horizontal shading reduces solar radiation on windows when the sun is high in the sky.		🟩	🟩	🟩		🟩	🟩	🟩		🟩			
Vertical shading	Vertical shading reduces solar radiation on windows when the sun is low in the sky.		🟩	🟩	🟩		🟩	🟩	🟩		🟩			
Combined horizontal and vertical shading	Combined shading reduces solar radiation and is used for differing sun angles based on the orientation of the facade.		🟩	🟩				🟨						
Thermal transmittance of glass (U-value)	Thermal transmittance is the amount of heat that a material transfers from outdoors to indoors to raise the temperature by 1 Kelvin. This is also called U-value. The lower the U-value, the greater the insulating properties of the material. The inverse of U-value is R-value.		🟩	🟩		🟩	🟩	🟨				🟩	🟩	🟩
Glass solar heat gain coefficient	The solar heat gain coefficient is expressed as a fraction or %age (0.1=10 %, 0.65=65 %). It is the amount of heat that glass admits from direct solar radiation incident on the surface of the glass. Shading the window reduces the solar heat gain coefficient, as does tinting the glass.		🟩	🟩	🟩	🟩	🟩				🟩			🟩
Combined glazing assembly properties	Combined glazing properties include the U-value of the glass and the frame and the SHGC.						🟩					🟩	🟩	🟩
Air infiltration (air leakage or building envelope sealing) (openings: e.g., doors, windows, glazing, sealing around duct inlets)	Air infiltration is the phenomenon of air leaking from one space to another, reducing the coolness (warm climate) or warmth (cold climate) of the space. A well-sealed door or window will minimize air infiltration. Joints of pipes and ducts entering the walls must also be effectively sealed, which may be done by caulking or skirting frames at the joints.		🟩	🟩		🟩	🟩					🟩	🟩	🟩
Daylighting	Abundent daylight in a building reduces the need for artificial lighting and hence energy use during the daytime.		🟩	🟩				🟨		🟩	🟨			🟩

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Table A.1. (cont.)

		Asia					Africa				South America	Europe		USA
		Singapore	India	Sri Lanka	Vietnam	Dubai	South Africa	Rwanda	Ghana	Egypt	Colombia	England L1	England L2	California
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Version and issue date		2016 R1	2017 (NR)	2020	2017	2015	2021	2019	2018	2011	2015	2021	2021	2019
2. ENERGY EFFICIENCY MEASURES (cont.)														
Demand-side management (increasing energy efficiency) (cont.)														
Natural ventilation	Natural ventilation reduces reliance on artificial ventilation.	🟩	🟩	🟩	🟩			🟨		🟩	🟨	🟩		🟩
Thermal transmittance of wall (U-value)	A low U-value for a wall helps keep a building cool or warm and can be achieved by choosing the right masonry material or insulating the wall surface.		🟩	🟩	🟩	🟩	🟩	🟨				🟩	🟩	🟩
Wall reflectivity	Heating of a wall through direct solar radiation is a function of its color and texture. Using walls with high reflectivity for warm climates reduces heat gain.		🟩	🟩										
Thermal transmittance of roof (U-value)	A roof with a low U-value helps keep a building cool or warm and can be achieved by choosing the right roof material or insulating the roof surface.		🟩	🟩	🟩	🟩	🟩	🟨				🟩	🟩	🟩
Roof reflectivity	Heating of the roof through direct solar radiation is a function of its color and texture. Using roofs with high reflectivity in warm climates reduces heat gain.		🟩	🟩										
Energy-efficient equipment			🟩	🟩										
Lighting														
Daylight sensors	Daylight sensors are used on light fixtures that are close to windows. In large-occupancy spaces, they switch off lights when sufficient daylight is available, reducing energy use. They are usually found in large, open-plan offices, classrooms, and lecture halls, where workstations near windows receive adequate daylight.		🟩	🟩		🟩	🟩				🟩			🟩
Occupancy sensors	Occupancy sensors switch lights that are not used regularly off and on and can be used in spaces such as corridors and office areas where low levels of light are sufficient for one to enter the space. When someone enters the space, the remaining lights switch on for full functionality. The extra lights then switch off after the occupant exits the space.		🟩	🟩		🟩	🟩				🟩		🟩	🟩

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Table A.1. (cont.)

		Asia					Africa				South America	Europe		USA
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Version and issue date		2016 R1	2017 (NR)	2020	2017	2015	2021	2019	2018	2011	2015	2021	2021	2019
2. ENERGY EFFICIENCY MEASURES (cont.)														
Lighting (cont.)														
Daylight sensors	Daylight sensors are used on light fixtures that are close to windows. In large-occupancy spaces, they switch off lights when sufficient daylight is available, reducing energy use. They are usually found in large, open-plan offices, classrooms, and lecture halls, where workstations near windows receive adequate daylight.		🟩	🟩		🟩	🟩				🟩			🟩
Occupancy sensors	Occupancy sensors switch lights that are not used regularly off and on and can be used in spaces such as corridors and office areas where low levels of light are sufficient for one to enter the space. When someone enters the space, the remaining lights switch on for full functionality. The extra lights then switch off after the occupant exits the space.		🟩	🟩		🟩	🟩				🟩		🟩	🟩
Automatic exterior lighting controls	Daylight sensors can be fitted to exterior lights (e.g., street lights, garden lights) to switch them on at the dusk and off at dawn. They may be based		🟩	🟩										🟩
Occupancy sensor for garage lighting	Occupancy sensors switch lights that are not used regularly of and on and can be used in spaces such as parking areas where low levels of lighting are sufficient for one to enter the space. When someone enters the space, the remaining lights switch on for full functionality. The extra lights then switch off after the occupant exits the space.				🟩									
Heating, ventilation, and air conditioning (HVAC) systems	In a fully air-conditioned building in a warm climate, HVAC systems can account for 60 % to 70 % of energy use. Many components of HVAC systems can be made more efficient to decrease this energy use.	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟩	🟩		🟩	🟩	🟩
Air economizers	Air economiers are installed in air conditioning equipment to let fresh air into the system when the outdoor temperature matches the desired indoor temperature. They also cut off the chiller operation, saving energy. They are an add-on feature to an HVAC air handling unit that draws in outdoor air and mixes it with return air from indoors.		🟩								🟩		🟩	

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Table A.1. (cont.)

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2. ENERGY EFFICIENCY MEASURES (cont.)														
Heating, ventilation, and air conditioning (HVAC) systems (cont.)														
Coefficient of performance (COP) for air conditioning	The COP is the ratio of the amount of cooling or heating achieved to the amount of energy used. It can also be expressed as energy efficiency ratio, seasonal energy efficiency ratio, or integrated energy efficiency ratio. All manufacturers include one of these values in their technical data sheet.	🟩			🟩		🟩	🟨			🟩			🟩
COP for heating equipment	The COP is the ratio of the amount of cooling or heating achieved to the amount of energy used. It can also be expressed as energy efficiency ratio, seasonal energy efficiency ratio, or integrated energy efficiency ratio. All manufacturers include one of these values in their technical data sheet.				🟩		🟩					🟩	🟩	🟩
Variable-frequency drives for air handling units	Variable frequency drives in air handling units help control fan speed and hence energy use based on occupancy of the space.		🟩											
Variable-speed drives for chillers	Variable speed drives for chillers reduce the load on compressors in the chiller based on the cooling load required.		🟩								🟩		🟩	🟩
Variable-speed drives for pumps	Variable speed drives for pumps in HVAC systems reduce the load based on cooling load required.								🟩		🟩			
Heat recovery from return air	Heat recovery units in HVAC systems ensure that cooling and heating energy is transferred from the exhaust air to the fresh air, reducing the load on the chiller or heating unit. These are usually used in warm, humid climates.	🟩				🟩					🟩	🟩	🟩	🟩
CO sensors for garages	Enclosed garages usually have exhaust systems that run continuously to prevent concentration of CO from vehicle exhaust. A CO sensor ensures that the fans switch on only when CO concentrations exceed the prescribed limit.	🟩												🟩
Occupancy sensors and other controls			🟩	🟩		🟩							🟩	🟩
Pipe and duct insulation	Pipes and ducts transport water or air at temperatures higher or lower than the ambient temperature. An insulated pipe or duct will ensure that heat loss or gain is minimized, reducing the load on the heating or cooling system.		🟩	🟩		🟩	🟩					🟨	🟩	🟩

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Table A.1. (cont.)

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2. ENERGY EFFICIENCY MEASURES (cont.)														
Heating, ventilation, and air conditioning (HVAC) systems (cont.)														
Other: Regenerative elevators, pumps, motors, generator sets	Many pieces of equipment have more-efficient versions. For example, elevators come with an option for regenerative brakes that convert heat generated during braking into electrical energy that another elevator or any equipment in the building can use.	🟩	🟩	🟩	🟩	🟩		🟨				🟩		
Calculation of energy efficiency index	Most countries mandate that all equipment that uses energy adheres to the minimum efficiency prescribed in national or international standards.	🟩	🟩	🟩				🟨						
Elevator and escalator efficiency	Most countries require that elevators and escalators adhere to the minimum efficiency prescribed in national or international standards.	🟩				🟩		🟨						🟩
Electricity submetering	Submetering enables the energy consumption of various components of the building to be determined, for example, lighting, pumps, HVAC systems. Submetering provides data that can be used to increase energy efficiency.		🟩	🟩		🟩					🟨		🟩	
Power factor correctors	Power quality is essential for efficient equipment operation, and power factor, which is the measure of how efficiently incoming power is used in an electrical installation, contributes to this. Power factor correctors are electronic circuits that increase the efficiency of equipment.		🟩	🟩									🟩	
Heat recovery from waste water	In cold climates, heat is extracted from waste water through heat exchange.											🟩		
Supply-side management (augmenting supply with renewable energy)														
Solar water heaters	Heating water for bathing, cooking, and other purposes uses considerable energy. Solar water heaters use freely available solar energy.	🟩	🟩	🟩		🟩		🟨	🟩		🟩	🟩		🟩
Renewable energy	Solar power or wind can be used to generate energy on site by installing a renewable energy power plant or connecting to a grid that provides off-site renewable energy.	🟩	🟩		🟩	🟩		🟨	🟩			🟩	🟩	🟩
Net-zero and net-positive buildings	A net-zero building produces all the energy that it uses. A net-positive building produces more energy than it needs.	🟩										🟩	🟩	
Knowledge and behavior management														
Electricity submetering	Submetering enables the energy consumption of various components of the building to be measured, for example, lighting, pumps, and HVAC. Submetering provides data that can be used to increase energy efficiency.		🟩	🟩		🟩					🟨		🟩	

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2. ENERGY EFFICIENCY MEASURES (cont.)														
Knowledge and behavior management (cont.)														
Use of smart systems to monitor and control energy use	Building management systems monitor use of resources in the building and provide data that can be used to reduce energy use.	🟩				🟩					🟨		🟩	🟩
Documentation, regulation, implementation, and commissioning	This is an important step in ensuring that the various components of a building run smoothly in tandem with the use case of the building and that the least amount of energy possible is used.	🟩		🟩	🟩	🟩						🟩	🟩	🟩
3. WATER EFFICIENCY														
Demand-side management (increasing water efficiency)	Reducing demand for water by using the most water-efficient fixtures available in the market while providing the same "wash feel" and hygiene is important.													
Water-efficient fixtures		🟩				🟩		🟩	🟩	🟩	🟩	🟩		🟩
Low-flow faucets		🟩				🟩						🟩		🟩
Low-flow showers		🟩				🟩		🟩			🟩			🟩
Dual-flow flushes		🟩				🟩		🟩			🟩			🟩
Water-efficient irrigation system	Use of drip irrigation instead of conventional systems such as sprinklers and planting native and drought-resistant species of plants increase water efficiency.	🟩				🟩				🟩				🟩
Swimming pool covers	Covering pools when they are not in use prevents water from evaporating.		🟩			🟩								
Supply-side management (augmenting through alternative sources of supply)														
Condensate recovery	Condensate, water that collects and drips out of the compressor of an air conditioner, can be captured and recycled.	🟩				🟩				🟩				
Wastewater treatment	About 80 % to 85 percdent of water consumed in a building is ejected as waste water that must be treated for hygiene and safety before it can be disposed of. Most cities and town have a centralized facility or require that buildings larger than a certain size have their own sewage treatment plant.	🟩				🟩		🟩	🟩	🟩	🟩			

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Table A.1. (cont.)

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3. WATER EFFICIENCY (cont.)														
Supply-side management (augmenting through alternative sources of supply) (cont.)														
Reuse of treated water for nonpotable purposes	Most sewage treatment plants provide treated water that can be used for flushing toilets and landscaping. Such water usually has a biological oxygen demand of less than 10 parts per million of bacteria present in water.	🟩				🟩		🟨	🟩	🟩	🟩			
Reuse of treated water for potable purposes	Wastewater can be ultrafiltered and used for potable purposes.	🟩												
Roof rainwater harvesting	Rainwater can be harvested by collecting it and recharging it into the ground or can be collected and filtered and used to augment or replace conventional water supply sources.	🟩						🟩	🟩		🟩			
Storm water attenuation	Storm water must be attenuated so that as much rain water as possible is retained within the boundaries of the property. This has two effects. 1. It primarily reduces chances of downstream flooding outside the property. 2. It improves the water table of the property.	🟩							🟩		🟨			🟩
Knowledge and behavior management														
Water use submetering	Submetering enables the water consumption of various components of the building to be measured, for example, sinks, toilets, showers. Supply-side inlets such as water from the city, town, or village authority; water from rainwater harvesting; and treated water from a sewage treatment plant can also be submetered. Submetering provides data that can be used to increase water efficiency.	🟩				🟩		🟨		🟩	🟨			🟩
4. BUILDING MATERIALS														
Recycled building materials	Some codes require that a certain %age of building components be of recycled raw materials. For example, Pozzolanic Portland cement contains a significant %age of fly ash (a by-product of coal power production) or ground granulated blast furnace slag (a by-product of steel production).	🟩								🟩				
Building materials with low embodied energy	Manufacturing building materials consumes a significant amount of energy, which is called embodied energy. Using materials with less embodied energy reduces the carbon footprint of a building. For example a burnt brick consumes 4 times as much energyas producing a concrete block.	🟩				🟩								

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Table A.1. (cont.)

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4. BUILDING MATERIALS														
Effect of building material production on environment (resource conservation)	Some countries encouage use of building materials that do not affect the environment significantly in terms of pollution or use of scarce resources such water.					🟩				🟩				
5. CONSTRUCTION PROCESS														
Dust	Construction dust is a huge problem, especially in fast-developing urban areas. It is possible to control it using various methods such as spraying water and ensuring that the site is well covered on the sides.									🟩				
Soil retention during storm water discharge	Excavated soil is normally heaped in piles around the construction site. When it rains, the soil can mix with the runoff, clogging streets and stormwater drains. Care must be taken to cover the soil properly or dispose of it safely elsewhere.													🟩
Operational waste management	Construction sites generate considerable waste. For example, pieces of tile, cardboard, polystyrene foam, paper, all types of plastics, leftover insulation, and scraps of steel must be segregated, stored temporarily, and disposed of responsibly.	🟩				🟩				🟩				
6. OCCUPANT HEALTH, SAFETY, AND COMFORT														
Indoor air quality	Carcinogenic volatile organic compounds in paints, carpets, and adhesives used for fixing wood and wood products decrease indoor air quality. Low-volatile organic compound materials are widely available.	🟩	🟩	🟩		🟩		🟩	🟩	🟩				🟩
CO_2 sensors for fresh air supply	In spaces with a high concentration of people (e.g., offices, auditorims), CO_2 concentrations can build up above safe limits. CO_2 sensors connected to the HVAC system will signal the air handling unit to increase fresh air intake.	🟩		🟩		🟩								
Indoor lighting	Adequate indoor lighting is important for physical and mental health.	🟩	🟩	🟩						🟩				
Acoustical comfort and control	Urban settings have become noisy. Some codes require measures such as well-sealed windows and doors to prevent undue amounts of noise from coming inside. Prolonged exposure to loud noise is harmful to health.	🟩				🟩		🟩		🟩				

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Table A.1. (cont.)

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6. OCCUPANT HEALTH, SAFETY, AND COMFORT (cont.)														
Nature-connected spaces and views	Spaces connected with nature (e.g., a window overlooking a garden, or the city skyline) help occupants have a sense of connection with the outdoors, which improves overall well-being.	🟩				🟩		🟩						
7. SOLID WASTE MANAGEMENT														
Segregation of solid waste	Responsible solid waste management is extremely important for the local ecosystem. Spaces in a building that provide for safe segregation and storage until disposal are important. Wet waste can be composted on site and used as fertilizer for landscaping.					🟩		🟨	🟩		🟨			

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Canal restoration project in Bangkok, Thailand. Photo: © holgs

Globally, buildings account for 37% of energy and process-related carbon dioxide (CO_2) emissions. With increasing urbanization and population growth, demand for energy will continue to increase faster than the supply of renewable energy. This means that increasing the efficiency of current energy use is critical to climate change mitigation efforts while also meeting the development requirement of growing economies. Regulations that can increase the energy efficiency of buildings and reduce the carbon footprint of buildings are thus vital to reducing greenhouse gas (GHG) emissions and to achieving the Paris Agreement's goal of keeping the increase in average global temperature below 2°C. This checklist aims to facilitate a robust approach to reviewing green building provisions in building regulations by providing a discussion of fundamental green building components of building regulations, and a systematic approach to review green building provisions in regulations.

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