

# Unlocking Efficiency:

## The Global Landscape of Building Energy Regulations and Their Enforcement



City Climate  
Finance Gap Fund



WORLD BANK GROUP



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and Sustainable Development



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# Acronyms

<b>AC</b>	Air Conditioning
<b>ACH</b>	Air Changes per Hour
<b>BEC</b>	Building Energy Code
<b>CARICOM</b>	Caribbean Community
<b>CEPAS</b>	Comprehensive Environmental Performance Assessment Scheme
<b>COP</b>	Coefficient of Performance
<b>CREEBC</b>	CARICOM's Regional Energy Efficiency Building Code
<b>DECIG</b>	Development Economics Indicators Group
<b>DR</b>	Desk Research
<b>ECBC</b>	Energy Conservation Building Code
<b>EER</b>	Energy Efficiency Ratio (see also: SEER)
<b>EF</b>	Energy Factor
<b>ETTV</b>	Envelope Thermal Transfer Value
<b>IEA</b>	International Energy Agency
<b>IECC</b>	International Energy Conservation Code
<b>GHG</b>	Greenhouse Gas
<b>GMIS</b>	Green Mark Incentive Scheme
<b>HVAC</b>	Heating, Ventilation, and Air Conditioning
<b>MEPS</b>	Minimum Energy Performance Standards
<b>NCAP</b>	National Cooling Action Plan
<b>NDC</b>	Nationally Determined Contribution
<b>OTTV</b>	Overall Thermal Transfer Value (see also: RTTV)
<b>RTTV</b>	Roof Thermal Transfer Value (see also: OTTV)
<b>SA</b>	Survey Answers
<b>SEER</b>	Seasonal Energy Efficiency Ratio (see also: EER)
<b>SHGC</b>	Solar Heat Gain Coefficient

# Executive Summary



# Building Energy Codes - A Key Driver for Energy Efficiency and Sustainable Development

The global imperative for reducing building sector emissions has never been more urgent. Around 2.4 billion square meters of floor space was built in 2022 that was not mandated to meet any energy-related performance requirements.<sup>1</sup> In 2023, this number increased to 2.55 billion square meters—meaning more than 50 percent of all newly built floor area in the world is not yet covered by mandatory energy efficiency requirements<sup>2</sup>, potentially locking in inefficiencies in building envelopes for at least several decades (until the next renovation). The decisions made today about building energy efficiency will shape emissions trajectories for decades to come.

The Declaration of Chaillot in March 2024 marks a significant step in global efforts to enhance building energy efficiency<sup>3</sup>, with 70 countries pledging to implement mandatory building energy codes (BECs). This commitment reflects the growing recognition that BECs represent one of the most powerful tools available to governments for achieving their nationally determined contributions (NDCs) under the Paris Agreement. This builds on the momentum from COP28 in Dubai, where more than 130 countries pledged to triple renewable energy capacity and double the rate of energy efficiency improvements by 2030. The economic implications are substantial—the International Energy Agency (IEA) estimates that energy-efficient buildings could generate energy cost savings of over US\$1 trillion by 2050.<sup>4</sup>

Achieving these efficiency goals requires reducing building energy intensity per square meter by 30 percent by 2030.<sup>5</sup> However, the challenge extends beyond simply adopting new regulations. Many countries face barriers in implementing effective BECs, from technical capacity constraints to enforcement challenges, market readiness, and resource limitations. The rapid pace of urbanization, particularly in emerging economies, adds urgency to this challenge—the United Nations projects that 68 percent of the world's population will live in urban areas by 2050, driving unprecedented construction activity.

To understand these challenges and identify pathways forward, this report presents a comprehensive analysis of BECs across cities in 88 countries. The findings reveal both progress and significant gaps in code adoption, implementation, and enforcement. While some countries demonstrate how effective BECs can drive substantial energy savings and emissions reductions, many regions experiencing rapid urbanization lack basic regulatory frameworks for building energy efficiency.

## Key Message 1

**The buildings sector faces unprecedented construction growth, with decisions made today locking in energy consumption patterns for decades.**

The building sector is at a critical juncture in global climate action. Currently accounting for 37 percent of global CO<sub>2</sub> emissions, buildings' energy demand continues to rise at an alarming rate.<sup>6</sup> In 2022–2023 alone, construction added 2.55 billion square meters of floor space without mandatory energy efficiency requirements—equivalent to building a new city the size of Paris every week. This unregulated construction, predominantly occurring in rapidly urbanizing regions of Asia and Africa, risks locking in decades of excessive energy consumption and emissions.

The economic implications are substantial. Implementing BECs during initial construction is significantly more cost-effective than retrofitting buildings later. Energy-efficient buildings deliver measurable reductions in operating costs throughout their lifetimes, while delays in implementing codes lock in decades of unnecessary energy expenditure. This is particularly crucial in rapidly urbanizing regions, where today's

construction decisions will determine energy costs for generations to come. Building owners and occupants end up paying for inefficiency through higher utility bills and operating expenses when energy performance requirements are absent during construction.

The challenge is magnified by unprecedented urban growth projections. With urban populations expected to increase by 2.5 billion by 2050, nearly 70 percent of global building stock that will exist in 2050 is yet to be built.<sup>7</sup> Without immediate action to strengthen BECs, these new constructions could consume energy equivalent to the entire current energy use of the United States and European Union combined. This growth trajectory presents both a critical challenge and an opportunity to reshape the global built environment.

### Key Message 2

**Dramatic regional disparities in building code adoption and enforcement leave rapidly urbanizing areas vulnerable to high energy consumption.**

While 71 countries have adopted mandatory BECs, only 52 demonstrate consistent enforcement. Significant regional disparities exist—Europe shows near-universal adoption (40 countries), while rapidly urbanizing regions in Africa and South Asia remain largely unregulated. The enforcement gap between code adoption and implementation persists across all regions but is most pronounced where institutional capacity and technical resources are limited. This disparity becomes critical given the scale of projected construction in these regions—India and Africa together will add more than 100 billion square meters of new floor space between 2022 and 2050, representing over 40 percent of new global construction during this period.<sup>8</sup> Without immediate action to strengthen the regulatory frameworks, this unprecedented building boom could lock in decades of inefficient building stock.

The market transformation opportunity is substantial, particularly for developing nations. Beyond energy savings, comprehensive BECs drive innovation in construction practices, develop local supply chains for efficient building materials, and create skilled employment opportunities. These codes also serve as foundational policy tools for improving building quality and resilience, especially important in regions experiencing rapid urbanization.

### Key Message 3

**Effective implementation requires stronger verification systems and targeted support mechanisms to bridge the gap between policy and practice.**

Meeting Paris Agreement targets requires improving building energy intensity by 30 percent before 2030, but achieving this goal faces significant barriers. While 52 countries demonstrate consistent enforcement, the quality of enforcement infrastructure varies widely—only 33 out of 88 countries have comprehensive systems for inspector qualification and oversight. This suggests potential gaps between enforcement practices and verification frameworks across different regions. This gap in verification capabilities particularly affects developing regions, where the rate of new construction often exceeds the capacity to effectively verify compliance. The experience of countries with successful enforcement programs suggests that establishing clear accountability mechanisms and standardized verification procedures is as important as technical resources and training.

Building energy codes are requirements that establish minimum performance standards. While compliance is required regardless of financial support, our analysis shows that well-designed incentive programs can help accelerate market transformation and improve compliance rates. Among the 88 cities studied, 43 percent have implemented various forms of financial incentives including tax credits, grants, loans,



and rebates. Cities such as Berlin (Germany) combine mandatory requirements with programs such as the KfW initiative offering preferential financing for high-performance buildings, while Singapore's Green Mark Incentive Scheme helps offset the incremental costs of energy-efficient systems. These incentives have proven particularly effective during code transitions, helping markets adapt to new requirements while maintaining construction activity. However, the data show that incentives are most effective when designed to complement strong enforcement frameworks rather than substitute for them.

#### Key Message 4

#### **Current building energy codes have critical gaps in scope and stringency, particularly for existing buildings and fossil fuel phaseout.**

Our comprehensive analysis of 88 cities globally reveals significant variations in code comprehensiveness and enforcement. The data show distinct patterns in regulatory coverage: space cooling emerges as the most widely regulated aspect (52 countries), followed by lighting (41 countries) and heating systems (36 countries). However, only 16 countries have established requirements for existing building retrofits, despite their significance for long-term cost reduction. This limited scope, combined with resource and capacity constraints, results in many regions achieving only a fraction of potential energy savings.

The analysis reveals an emerging trend in regulatory approaches—the strategic phase-out of fossil fuel heating systems. Leading jurisdictions like the Netherlands, France, and Denmark have implemented bans on new fossil fuel heating installations, particularly in new construction and areas with district heating access. However, only a small number of countries have established clear phase-out timelines, with most focused in Europe. This policy gap is particularly concerning given heating systems' long lifespans and significant contribution to building operating costs. While some cities like New York have announced fossil fuel bans in new construction, the limited adoption of similar policies globally represents a missed opportunity for operational cost reduction.

Existing building stock represents a major untapped opportunity for energy savings, particularly in low- and middle-income countries. With most countries focusing regulations primarily on new construction, the lack of comprehensive retrofit requirements represents a significant missed opportunity. This regulatory gap becomes particularly concerning as existing buildings will constitute the majority of building stock for decades to come, especially in developed regions where new construction rates are lower. Without effective retrofit regulations, a substantial portion of building energy consumption and operational costs remains largely unaddressed by current BECs.

#### Key Message 5

#### **Countries need context-appropriate implementation strategies tailored to their economic capacity and market readiness.**

Successful implementation requires approaches tailored to the local context and economic capacity. Countries starting from minimal requirements should focus first on no-cost and low-cost measures such as passive design strategies that deliver immediate savings with minimal implementation expense. As market capacity develops, countries can progressively expand to more complex requirements—from basic envelope improvements and efficient lighting to comprehensive performance standards. This progression should be guided by market readiness and institutional capacity, supported by appropriate technical resources and financial incentives. Those with existing codes should prioritize strengthening enforcement mechanisms while systematically expanding technical coverage. This staged approach enables countries at all economic levels to capture energy savings while building lasting market capacity for high-performance buildings.

## Key Message 6

### **Successful implementation models demonstrate that effective code enforcement is achievable across diverse economic contexts.**

The Building Energy Codes Global Dataset reveals consistent patterns in successful BEC implementation across different contexts. Rwanda, as the only low-income country with comprehensive requirements, demonstrates how phased implementation focusing on large commercial buildings can build implementation capacity systematically. Their experience shows that starting with clear, enforceable requirements in major urban centers enables effective expansion as markets develop.

Regional cooperation emerges as an effective implementation strategy, particularly for developing markets. The European Union's coordinated approach to building energy standards demonstrates how shared technical resources and harmonized requirements can accelerate adoption while reducing implementation costs. This collaborative model shows particular promise for regions with similar climate conditions and construction practices.

Successful enforcement systems share common elements regardless of the economic context. These include clear compliance pathways, systematic verification procedures, and appropriate support mechanisms for market participants. Singapore's integration of building energy requirements into existing building control systems demonstrates how enforcement effectiveness depends more on systematic implementation than resource intensity.

## The Path Ahead

The urgency for action on BECs has never been greater. By 2030, the global demand for additional housing will grow by more than 77 billion square meters of floor space,<sup>9</sup> equivalent or exceeding the current built footprint of China. Forecasts report that during the next 30 years, the total floor area of buildings will increase by 75 percent, or by more than 100 percent by 2070, adding a total floor area equal to the city of Paris per week.<sup>10</sup>

Our analysis identifies three critical priorities for advancing BECs globally. First, expanding coverage to regions with limited or no current requirements, particularly in rapidly urbanizing areas of Asia and Africa. Second, strengthening enforcement mechanisms in jurisdictions with existing codes could increase significant energy savings with minimal policy changes. Finally, addressing existing buildings through retrofit requirements and performance standards to reduce current building energy consumption.

Our analysis of data collected shows that countries need differentiated approaches based on their development stage and institutional capacity. For countries introducing building efficiency standards for the first time, the focus should be on establishing basic regulatory frameworks with clear compliance pathways. For those with existing codes, priorities include strengthening enforcement mechanisms and expanding technical requirements. Advanced economies need to address the challenge of existing buildings, where retrofit requirements and performance standards can have a significant impact on energy consumption.

The opportunities for impact through enhanced BECs are substantial, but time sensitive. According to IEA's World Energy Outlook 2023, the buildings sector accounts for a significant portion of global energy consumption and emissions, making it crucial for achieving climate goals. However, these opportunities require urgent action—decisions made about building energy efficiency today will shape energy consumption and emissions patterns for decades to come.





# 1. Introduction

# 1.1 Building Energy Codes: Paving the Path to Energy Savings and Economic Value

The global imperative for improving building energy efficiency has never been more urgent. In 2022, buildings accounted for approximately 34 percent of global energy demand, with significant implications for energy security, economic competitiveness, and household affordability. The sector's energy intensity continues to rise—it is estimated that around 80 percent of projected floor area growth by 2030 is expected to occur in developing and emerging economies<sup>11</sup> and most of these countries lack the necessary building energy codes (BECs) and enforcement to limit the growth of energy demand, potentially locking in high energy consumption patterns for decades to come.

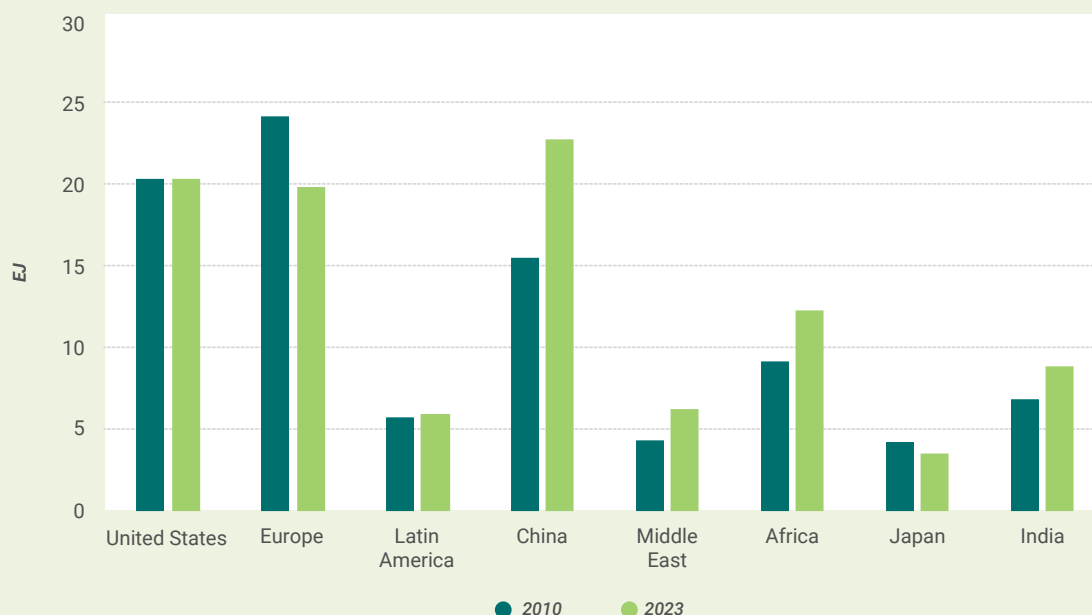
Buildings' high energy consumption has multiple impacts. At the household level, inefficient buildings lead to higher energy bills and reduced comfort, particularly affecting vulnerable populations. For businesses, building energy costs directly affect competitiveness and operating expenses. At the national level, building energy demand affects energy security and infrastructure requirements. These energy consumption patterns also contribute to environmental challenges, including local air quality issues and greenhouse gas (GHG) emissions.

The magnitude of potential benefits from building energy efficiency is substantial. The IEA estimates that efficient buildings could generate energy cost savings of over US\$1 trillion by 2050. Beyond direct cost savings, energy-efficient buildings create jobs in construction and renovation, improve indoor comfort and health outcomes, reduce pressure on energy infrastructure, and support national energy security goals. These multiple benefits make building energy efficiency a priority for policy makers across different contexts.

BECs serve as a fundamental policy tool for capturing these benefits. When properly implemented, BECs have demonstrated remarkable success: buildings constructed under modern energy codes in the European Union consume approximately 50 percent less energy than those built before such regulations. Specifically, new residential buildings in Europe are estimated to consume about 60 percent less energy on average compared to those constructed before the mid-1970s.<sup>12</sup> Similarly, stringent BECs in China have led to significant reductions in energy consumption, with improvements of up to 75 percent compared to buildings from the 1980s, as seen in national standards and cities like Shanghai.<sup>13</sup> These improvements translate into significant economic benefits—studies indicate that every dollar invested in building energy efficiency generates an average of three dollars in lifetime energy savings.<sup>14</sup>

The urgency of implementing effective BECs is amplified by unprecedented urbanization. According to the World Bank's Urban Development overview, 56 percent of the world's population—4.4 billion people—currently live in cities, with projections showing this will reach 70 percent by 2050.<sup>15</sup> This ongoing urbanization drives massive construction activity, making today's decisions about building energy efficiency crucial for future energy consumption patterns, infrastructure requirements, and economic competitiveness.

The implementation gap in BECs takes multiple forms, as our analysis of 88 countries reveals. First, there is the coverage gap—many rapidly urbanizing countries still lack any mandatory building energy requirements. Second, where codes exist, they often have limited scope, covering only certain building types or systems while leaving significant energy uses unregulated. Third, technical requirements in many countries lack the stringency needed to achieve meaningful energy savings. Fourth, even countries with comprehensive codes often struggle with enforcement—our data shows that of 71 countries with mandatory requirements, only 52 demonstrate consistent enforcement. Finally, many codes lack specific provisions for existing buildings, despite their dominant share of energy consumption. Bridging these multiple

**Figure 1 // Total Energy Consumption in Buildings**

Source: World Energy Outlook 2024

implementation gaps requires a multifaceted approach that combines strengthening technical requirements, expanding coverage to new regions and building types, developing enforcement capacity, and establishing clear compliance pathways for both new construction and existing buildings. The success of countries such as Singapore demonstrates how systematic implementation frameworks combining all these elements can achieve substantial energy savings across the building sector.

## 1.2 Evolution of Building Energy Codes: From Energy Crisis to Climate Response

The evolution of BECs reflects changing global priorities and understanding of environmental challenges. While today's codes focus primarily on emissions reduction and climate action, their origins stem from the energy security concerns of the 1970s. Denmark's pioneering approach in 1961, incorporating energy consumption limits into building codes, demonstrated early recognition of buildings' role in energy efficiency. This foundation proved particularly valuable when the 1970s energy crisis sparked broader adoption of building energy regulations across industrialized nations.

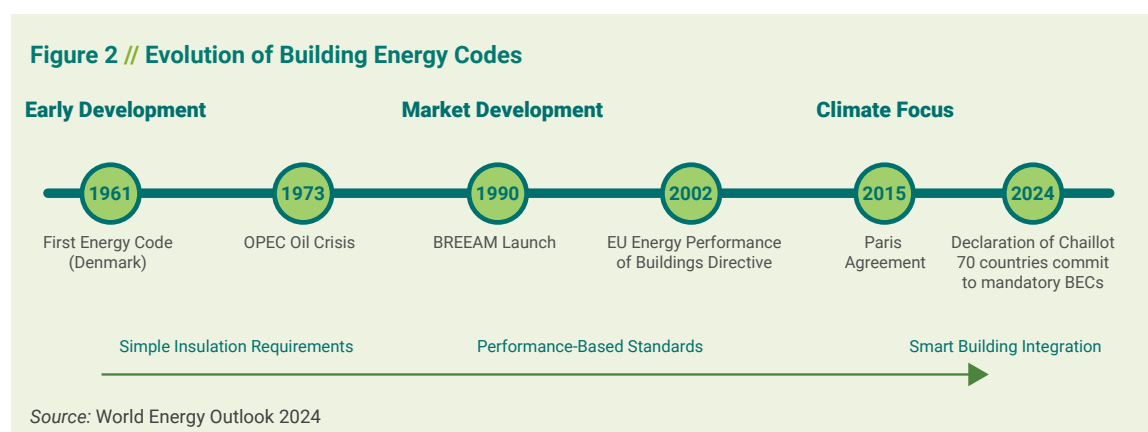
The development of BECs accelerated significantly through the 1980s and 1990s, driven by technological advances and growing awareness of energy efficiency benefits. This period saw the transition from simple prescriptive requirements to more sophisticated performance-based standards. Computer modeling enabled complex energy calculations, while the scope expanded beyond basic insulation and heating to encompass comprehensive building energy systems. The advancement of simulation tools and energy modeling capabilities allowed codes to incorporate more sophisticated requirements for heating, ventilation, and air conditioning (HVAC) systems, lighting controls, and whole-building energy performance, enabling more flexible compliance pathways while maintaining clear performance targets.



The turn of the millennium marked a transformative shift, with climate change becoming the central driver of building energy policy. The 2015 Paris Agreement's explicit recognition of buildings as a key sector for emission reduction spawned a new generation of codes focused on carbon reduction. Contemporary BECs now address multiple objectives simultaneously—from energy efficiency and GHG reduction to climate resilience and smart grid integration. This evolution reflects both practical necessity and growing recognition of buildings' critical role in achieving global climate goals.

At COP28 in December 2023, the Buildings Breakthrough was formally launched with support from 28 countries and the European Commission, growing to 29 countries by June 2024. The initiative aims to make near-zero emission and resilient buildings 'the new normal' in all regions by 2030. Building on this momentum, participating countries have begun developing implementation frameworks to strengthen their building energy codes and standards.

Today's BECs combine decades of implementation experience with modern environmental imperatives. They have evolved from simple energy conservation measures to sophisticated frameworks that balance multiple objectives: operational efficiency, carbon reduction, climate resilience, occupant comfort, and grid integration. This comprehensive approach positions BECs as essential tools for addressing both immediate energy challenges and long-term climate goals.



## 1.3 Specific Objectives

This report addresses a critical gap in the understanding of global BECs and their implementation. Through a comprehensive analysis of data from 88 countries, the Building Energy Codes Global Dataset provides actionable insights that can accelerate the adoption and enforcement of effective building energy policies worldwide. The objectives extend beyond mere documentation to create a strategic framework for advancing building energy efficiency in both developed and developing economies.

The primary analysis focuses on three interconnected dimensions: the current state of BECs, their effectiveness in implementation, and the pathways for improvement. Through a detailed examination of existing energy efficiency standards and their practical application, the research identifies both successful approaches and critical shortcomings that affect the progress toward climate targets. This analysis is particularly timely given the urgency of meeting Paris Agreement commitments and the rapidly evolving landscape of building technology and design.

This comprehensive analysis examines BECs through three core dimensions.

**First**, the report conducts a **detailed assessment of existing BECs** across different jurisdictions, analyzing their stringency, comprehensiveness, and technical requirements. This includes evaluation of both mandatory and voluntary standards, their coverage of new construction versus existing buildings, and their adaptation to local climate conditions and construction practices.

**Second**, the analysis examines the **enforcement mechanisms and institutional frameworks** supporting these codes. This investigation reveals significant variations in implementation effectiveness, highlighting the gap between policy adoption and practical outcomes. By identifying successful enforcement strategies and common implementation barriers, the research provides valuable insights for strengthening regulatory frameworks.

**Third**, the study analyzes the **relationship between BECs and broader climate objectives**. This includes assessment of how current standards align with national and international climate commitments, and identification of areas where more ambitious requirements are needed to meet emissions reduction targets.

The report's findings draw from a meticulously compiled dataset, which represents the most comprehensive collection of BEC information to date. The methodology combines quantitative analysis of code requirements with qualitative assessment of implementation experiences, providing a nuanced understanding of policy effectiveness across different contexts.

Through this analysis, several critical patterns emerge. The research highlights the varying maturity of BECs across different regions and income levels. It identifies common barriers to effective implementation and enforcement, as well as successful strategies for adapting codes to local conditions. Additionally, the report points out opportunities for strengthening standards to meet climate targets and emphasizes the importance of capacity building and technical assistance in supporting code adoption.

The recommendations offered in the report focus on practical steps for enhancing BECs and their implementation. These include developing more robust legal and institutional frameworks, improving enforcement mechanisms, integrating new technologies and performance standards, harmonizing codes with climate objectives, and creating models to support developing countries in adopting and implementing these codes.

This report is intended for multiple audiences, including policy makers looking to develop or strengthen BECs, practitioners involved in code implementation and enforcement, and stakeholders interested in understanding the role of building regulations in climate action. By providing both comprehensive analysis and actionable recommendations, the research aims to accelerate the transition toward more energy-efficient and sustainable built environments globally.

The urgency of this work is paramount. As global construction activity continues at an unprecedented pace—particularly in rapidly urbanizing regions—the decisions made today regarding building energy efficiency will have lasting impacts on emissions and energy consumption for decades to come. This report provides the necessary evidence base and strategic framework to ensure that these decisions contribute to, rather than undermine, collective climate objectives.

Through this comprehensive analysis and strategic framework, the research aims to catalyze the development of more effective BECs worldwide, contributing to both immediate energy efficiency improvements

and long-term climate goals. The insights and recommendations presented offer a roadmap for strengthening building energy policies at all levels, from local to national to international.

## 1.4 Description of the Data Collection Methodology

**The Building Energy Codes Global Dataset's data collection followed a multi-phase methodology, engaging stakeholders from the architecture, engineering, and construction sectors.** The process was facilitated through online questionnaires in five languages and a downloadable Word document, encouraging broad global participation. The approach benefited from the expertise of the Development Economics Indicators Group (DECIG), which has extensive experience in gathering detailed regulatory data, including building control standards.

### 1.4.1 A CITY-LEVEL ANALYSIS

While the project's analysis acknowledges that many of the examined BECs and standards operate at a national level, the Building Energy Codes Global Dataset specifically references **one city per country**. This focused approach is adopted due to the recognition that, in several instances, BECs are implemented at the city level, resulting in variations that are not captured by national standards alone. This distinction is crucial for understanding the nuanced application of energy efficiency regulations and ensuring that the dataset accurately reflects the real-world scenario where cities might adopt additional or more stringent measures than those outlined at the national level. This city-specific approach enables the dataset to provide a more detailed and accurate picture of the energy efficiency landscape, accommodating the diversity of regulatory frameworks across different geographical and administrative regions. By selecting a representative city from each country, the project aims to illustrate how national standards are adapted and applied in urban contexts, highlighting the importance of local governance in the enforcement and enhancement of building energy efficiency measures. This methodology ensures that the Building Energy Codes Global Dataset offers valuable insights for policy analysis and research, catering to the specific needs and challenges of urban areas in the realm of energy-efficient building practices.

### 1.4.2 CLIMATE ZONE CLASSIFICATIONS FOR BUILDING STANDARDS

Understanding the importance of climate zone classifications for buildings is crucial when analyzing and comparing regulations and standards across different geographic areas. The Building Energy Codes Global Dataset provides data at the city level rather than the country level due to significant geographic and climate differences that can exist within individual countries. This granular approach enables a more accurate analysis and comparison of data, as climate conditions can vary greatly from one city to another, thereby influencing the energy efficiency requirements for buildings in those locations. The dataset has integrated the Climatic Data for Building Design from Addendum A of the ANSI/ASHRAE Standard 169-2020, identified by the variable 'Climate\_class'.<sup>16</sup> This approach and the specific classification it represents are also widely recognized and utilized in academic research,<sup>17</sup> reflecting a common methodology for analyzing and addressing climatic impacts on building design and energy efficiency.

### 1.4.3 EXPERT SURVEYS FOR SOURCES AND QUALITATIVE DATA

A key component of the data collection process was the questionnaire, which targeted professionals across various fields such as architecture, engineering, environmental consulting, and academia. By offering digital and downloadable formats, the survey ensured accessibility for participants from diverse



backgrounds, underlining the value of their unique perspectives. The questions focused on mandatory minimum energy performance standards, gathering critical insights into this important aspect of building energy efficiency. Notably, most respondents came from the private sector, underscoring the private market's active role in addressing energy efficiency in buildings and highlighting the alignment between private and public sectors in advancing this agenda. The input from a broad spectrum of experts, each with their unique perspective, enriched the dataset, offering practical perspectives on the implementation and challenges of enforcing energy efficiency standards.

#### 1.4.4 DESK RESEARCH FOR QUANTITATIVE DATA FOR BENCHMARKING

**On the other hand, desk research formed a foundational element of the data collection strategy, focusing on national building energy efficiency standards.** Given the significant variations within countries, a targeted approach was adopted, mainly due to different climate zones. One city per country was selected for detailed analysis based on factors such as building demand, population growth, and climate zone, often coinciding with the capital. This allowed the research team to examine how national standards translate into local requirements. Cross-referencing the cities selected for desk research with those included in the survey ensured consistency between the findings, offering a comprehensive and climate-specific perspective on building energy efficiency codes and standards. This integrated approach provided valuable insights into how regions address the challenges and opportunities of energy-efficient building practices.

For a detailed explanation of the methodology used to create the database, please refer to the [Methodology Note](#).



## 2. Global Status

## 2.1 Building Energy Codes Global Dataset Overview and Distribution

The analysis examines BECs across 88 countries through a city-specific lens, where one representative city was selected per country (Annex 1). This sample represents almost every country with a mandatory BEC as of January 2025, which leaves more than half of the world still lacking a framework to promote energy efficiency in buildings. While many of the examined building energy codes and standards operate at a national level, this city-focused approach recognizes that in several instances, BECs are implemented at the municipal level, resulting in variations that may not be captured by national standards alone. This dataset encompasses countries that have established some form of building energy efficiency requirements, ranging from basic standards to comprehensive codes, providing insight into the diverse approaches to regulating building energy performance across different geographic, economic, and climatic contexts.

The regional distribution of these 88 countries reflects both the historical evolution of building energy regulations and current gaps in global coverage. Europe and Central Asia show the strongest representation with 40 countries, reflecting the region's early adoption and continued leadership in building energy efficiency regulation. East Asia and Pacific follows with 14 countries, while Latin America and Caribbean and the Middle East and North Africa register 12 and 11 countries, respectively. The more limited representation from South Asia (4 countries), Sub-Saharan Africa (5 countries), and North America (2 countries) highlights significant regional disparities in BEC adoption and implementation.

The economic profile of the surveyed countries reveals important patterns in code adoption and enforcement capability. High-income countries constitute the majority with 47 nations, while 22 are classified as upper-middle-income, and 17 as lower-middle-income. Notably, only one low-income country appears in the Building Energy Codes Global Dataset, underscoring a critical gap in regulatory coverage among economically disadvantaged nations. This disparity becomes particularly concerning given that many rapidly urbanizing regions fall within lower-income categories, where building energy efficiency could have the most significant impact on future energy consumption patterns.

Climate classification of the studied cities adds another crucial dimension to understanding BEC implementation patterns (Annex 1). The largest group comprises 22 cities in warm climate zones, followed by 19 in mixed climate zones, and 18 in extremely hot zones. Cool climate zones account for 11 cities, while hot climate zones include 8 cities. The smallest representations are from cold climate zones (7 cities) and very hot climate zones (2 cities). This distribution shows that many cities in warmer climates have not yet implemented BECs. Given projections of increasing cooling demand in these regions over the next three decades, this presents an opportunity to shape future energy consumption patterns through building design and system efficiency requirements. The variation in requirements across climate zones thus reflects both different environmental conditions and varying stages of BEC development.

**Table 1 // Distribution of Global Dataset Cities by Climate Zone and Income Group**

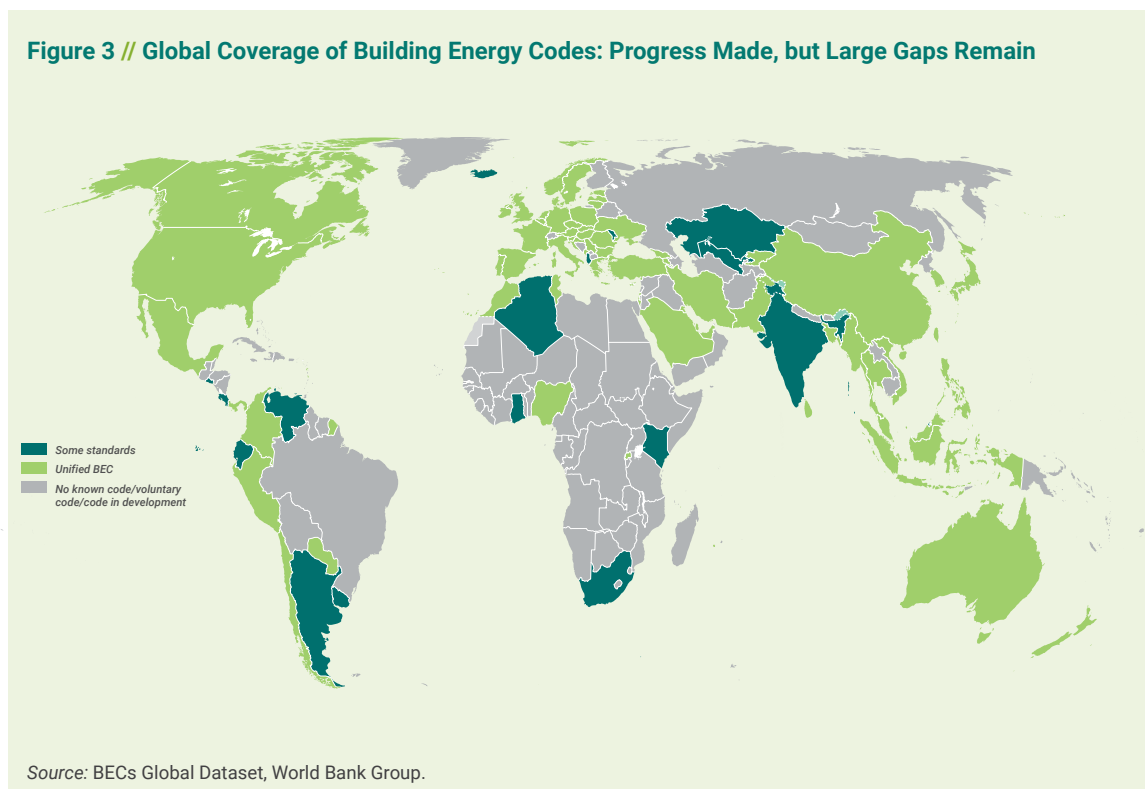
Income Group	Cold	Cool	Mixed	Warm	Hot	Very hot	Extremely hot
High income	7	8	12	10	2	1	7
Upper middle income		2	5	8	3		4
Lower middle income		1	2	4	2	1	7
Low income					1		

Source: Building Energy Codes Global Dataset, World Bank Group.



## 2.2 Global Adoption of Building Energy Codes and Standards

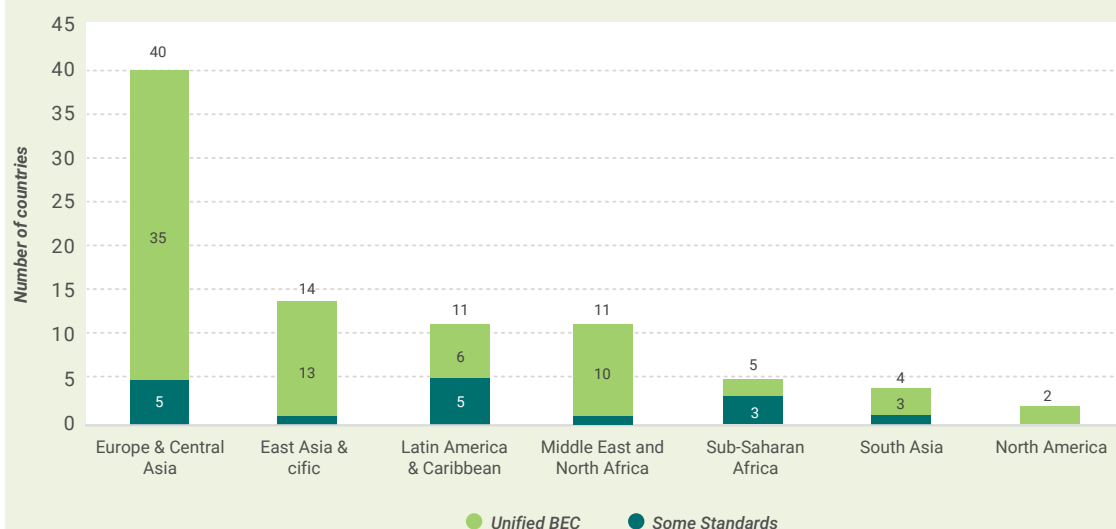
**Figure 3 // Global Coverage of Building Energy Codes: Progress Made, but Large Gaps Remain**



BECs serve as a fundamental policy tool for transforming the construction sector and addressing climate change. These regulations serve as the primary mechanism for ensuring that new buildings meet minimum energy performance requirements, while also providing frameworks for improving existing building stock. Unlike voluntary green building programs or market-based incentives, mandatory BECs can systematically raise the baseline for building performance across entire jurisdictions. Their impact extends far beyond individual buildings—well-designed and properly enforced codes shape construction practices, influence material and equipment markets, develop workforce expertise, and create lasting change in how buildings are designed, constructed, and operated.

Our analysis of BECs reveals that 71 out of 88 countries have unified BECs,<sup>18</sup> while the remaining 17 countries have some standards related to building energy efficiency but lack a comprehensive unified framework. This reflects a significant global gap in energy efficiency regulation, as the absence of BECs in the majority of countries remains a major challenge. While our findings highlight variations in implementation and enforcement among these 88 countries, the broader issue is that most countries worldwide still lack mandatory BECs (Figure 3).

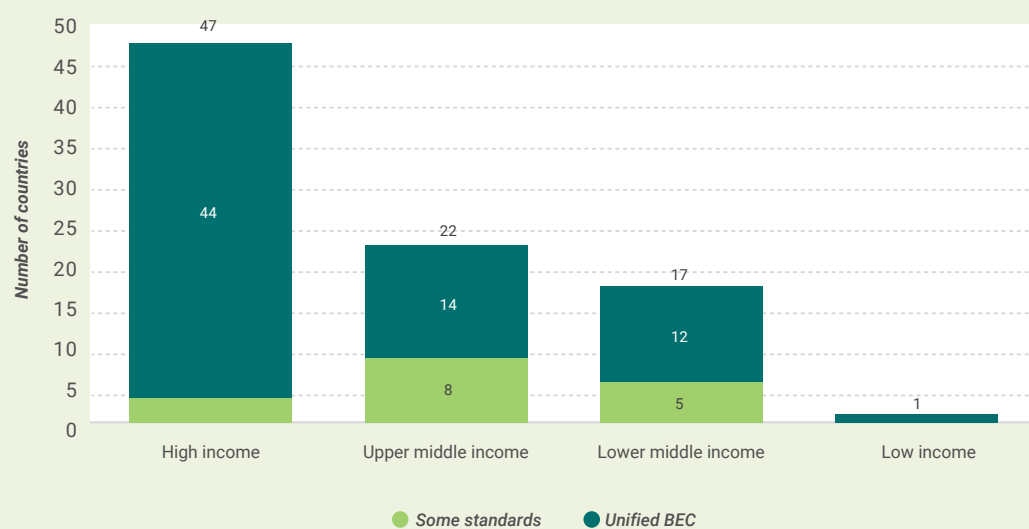
Europe and Central Asia constitutes the region with the most comprehensive adoption, with 35 out of 40 countries maintaining unified BECs (Figure 4). This success stems from strong institutional frameworks, particularly the European Union's regulatory influence, and decades of capacity building. Similar progress is evident in the Middle East and North Africa, where 10 out of 11 countries have implemented codes, often driven by the imperative to manage cooling energy demands in extreme climates. In contrast, Latin

**Figure 4 // Building Energy Codes by Region**

Source: Building Energy Codes Global Dataset, World Bank Group.

America and the Caribbean shows more limited adoption, with only 6 out of 12 countries maintaining unified codes, while Sub-Saharan Africa has just 5 countries with mandatory requirements.

The relationship between economic development and code implementation reveals both expected patterns and surprising exceptions (Figure 5). Among high-income countries, code adoption is nearly universal. Upper-middle-income countries show strong but varied implementation, while the 17 lower-middle-income countries demonstrate emerging engagement. Low-income countries remain significantly underrepresented, with Rwanda standing as a notable exception that offers crucial lessons for developing

**Figure 5 // Building Energy Codes by Income Group**

Source: Building Energy Codes Global Dataset, World Bank Group.

nations. Similarly, Nigeria demonstrates how federal systems can effectively implement codes despite complex governance structures, providing valuable insights for other large, diverse nations.

The varied landscape of BEC adoption reflects both common challenges and innovative solutions. Regions with strong adoption share key success factors, including robust technical capacity, clear enforcement mechanisms, and strong coordination between authorities. Areas with limited implementation often face institutional capacity constraints and competing priorities. However, innovative approaches are emerging to address these barriers. Some countries are adopting simplified codes as a first step, while others are focusing on larger buildings initially before expanding to broader coverage. These diverse implementation pathways demonstrate the importance of tailoring approaches to local contexts while drawing on established best practices.

This analysis sets the stage for a deeper examination of specific technical requirements, enforcement mechanisms, and market transformation strategies detailed in subsequent sections. Understanding these patterns helps identify both immediate opportunities for code enhancement and longer-term strategies for expanding coverage to currently unregulated construction. The experiences of early adopters and successful implementers offer valuable lessons for countries at all stages of code development, while highlighting the urgent need to address gaps in coverage as global construction continues at unprecedented rates. The decisions made today about building energy efficiency will shape emissions trajectories for decades to come. Countries that have achieved success in implementing and enforcing BECs demonstrate that while challenges exist, they can be overcome through systematic approaches and strong institutional frameworks.

## 2.3 Building Energy Code Classification and Types

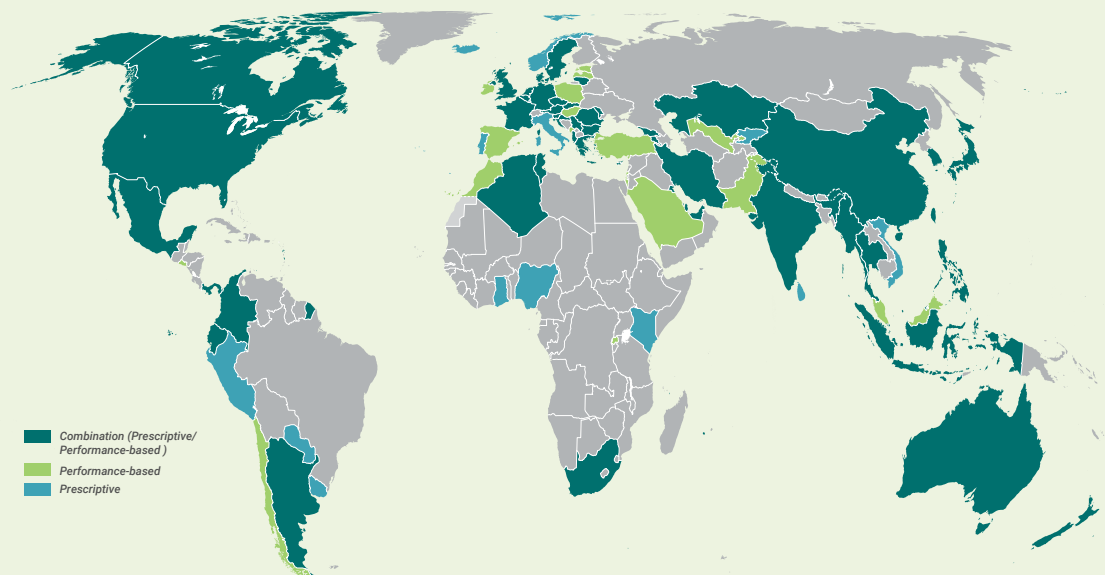
### 2.3.1 BEC CLASSIFICATION

Building energy codes (BEC) represent a foundational policy instrument for improving sustainability and reducing energy consumption in the built environment. These codes provide standards and guidelines that shape the design, construction, and operation of buildings to minimize GHG emissions and achieve high levels of energy efficiency. However, countries around the world have adopted diverse approaches to implementing BECs and can be classified broadly as either prescriptive or performance-based models. Understanding these different code classification systems is essential for evaluating the strengths, weaknesses, and optimal strategies for realizing the full benefits of energy-efficient buildings<sup>19</sup>. Most countries in the global database blend performance and prescriptive (combined approach), followed by performance and prescriptive BECs (Figure 6).

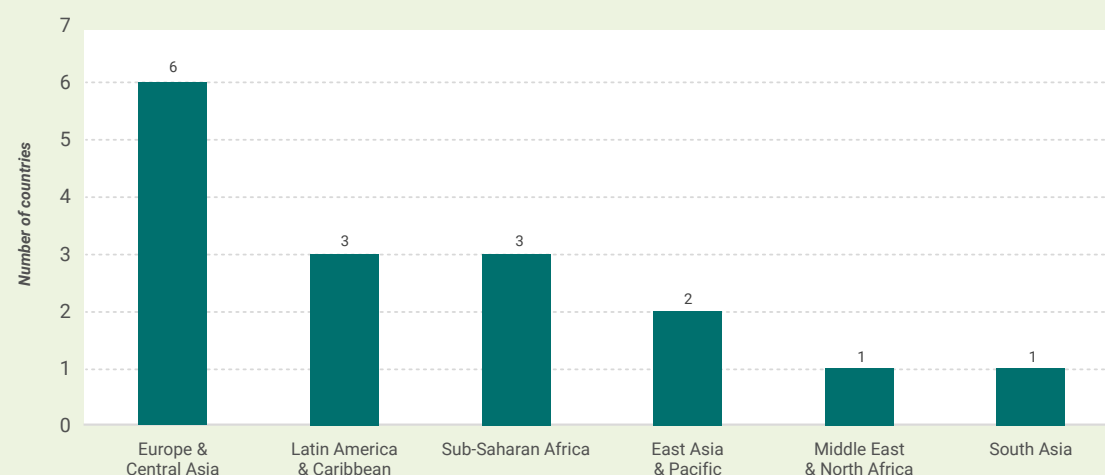
### 2.3.2 PRESCRIPTIVE BUILDING ENERGY CODES

Prescriptive BECs specify minimum performance requirements for individual building components and systems (Figure 7). These include specific criteria for elements like HVAC, lighting, windows, walls, and roofs. Their primary advantages are simplicity and ease of enforcement—authorities can readily verify compliance through straightforward checklists. These codes establish clear thresholds such as maximum U-values for building envelopes, minimum efficiency ratings for equipment, and specific requirements for insulation thickness or window-to-wall ratios. While prescriptive codes offer clarity for builders and code officials alike, they can sometimes limit design flexibility and innovation by requiring specific solutions rather than focusing on overall building performance. Despite these limitations, prescriptive



**Figure 6 // Global Distribution of Building Energy Code Approaches by Country**

Source: Building Energy Codes Global Dataset, World Bank Group.

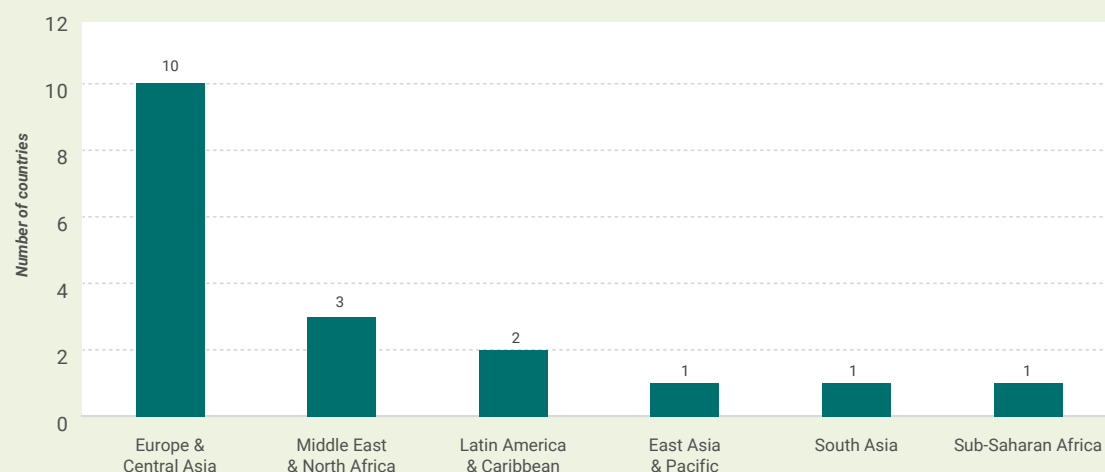
**Figure 7 // Regional Distribution of Prescriptive Building Energy Codes**

Source: Building Energy Codes Global Dataset, World Bank Group.

approaches remain particularly valuable for markets with limited technical capacity or in early stages of building energy regulation, as they provide concrete standards that can be incrementally strengthened over time. The Kyrgyz Republic's BEC exemplifies this approach, with specific U-values prescribed for building envelope components: walls (0.42 W/m<sup>2</sup>K), roofs (0.35 W/m<sup>2</sup>K), and windows (1.67 W/m<sup>2</sup>K). The global dataset reveals that 16 out of 88 countries have what could be described as fully prescriptive BECs.

### 2.3.3 PERFORMANCE-BASED BECS

**Figure 8 // Regional Distribution of Performance-Based Building Energy Codes**



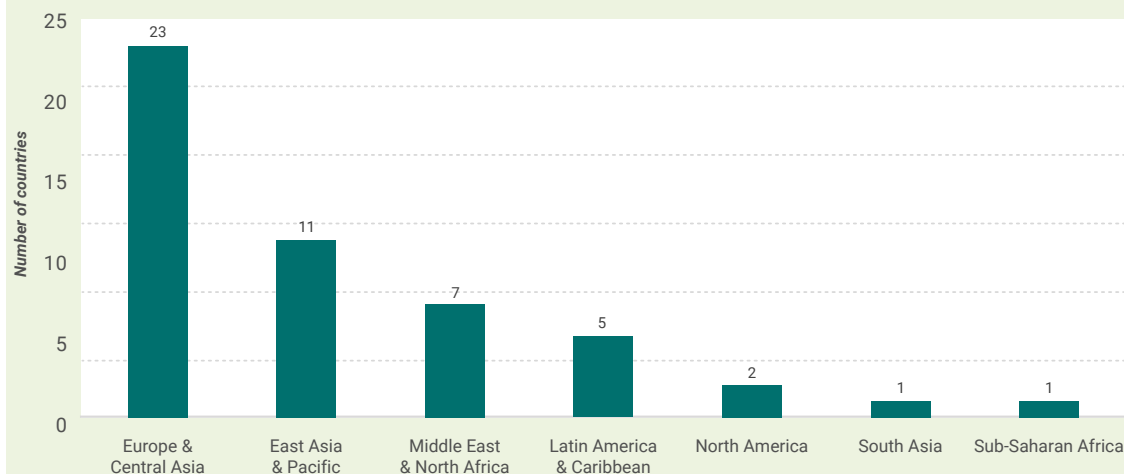
Source: Building Energy Codes Global Dataset, World Bank Group.

Performance-based codes establish whole-building energy efficiency targets without dictating specific component requirements. Instead of prescribing individual element specifications, they define overall energy use intensity (EUI) or similar performance metrics that buildings must achieve. Estonia demonstrates this approach, focusing on overall building energy performance targets rather than prescribing specific U-values for individual components, allowing designers flexibility in achieving energy efficiency goals). This approach encourages innovation by permitting architects and engineers to explore diverse strategies and technologies to meet the performance criteria. Under this framework, designers might optimize building orientation, incorporate passive design elements, select high-efficiency systems, or integrate renewable energy sources based on project-specific conditions and cost-effectiveness. The verification of these codes demands advanced modeling capabilities and technical expertise to accurately predict building energy performance, though this complexity is balanced by potential cost optimizations and greater energy savings through integrated system approaches. The global dataset reveals that 18 out of 88 countries have performance-based BECs (Figure 8).

### 2.3.4 COMBINED (PRESCRIPTIVE/PERFORMANCE-BASED) BUILDING ENERGY CODES

Many jurisdictions adopt a hybrid approach combining prescriptive and performance elements (Figure 9). This approach typically includes baseline prescriptive requirements ensuring minimum standards, supplemented by performance-based options allowing design flexibility. The prescriptive component establishes clear minimum specifications for building elements and systems, providing a straightforward compliance path for simpler projects. Meanwhile, the performance-based component enables projects to explore innovative solutions and trade-offs between different systems while meeting overall energy targets. The global dataset reveals that 50 out of 88 countries have combined BECs.

Singapore's BEC exemplifies this combined approach, setting prescriptive requirements for envelope thermal transfer values (ETTVs) and minimum equipment efficiencies while also allowing performance-based compliance paths for overall building energy efficiency. Projects can either meet specific component

**Figure 9 // Regional Distribution of Combination (Prescriptive/Performance-based) BECs**

Source: Building Energy Codes Global Dataset, World Bank Group.

requirements (like maximum ETTV of 50 W/m<sup>2</sup>) or demonstrate equivalent overall performance through energy modeling, enabling innovation while maintaining robust minimum standards.

The combined approach offers several advantages: it provides clear guidance through prescriptive requirements while enabling innovation through performance pathways; it accommodates both simple and complex projects within the same regulatory framework; and it helps bridge the gap between theoretical design intent and actual building performance. This hybrid method has proven particularly effective in jurisdictions transitioning from purely prescriptive approaches to more sophisticated performance-based requirements.

### 2.3.5 MANDATORY VERSUS VOLUNTARY BUILDING ENERGY CODES

The choice between mandatory and voluntary BECs significantly affects their effectiveness and market transformation potential. Mandatory codes carry legal force, ensuring widespread adoption and compliance across the building sector. These codes establish clear minimum requirements that all new construction and major renovations must meet, creating a level playing field and driving systematic improvement in building energy performance. Japan demonstrates successful implementation of mandatory codes through its Energy Conservation Law, which requires specific energy performance standards for all new buildings above a certain size. The mandatory nature of these requirements has helped Japan achieve significant reductions in building energy consumption while fostering innovation in energy-efficient building technologies.

Voluntary codes serve as recommended guidelines but lack enforcement mechanisms. While they may achieve lower immediate impact, voluntary codes can play a crucial role in market development and capacity building. The CARICOM countries exemplify this approach, using voluntary energy efficiency building codes as stepping-stones toward mandatory implementation. CREEBC provides technical guidelines while allowing member states to build market capacity and adapt requirements to local conditions. This voluntary phase helps identify implementation challenges, develop professional expertise, and demonstrate feasibility before mandatory requirements are introduced.

**BOX 1. CARICOM: Regional Cooperation in Voluntary Building Energy Codes**

The Caribbean Community and Common Market (CARICOM) is a regional economic and political organization consisting of 20 developing nations located within the Caribbean and Atlantic Ocean region. Despite possessing abundant renewable energy resources, CARICOM member states face significant challenges such as economic fragility, development inequality, high energy costs, and frequent natural disasters.

In recent years, the CARICOM region has made substantial progress toward collectively developing and implementing a regional standard for green buildings, known as the CARICOM Regional Energy Efficiency Building Code (CREEBC). This initiative reflects a collective regional approach to enhancing energy efficiency and environmental sustainability within the Caribbean.

The CREEBC standard was designed based on the International Energy Conservation Code 2018 but has been locally modified to address the unique challenges faced by the Caribbean, such as high energy costs primarily due to heavy reliance on expensive hydrocarbon-based electricity generation, as well as the region's vulnerability to natural disasters.

The national standards bureaus of CARICOM member nations have played a crucial role in the design and adoption of the CREEBC standard. For instance, the Antigua and Barbuda Bureau of Standards has led the development of the CREEBC and introduced several other green policies at the national level, resulting in notable reductions in carbon emissions and cost savings.

To encourage the adoption of the regional standard and promote further green building development, many CARICOM governments have implemented various incentives, including rebates, fee reductions, and financial grants. However, the degree of acceptance and implementation of the CREEBC standard varies across the member states, with some countries still working on modifying the code to align with local circumstances.

Significant progress has also been achieved in green building construction within the CARICOM region, with several projects earning prestigious LEED certifications. The Discovery Center at Mount Obama National Park in Antigua and Barbuda, which is completely powered by renewable energy, stands out as the first LEED-certified project<sup>a</sup> in the country.

Despite these advancements, challenges remain in the full implementation of the CREEBC standard. The lack of comprehensive data on the number of green buildings, as well as specific difficulties faced by smaller and more disaster-prone CARICOM countries, are among the key issues that need to be addressed.

Continued collaboration and support at both the regional and international levels will be crucial to realizing the full potential of this green building initiative. Initiatives such as the establishment of the CARICOM Resilience Fund and the Caribbean Centre for Renewable Energy and Energy Efficiency's Sustainable Building Program demonstrate the commitment to driving sustainable development in the region.

a. Jenkins, M. (2021, May 14). *The Caribbean commitment: Antigua and Barbuda's first LEED project*. U.S. Green Building Council

The choice between mandatory and voluntary BECs depends on a country's institutional capacity, enforcement mechanisms, and overall ability to implement and sustain compliance. Mandatory codes are most effective when supported by strong governance structures, sufficient enforcement resources, and an industry capable of meeting regulatory requirements. In contrast, voluntary codes can serve as a stepping-stone when accompanied by incentives, technical support, and a clear transition plan toward mandatory adoption. Some jurisdictions take a phased approach, initially applying voluntary standards to specific building types or size thresholds before expanding to broader mandatory requirements. This gradual transition allows markets to adapt, strengthens enforcement mechanisms, and builds industry capacity over time.



## 2.4 Building Classification

BECs typically classify buildings based on their use, size, and complexity to establish appropriate energy efficiency requirements. However, the approach to building classification varies significantly across jurisdictions, reflecting local priorities, climate conditions, and building sector characteristics.

Most jurisdictions make a fundamental distinction between residential and non-residential buildings in their BECs. For example, the European Union's Energy Performance of Buildings Directive (EPBD) requires member states to establish separate energy performance requirements for different building categories. France's thermal regulations (RE2020) set distinct energy consumption targets for residential buildings (50 kWh/m<sup>2</sup>/year) versus office buildings (70 kWh/m<sup>2</sup>/year), recognizing their different usage patterns and energy needs.

Some countries employ more nuanced classification systems. Canada's National Energy Code for Buildings (NECB) categorizes buildings into eight distinct groups: residential (low and high-rise), office, mercantile, assembly, institutional, industrial, and storage/warehouse. Each category has customized energy performance requirements that account for specific usage patterns, occupancy schedules, and equipment loads. Similarly, China's BEC system distinguishes between residential, public (including commercial), and industrial buildings, with separate technical requirements and compliance paths for each type.

Building size often plays a crucial role in classification schemes. The United States ASHRAE 90.1 standard, widely adopted across multiple jurisdictions, includes specific provisions for buildings based on their conditioned floor area, recognizing that larger buildings often have more complex energy systems and greater potential for efficiency improvements.

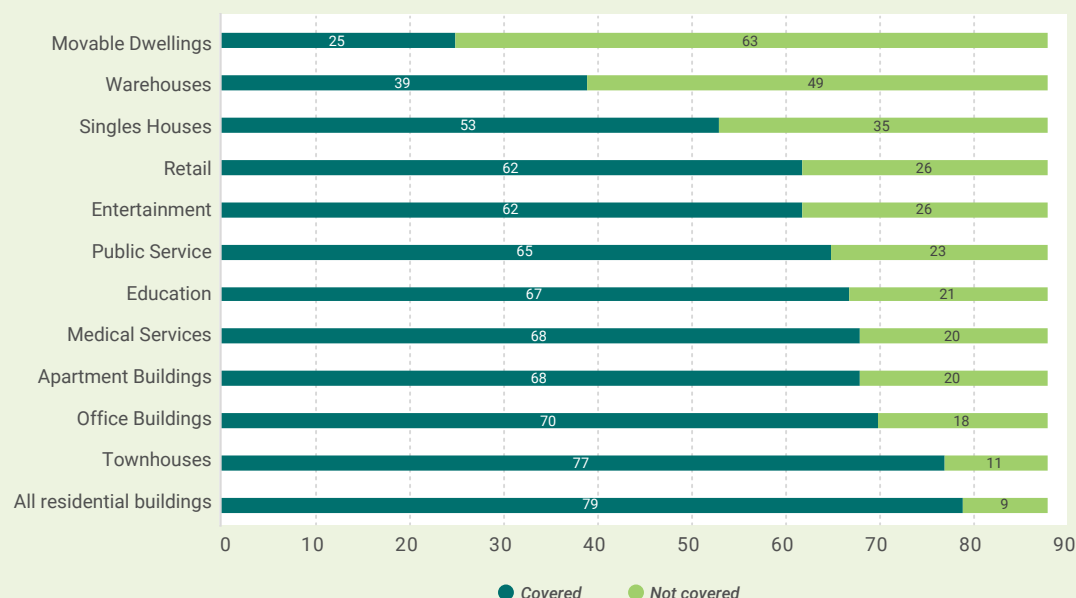
Many jurisdictions incorporate climate zones into their building classification systems to account for varying environmental conditions. The International Energy Conservation Code (IECC), used extensively in the United States, defines eight climate zones with distinct energy efficiency requirements for each. Similarly, India's Energy Conservation Building Code (ECBC) divides the country into five climate zones, with building requirements tailored to each zone's specific challenges and opportunities.

### 2.4.1 CONSTRUCTION TYPES COVERED IN BUILDING ENERGY CODES

The types of construction projects covered by BECs fundamentally shape their market impact and effectiveness in reducing energy consumption. While new construction presents the most straightforward opportunity for implementing energy efficiency requirements, renovation projects, additions, and changes in building use collectively represent a massive opportunity for improving building energy performance. Understanding which construction activities trigger code compliance helps identify both the reach and limitations of current regulatory frameworks. These coverage decisions reflect practical trade-offs between maximizing energy savings potential and maintaining feasible implementation pathways, particularly in markets with limited enforcement capacity. Our analysis reveals how different jurisdictions balance these considerations, providing insights into effective strategies for expanding code coverage while ensuring consistent enforcement.

#### Analysis from the Building Energy Codes Global Dataset

Most cities impose codes or standards on various types of commercial and residential buildings, with specific scope definitions for which building categories are covered (Figure 10). Codes in Singapore, Kuala Lumpur, Tokyo, and Beijing geared toward commercial buildings and exempt residential buildings

**Figure 10 // Number of Cities by Building Type Coverage in BECs**

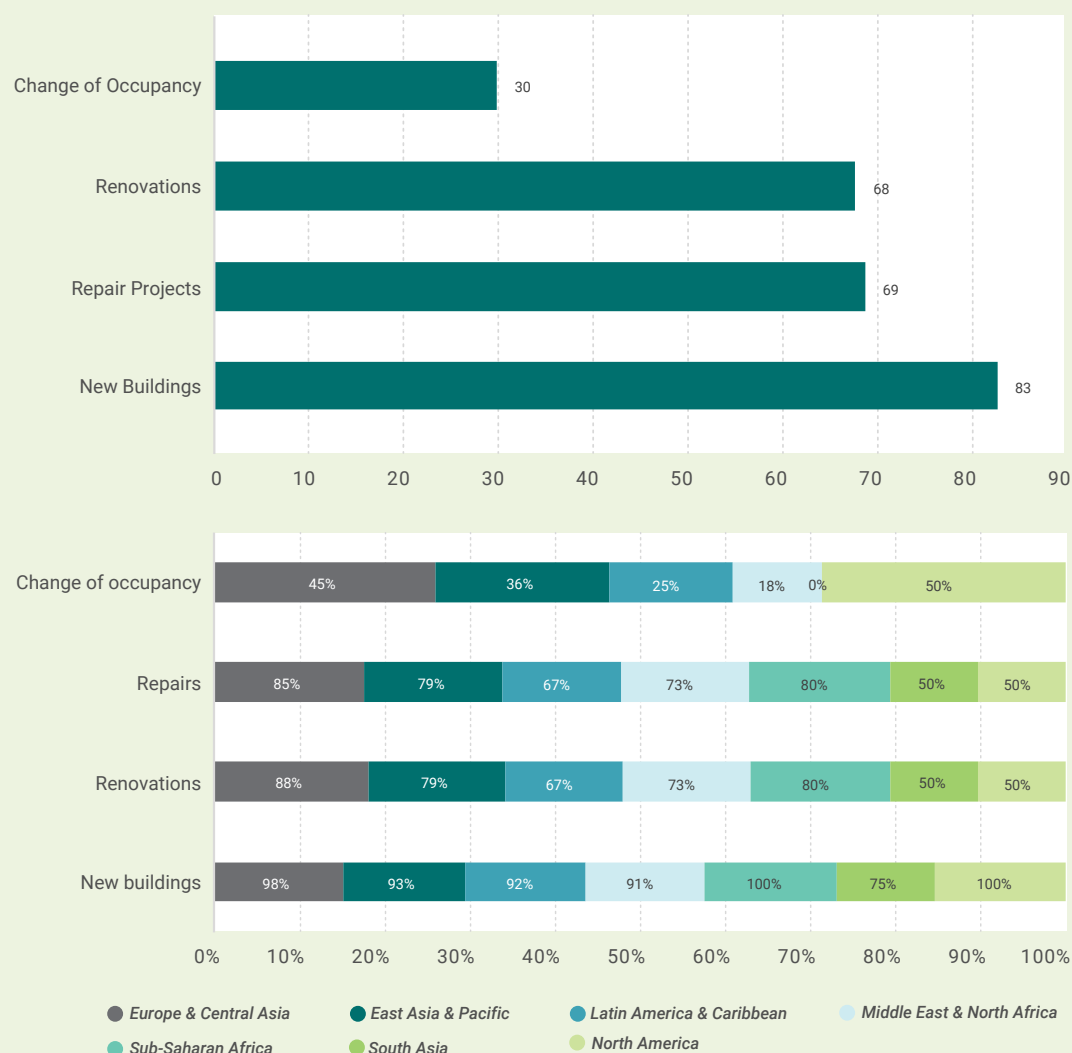
Source: Building Energy Codes Global Dataset, World Bank Group.

(apartment buildings, townhouses, and single houses). Townhouses are the residential buildings covered in the most cities (77) while single houses are exempt in 35 cities. Nearly all codes cover office buildings (70); similarly, public buildings (65) are usually one of the first categories targeted for coverage.

The global dataset adopts a comprehensive approach, collecting data on key construction activities and alterations that are most commonly addressed in BECs. These categories include new buildings, renovations, additions, alterations, repair projects, and changes in occupancy (Figure 11). The analysis reveals varying levels of coverage across different project types: new construction shows the highest adoption with 83 countries incorporating requirements for new buildings, followed by repair projects (69 countries) and renovations (68 countries). Changes in occupancy demonstrate significantly lower coverage, with only 30 countries including such requirements in their BECs. While the data shows strong adoption of core construction requirements, the substantial drop in coverage for occupancy changes suggests an important opportunity for expanding BEC scope in many jurisdictions.

The dataset reveals distinct patterns in how BECs cover different construction types across 88 countries. New construction shows the highest adoption rate with 83 countries incorporating requirements, followed by repair projects (69 countries) and renovations (68 countries). The coverage drops significantly for changes in occupancy, with only 30 countries including such requirements. This distribution indicates a strategic prioritization among regulators, with the primary focus on new buildings where energy efficiency measures can be most cost-effectively implemented.

Across income groups, a gradual progression in comprehensive coverage is evident. Among high-income countries, approximately 47 percent have established requirements covering all six construction/project types, while another 38 percent address five of the six categories. Upper-middle-income countries show similar patterns with 27 percent covering all types and 55 percent covering five categories. In lower-middle-income countries, 47 percent maintain requirements for at least five project types.

**Figure 11 // Building Energy Code Coverage by Project Type across Countries**

Source: Building Energy Codes Global Dataset, World Bank Group.

Geographic analysis reveals regional variations in code coverage scope. Countries in the Europe and Central Asia region generally demonstrate the most comprehensive coverage across multiple construction types, likely influenced by coordinated regional frameworks. East Asia and Pacific shows diverse approaches, with several countries implementing robust coverage while others focus primarily on new construction. Other regions exhibit varied implementation patterns that reflect different development priorities and institutional capacities.

The sequential adoption pattern—beginning with new construction before expanding to renovations and repairs—suggests a strategic implementation pathway that policy makers in early-stage markets might consider. This approach allows for building market capacity and enforcement mechanisms around new construction before addressing the often more complex regulatory challenges of existing building modifications. The data indicates that comprehensive coverage typically develops gradually as markets mature and technical capacity expands, providing a potential roadmap for countries in earlier stages of code development.

## Recommendations for policy makers on formulating BECs

**Select appropriate BEC type and regulatory approach:** For jurisdictions developing or implementing BECs, selecting the right type of code is fundamental to success. The analysis shows combined prescriptive/performance-based approaches have been most widely adopted (50 out of 88 countries) as they provide both clear guidance and design flexibility. Jurisdictions at early implementation stages should consider prescriptive codes with specific requirements that are easily verifiable, while more advanced markets can benefit from combined approaches that allow innovation in complex projects. When considering mandatory versus voluntary implementation, policy makers should evaluate their institutional capacity for enforcement, market readiness, and implementation timeline. While mandatory codes provide a clear regulatory signal, voluntary codes can serve as stepping stones toward mandatory implementation, allowing markets to build capacity and adapt requirements to local conditions before establishing legally binding frameworks. This selection of code type should evolve as markets mature and institutional capabilities.

**Establish clear classifications:** For jurisdictions developing or planning to implement BECs, establishing an effective building classification system is a crucial first step. A well-designed classification framework can have significant impact on the successful implementation and enforcement of BECs, while a poorly structured system may create unnecessary complexity and compliance challenges.

**Begin with basic categories:** Policy makers should consider beginning with fundamental distinctions between residential and non-residential buildings, as these categories typically have distinct energy use patterns and requirements. This simplified initial approach allows for easier implementation and enforcement, clear communication with stakeholders, gradual capacity building among building professionals, and the establishment of baseline data for future refinements. Starting with basic classifications helps build market understanding and acceptance while allowing regulatory bodies to develop their enforcement capabilities.

**Prioritize local context:** Local context should play a central role in shaping building classification systems rather than directly adopting frameworks from other jurisdictions. Policy makers must consider predominant building types in the local market, construction practices and materials, climate conditions and seasonal variations, available technical capacity for implementation, and economic considerations and market readiness. This localized approach ensures that the classification system reflects the realities of the local building sector and can be effectively implemented with available resources.

**Implement gradually:** A phased implementation approach can help manage the transition to new BECs. Jurisdictions might begin by focusing on larger buildings or those with the highest energy consumption, such as commercial buildings over 10,000 square meters, before expanding to medium-size commercial and large residential buildings and eventually including smaller buildings and other categories. This graduated approach allows for learning and adjustment before full-scale implementation, helping to identify and address potential challenges early in the process.

**Maintain regulatory alignment:** The new building energy classification system should align closely with existing building codes and regulations. This alignment minimizes confusion among stakeholders, leverages existing enforcement mechanisms, reduces administrative burden, and creates a coherent regulatory framework. When energy code classifications complement rather than complicate existing building regulations, compliance and enforcement become more straightforward for all parties involved.





### 3. Passive Design in Building Energy Codes

## 3.1 Role of Passive Design in Energy Performance

Passive design represents a fundamental approach to achieving building energy efficiency by leveraging natural and building-integrated strategies to minimize reliance on mechanical systems. It includes both climate-responsive design elements—such as orientation, shading, and natural ventilation—and high-performance building envelope components, including insulation, air tightness, and high-efficiency windows. These elements work together to optimize thermal comfort and reduce energy demand. Unlike mechanical systems, which require ongoing maintenance and eventual replacement, passive measures provide lasting energy savings throughout the building's lifespan.

The durability of passive design strategies is a key advantage. Equipment-based solutions, such as HVAC and lighting systems, have finite operational lifespans and will inevitably need to be replaced. In contrast, passive features—such as high-performance insulation, thermal mass, and airtight windows—are integral to the building structure and remain effective for decades. Because retrofitting passive measures is significantly more costly and disruptive than incorporating them at the design stage, it is crucial to integrate these elements from the outset. A well-designed building envelope can dramatically reduce heating and cooling loads, lowering long-term operational costs and improving occupant comfort.

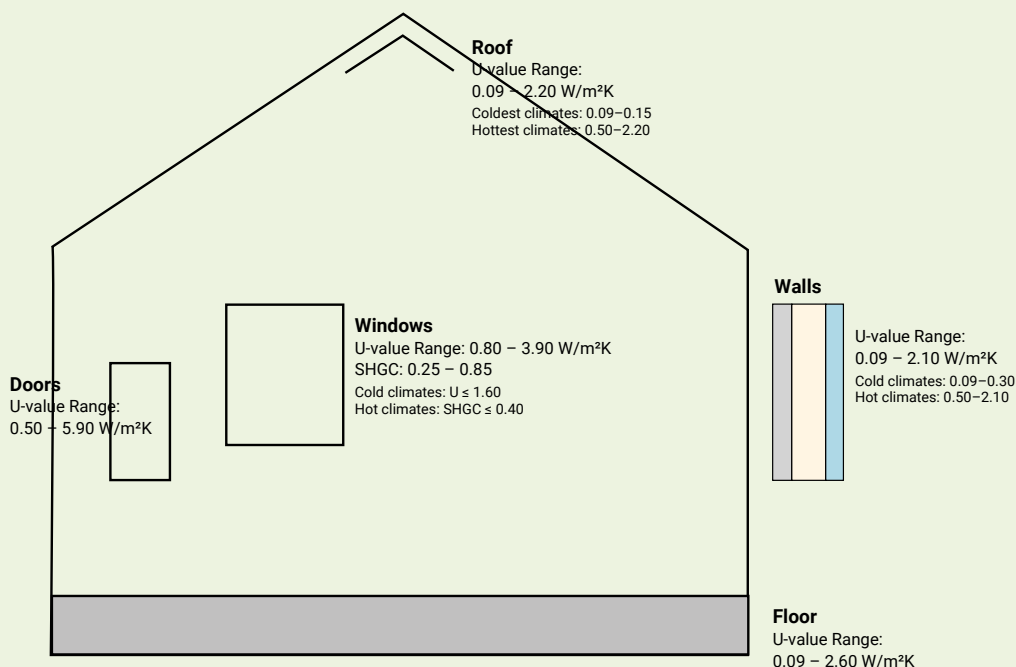
Different climatic zones demand distinct passive strategies. In cold climates, buildings benefit from high-performance insulation and solar gain optimization, while hot-arid regions require reflective surfaces, shading, and natural ventilation. Tropical climates prioritize cross-ventilation and high-albedo materials to minimize heat retention. In all cases, prioritizing passive measures at the design phase ensures that buildings achieve long-term energy efficiency, reducing dependence on mechanical systems and lowering lifetime energy costs.

## 3.2 Technical Requirements for Building Envelope Components

The building envelope serves as the primary defense against external environmental conditions and plays a crucial role in determining a building's energy performance (Figure 12). Heat transfer through the envelope occurs in both directions—heat loss in colder climates and heat gain in hotter climates—making effective envelope design critical across all regions. When considering envelope components, there is a clear hierarchy of importance: roofs, which can account for up to 25–35 percent of heat loss, are the most critical, followed by walls, floors, doors, and windows.<sup>20</sup> In hot climates, uninsulated or poorly designed roofs and walls contribute significantly to indoor overheating, increasing cooling demand. In contrast, in colder climates, these elements primarily influence heat retention. This underscores the importance of climate-responsive envelope design to reduce unnecessary energy consumption, whether for heating or cooling.

The significant focus on building envelopes stems from their direct impact on energy consumption patterns. Modern buildings typically see 42–68 percent of their total energy consumption attributed to HVAC systems, making them the largest energy consumers in both residential and commercial buildings.<sup>21</sup> This is followed by domestic hot water systems, consuming 16–26 percent, while lighting and appliances account for 16–32 percent. The design of the building envelope significantly affects how much energy HVAC systems and lighting use.<sup>22</sup> A well-designed envelope minimizes energy losses by reducing the need for heating and cooling, thus ensuring a more stable indoor climate. This can be achieved through high-quality insulation, airtightness, and proper window and door placement. In hot climates, it helps

**Figure 12 // Building Envelope Elements**



**Notes:**

- Ranges based on analysis of 88 countries
- U-value: Thermal transmittance (W/m<sup>2</sup>K)
- SHGC: Solar Heat Gain Coefficient
- Values vary by climate zone and building type

Source: Building Energy Codes Global Dataset, World Bank Group.

prevent heat gain; in cold climates, it retains warmth, making the building more comfortable and reducing energy consumption.

## Building envelope - what is measured

The global dataset measures the thermal transmittance (U-values) requirements of roofs, walls, floors, windows, and doors for residential and commercial buildings. Each element plays a distinct role in a building's thermal envelope, with varying levels of regulatory focus on their insulation standards across different climates. The effectiveness of building envelopes in energy conservation is particularly evident in extreme climates. In cold regions, high-performance envelopes can reduce heating loads by up to 75 percent compared to poorly insulated buildings.<sup>23</sup> Similarly, in hot climates, optimized envelope design incorporating reflective surfaces and proper insulation can decrease cooling energy needs by 40–50 percent.<sup>24</sup>

## Analysis from the Building Energy Codes Global Dataset

The thermal performance of building envelopes reveals clear regulatory priorities worldwide. Among 88 surveyed countries, roofs receive the highest regulatory attention, with 62 countries implementing U-value standards for residential buildings (Figure 13). This focus on roofs highlights their significant impact on

**BOX 2. Technical Aspects of BECs**

Building energy codes establish minimum requirements for building energy performance through a complex array of technical parameters. These requirements serve as the foundation for ensuring buildings operate efficiently while maintaining occupant comfort. The technical stringency of these codes addresses both passive design elements that minimize energy demand and active systems that consume energy, creating a comprehensive approach to building energy efficiency.

**Building Envelope Performance**

The building envelope represents the primary interface between indoor and outdoor environments, making it crucial for energy efficiency. Technical requirements for the envelope focus on its thermal performance, typically measured through thermal transmittance (U-values) for walls, roofs, floors, and other opaque elements. For transparent elements like windows, codes specify SHGCs to control solar heat gain while maintaining adequate natural light. Many advanced codes also incorporate Overall Thermal Transfer Value (OTTV) requirements, providing a holistic measure of the envelope's thermal performance.

Airtightness requirements form another critical component of envelope performance, as they control unwanted air infiltration that can significantly affect energy consumption. Window-to-wall ratio limitations and shading requirements further help manage solar gains and daylighting, balancing energy efficiency with occupant comfort and well-being.

**HVAC Systems**

Requirements for heating, ventilation, and air conditioning systems represent some of the most technically detailed aspects of BECs. These specifications typically begin with minimum efficiency ratings for equipment, including Coefficient of Performance (COP) for heat pumps and Energy Efficiency Ratio (EER) for air conditioners. Beyond basic equipment efficiency, codes often mandate heat recovery systems, specify ventilation system efficiency, and require sophisticated control systems for optimal operation.

The stringency of HVAC requirements often varies by climate zone and building type, recognizing that different contexts demand different solutions. Advanced codes increasingly require smart controls and zoning systems that can adjust operation based on occupancy patterns and thermal loads.

**Lighting and Water Heating Systems**

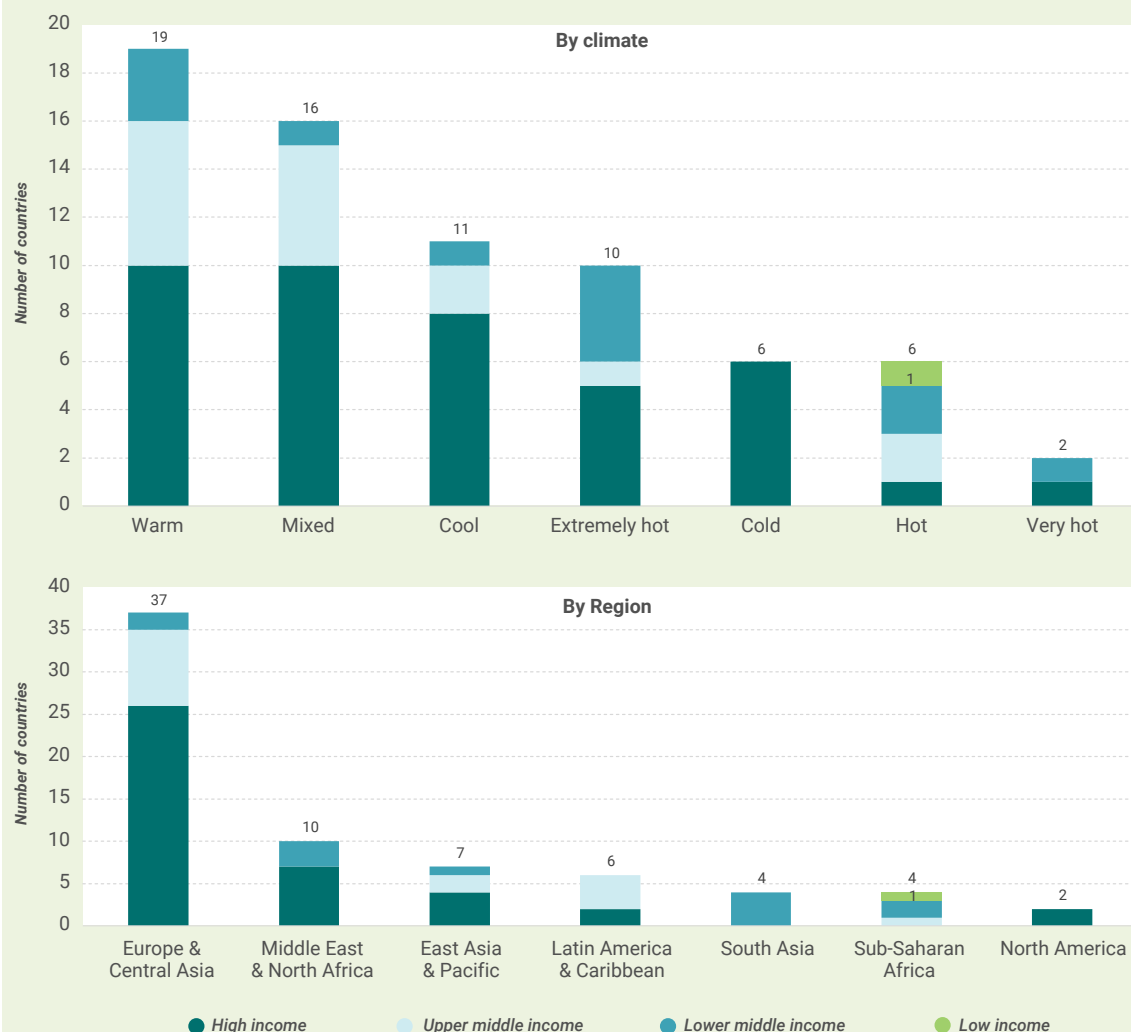
Lighting efficiency requirements combine several technical elements to ensure efficient illumination. These include maximum lighting power density allowances, minimum luminaire efficacy requirements, and specifications for control systems. Advanced codes increasingly emphasize the integration of natural and artificial lighting through daylighting controls and occupancy sensing, creating opportunities for significant energy savings.

Water heating requirements similarly combine equipment efficiency standards with system design requirements. These include minimum efficiency ratings for heating equipment, insulation specifications for storage tanks and distribution pipes, and increasingly, requirements for solar water heating in suitable climates. Heat recovery specifications and control system requirements ensure optimal system operation.

overall energy efficiency, particularly in controlling heat loss in cooler climates and heat gain in warmer ones.

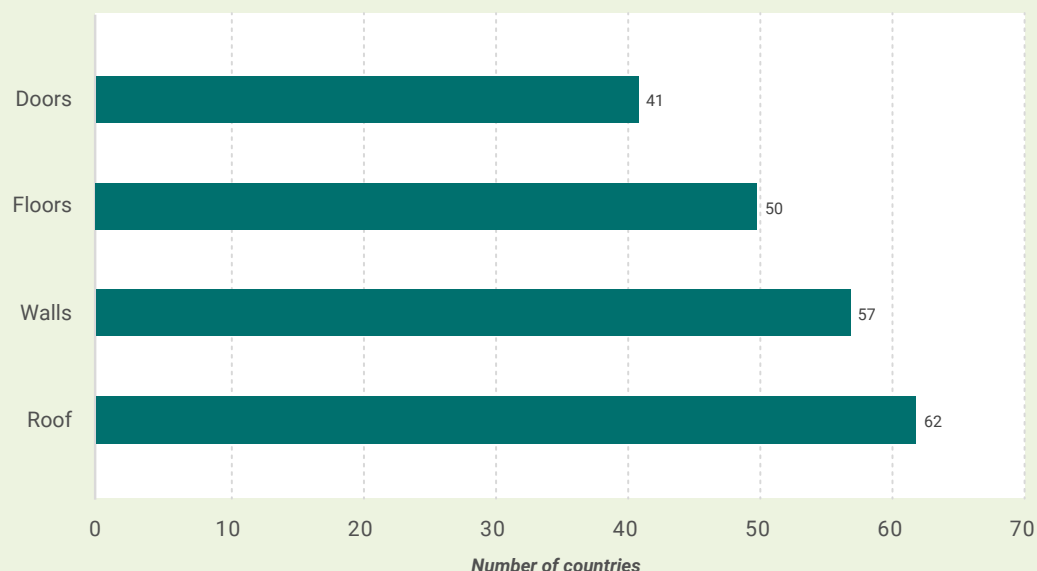
Walls also receive substantial regulatory attention, with U-value standards applied in 57 countries. Walls are essential for maintaining indoor temperatures and minimizing energy loss, making them a critical component in energy-efficient building design. Floor standards are present in 50 countries, particularly important in regions with extreme temperature variations, adding to the building's thermal stability. Doors and windows, while covering smaller surface areas as compared to walls and roofs, are regulated in 41 countries, acknowledging their role in preventing drafts and maintaining indoor comfort.



**Figure 13 // Thermal Transmittance Coverage in Building Envelopes by Climate and by Region**

Source: Building Energy Codes Global Dataset, World Bank Group.

The analysis of building envelope standards across climate regions reveals important policy implications (Figure 14). While regions with cold climate require comprehensive insulation and airtightness requirements to effectively manage heating loads, hot and tropical regions face equally critical needs for envelope performance standards to control cooling demand. Although our data shows fewer envelope requirements in warmer climates, this appears to reflect historical policy development rather than optimal technical approaches. Given that cooling energy demand is projected to grow significantly in tropical and hot arid zones, comprehensive envelope standards addressing solar heat gain, thermal mass, and insulation become crucial for managing long-term energy consumption. The data suggests that effective building envelope policies should align with climate-specific thermal performance needs rather than following simpler implementation paths.

**Figure 14 // Distribution of Thermal Transmittance Coverage in Building Envelopes by Climate Zones**

Source: Building Energy Codes Global Dataset, World Bank Group.

### BOX 3. Building Envelope Performance Standards

Building codes establish rigorous standards for envelope thermal performance through U-values, also known as thermal transmittance, which are measured in watts per square meter-Kelvin ( $\text{W/m}^2\text{K}$ ). These values serve as crucial metrics that quantify the rate of heat transfer through various building components. Different building elements have distinct U-value requirements based on their function and location in the structure. Typically, roofs require U-values between  $0.1\text{--}0.2\text{ W/m}^2\text{K}$ , while walls should maintain values between  $0.15\text{--}0.30\text{ W/m}^2\text{K}$ . Floors generally need to achieve U-values of  $0.2\text{--}0.3\text{ W/m}^2\text{K}$ . Windows and doors, being more complex components, have higher allowable U-values, ranging  $0.8\text{--}2.0\text{ W/m}^2\text{K}$  for windows and  $1.0\text{--}2.2\text{ W/m}^2\text{K}$  for doors.

The requirements for U-values vary significantly based on climate zones, with cold climates necessitating lower U-values for better insulation performance. In hot climates, building codes often balance U-values with solar heat gain coefficients (SHGC) to optimize overall thermal performance. Compliance with these standards can be achieved through either prescriptive paths, where specific U-values must be met, or performance paths that consider the overall envelope performance. Some jurisdictions also allow trade-off options between different components, providing flexibility in design while maintaining overall energy efficiency.

While achieving lower U-values typically involves higher initial construction costs, these investments generally result in reduced operational costs over the building's lifetime. The typical payback period for investments in better thermal performance ranges from 5 to 10 years, depending on local energy costs and climate conditions. To ensure compliance with building codes and energy efficiency standards, U-values must be verified through certified testing and documentation, providing assurance that the building envelope meets the required performance standards.

### 3.2.1 ROOFS IN BUILDING ENERGY CODES

#### Why it matters

Roof insulation is a critical component of energy-efficient building design, playing a pivotal role in both building envelopes and passive design strategies. Its importance stems from several technical factors. First, roofs typically have the largest surface area exposed to external conditions, particularly solar radiation, making them essential for managing heat gain in hot climates and heat loss in cold climates. They experience the most extreme temperature fluctuations compared to other building components, which makes insulation vital for maintaining stable indoor temperatures. Proper roof insulation significantly reduces the need for artificial heating and cooling, leading up to 20 percent of energy savings.<sup>25</sup> In our dataset of 88 countries, 62 include roof thermal transmittance (U-value) requirements in their building codes and standards, though the stringency and effectiveness of these requirements varies considerably. High-performance roof insulation is particularly crucial in both cold climates where heat loss must be minimized, and in hot climates where solar heat gain through roofs can significantly affect cooling loads.

#### Analysis from Building Energy Codes Global Dataset

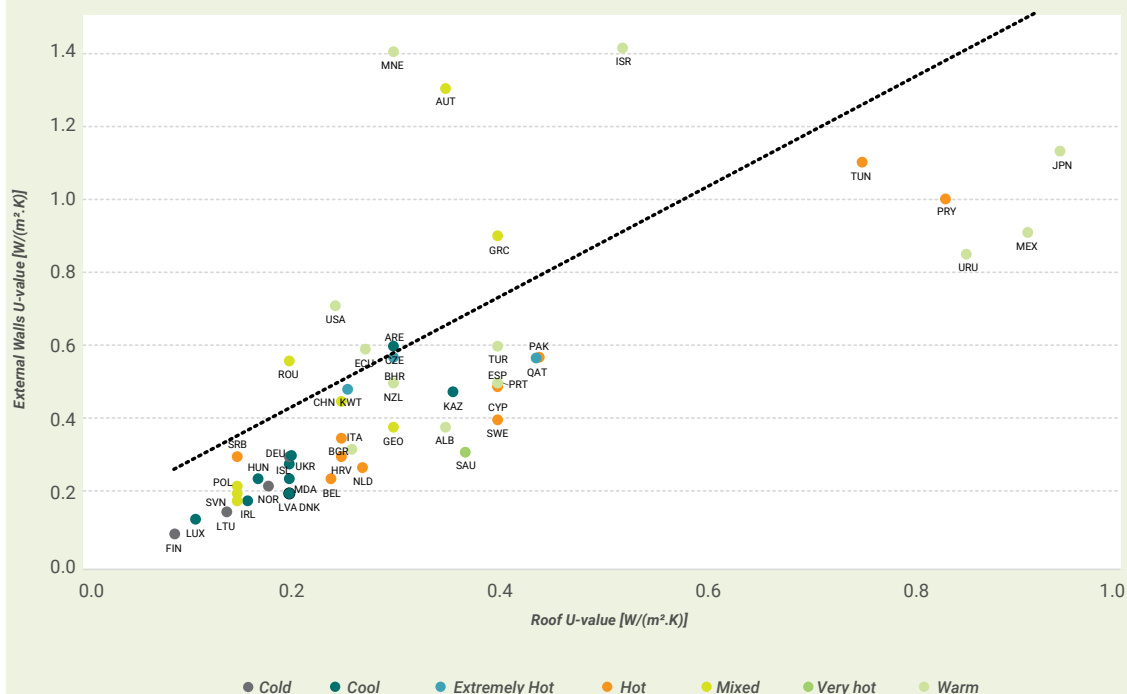
**Roof insulation fundamentals:** For existing buildings, upgrading roof insulation is generally less disruptive and more straightforward than modifying walls or foundations. The primary function of roof insulation in BECs is to reduce heat transfer between the building interior and exterior—controlling heat loss in cold climates and heat gain in warm climates. BECs typically impose stricter U-value requirements for roof insulation compared to other envelope components, recognizing its outsized impact on overall building energy performance.

**Global comparison of roof versus wall standards:** Among the 57 countries in the global dataset, requirements are in place for both roofs and walls, with 47 countries imposing stricter standards for roofs than walls (Figure 15). Seven European countries, along with Mexico and Uruguay, apply equal stringency to both elements. Only Saudi Arabia enforces more stringent standards for walls than roofs. This difference is especially pronounced in mixed, warm, hot, and extremely hot climates, where roofs face intense solar radiation.

Roof U-values in cold climate zones are the most stringent globally, with Helsinki (Finland) leading at 0.09 W/m<sup>2</sup>K, followed by Lithuania, Norway, Latvia, and Iceland at or below 0.20 W/m<sup>2</sup>K. Sweden shows an unusual pattern with higher residential U-values (0.40 W/m<sup>2</sup>K) but stricter commercial requirements (0.33 W/m<sup>2</sup>K). Estonia uniquely employs a performance-based approach without specific values.

Cool climate regions maintain strong standards, with Luxembourg (0.11 W/m<sup>2</sup>K) leading, followed by Poland, Canada, Ireland, and Hungary (0.15–0.17 W/m<sup>2</sup>K). Germany, Denmark, Moldova, and Ukraine cluster around 0.20 W/m<sup>2</sup>K, while the Czech Republic and Kazakhstan show more relaxed requirements (0.30–0.36 W/m<sup>2</sup>K). Ukraine's standards match high-income European peers despite resource constraints.

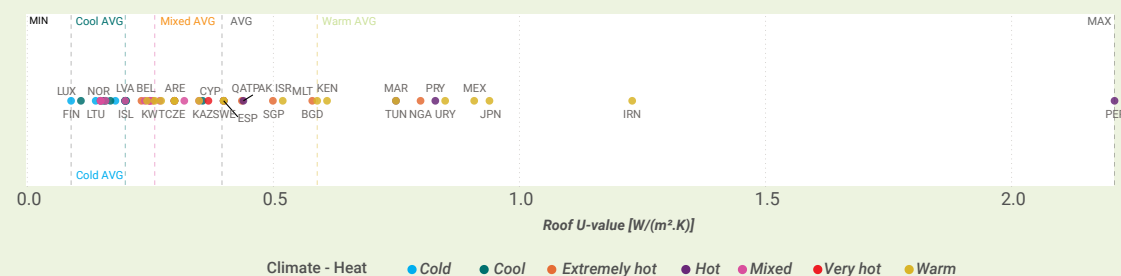
In extremely hot climates, only five out of fifteen countries have roof U-value requirements. Kuwait, the United Arab Emirates, and Bahrain lead (0.26–0.30 W/m<sup>2</sup>K), followed by Qatar (0.44 W/m<sup>2</sup>K), Singapore (0.50 W/m<sup>2</sup>K), and Bangladesh (0.58 W/m<sup>2</sup>K). Nigeria maintains 0.80 W/m<sup>2</sup>K despite its lower-middle-income status. Hot and very hot zones show varied adoption. India specifies 0.33 W/m<sup>2</sup>K for commercial buildings only, while Pakistan requires 0.44 W/m<sup>2</sup>K across all buildings. Rwanda, despite being a low-income country, maintains progressive standards at 1.0 W/m<sup>2</sup>K for commercial buildings. Peru stands out with significantly higher requirements at 2.2 W/m<sup>2</sup>K.

**Figure 15 // External Walls versus Roof U-values (Residential)**


Source: Building Energy Codes Global Dataset, World Bank Group.

Mixed climate zones show strong roof U-values in European cities, with Slovenia, Slovakia, Serbia, UK, and Romania ranging from 0.15 to 0.20 W/m²K, while Greece, Spain, and Austria maintain more relaxed standards below 0.40 W/m²K. China is the only non-European country with specific requirements in this zone.

Warm climate zones show the widest variation, from Los Angeles's strict 0.24 W/m²K to Tehran's 1.2 W/m²K. Upper-middle income countries like Ecuador and Montenegro show strong performance (0.27–0.30 W/m²K), while some developed nations maintain less stringent standards (Japan: 0.94 W/m²K, Uruguay: 0.85 W/m²K). Emerging economies Kenya and Morocco have established relatively stringent standards at 0.61 W/m²K and 0.75 W/m²K, respectively.

**Figure 16 // Roof Thermal Transmittance Requirements (Residential)**


Source: Building Energy Codes Global Dataset, World Bank Group.

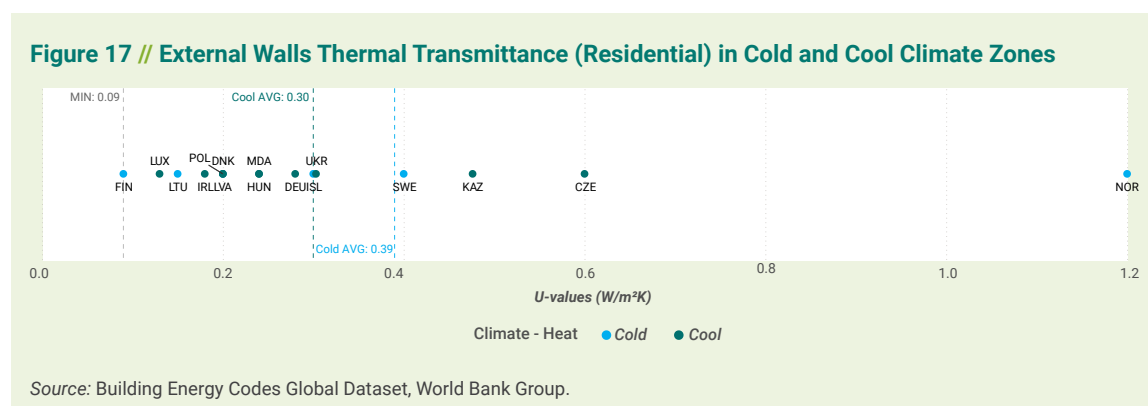


### 3.2.2 WALLS IN BUILDING ENERGY CODES

#### Why it matters

Wall insulation is essential for energy efficiency, particularly in buildings with extensive vertical surfaces where walls account for significant energy loss. Beyond thermal regulation, effective wall insulation serves multiple purposes: it helps stabilize indoor temperatures, reduces the load on heating and cooling systems, contributes to structural stability, and provides crucial moisture control, preventing mold, corrosion, and structural damage while reducing drafts. This insulation enhances comfort, raises living standards in homes, and boosts productivity in workplaces.

#### Analysis from Building Energy Codes Global Dataset



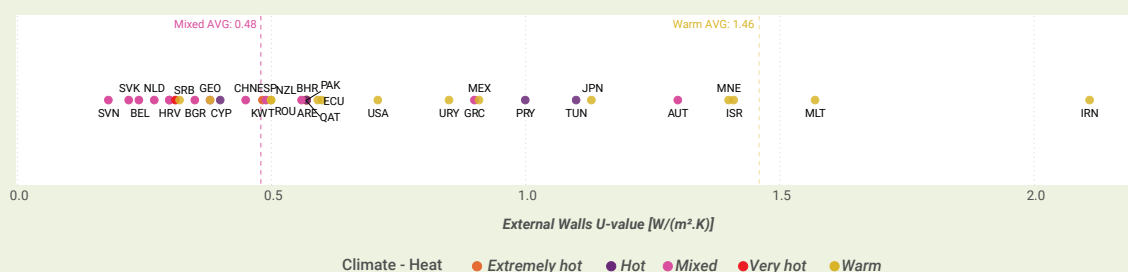
**Cold and cool climate zones** demonstrate the most stringent U-value requirements for wall insulation, ranging from 0.09 to 0.6 W/m²K (Figure 17). This range primarily reflects the demands of colder climates, predominantly in Europe and Central Asia. The European Union's influence is particularly notable, with 13 out of 18 countries in these zones being EU members. Finland leads with Helsinki's requirement of 0.09 W/m²K, while the Baltic states maintain similarly strict standards of 0.15–0.30 W/m²K. Prague (Czech Republic) has the least stringent requirement of 0.6 W/m²K in this group.

**Hot and extremely hot climate zones** present a different regulatory approach, reflecting distinct cooling challenges. Dubai (United Arab Emirates) and Doha (Qatar) lead with requirements of 0.57 W/m²K, while Saudi Arabia sets the region's most stringent standard at 0.31 W/m²K for residential buildings. Traditional architecture in these regions has historically prioritized natural ventilation through features like courtyards and perforated screens. However, rising urban temperatures and increasing air conditioning (AC) dependence are prompting a shift toward greater envelope insulation. This evolution is particularly evident in the Gulf states, where stringent wall requirements now complement traditional passive cooling strategies to manage growing cooling demands.

**Mixed climate zones** generally maintain stringent requirements, with Ljubljana (Slovenia) leading at 0.18 W/m²K for residential buildings. Eastern European cities follow with requirements ranging from 0.22 to 0.56 W/m²K, though many limit these standards to residential buildings. Beijing maintains moderate standards with U-values of 0.45 W/m²K for residential and 0.60 W/m²K for commercial buildings.

**Warm climate zones** show significant variation (Figure 18). Among high-income countries, Rome leads with 0.32 W/m<sup>2</sup>K for residential buildings, while Los Angeles demonstrates a notable disparity between residential (0.71 W/m<sup>2</sup>K) and commercial (3.9 W/m<sup>2</sup>K) requirements. Lower-middle-income countries generally show less stringent standards, from Iran's 2.1 W/m<sup>2</sup>K to Morocco's 5.8 W/m<sup>2</sup>K. Albania stands out among upper-middle-income countries with stringent requirements of 0.38 W/m<sup>2</sup>K, significantly outperforming regional peers.

**Figure 18 // External Walls Thermal Transmittance (Residential) in Warmer Climate Zones**



Source: Building Energy Codes Global Dataset, World Bank Group.

#### BOX 4. Temperature Differentials and Building Envelope Requirements

In hot climate zones, the insulation requirements are less stringent due to the temperature differences between the inside and outside of the building. In cold climate zones, the temperature difference is much greater—ranging from -40°F/C outside to 68°F (20°C) inside, making the insulation of the envelope very important to keep the warmth inside and reduce the energy use. In contrast, hot climate zones experience a smaller temperature difference, with temperatures typically ranging from 110°F (43°C) outside to 68°F (20°C) inside.

In hot climates, significant heat transfer occurs through fenestration systems, with window frames often acting as thermal bridges. Outer frame temperatures can rise considerably above the surrounding air temperature, especially on darker-colored frames, leading to increased interior temperatures and higher cooling demands.

Thus, it is essential for countries in hot climates to pay close attention to the U-values of fenestration, especially the window frames. These U-values are just as critical in hot climates as they are in cold ones, as they greatly influence the building's thermal performance. The use of thermal breaks and warm-edge spacers can significantly minimize solar heat gain at the edges of windows and frames.

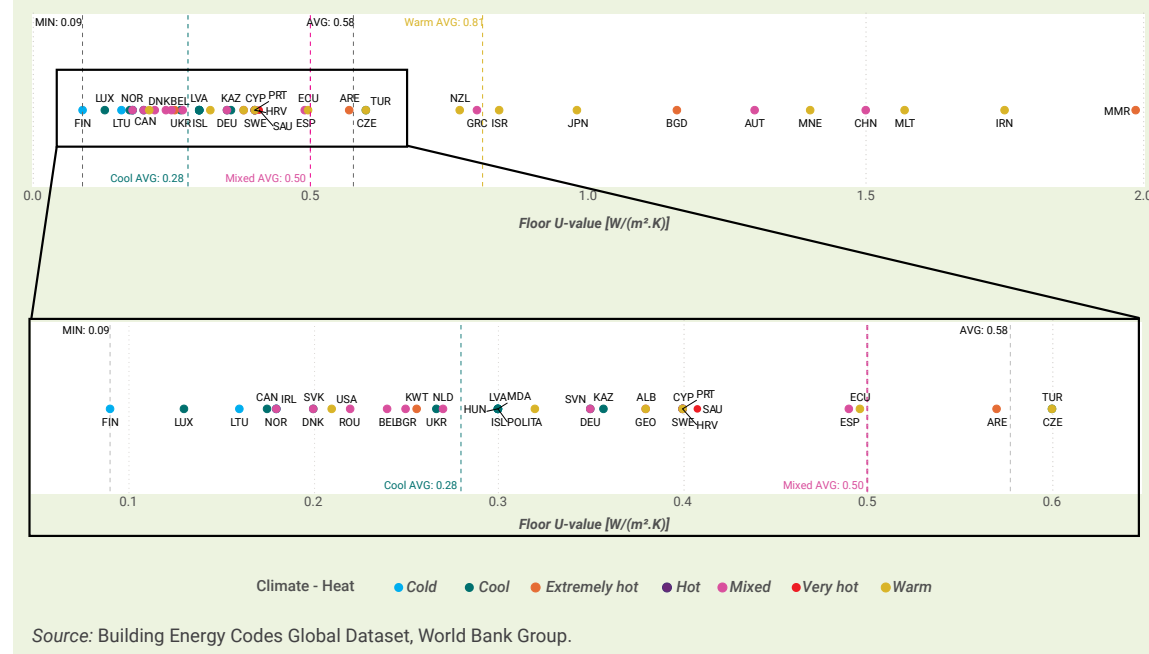
### 3.2.3 FLOORS IN BUILDING ENERGY CODES

#### Why it matters

Floor systems represent another crucial element in building thermal performance, particularly due to their direct contact with colder surfaces below, such as the ground or unheated spaces. By using floors with lower U-values, it is possible to significantly reduce heat loss. This thermal resistance minimizes the transfer of heat from the interior of the building, contributing to improved energy efficiency, lower heating costs, and a more comfortable indoor environment. Proper floor insulation can contribute to energy savings of 10–20 percent in residential buildings, with variations depending on climate zone and building type.<sup>26</sup> Floor insulation improvements in renovation projects showed payback periods ranging from 4–8 years in continental European climates, with shorter periods in colder regions.<sup>27</sup> Upgrading floor insulation to current building standards resulted in average annual carbon emission reductions of 25–30 kg CO<sub>2</sub>/m<sup>2</sup>

in residential buildings.<sup>28</sup> The US Department of Energy's Building America Program (2019)<sup>29</sup> reported that proper floor insulation systems, when combined with appropriate moisture management strategies, extended the service life of floor structures by 20–25 percent by preventing moisture-related deterioration. These findings from multiple high-level sources reinforce the importance of floor thermal performance in building energy efficiency regulations, both for new construction and renovation projects.

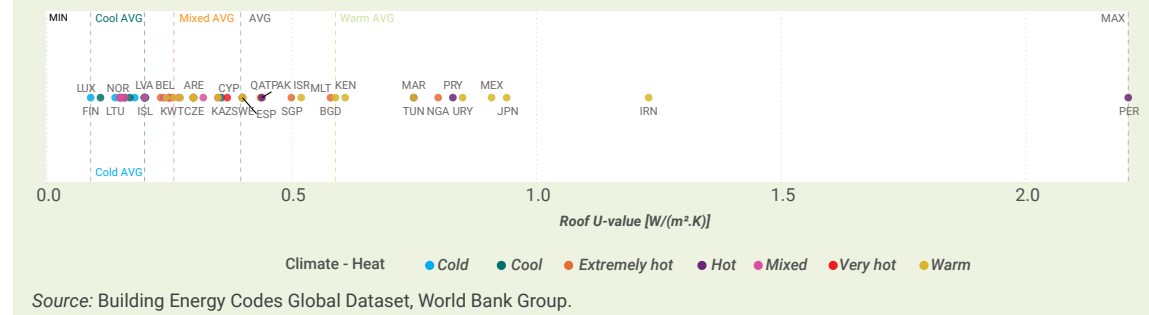
**Figure 19 // Floor U-Values in Residential Buildings by Country**



### Analysis from Building Energy Codes Global Dataset

Analysis of floor thermal performance requirements reveals a clear correlation with climate zones (Figure 19). As expected, countries in cold and cool climate zones demonstrate the most stringent standards in their building regulations. Leading cities and countries in floor thermal performance include Helsinki (Finland), Luxembourg, Vilnius (Lithuania), Toronto (Canada), Dublin (Ireland), Oslo (Norway), London (UK), and Copenhagen (Denmark), with U-values ranging from 0.09 W/m²K to 0.20 W/m²K. These stringent requirements reflect the significant impact of floor heat loss in colder climates. Within these climate categories, Czechia stands as an outlier, maintaining comparatively lenient standards with floor U-values

**Figure 20 // Floor U-Value Requirements for Residential Buildings in Hot Climate Zones**

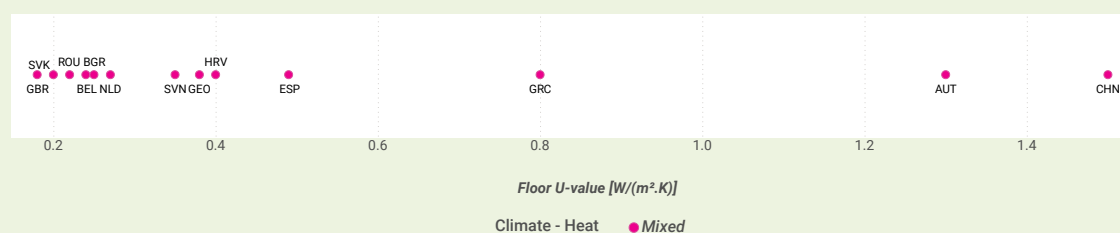


of 0.60 W/m<sup>2</sup>K for both residential and commercial buildings. This requirement is notably less stringent than other countries in similar climate zones, suggesting potential room for regulatory advancement. Most countries in these climate zones maintain uniform standards across both residential and commercial buildings, indicating a consistent approach to building energy efficiency. However, several exceptions exist. Luxembourg, Lithuania, Ireland, and Latvia impose slightly higher (less stringent) U-values for commercial buildings. Sweden takes a unique approach, enforcing stricter standards for commercial buildings compared to residential structures. Notable gaps exist in the regulatory framework of Germany and Kazakhstan, where specific floor requirements for commercial buildings are currently absent from building codes.

**Analysis of floor thermal performance requirements in extremely hot climate zones** reveals an interesting pattern: only 4 out of 18 countries in these regions have implemented floor insulation standards, reflecting the distinct thermal dynamics of hot climates. Among these countries, a clear economic divide emerges in the stringency of requirements. High-income Middle Eastern nations lead with the most demanding standards: Kuwait and the United Arab Emirates require U-values of 0.26 W/m<sup>2</sup>K and 0.57 W/m<sup>2</sup>K, respectively, applied consistently across both residential and commercial buildings. In contrast, Bangladesh and Myanmar maintain more modest requirements, with U-values of 1.2 W/m<sup>2</sup>K and 2.0 W/m<sup>2</sup>K, respectively, for all building types (Figure 20). The limited adoption of floor U-value requirements in extremely hot climates can be attributed to specific environmental and physical factors. In these regions, ground temperatures typically remain lower than ambient air temperatures, creating a natural cooling effect. In comparison to heat uptake through directly exposed walls and roofs, heat transfer through the floor is therefore less important. Also, the thermal mass of the earth functions as an insulator in buildings. This pattern underscores how climate-specific thermal dynamics influence building energy efficiency regulations, suggesting that prescriptive requirements must be carefully tailored to local conditions rather than universally applied across different climate zones.

**Countries in hot and very hot climate zones** follow the same approach. In these climate zones only three countries have floor U-values in place and the group is led by Nicosia (Cyprus) at 0.40 W/m<sup>2</sup>K, closely followed by Riyadh (Saudi Arabia) at 0.41 W/m<sup>2</sup>K, and it is closed by Lima (Peru), with some lax requirements of 2.6 W/m<sup>2</sup>K for residential buildings and 3.3 W/m<sup>2</sup>K for commercial ones.

**Figure 21 // Floor Thermal Transmittance (Residential) in Mixed Climate Zones**



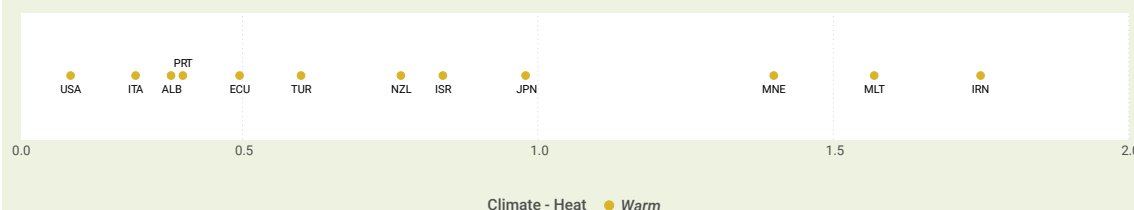
Source: Building Energy Codes Global Dataset, World Bank Group.

**Mixed climate zones** demonstrate a higher adoption rate of floor thermal requirements, with 14 out of 19 countries implementing regulations for residential buildings (Figure 21). However, commercial building coverage is lower, with only 10 countries extending these standards to the commercial sector. This variation suggests a potential regulatory gap in commercial building energy efficiency within mixed climates. London (UK) sets the benchmark for this climate with the most stringent requirements mandating U-values of 0.18 W/m<sup>2</sup>K for both types of buildings. Notably, several upper-middle-income countries have established comparably stringent standards, challenging the assumption that robust building energy



regulations are limited to high-income nations. Bulgaria is the best ranked from this income group, with requirements at 0.25 W/m<sup>2</sup>K only for residential buildings. Tbilisi (Georgia) is the second one requesting floor insulations at 0.38 W/m<sup>2</sup>K. Beijing (China) is the last from this economic rank having requirements in place which are on the relaxed side at 1.5 W/m<sup>2</sup>K. Within the EU context, several unexpected patterns emerge. Vienna (Austria), despite its high-income status and strong environmental policies, maintains relatively lenient U-values of 1.3 W/m<sup>2</sup>K for both building types, significantly higher than its EU counterparts. Similarly, Athens (Greece) requires U-values of 0.80 W/m<sup>2</sup>K, positioning it well behind other EU member states. These disparities within the EU, particularly among high-income nations, suggest opportunities for regulatory enhancement to align with best practices demonstrated by other member states in similar climatic conditions.

**Figure 22 // Floor Thermal Transmittance (Residential) in Warm Climate Zones**



Source: Building Energy Codes Global Dataset, World Bank Group.

**In warm climate zones**, floor thermal transmittance requirements show moderate adoption rates, with 12 out of 22 countries implementing standards for residential buildings (Figure 22). However, only 9 of these countries extend their regulations to commercial buildings, indicating a potential gap in comprehensive building energy policy. U-value requirements in this climate zone span from 0.21 W/m<sup>2</sup>K to 1.8 W/m<sup>2</sup>K, representing a wide range of regulatory stringency. The least stringent country is the Islamic Republic of Iran, but it is worth mentioning that it is the only lower-middle-income country with standards in place and has standards for both types of buildings. Several high-income countries in this zone show unexpectedly lenient standards. Malta, despite its EU membership and high-income status, requires floor U-values of 1.6 W/m<sup>2</sup>K, placing it close to the Islamic Republic of Iran's requirements. Similarly, Japan, another high-income nation known for technological advancement, maintains relatively modest standards with U-values of 0.98 W/m<sup>2</sup>K. These cases suggest significant room for improvement, particularly considering these nations' economic capabilities and their commitments to energy efficiency and climate action.

### 3.2.4 DOORS IN BUILDING ENERGY CODES

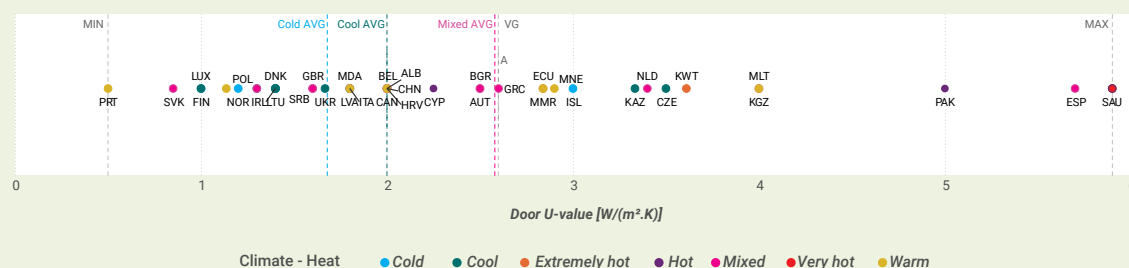
#### Why it matters

While doors represent a relatively small portion of building envelope surface area, their thermal performance remains significant, particularly in buildings without centralized HVAC systems. In such cases, doors play a crucial role in room-specific temperature regulation and localized heating or cooling needs. Their importance extends beyond their size due to their frequent use and potential for air leakage—poorly insulated or sealed doors can create significant thermal bridges, leading to substantial heat loss in cold climates or unwanted heat gain in warm regions. This impact is particularly pronounced in commercial buildings with high-traffic entries and in residential buildings where exterior doors connect directly to heated or cooled spaces.

## Analysis from Building Code Dataset

The global dataset reveals distinct patterns in door thermal transmittance requirements across different climate zones and economies. Among the 88 countries surveyed, 41 have implemented specific U-value requirements for doors, with requirements ranging from 0.5 W/m<sup>2</sup>K to 8.2 W/m<sup>2</sup>K. The stringency of these requirements generally correlates with climate conditions, though with notable exceptions that reflect different regulatory approaches. As shown in Figure 23, high-income European countries tend to maintain the most stringent requirements, while requirements in warmer climates show greater variation. This pattern suggests that while climate plays a significant role in determining door thermal standards, other factors such as market development and institutional capacity also influence regulatory choices.

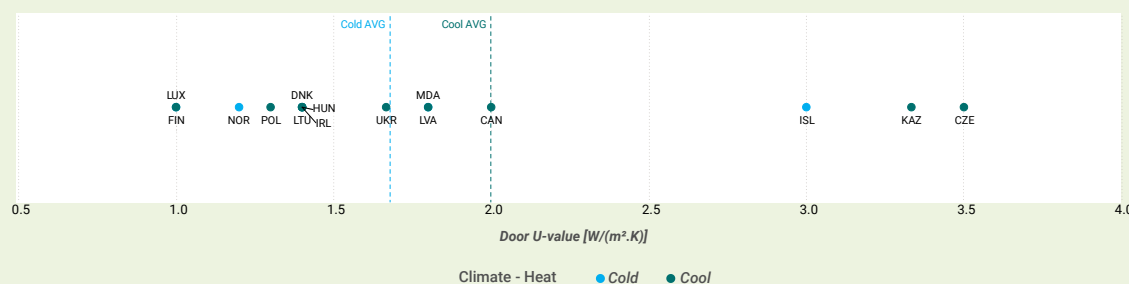
Figure 23 // Door Thermal Transmittance (Residential)



Source: Building Energy Codes Global Dataset, World Bank Group.

**In cold and cool climate zones door thermal requirements show consistent adoption, with 15 countries implementing standards for residential buildings, and foremost extending to commercial buildings as well (Figure 24).** Kazakhstan stands out as an exception, lacking commercial building requirements, while Germany, Sweden, and Estonia follow performance-based approaches without specific door thermal requirements. U-values in these regions range from 1 W/m<sup>2</sup>K to 3.5 W/m<sup>2</sup>K, notably less stringent than other envelope components. Northern European countries maintain the strictest standards, while Czechia, Kazakhstan, Iceland, and Canada implement more relaxed requirements. Notable efforts come from Ukraine, Moldova, and Kazakhstan—the only lower to upper-middle income countries in these climate zones demonstrating commitment to door thermal regulations.

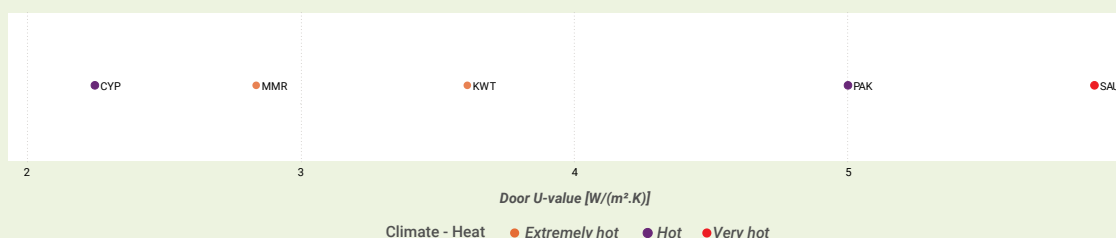
Figure 24 // Door Thermal Transmittance (Residential) in Cooler Climate Zones



Source: Building Energy Codes Global Dataset, World Bank Group.

**Extremely hot climate zones** generally lack door thermal transmittance requirements, with only Myanmar and Kuwait as exceptions, each taking distinctly different approaches. Naipyidó (Myanmar) implements stringent residential requirements ( $2.8 \text{ W/m}^2\text{K}$ ) but relaxed commercial standards ( $8.2 \text{ W/m}^2\text{K}$ ), while Kuwait reverses this pattern with stricter commercial requirements ( $1.1 \text{ W/m}^2\text{K}$ ) compared to residential ( $3.6 \text{ W/m}^2\text{K}$ ).

**Figure 25 // Door Thermal Transmittance (Residential) in Hotter Climate Zones**

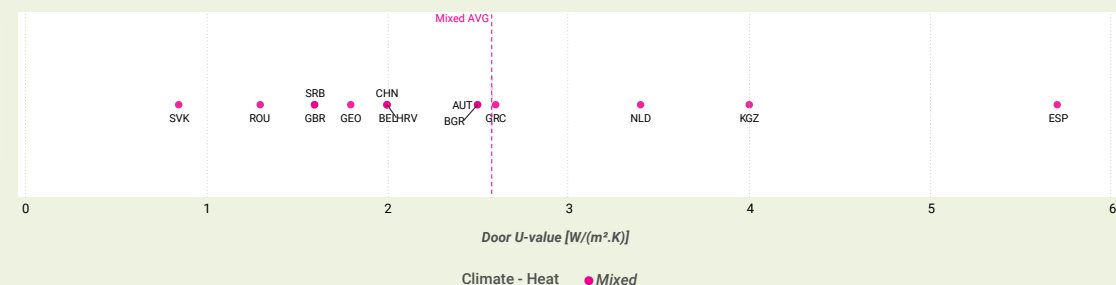


Source: Building Energy Codes Global Dataset, World Bank Group.

Similarly, **hot and very hot climate zones** maintain minimal door requirements. Nicosia (Cyprus) leads this category ( $2.3 \text{ W/m}^2\text{K}$  for both building types), followed by Islamabad (Pakistan) ( $5 \text{ W/m}^2\text{K}$ ) and Riyadh (Saudi Arabia) ( $5.9 \text{ W/m}^2\text{K}$ ). This limited adoption reflects practical considerations—in hot climates, air circulation is crucial for cooling and heat removal, and heavily insulated doors might trap heat, potentially increasing cooling energy demands (Figure 25).

**Mixed climate zones** show broader adoption but wider requirement ranges, with some countries exceeding cold climate zone stringency (Figure 26). Bratislava (Slovak Republic) leads with the most stringent residential requirements ( $0.85 \text{ W/m}^2\text{K}$ ), followed by Bucharest (Romania) ( $1.3 \text{ W/m}^2\text{K}$ ). However, Madrid (Spain) ( $5.7 \text{ W/m}^2\text{K}$ ) and Bishkek (Kyrgyz Republic) ( $4.0 \text{ W/m}^2\text{K}$ ) maintain notably relaxed standards, highlighting significant regional variations. However, the limitation of these requirements to residential buildings represents a significant missed opportunity. Commercial and other building types often have higher occupancy rates, more frequent door operation, and greater temperature differentials due to varied internal loads, making door thermal performance equally, if not more, critical for their energy efficiency.

**Figure 26 // Door Thermal Transmittance (Residential) in Mixed Climate Zones**

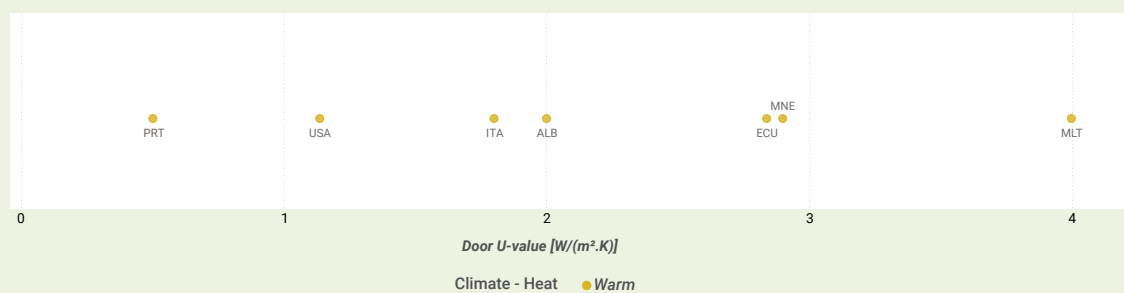


Source: Building Energy Codes Global Dataset, World Bank Group.

**Warm climate zones** present particularly interesting approaches, with 7 out of 22 countries implementing requirements for both building types (Figure 27). Lisboa (Portugal) sets the dataset's most stringent standards ( $0.5 \text{ W/m}^2\text{K}$  residential,  $0.7 \text{ W/m}^2\text{K}$  commercial), creating a striking contrast with neighboring Spain's relaxed requirements despite similar economic levels. Los Angeles (USA) shows an unusual

pattern with strict residential requirements ( $1.1 \text{ W/m}^2\text{K}$ ) but significantly relaxed commercial standards ( $8.2 \text{ W/m}^2\text{K}$ )<sup>30</sup>. Among upper-middle-income countries in this zone, Albania leads with  $2.0 \text{ W/m}^2\text{K}$  for both building types, followed by Ecuador ( $2.8 \text{ W/m}^2\text{K}$ ) and Montenegro ( $2.9 \text{ W/m}^2\text{K}$ ), while Malta maintains the least stringent requirements at  $4.0 \text{ W/m}^2\text{K}$ .

**Figure 27 // Door Thermal Transmittance (Residential) in Warm Climate Zones**



Source: Building Energy Codes Global Dataset, World Bank Group.

### 3.2.5 FENESTRATION AND SOLAR HEAT GAIN CONTROL

#### Why it matters

Windows and skylights represent critical points of heat transfer in buildings, significantly affecting both energy consumption and occupant comfort. The scale of this impact is substantial: windows account for approximately 8.6 percent of total heat loss in US buildings through thermal transmittance, air leakage, and radiation effects. Through these heat transfer mechanisms, windows influence building heating and cooling loads that make up about 43 percent of total building energy use. However, by improving the performance of windows, US annual energy use could reduce by 1.7 percent, and CO<sub>2</sub> **emissions could fall by 1.9 percent** in 2050.<sup>31</sup>

Beyond energy savings, effective fenestration and management of solar heat gain deliver multiple benefits. The US Department of Energy reports that ENERGY STAR certified windows can save households between US\$101 and US\$583 annually when replacing single-pane windows. The Solar Heat Gain Coefficient (SHGC)—which measures the fraction of solar radiation admitted through a window—becomes particularly crucial as cooling demand increases globally. Proper window specifications with optimized SHGC values can significantly reduce cooling loads while maintaining natural light and views. Climate-specific fenestration standards are particularly effective, as they ensure optimal performance across different weather conditions while providing flexibility through both prescriptive and performance-based compliance approaches.



### BOX 5. Beyond Basic Building Energy Codes: Stretch Codes for Advanced Fenestration

Several jurisdictions have implemented stretch codes that go beyond minimum BEC requirements, particularly in the realm of fenestration.<sup>32</sup> These enhanced standards demonstrate pathways toward more ambitious building energy performance while maintaining market feasibility. Their adoption is driven by a combination of market incentives, regulatory benefits, and long-term cost advantages.

China's Optional Enhanced Requirements for Public Buildings, introduced alongside the mandatory GB 50189-2015, sets significantly more stringent fenestration requirements for voluntary adoption. While the base code requires a maximum U-factor of 2.5–2.7 W/m<sup>2</sup>K for windows in cold climate zones, the stretch requirements push this to 1.8 W/m<sup>2</sup>K. The enhanced code also mandates dynamic shading devices for windows with high solar exposure, going beyond the static shading requirements in the base code.

In India, the ECBC+ and SuperECBC tiers build upon the base ECBC requirements. For fenestration, the SuperECBC requirements are particularly noteworthy, mandating a maximum U-factor of 1.8 W/m<sup>2</sup>K and SHGC of 0.25 for all climate zones, compared to the base ECBC requirements of 3.0 W/m<sup>2</sup>K and 0.27 respectively. These stretch codes also introduce mandatory visual light transmittance (VLT) requirements to ensure optimal daylighting while managing heat gain.

Republic of Korea's Green Building Certification Criteria (GBCC) includes voluntary enhanced fenestration requirements that supplement the base BEC. These stretch requirements focus on the integration of fenestration systems with natural ventilation, requiring automated window controls and sensors that optimize natural ventilation while maintaining thermal performance. Windows must achieve a U-factor of 1.0 W/m<sup>2</sup>K in cold regions, pushing the market toward triple-glazed solutions.

Singapore's Green Mark certification system, while voluntary, effectively functions as a stretch code with its Platinum requirements setting new market standards. For fenestration, it requires an enhanced ETTV performance standard of 38 W/m<sup>2</sup> compared to the base code's 50 W/m<sup>2</sup>, achieved primarily through improved window performance and smart glazing technologies that adjust tint levels based on solar exposure and indoor conditions.

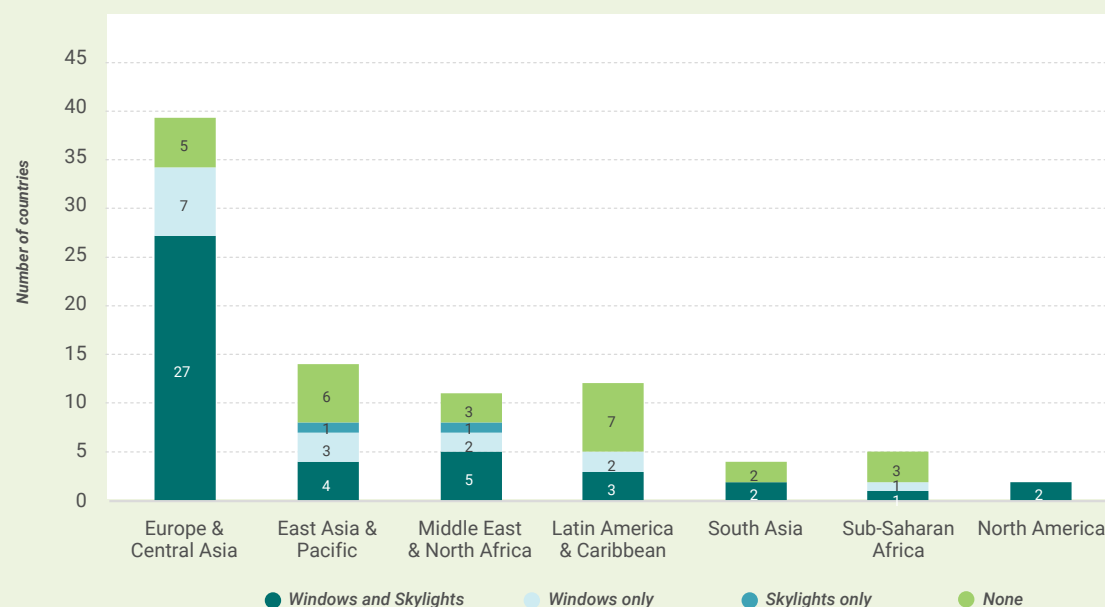
The success of these stretch codes in driving market transformation depends heavily on their implementation mechanisms. Most jurisdictions have paired enhanced requirements with incentives such as expedited permitting, density bonuses, or tax incentives. They also typically include a robust technical assistance program to support compliance, recognizing that advanced fenestration systems often require specialized design and installation expertise. The codes are usually introduced with phase-in periods that allow the market to develop supply chains for high-performance windows and glazing systems.

These examples demonstrate how well-designed stretch codes can effectively push the market toward higher-performing fenestration systems while maintaining practical feasibility. The combination of regulatory incentives, market advantages, and demonstrated cost benefits has proven effective in driving voluntary adoption of enhanced standards. This suggests that future stretch codes should continue to pair technical requirements with carefully calibrated incentive packages that address both initial cost barriers and long-term market value.

## Analysis from Building Code Dataset

Regulation of fenestration is widespread due to its direct impact on energy use. Among 88 cities included in the dataset, 56 have thermal transmission standards for windows, and 46 have similar requirements for skylights. The geographic distribution shows strong concentration in Europe and Central Asia, where 35 out of 40 countries have window requirements, reflecting the region's historical emphasis on heating energy efficiency (Figure 28). This high adoption rate aligns with the region's predominantly cool and mixed climate conditions where window thermal performance significantly affects building energy consumption.

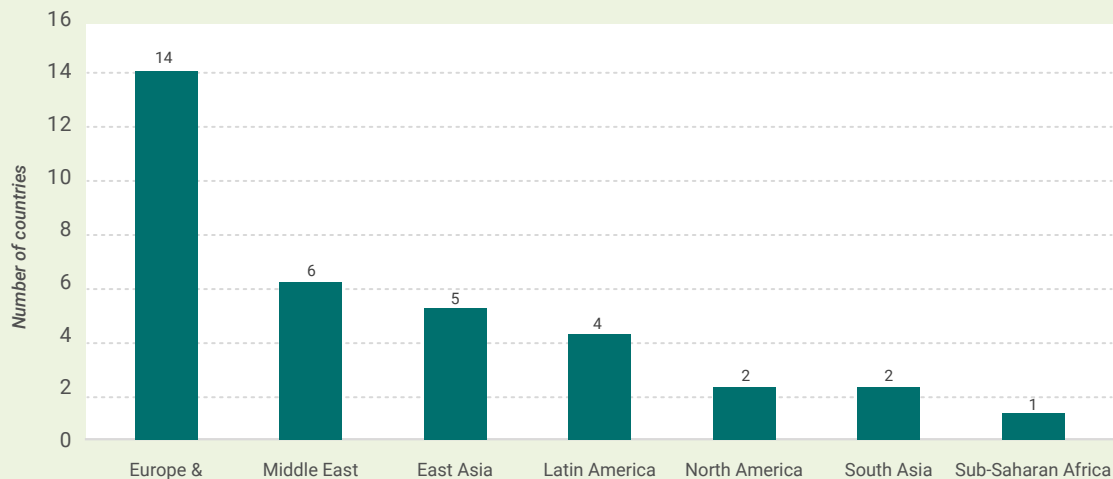
**Figure 28 // Regional Adoption of Thermal Transmittance Requirements for Windows and Skylights**



Source: Building Energy Codes Global Dataset, World Bank Group.

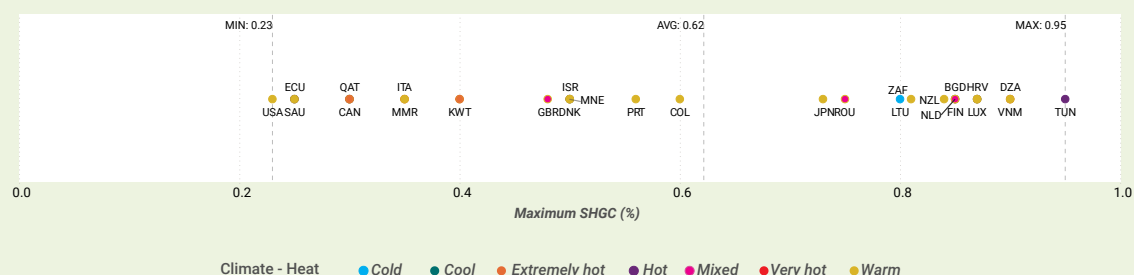
In terms of solar heat gain calculations, 37 countries demonstrate consistent enforcement of SHGC calculations in their building codes, while 8 countries report inconsistent enforcement practices. The maximum SHGC requirements have been established in 35 countries, with the highest adoption rate in warm climate zones where 15 countries have implemented such standards, followed by mixed climate zones with 6 countries. Cities in very hot climates exhibit strict standards, with Doha (Qatar), Naipyidó (Myanmar), and Kuwait implementing SHGC limits between 0.3 and 0.4. Myanmar's case is significant—its stringent requirement of 0.35 demonstrates that effective solar heat management is achievable even in lower-middle-income countries.

The implementation of solar heat gain calculation requirements shows significant variation across cities. Figure 29 shows the number of countries in each region that have incorporated SHGC measurement requirements into their building regulations. Europe and Central Asia lead with the highest number of countries requiring SHGC calculations, followed by East Asia and Pacific. Latin America and Caribbean and South Asia show more limited adoption of these requirements, suggesting significant regional variation in the incorporation of solar heat gain calculations into building regulations.

**Figure 29 // Countries with Solar Heat Gain Coefficient (SHGC) Requirements by Region**

Source: Building Energy Codes Global Dataset, World Bank Group.

The United States, Saudi Arabia, and Ecuador lead globally with the most stringent SHGC requirements, setting standards between 0.23 and 0.25. Ecuador's position is particularly notable in the context of upper-middle-income countries, with Montenegro and Colombia following closely behind with marginally higher coefficients, illustrating that ambitious solar heat gain standards can be successfully implemented regardless of economic development status.

**Figure 30 // Maximum Solar Heat Gain Coefficient - Residential**

Source: Building Energy Codes Global Dataset, World Bank Group.

Tunisia presents an interesting case study, with the highest SHGC among hot climate countries. Its Mediterranean climate, characterized by very hot summers and relatively cold winters with significant diurnal temperature variations, demonstrates the complexity of managing solar heat gain in regions with high seasonal fluctuations. This variability underscores the need for tailored solar heat management strategies that can adapt to diverse seasonal conditions.

## Recommendations for policy makers

### Climate-Responsive Technical Requirements

Policy makers should develop climate-specific performance standards that reflect local conditions across all building envelope elements. For roofs, requirements should range from stringent U-values below 0.20

W/m<sup>2</sup>K in cold climates—such as those in ASHRAE Climate Zones 7 and 8 (very cold regions)—to moderate values of 0.30–0.49 W/m<sup>2</sup>K in hot regions, as reflected in standards like ASHRAE 90.1 and the International Energy Conservation Code (IECC). These standards ensure energy efficiency by tailoring insulation requirements to specific climate zones, thereby optimizing thermal performance and reducing energy consumption.

Wall insulation standards should similarly be tailored from highly insulated assemblies in cold regions to balanced thermal performance in hot zones, recognizing their significant contribution to overall building energy balance. Floor requirements can be appropriately scaled to climate needs, with more attention in colder climates where heat loss is significant and appropriately relaxed standards in warmer regions. For fenestration, climate-responsive standards should address both thermal transmittance and solar heat gain, with cold climates focusing on U-values while hot regions prioritize solar control. Door requirements should balance thermal performance with practical usage patterns and ventilation needs, particularly in hot climates where natural airflow is beneficial.

### **Implementation and Enforcement**

Effective implementation requires verification frameworks that address the unique challenges of each envelope component. Roof inspections should verify both insulation installation and reflective properties in hot climates. Wall verification should focus on continuity of insulation, proper installation techniques, and thermal bridge prevention at critical junctions. Floor systems need inspections before concrete pours or enclosure, with particular attention to moisture barriers and edge insulation. Fenestration verification requires both performance documentation and installation quality checks to ensure proper air sealing and thermal breaks. Door installations should be verified for proper fit, weather sealing, and operation. Compliance pathways should be established for all components, with prescriptive options for standard assemblies and performance-based alternatives for innovative solutions, allowing flexibility while maintaining minimum standards.

### **Market Development and Capacity Building**

A phased implementation approach should recognize the different market readiness levels for various envelope components. Roof standards can often be implemented first, as insulation practices are generally well-established in most markets. Wall assembly requirements might need more gradual implementation in markets transitioning to higher performance standards, with capacity building for proper installation techniques. Floor insulation may require technical support in regions where it has not been common practice. For windows and doors, market development should include certification programs and performance labeling to build supply chains for high-performance products. Supporting infrastructure should include testing facilities for all envelope components, technical training programs, and clear guidance documents tailored to local construction practices, with regular updates that progressively strengthen standards across all elements.

### **Existing Buildings and Retrofits**

Retrofit strategies should address the unique challenges of upgrading each envelope component in existing buildings. Roof improvements often provide the most cost-effective intervention point, with requirements triggered by re-roofing activities. Wall retrofits need flexible approaches that account for existing conditions, potentially with staged improvements aligned with renovation cycles. Floor upgrades may be limited to accessible areas or perimeter insulation when full replacement is impractical. Window and door replacements should have specific standards that balance improved performance with installation constraints in existing openings. Alternative compliance pathways should recognize the practical limitations

of upgrading historic buildings or technically constrained structures, while still achieving meaningful energy improvements through targeted interventions in the most impactful envelope areas.

### ***System Integration and Performance Optimization***

Holistic design approaches should optimize interactions between envelope components and mechanical systems. Roof designs should integrate daylighting, solar control, and potentially renewable energy generation while maintaining thermal performance. Wall systems should balance insulation, thermal mass, moisture management, and integration with windows and doors. Floor assemblies should address thermal breaks at perimeters and connections to foundation systems. Fenestration should be optimized for both thermal performance and daylighting benefits, with appropriate sizing and placement to minimize energy use. Door specifications should consider both thermal performance and functional requirements such as traffic flow and emergency egress. Performance metrics should evaluate how these elements work together under actual operating conditions rather than isolated component compliance, encouraging integrated solutions that maximize energy efficiency while enhancing overall building performance, comfort, and resilience.





## 4. Technical Requirements for Buildings Services

The global dataset encompasses four critical areas of building energy use in active systems: **space heating, water heating, space cooling, and lighting**. For space heating, the dataset includes efficiency standards for heat pumps, fossil fuel boilers and furnaces, as well as electrical boilers and furnaces, addressing both residential and commercial buildings. Within the water heating domain, it captures data on efficiency requirements for both fossil fuel and electrical water heaters, covering both building types. In the space cooling category, the data highlights requirements for central AC systems, split AC systems, heat pumps, and fans, ensuring that both residential and commercial buildings are considered. For lighting, the dataset includes standards for maximum wattage or lighting allowances in outdoor and indoor settings, along with luminaire efficacy.

## 4.1 Space Heating and Cooling Requirements

HVAC systems and water heating equipment represent the largest energy consumers in buildings, accounting for approximately 40 percent of total energy consumption in residential buildings and up to 50 percent in commercial buildings.<sup>33</sup> In the EU, heating and cooling in buildings accounts for 80 percent of residential energy consumption, making it the single largest energy end-use in the sector.<sup>34</sup> This substantial energy footprint makes these systems central to any meaningful discussion of building energy efficiency and carbon reduction strategies.

The complexity of HVAC and water heating regulations stems from their intricate relationship with climate conditions, building types, and occupancy patterns. In cold climate regions, the US Department of Energy reports that space heating accounts for about 45 percent of energy use in typical US homes, with water heating adding another 20 percent.<sup>35</sup> Conversely, in hot climate regions, cooling demands dominate—for instance, in the Middle East, AC can constitute up to 70 percent of peak electricity demand during summer months.<sup>36</sup> This climate-dependent variation in energy demands necessitates carefully calibrated efficiency standards that reflect local conditions while promoting optimal system performance.

The significance of HVAC and water heating efficiency extends beyond immediate energy consumption to encompass broader environmental and economic implications. According to the Global Alliance for Buildings and Construction (2023), improvements in HVAC efficiency could reduce building-related CO2 emissions by up to 25 percent by 2050.<sup>37</sup> This further emphasizes why BECs must carefully balance minimum performance requirements, technology availability, and economic feasibility across different climate contexts.

### 4.1.1 SPACE HEATING

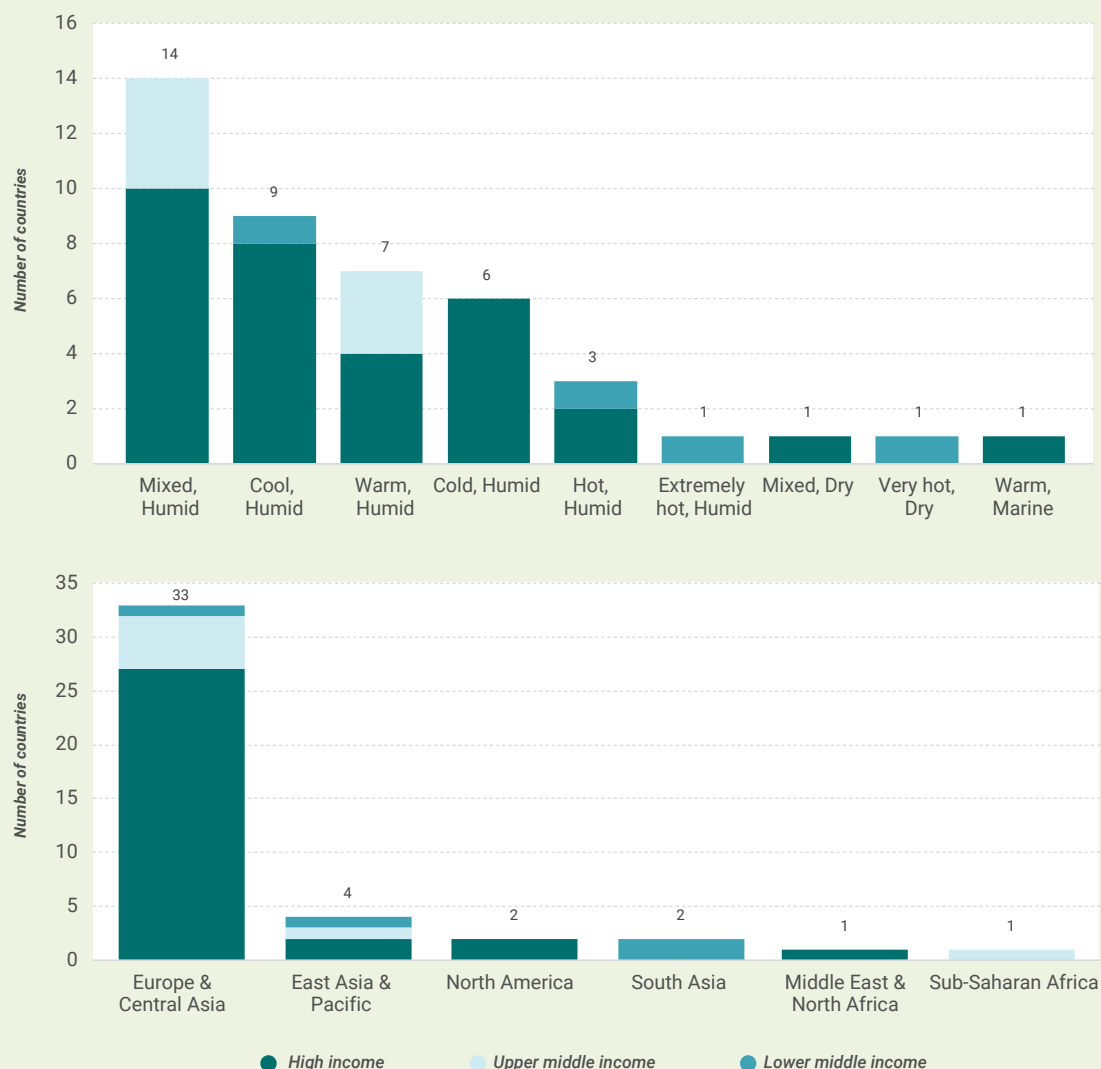
Space heating represents a dominant share of building energy consumption in many regions, with significant implications for both energy efficiency and carbon emissions. Unlike other building systems whose energy use may be intermittent, heating systems operate for extended periods in cold and mixed climates, making their efficiency crucial for overall building performance. The operation of heating systems also affects other aspects of building performance—from moisture management and indoor air quality to occupant comfort and productivity. This centrality to building operations makes heating efficiency requirements a cornerstone of BECs in regions where space heating is needed.

The importance of regulating heating systems extends beyond energy savings to resilience and public health. In cold climates, efficient heating systems with proper controls help prevent pipe freezing and structural damage during extreme weather events. They also play a crucial role in maintaining livable conditions for vulnerable populations during cold periods. Additionally, as buildings transition toward

electrification and renewable energy integration, heating system requirements in building codes help drive market transformation toward more sustainable technologies.

## Analysis from Building Energy Codes Global Dataset

**Figure 31 // Adoption of Space Heating Requirements across Cities by Climate Zones and by Region**



Source: Building Energy Codes Global Dataset, World Bank Group.

Analysis of space heating requirements across 88 countries reveals distinct patterns in regulatory coverage and stringency levels, strongly correlating with climate conditions and economic development (Figure 31). Of the 88 countries surveyed, 43 have implemented codes or standards governing heating system efficiency, with a notable concentration in high-income nations. This distribution reflects both climate necessity and economic capacity to implement and enforce such regulations. The geographic and climatic distribution shows clear patterns: cold and cool climate zones, particularly in Europe and Central Asia, dominate the coverage with 33 of the 43 countries with heating regulations located in these regions.

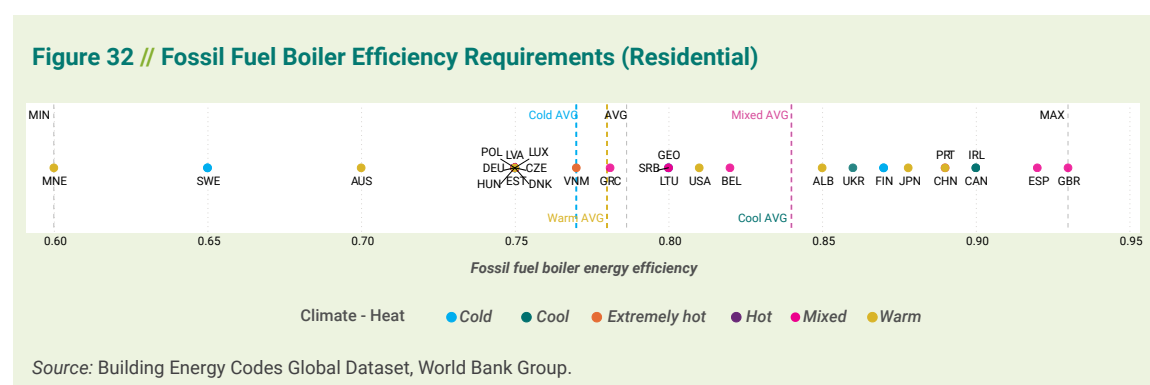
This concentration aligns with heating demand patterns, while hot to extremely hot climate zones show minimal coverage, implementing such standards only as part of broader national BECs rather than climate-specific needs.

Among the 43 cities with space heating regulations, there is a clear pattern in technological coverage: 42 cities include standards for fossil fuel boilers and/or furnaces, while 38 address heat pump efficiency. The regulations predominantly focus on performance-based requirements, specifically EERs—the relationship between useful heat output and total energy input, with higher ratios indicating stricter standards. This coverage pattern reflects a regulatory prioritization targeting the most carbon-intensive heating technologies, explaining the more comprehensive oversight of fossil fuel-based systems compared to electrical heating equipment.

## 4.2 Space Heating: Technology Coverage and Standards

### 4.2.1 BOILERS

Boiler efficiency standards remain a central component of BECs, with regulations varying significantly across fuel types and regions. The dataset reveals distinct patterns in both the coverage and stringency of boiler standards, reflecting different policy approaches to building decarbonization.



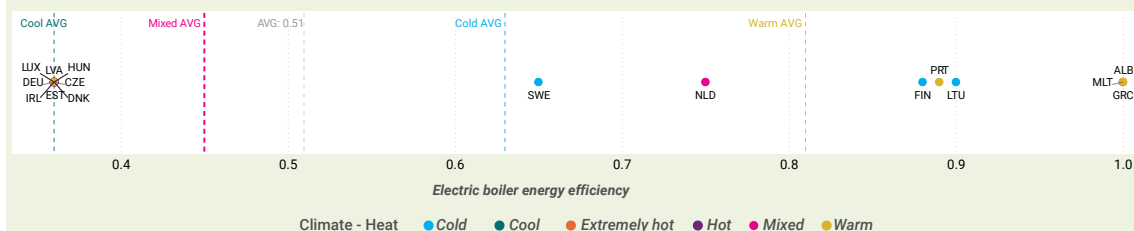
Fossil fuel boilers and furnace efficiency standards are the most common target in regulations, with 42 out of 43 countries establishing these requirements (Figure 32). The stringency varies significantly, with residential fossil fuel boiler efficiency requirements ranging from 0.60 in Podgorica (Montenegro) to 0.93 in London (UK). Four countries—the United Kingdom, Spain, Canada, and Ireland—stand out with particularly stringent standards, requiring efficiency ratings of 0.90 or higher, all characterized by cool to mixed climates requiring extended heating seasons. However, it is important to note that many countries have implemented or announced restrictions on new fossil fuel heating systems through environmental regulations and climate policies that operate parallel to BECs. For example, the Netherlands has banned natural gas connections in new buildings since 2018, while France has prohibited new gas boiler installations in single-family homes from 2022.

The regulatory landscape for electric boilers shows a distinct geographic concentration in Europe and Central Asia, with Malta being the only jurisdiction outside this region to implement such standards. While electric boiler regulations are less prevalent overall (32 countries compared to 42 for fossil fuel boilers) and typically specify different efficiency metrics and requirements, several jurisdictions are expanding



their focus to include requirements for heat pump systems, which offer potential for higher operational efficiency.

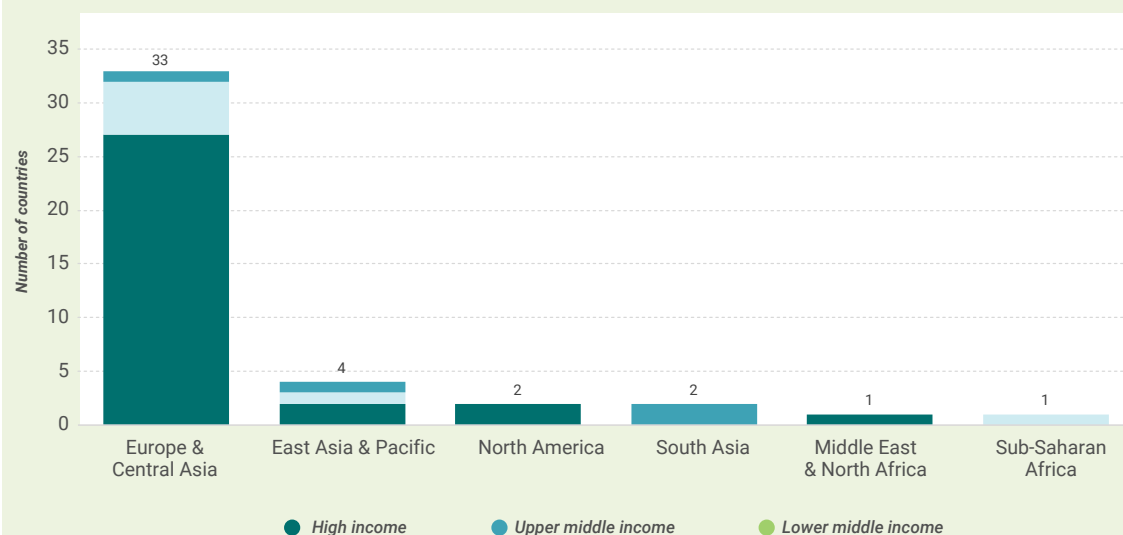
**Figure 33 // Electrical Boiler Efficiency Requirements (Residential)**



Source: Building Energy Codes Global Dataset, World Bank Group.

## 4.2.2 HEAT PUMPS

**Figure 34 // Heating coefficient of Performance Requirements for Heat Pumps by Region and income group**



Source: Building Energy Codes Global Dataset, World Bank Group.



## UNDERSTANDING HEAT PUMP TECHNOLOGY

Heat pumps represent a highly efficient heating and cooling technology that moves heat rather than generating it. Unlike traditional heating systems that convert fuel or electricity directly into heat, heat pumps extract existing heat from the outdoor environment (even in cold weather) and transfer it indoors. This process can be reversed for cooling, making heat pumps versatile for year-round climate control. The technology works similarly to a refrigerator but on a larger scale, using a refrigerant cycle to collect heat from the outdoor air (or ground/water in some systems), compress it to increase its temperature, transfer it into the building, and then return to collect more heat in a continuous cycle. This approach is particularly energy efficient because it typically delivers 3–4 units of heat energy for every unit of electricity consumed (represented by COPs of 3.0–4.0), making it a key technology for reducing building energy consumption and meeting climate goals. Modern heat pumps can operate effectively even in sub-zero temperatures, though their efficiency varies with outdoor conditions. The growing adoption of heat pumps in BECs reflects their potential to significantly reduce both energy consumption and carbon emissions from building heating and cooling. Their ability to provide both heating and cooling through a single system makes them especially valuable for climate zones with significant seasonal temperature variations.

Of the 88 countries covered by the dataset, 38 have codes or standards that include heat pump heating efficiency. Most of these are located in high-income countries and in Europe and Central Asia (Figure 34). Countries in Europe and Central Asia with heat pump standards typically have humid climates and are EU members, following a common EU performance standard (COP 1.84).

Amsterdam (the Netherlands), Beijing (China), and Bratislava (Slovak Republic) have the most stringent heat pump minimum energy performance standards for heating, with coefficient of performance (COP) requirements superior or equal to 4 when the average requirement is 2.42. The European Ecodesign directive's requirement of COP 1.84 is the least stringent. This lower standard reflects several key considerations within the EU context. The EU encompasses a wide range of climates, economic and technological capabilities, making heat pumps not equally relevant in all regions. Additionally, since heat pumps are already a very efficient heating mode, lower requirements may encourage broader adoption across diverse economic contexts. The variation in member states' economic and technological capabilities also influences this baseline standard. Furthermore, the EU's holistic approach to energy policy sometimes leads to less stringent requirements in specific areas to ensure overall policy coherence and feasibility across its diverse membership.

It must be noted that in addition to electric technologies, district heating is preferable to individual appliances due to its potential for higher system-wide efficiency, better integration of renewable energy sources, and economies of scale. District heating networks can leverage waste heat from industrial processes, incorporate large-scale heat pumps more efficiently, and provide more flexible load management across multiple buildings. This approach is particularly relevant in dense urban areas and regions with existing district heating infrastructure, such as Northern Europe and parts of Asia, where it can serve as a key enabler of building sector decarbonization alongside electric heating technologies.

Copenhagen demonstrates how district heating can be implemented at a citywide scale, with nearly all households connected to the system. The city's district heating network leverages multiple heat sources, including power plant waste heat and industrial processes, creating an integrated urban energy system. This approach has helped Copenhagen significantly reduce heating-related emissions while providing reliable and affordable heating to residents.

Stockholm's district heating system shows how these networks can evolve with changing technology and urban development. The city has successfully integrated new heat sources into its existing network,

including waste heat from data centers and other urban infrastructure. With most buildings connected to district heating, Stockholm's experience demonstrates how such systems can become a fundamental part of urban infrastructure while supporting broader sustainability goals.

### **Recommendations for policy makers**

**Technology-specific standards and timelines:** For fossil fuel systems, establish a clear phase-out schedule starting with the lowest performing units, as demonstrated by several leading jurisdictions. The Netherlands pioneered this approach by banning natural gas connections in new buildings from 2018, while France banned new gas boiler installations in single-family homes from 2022, extending to all new residential buildings from 2024. Denmark shows how phase-outs can target specific contexts, banning new natural gas heating systems from 2023 in areas where district heating is available.

For new installations, implement progressively stringent efficiency standards based on market-proven technologies. The EU's Ecodesign directive provides a baseline for heat pump performance (COP 1.84), while several countries demonstrate that higher standards are achievable—the Netherlands, China, and Slovak Republic have successfully implemented more ambitious requirements with COPs exceeding 4.0.

For electric heating systems, develop tiered efficiency requirements that reflect both current market capabilities and future performance targets. Albania, Greece, and Malta's experience with high-efficiency electric systems demonstrates the feasibility of ambitious standards when supported by appropriate market development programs.

**Implementation and market support:** Create dedicated funding mechanisms allocating at least 0.1 percent of construction value to support heating system upgrades. Establish certification programs for heat pump installers with mandatory training requirements—addressing a key barrier to heat pump adoption identified in the dataset. For countries with limited heat pump markets, start with commercial buildings where technical capacity is typically higher—following successful examples from several lower-middle-income countries in the dataset. Where district heating is viable (particularly in dense urban areas with significant heating loads), prioritize connection requirements over individual system regulations, and integrate district heating solution in urban development plans.

**Monitoring and verification:** Establish mandatory performance reporting systems for all heating installations above 50 kW capacity. Require annual efficiency testing for fossil fuel systems above 100 kW, with results feeding into national databases to inform future policy decisions. For heat pumps, implement seasonal performance monitoring for systems above 30 kW to verify actual versus rated performance. This data-driven approach will help identify implementation gaps and inform future standard updates.

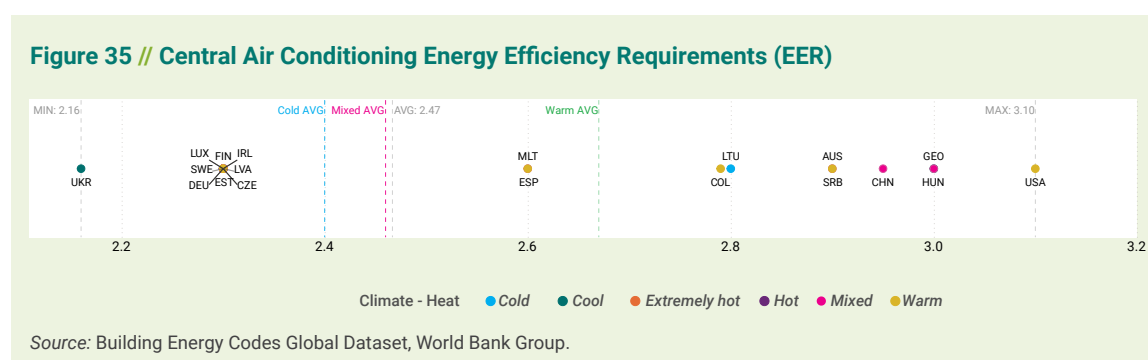
### **4.2.3 SPACE COOLING**

The global dataset measures Minimum Energy Performance Standards (MEPS) for various cooling technologies across both residential and commercial buildings. MEPS establish the minimum level of energy efficiency that products must meet before they can be sold or installed in buildings. For space cooling equipment, these standards are typically expressed through metrics such as Energy Efficiency Ratio (EER), Coefficient of Performance (COP), and Seasonal Energy Efficiency Ratio (SEER). These measurement standards provide an objective basis for comparing cooling system performance across different markets and technologies. The dataset tracks MEPS requirements for cooling technologies: central AC systems, split AC systems, and fans. Each of these technologies plays a distinct role in building cooling strategies, with their adoption and regulation varying significantly across different climate zones and economic contexts.

### 4.2.3.1 Central Air Conditioning

Analysis of central AC requirements across 88 countries reveals significant variations in regulatory adoption and stringency, reflecting diverse climate conditions and institutional frameworks. Of the surveyed countries, 33 have implemented specific energy efficiency requirements for central AC systems, with adoption patterns strongly influenced by regional cooperation and economic development.

Building energy efficiency codes of Europe and Central Asia countries represent the region with the most comprehensive coverage, with 28 of them establishing specific EER requirements (Figure 35). This high adoption rate largely stems from the EU's harmonized standards, evidenced by the consistent 2.3 EER requirement across member states. This standardization has created a unified market for cooling equipment while establishing a baseline for energy performance. However, several European cities have chosen to implement more stringent standards—for instance, Budapest (Hungary) and (Tbilisi) Georgia require an EER of 3.0, proving that regional frameworks can serve as a foundation for more ambitious requirements.



The data reveals a striking disconnect between cooling needs and regulatory coverage. Many countries in extremely hot climate zones, where cooling represents a significant portion of building energy consumption, lack specific EER requirements. This gap is particularly notable in the Middle East and North Africa region, where only Malta and the United Arab Emirates have established requirements despite the region's intense cooling demands. Similarly, in South Asia, only Mumbai (India) has implemented specific standards, though it focuses exclusively on commercial buildings with an EER requirement of 2.8.

Los Angeles (US) sets the highest standard globally with an EER requirement of 3.1 for residential systems and 2.8 for commercial buildings. This differentiation between residential and commercial requirements is relatively uncommon—only 5 out of 33 countries maintain distinct standards for these sectors. Vilnius (Lithuania) follows a similar pattern, requiring an EER of 2.8 for residential and 2.3 for commercial systems, though this appears more aligned with EU baseline standards.

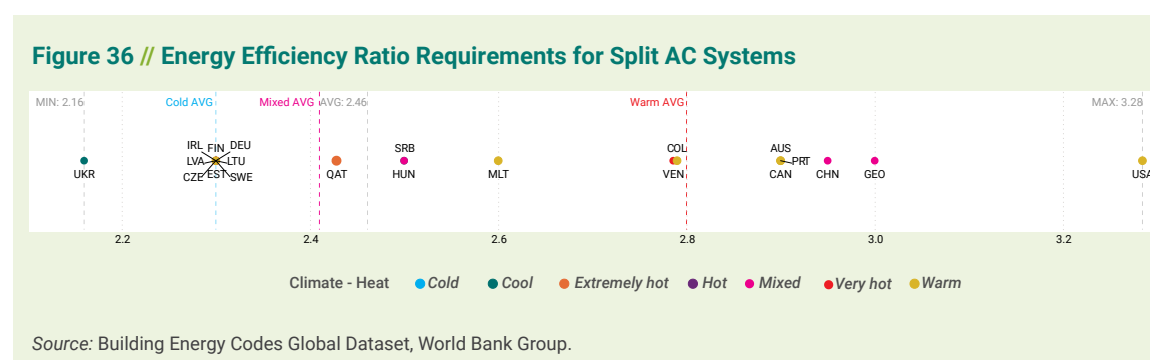
The stringency of air-cooling requirements shows surprising patterns across economic development levels. While high-income countries generally maintain more comprehensive requirements, several upper-middle-income countries have established equally ambitious standards. Beijing's (China) requirement of 3.0 EER for both residential and commercial systems matches the highest European standards, while Belgrade (Serbia) requires 2.9 EER across all building types. This suggests that economic constraints do not prevent ambitious efficiency standards.

The varying stringency of requirements, from Kyiv's (Ukraine) 2.2 EER to the Los Angeles' (US) 3.1 EER, represents a significant performance gap that has real implications for energy consumption and cooling costs. This range suggests substantial opportunities for improvement, particularly in regions where

cooling demands are high, but standards remain lenient or absent. The success of countries like China and Serbia in implementing stringent requirements demonstrates that ambitious standards are achievable across different economic contexts, providing valuable models for countries considering new or enhanced cooling efficiency requirements.

### 4.2.3.2 Split Air Conditioning

The global landscape of split AC regulations reveals important patterns in how countries approach this widely used cooling technology. Among the 88 surveyed countries, 36 have implemented specific EER requirements for split AC systems, slightly higher than the 33 countries regulating central AC systems (Figure 36). This difference, though modest, reflects the broader market penetration of split AC units, particularly in residential applications across diverse climate zones.



Los Angeles (US) maintains the most stringent standard globally with an EER requirement of 3.3 for residential split systems, notably higher than its central AC requirement of 3.1. This differentiation suggests a recognition of split systems' potential for higher efficiency, particularly in residential applications. Similar patterns emerge in other countries—Canada, for instance, requires an EER of 2.9 for split systems but does not specify requirements for central AC systems, while Portugal mandates 2.9 for split systems compared to 2.3 for central units.

The EU's common regulatory framework remains evident in split AC standards, with member states largely maintaining the standardized 2.3 EER requirement across both split and central systems. However, several European countries have established more ambitious standards—Georgia maintains its 3.0 EER requirement across both technologies, while Hungary has implemented a 2.5 EER requirement for split systems, differing from its 3.0 requirement for central AC systems. These variations suggest that countries are increasingly tailoring requirements to specific technology capabilities and market conditions.

Interestingly, several countries that lack central AC requirements have established standards for split systems. Caracas (Venezuela), for example, mandates an EER of 2.8 for split systems but has no requirements for central AC, while Doha (Qatar) requires a 2.4 EER for split systems specifically. This pattern likely reflects the dominance of split systems in these markets, particularly in residential applications.

The coverage in extremely hot climate zones shows a notable difference between technologies. While central AC requirements are limited in these regions, more countries have established split system standards, reflecting the prevalent use of this technology in high-cooling-demand environments. However, a significant gap remains—many countries in extremely hot climates still lack any efficiency requirements despite their substantial cooling needs.

The relationship between income and regulatory coverage shows similar patterns across both technologies, but with split systems showing slightly broader adoption among lower-middle-income countries. This wider adoption likely reflects both the lower cost of split systems and their prevalence in residential construction, making them a critical target for energy efficiency regulations in developing markets. The success of countries like Colombia and Venezuela in implementing meaningful standards (2.8 EER) demonstrates that ambitious requirements for split systems are achievable across different economic contexts.

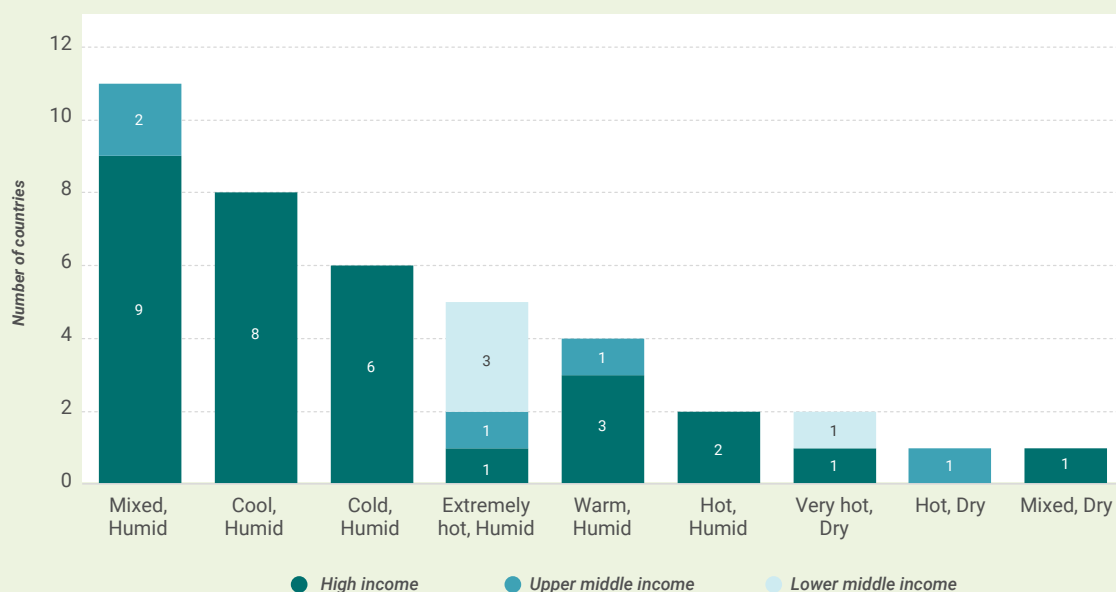
Looking at residential versus commercial requirements, split AC systems show more consistency across sectors compared to central AC units. Where differences exist, they tend to be more modest than those seen in central AC requirements, suggesting a more standardized approach to regulating this technology. This consistency might reflect the more standardized nature of split system applications, and the simpler regulatory frameworks needed for these systems.

### 4.2.3.3 Fans

The global dataset reveals significant variation in how countries approach fan regulations within their BECs. Of the 88 cities analyzed studied, fans show notably different treatment across climate zones and regions (Figure 37). The data indicates that extremely hot climate zones demonstrate the highest adoption of fan-specific requirements, with countries like Singapore, Malaysia, and Thailand leading in comprehensive fan efficiency standards. This pattern aligns logically with their cooling-dominated climates where fans play a crucial role in both stand-alone cooling and supporting AC systems.

Mixed and warm climate zones show moderate but inconsistent adoption of fan efficiency requirements. European countries in these zones tend to incorporate fan efficiency requirements within broader HVAC system regulations, particularly focusing on air handling units in commercial buildings. The data suggests that while many countries include basic fan power limitations, few have implemented comprehensive performance requirements covering all fan applications. Interestingly, several lower-middle-income

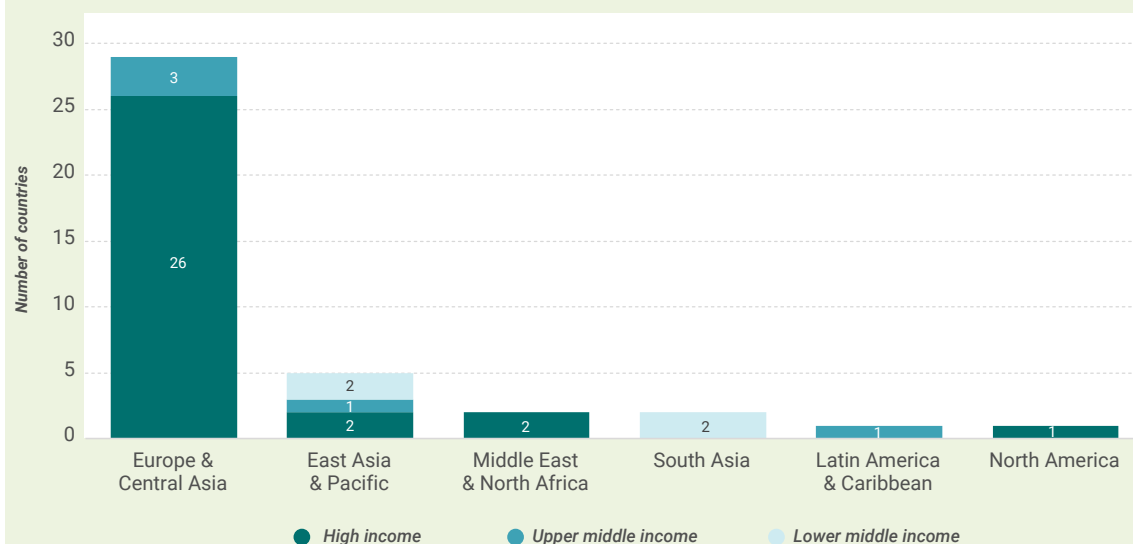
**Figure 37 // Coverage of Fan Requirements by Climate and Region**



Source: Building Energy Codes Global Dataset, World Bank Group.



Figure 37 (cont.)



Source: Building Energy Codes Global Dataset, World Bank Group.

countries in warm climates have established fan efficiency requirements, recognizing their importance as a cost-effective cooling strategy. However, cold climate zones show the lowest adoption of stand-alone fan requirements, typically incorporating them only within broader ventilation system standards.

### Recommendations for policy makers

**Develop and implement a comprehensive national policy on cooling:** It is crucial to introduce a stable, long-term framework that incorporates regulations, information programs, and incentives aimed at reducing both cooling-related energy consumption and refrigerant emissions. The development of this framework should involve stakeholders from government, industry, and consumer groups to ensure it is well-rounded and effective. Additionally, the framework must consider the multiple benefits of energy efficiency, including lifecycle energy use and carbon emissions.

**Enhance regulatory measures:** Governments should introduce or strengthen MEPS for AC equipment and BECs for new constructions. There should also be codes and standards for existing buildings, including requirements for maintenance and operation that improve demand-side management. Regulations should also modify any existing regulatory, fiscal, or local planning policies that inhibit the adoption of energy-efficient and renewable energy solutions for buildings. Ensuring that these regulations are enforceable and that enforcement mechanisms are properly funded is also essential.

**Adopt and enforce mandatory building energy codes and MEPS:** The adoption and enforcement of these standards for equipment and appliances must be at the heart of policies aimed specifically at energy use in buildings. Standards need to be expanded and strengthened quickly across all countries, drawing on extensive international experience and knowledge. Policies should account for capacity building, including appropriate training for skilled labor in the buildings sector to design, sell, install, and operate more efficient cooling equipment. Capacity building within governments and public bodies is also important. Policies need to take into consideration the opportunities arising from the emergence of digital technologies that can make cooling and other buildings-related energy services more sustainable.

**Integrate cooling into policies on sustainable buildings:** Cooling should be addressed as part of integrated energy policy planning to achieve sustainable, low-carbon energy use in buildings. This process includes considering buildings within the broader context of local and regional energy communities, where cost-effective, low-carbon synergies often depend on attaining a scale and density of supply and demand.

**Encourage the digitalization of cooling and other building technologies:** Advances in digital technologies, such as smart thermostats, can reduce energy consumption by automatically adjusting temperature settings according to the precise needs of occupants and in response to real-time price signals. However, there are obstacles to realizing the benefits of widespread digitalization in buildings, including data security, privacy, and technical and financial considerations.<sup>38</sup> Electricity utilities may need to offer financial incentives and introduce innovative tariff structures to encourage building owners and occupants to adopt digital technologies. Additionally, greater effort is needed to communicate the benefits of digitalization to end-users in terms of improved comfort and cost savings. Standards for connected devices will be crucial to the prospects for digitalizing buildings, ensuring that devices can provide and receive information using open-source or compatible software to allow for interoperability across technologies.

#### BOX 6. From Efficiency to Elimination: Leading Policies on Fossil Fuel Heating Phase-Out

Several countries have moved beyond efficiency requirements to announce complete phase-outs of fossil fuel boilers, marking a significant shift in building decarbonization policy. The Netherlands led this transition by becoming the first country to mandate that all new buildings must be fossil-free from 2018, effectively banning natural gas connections in new construction. France followed in 2022 by banning the installation of new gas boilers in single-family homes, extending this to all new residential buildings from 2024. Denmark announced that from 2023, no new natural gas heating systems can be installed in existing buildings where district heating or district cooling is available.

These pioneering policies demonstrate varying approaches to implementation.

The Dutch approach combines the boiler ban with robust support mechanisms, including subsidies for heat pumps and building retrofits, alongside significant investments in expanding district heating networks. This comprehensive strategy has helped manage the transition's social and economic impacts.

France adopted a gradual approach, first targeting new construction before expanding to existing buildings, while simultaneously introducing the 'MaPrimeRénov' program to provide financial support for low-carbon heating alternatives. The policy includes specific provisions for buildings where heat pumps may not be technically feasible, allowing for temporary exemptions while maintaining the long-term phase-out goal.

Denmark's policy leverages its extensive district heating infrastructure, making the fossil fuel boiler ban part of a broader strategy to expand and decarbonize district heating networks. This approach demonstrates how existing infrastructure can support the transition away from individual fossil fuel heating systems.

While European countries have led the initial wave of fossil fuel boiler bans, similar policies are emerging in other regions. In North America, New York City became the first major US city to ban fossil fuel connections in new buildings (starting from 2024 for buildings under seven stories), effectively prohibiting fossil fuel boilers in new construction. Several other US cities including Berkeley and Seattle have followed suit. At the state level, Washington State introduced requirements that all new commercial and multi-family constructions must use electric space heating from 2023.

In Asia-Pacific, New Zealand announced plans to phase out new fossil fuel boilers in buildings by 2025 as part of its emissions reduction plan. The policy will first restrict new coal boiler installations before expanding to other fossil fuels, supported by a NZ\$650 million fund to help businesses transition to cleaner heating technologies.

## 4.3 Water Heating Systems

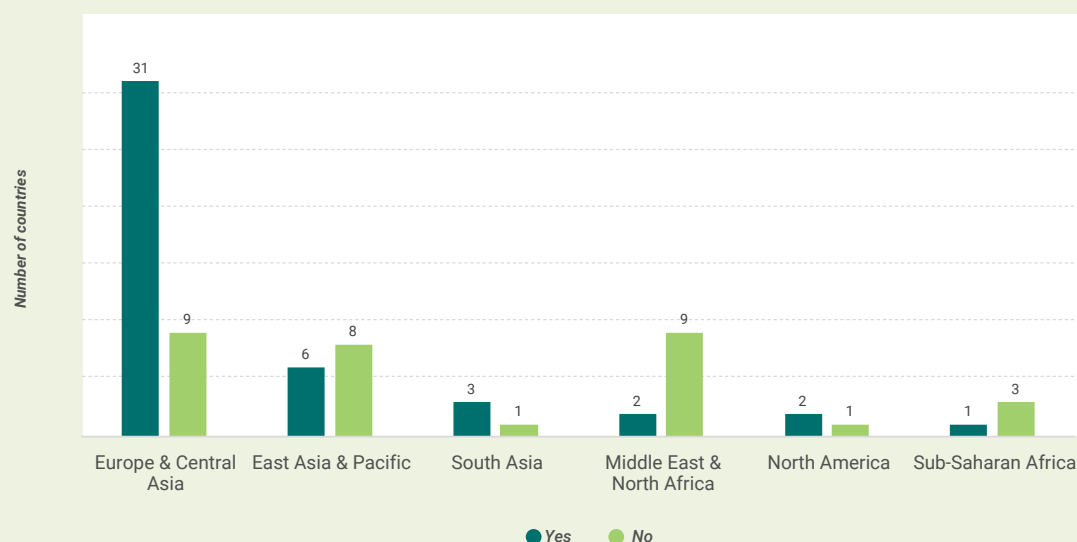
### Why it matters

Water heating represents a consistent and significant energy load across all building types and climate zones, unlike space heating or cooling which vary by region. According to the IEA's 2023 Buildings Report, water heating accounts for approximately 18 percent of residential energy use in countries of the Organisation for Economic Co-operation and Development (OECD), making it one of the largest end-uses in buildings. Commercial buildings present an even more diverse demand pattern, with high-intensity users like hotels and food service establishments requiring substantial hot water supply throughout their operating hours. The choice of water heating technology and its efficiency directly affects not just energy consumption and operating costs, but also peak load demands on energy infrastructure. Moreover, as buildings become more efficient in other areas through improved envelopes and HVAC systems, the relative importance of water heating efficiency grows, making it a crucial component of comprehensive BECs.

### Analysis from Building Energy Codes Global Dataset

The distribution of water heating regulations across regions reveals significant patterns in regulatory adoption, often influenced by climate conditions. Europe and Central Asia leads with 31 out of 40 countries implementing water heating requirements, reflecting both the region's predominant cool and mixed climates where water heating represents a substantial energy load and the EU's comprehensive approach to building energy efficiency. East Asia and Pacific follows with 6 out of 14 countries, spanning diverse climate zones from cool to extremely hot, while other regions show more limited adoption despite varying heating needs.

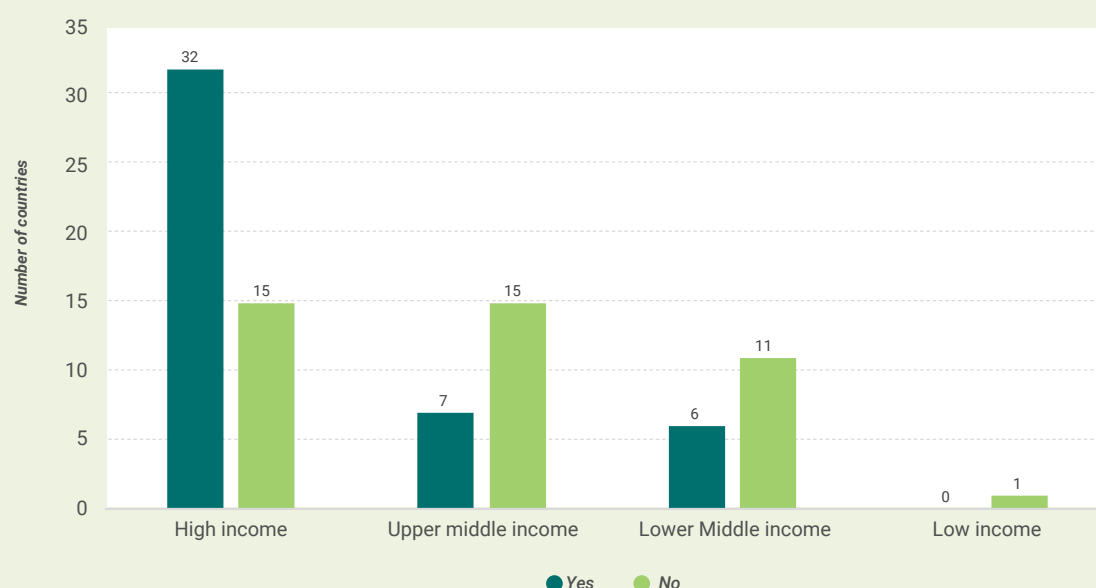
**Figure 38 // Water Heating Coverage by Region**



Source: Building Energy Codes Global Dataset, World Bank Group.

The implementation across income groups demonstrates a clear economic gradient that influences adoption patterns across different climate contexts. High-income countries lead with 32 out of 47 countries having established water heating regulations, consistently across cold, cool, mixed, and warm climate zones. Meanwhile, just 7 out of 22 upper-middle-income and 6 out of 17 lower-middle-income countries have implemented requirements, even in regions where climate conditions would suggest significant benefits from water heating efficiency. This pattern indicates that while economic capacity significantly influences adoption, some lower-middle-income countries like Philippines and Sri Lanka have successfully implemented requirements despite resource constraints, demonstrating that effective water heating regulations are achievable across diverse economic and climatic contexts.

**Figure 39 // Water Heating Coverage by Income Group**



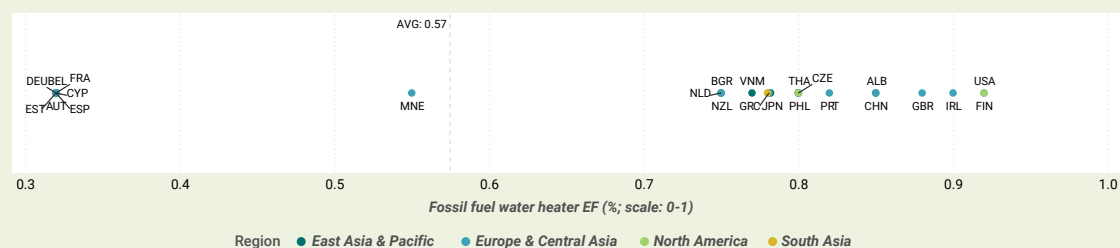
Source: Building Energy Codes Global Dataset, World Bank Group.

### 4.3.1 FOSSIL FUEL WATER HEATERS

The analysis reveals interesting patterns in fossil fuel water heater regulations across different regions and economic contexts. Of the 88 countries surveyed, 43 have implemented specific energy factor (EF) requirements for fossil fuel water heaters. The EF, which represents the ratio of useful energy output to total energy input, provides a standardized measure of water heater efficiency. Among the surveyed countries, EF requirements range from 0.32 to 0.92, reflecting significant variation in performance standards (Figure 40).

Helsinki (Finland) leads with the most demanding standards, requiring an EF of 0.92 for both residential and commercial applications, matched only by Los Angeles (US). London (UK) follows with an EF requirement of 0.88 across all building types, while Dublin (Ireland) maintains a 0.90 standard. These high EF requirements demonstrate ambitious but achievable performance targets for fossil fuel systems.

EU member states generally maintain consistent baseline EF requirements of 0.32, though several countries exceed this minimum. This pattern demonstrates how regional frameworks can establish baseline standards while enabling individual countries to implement more stringent requirements. Beyond Europe,

**Figure 40 // Energy Factor Requirements for Fossil Fuel Water Heaters**

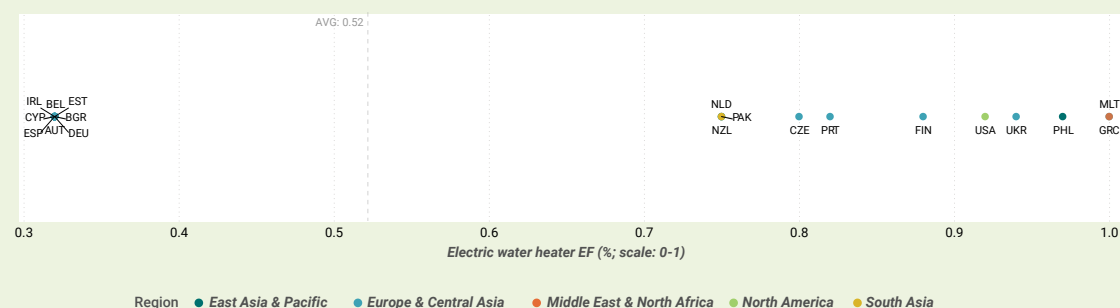
Source: Building Energy Codes Global Dataset, World Bank Group.

Toronto (Canada) shows an interesting split approach, requiring an EF of 0.80 for residential systems but a more stringent 0.94 for commercial applications—the highest commercial-specific requirement in the dataset.

Among upper-middle-income countries, China stands out with an EF requirement of 0.85 across both residential and commercial sectors, matched by Albania. Bangkok (Thailand) and Manila (Philippines) have established EF requirements of 0.80, demonstrating that ambitious standards are achievable in developing markets. In the lower-middle-income category, Islamabad (Pakistan) has implemented an EF of 0.78, while Hanoi (Viet Nam) maintains 0.77 for residential systems.

### 4.3.2 ELECTRIC WATER HEATERS

Electric water heater regulations show slightly lower adoption rates compared to fossil fuel systems, with 37 countries implementing specific requirements. The EF requirements demonstrate significant variation, ranging from 0.32 to 1.0. Athens (Greece) and Valletta (Malta) lead with the most stringent standards, requiring an EF of 1.0 for both residential and commercial applications, representing optimal energy conversion efficiency. Manila (Philippines) follows with an EF of 0.97 across all building types, while Kyiv (Ukraine) has established a 0.94 standard for residential systems (Figure 41).

**Figure 41 // Energy Factor Requirements for Electric Water Heaters**

Source: Building Energy Codes Global Dataset, World Bank Group.

Similar to fossil fuel systems, EU countries maintain baseline EF requirements of 0.32, though with notable exceptions. Helsinki (Finland) again demonstrates leadership with EF requirements of 0.88 for both sectors. Lisboa (Portugal) takes a unified approach with 0.82 standards across all applications, showing how requirements can be streamlined across building types.



The data reveals interesting regional variations in electric water heater regulations. While Europe shows strong adoption, coverage in other regions is more limited. Among Asian countries, the Philippines stands out with its comprehensive EF requirement of 0.97, significantly exceeding standards in many high-income nations. Pakistan has implemented balanced requirements with an EF of 0.75 across both residential and commercial sectors, while other lower-middle-income countries generally show limited coverage of electric water heating systems.

### Recommendations for policy makers

**Technology-specific efficiency standards:** Policy makers should establish clear minimum efficiency requirements based on proven benchmarks—85 percent for fossil fuel water heaters and 90–95 percent for electric systems, following successful implementations in multiple regions. The success of countries like Finland (92 percent fossil fuel, 88 percent electric) and the Philippines (97 percent electric) demonstrates these targets are achievable across different economic contexts. Implementation should consider differentiated standards for residential and commercial applications, following Canada’s model of higher requirements (94 percent) for commercial systems.

**Regional frameworks and capacity building:** Following the EU’s successful tiered approach model, policy makers should develop regional cooperation frameworks that enable progressive improvements while maintaining market stability. This is particularly crucial for regions with low adoption rates like Sub-Saharan Africa and Middle East and North Africa. Regional frameworks should include technical capacity sharing programs and standardized compliance tools, helping overcome the institutional barriers evident in the data. The success of Albania and Ukraine shows how regional cooperation can support ambitious standards even in developing economies.

**Market segmentation and phased implementation:** High-income countries should leverage their technical capacity to expand coverage across both building types and technologies, addressing gaps like those seen in Japan and New Zealand’s programs. Middle-income countries should adopt phased implementation strategies following the Philippines’ model of clear technical specifications and gradual stringency increases. Countries with existing fossil fuel standards, like China and Thailand, should prioritize expanding to electric water heaters while maintaining achievable compliance targets.

**Enforcement mechanisms and compliance systems:** Establish comprehensive enforcement frameworks with regular review cycles, following Finland’s successful model across both residential and commercial sectors. Compliance systems should include clear technical specifications, verification protocols, and regular updates aligned with market capacity. The experience of Los Angeles and Beijing demonstrates how robust enforcement mechanisms can achieve high compliance rates while maintaining ambitious standards.

## 4.4 Lighting Requirements and Controls

### Why it matters

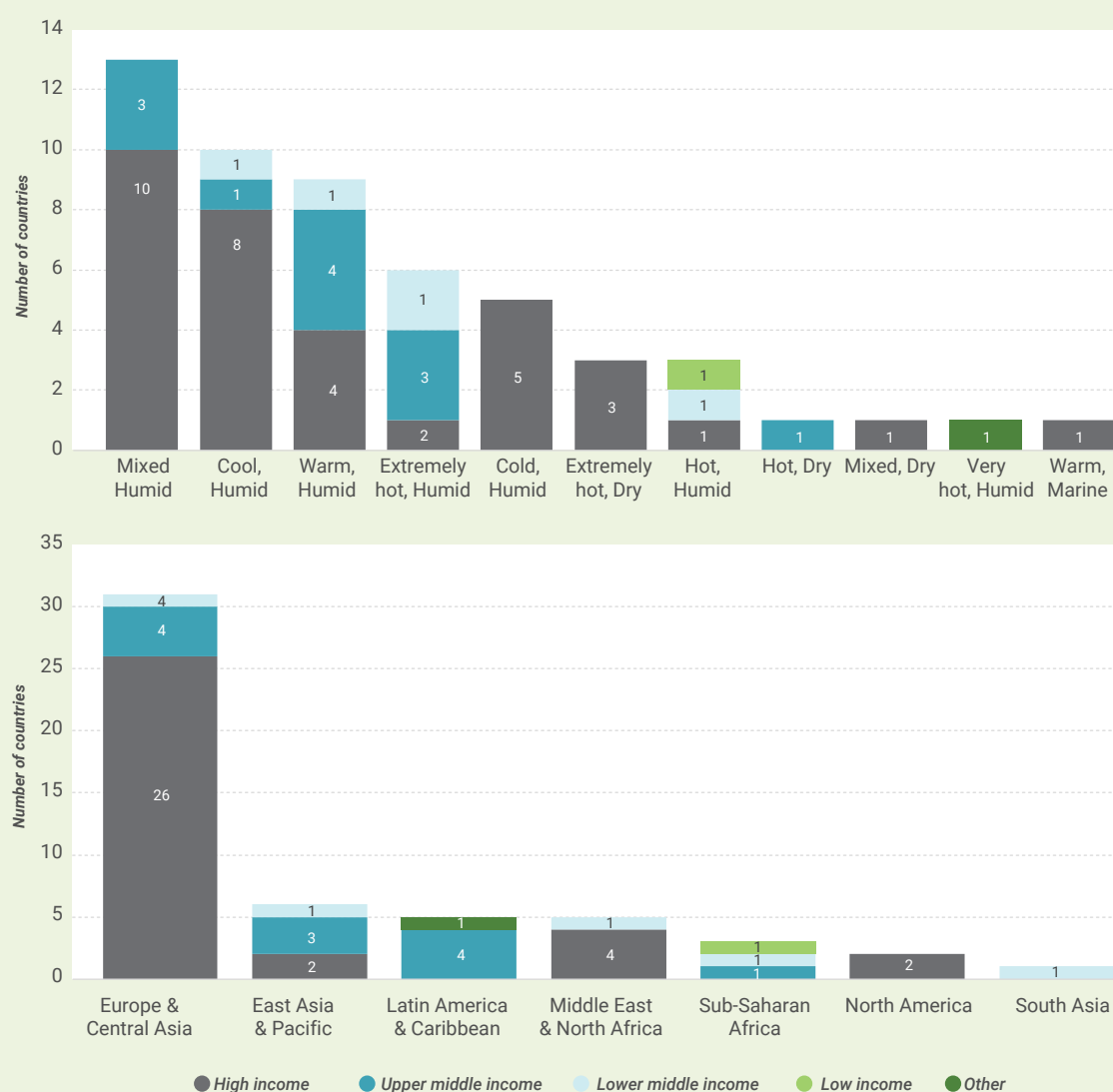
Lighting contributes significantly to building energy consumption across all building types and climate zones, making it a key component of energy efficiency regulations. While heating and cooling loads vary by region and season, lighting power density and usage patterns remain relatively stable, though they differ based on building function and occupancy schedules. According to the World Green Building Council, lighting accounts for 13 percent of all electricity usage worldwide.<sup>39</sup>

The shift to solid-state lighting technologies, particularly LED systems, has substantially improved the technical potential for energy savings through BECs. Lighting efficiency affects both direct electricity consumption and cooling loads—conventional lighting systems convert 60–80 percent of input power to heat, directly affecting cooling energy demand in conditioned spaces. This interaction between lighting power density and HVAC loads makes lighting requirements a critical element in building energy efficiency regulations, enabling compounded energy savings through integrated system performance requirements.

### Analysis from Building Energy Codes Global Dataset

The analysis of lighting requirements across 88 countries reveals significant patterns in both coverage and technical specifications. Of the surveyed countries, 53 have implemented lighting-related requirements, with varying degrees of comprehensiveness (Figure 42). The most striking pattern emerges in

**Figure 42 // Adoption of Lighting Requirements and Enforcement Mechanisms**

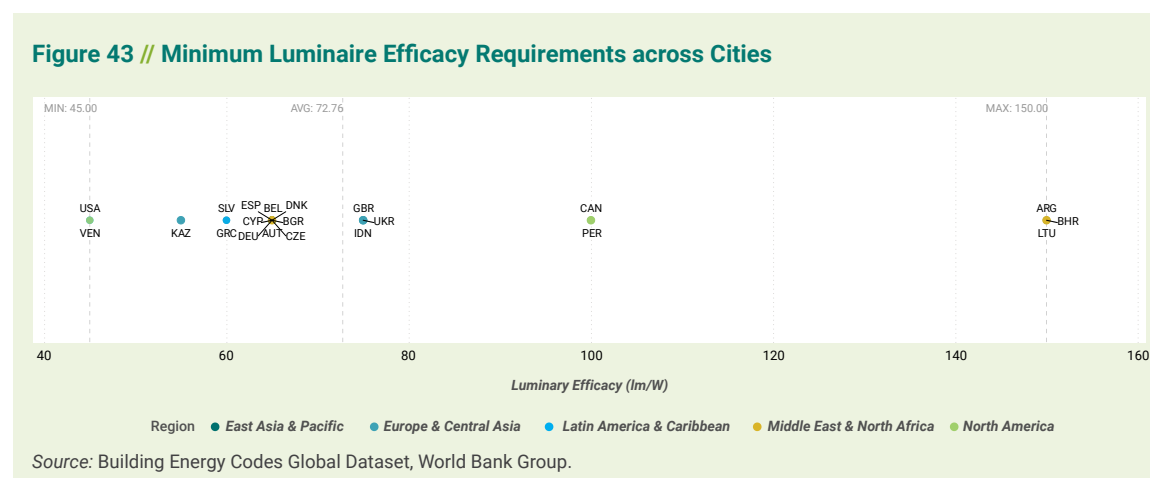


Source: Building Energy Codes Global Dataset, World Bank Group.

enforcement mechanisms, where 41 countries have established specific procedures for verifying lighting compliance. Among these, 24 countries maintain two distinct enforcement mechanisms, while 17 countries have implemented a single verification procedure. This split suggests a relationship between regulatory maturity and enforcement complexity.

The technical requirements show interesting differentiation across indoor and outdoor applications. Of the countries with lighting regulations, 31 have established specific indoor lighting requirements, while only 15 have implemented outdoor lighting standards. This disparity likely reflects the greater complexity of regulating outdoor lighting, which must balance safety and security needs with energy efficiency. Countries like Canada, Spain, and Latvia stand out for maintaining comprehensive requirements covering both indoor and outdoor applications, while many nations focus exclusively on indoor lighting power density limits.

Luminaire efficacy requirements provide particularly revealing insights into technical stringency. Among the countries specifying minimum efficacy, the requirements range from 45 to 150 lumens per watt (lm/W) (Figure 43). Buenos Aires (Argentina) sets the highest standard at 150 lm/W, matched by Vilnius (Lithuania) and Manama (Bahrain), while Caracas (Venezuela) and Los Angeles (US) maintain more modest requirements at 45 lm/W. EU member states generally maintain consistent efficacy requirements of 65 lm/W, demonstrating the influence of regional frameworks in standardizing technical specifications. Several emerging economies have established ambitious efficacy standards—Indonesia mandates 75 lm/W, matching the United Kingdom’s requirement, while Kazakhstan has implemented a 55 lm/W standard.



The geographic distribution of lighting regulations reveals interesting patterns. Europe and Central Asia show the strongest adoption with 31 out of 40 countries implementing requirements. East Asia and Pacific follows with 6 out of 14 countries regulating lighting efficiency, while Latin America and the Caribbean show more limited adoption with 5 out of 12 countries. The Middle East and North Africa region demonstrates moderate coverage with 5 out of 11 countries implementing requirements. This distribution suggests that regional policy frameworks, particularly the EU’s influence, play a significant role in driving regulatory adoption.

The economic analysis reveals that while high-income countries generally show more comprehensive coverage, several middle- and lower-income countries have implemented robust lighting requirements. Among high-income countries, 34 out of 47 have lighting regulations, while 12 out of 22 upper-middle-income

countries and 5 out of 17 lower-middle-income countries have established requirements. Rwanda, as the only low-income country in the dataset, demonstrates that meaningful lighting efficiency requirements are achievable even with limited resources. This pattern suggests that while economic capacity influences regulatory adoption, it need not prevent the implementation of effective lighting standards.

### *Recommendations for policy makers*

**Staged Efficiency Requirements.** Policy makers should establish tiered luminaire efficacy requirements that reflect both market maturity and economic context. Begin with achievable baseline requirements—for example, 65 lm/W where local markets already supply such products—while creating clear pathways to higher performance tiers as markets develop. For emerging markets, focus initially on larger commercial buildings where efficiency investments are most viable, then expand coverage as costs decrease and product availability improves.

**Simplified Control Verification.** Start with basic control requirements that can be visually verified during inspection—manual switching zones, occupancy sensors in enclosed spaces, and simple daylight controls near windows. This allows markets to build verification capacity without requiring sophisticated testing equipment. As implementation capacity grows, expand to more advanced control requirements while maintaining practical verification methods. Create standard testing protocols that can be implemented with minimal specialized equipment while ensuring basic performance verification.

**Market-Appropriate Testing.** Design verification systems that match local testing capabilities. Begin with documentation review and simple field measurements of illuminance levels, which require minimal equipment investment. Establish relationships with regional testing facilities to enable more sophisticated performance verification while sharing resources across jurisdictions. Create standardized test protocols that focus on essential performance metrics while remaining achievable within local technical constraints.

**Technology Support Framework.** Develop technical requirements that encourage LED adoption without creating market disruption. Establish minimum efficiency requirements that can be met by multiple manufacturers while maintaining competition. Create product registration systems scaled to local capacity—from basic qualified product lists to more comprehensive performance databases as markets mature. Support local supply chains through clear technical standards and verification procedures that align with regional manufacturing capabilities.



## 5. From Policy to Practice: Enforcement Systems



The transformation of BECs from policy documents to effective tools for energy efficiency requires robust enforcement systems and practical implementation mechanisms. These systems—spanning pre-construction verification, construction-phase inspections, and post-occupancy monitoring—form the crucial bridge between technical requirements and actual building performance. The sophistication and effectiveness of enforcement frameworks vary significantly across jurisdictions, reflecting different institutional capacities, market conditions, and implementation approaches. Understanding these enforcement mechanisms, their practical application, and factors influencing their success provides essential insights for strengthening BEC implementation globally.

### BOX 7. Building Energy Certification in Brazil: From Voluntary to Mandatory Implementation

Brazil's PBE Edifica program, launched in 2009, represents a significant initiative in building energy certification that has achieved important successes while facing implementation challenges. The program's technical framework demonstrates considerable sophistication through its five-tier rating system (A to E) that comprehensively evaluates building envelope performance, lighting efficiency, and HVAC systems. This thorough approach ensures high-quality assessment of building energy performance, with over 6,300 buildings certified through 2020, including 6,095 residential and 250 commercial/public buildings.

The program's mandatory requirement for federal public buildings, implemented in 2014, has created a valuable testing ground for certification procedures and demonstrated the feasibility of compliance requirements. Market research from the CERTI Foundation shows strong stakeholder support, with 88% favoring broader mandatory implementation. The planned transition to primary energy consumption metrics further demonstrates the program's commitment to alignment with international standards.

However, the program's predominantly voluntary nature has constrained its market impact given Brazil's building stock size. The limited number of accredited inspection bodies—only three nationwide—creates significant capacity constraints. Additionally, the certification process requires multiple specialized professionals, which can create procedural bottlenecks and increase certification costs. The absence of minimum performance thresholds and reference values makes it challenging for building professionals to benchmark their designs effectively, while the lack of standardized improvement recommendations limits the program's potential impact on building stock improvement.

Recent developments suggest progress in addressing these challenges. The program is moving toward phased mandatory implementation beyond federal buildings and working to streamline certification processes while maintaining technical rigor. These efforts aim to expand certification capacity while developing clearer market incentives and enhanced technical guidance for professionals. The evolution of PBE Edifica demonstrates how building energy certification can develop in emerging economies while balancing technical standards with market realities.

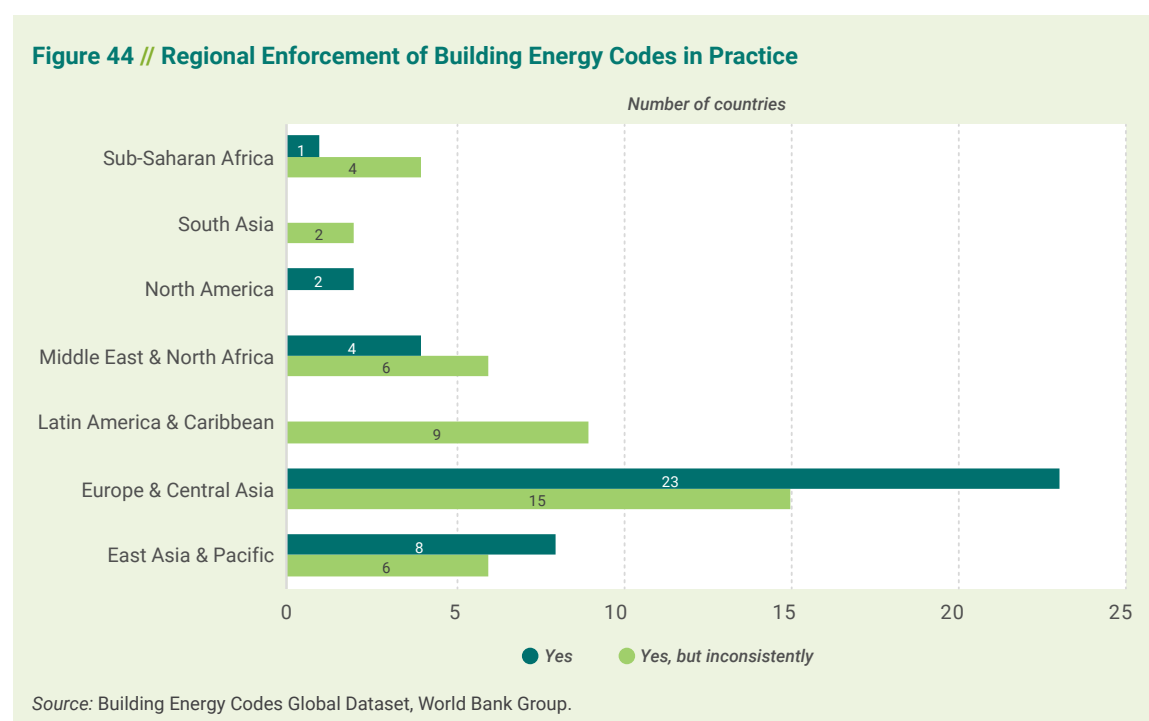
The program's experience offers valuable insights for building energy certification in developing economies. It highlights the importance of balancing rigorous technical assessment with practical market considerations—maintaining high standards while ensuring certification processes remain accessible and economically viable. As Brazil continues to refine and expand PBE Edifica, its approach to building market capacity alongside regulatory requirements provides important lessons for other developing economies working to improve building energy efficiency.

The continued evolution of PBE Edifica, particularly its strategic expansion of mandatory requirements and efforts to streamline processes, suggests growing recognition of both the program's importance and the need to address implementation barriers. These developments, combined with strong stakeholder support and existing technical standards, position the program to play an increasingly significant role in advancing building energy efficiency across Brazil's diverse building sector.

## 5.1 Global Enforcement Status

While BECs and standards are critical tools for advancing energy efficiency in the building sector, their effectiveness depends heavily on implementation. Analysis of enforcement patterns across 88 countries as reported by practitioners reveals significant variation in both coverage and consistency. The data shows that 80 out of 88 countries enforce their BECs, demonstrating broad adoption of enforcement mechanisms. However, a critical gap emerges in the consistency of this enforcement—42 countries report inconsistent application of their requirements, highlighting a significant challenge in achieving reliable implementation.

The analysis reveals distinct regional patterns in BEC enforcement, with Europe and Central Asia showing the strongest enforcement framework with 38 countries maintaining some form of enforcement mechanism (Figure 44). However, even within this region there is variation in consistency, demonstrating that geographic proximity and shared policy frameworks (like the EU) do not guarantee uniform implementation. East Asia and Pacific follows as the second most represented region with 14 countries enforcing BECs, while Latin America and Caribbean shows 9 countries with enforcement mechanisms, and the Middle East and North Africa has 10 countries. South Asia demonstrates limited representation with only 2 countries implementing enforcement, while Sub-Saharan Africa shows the lowest regional coverage with just 4 countries enforcing BECs.



The pattern of enforcement shows clear correlation with economic capacity. Among high-income countries, 44 out of 47 enforce their BECs, representing the strongest implementation rate across all economic groups. However, even within this well-resourced category, 11 countries report inconsistent enforcement, suggesting that economic capacity alone does not guarantee effective implementation. The challenge becomes more pronounced in upper-middle-income countries, where 21 out of 22 countries enforce their codes, but 17 of these struggle with consistent enforcement. This pattern suggests that while establishing

enforcement mechanisms is achievable, maintaining consistent application presents significant challenges even for relatively well-resourced economies.

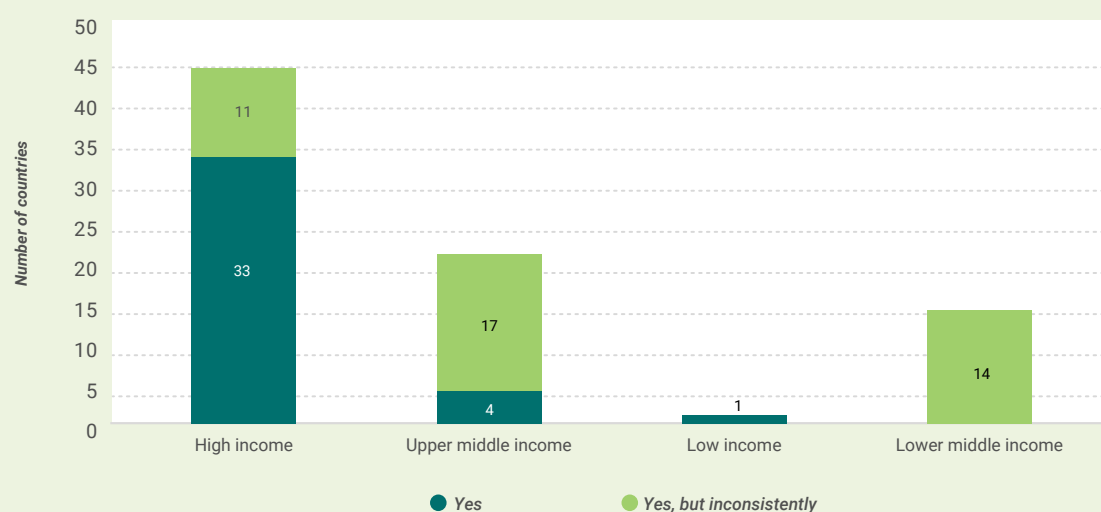
In the lower-middle-income group, enforcement shows universal but inconsistent implementation (Figure 45). The experience of Ghana illustrates common challenges faced by countries in this economic category, where the absence of specific legal mandates and limited institutional capacity create significant barriers to effective enforcement, even when standards are in place.

The root causes of incomplete enforcement often share common elements across different contexts. These include insufficient political will, complex regulatory landscapes that complicate implementation, gaps in technical and administrative capacity, economic constraints that limit enforcement resources, and inadequate coordination among various agencies and stakeholders.

This enforcement gap carries significant implications for the effectiveness of BECs. Without consistent enforcement, even well-designed technical requirements fail to achieve their intended impact on building energy performance. The pattern suggests that strengthening enforcement mechanisms, particularly in middle- and lower-income countries, represents a critical opportunity for improving the overall effectiveness of BECs globally.

These broad enforcement patterns reveal the importance of systematic implementation frameworks. While 80 countries report some form of enforcement, the effectiveness of these efforts varies significantly based on their underlying enforcement systems and mechanisms. It is important to note that this analysis focuses on one city within each country and the largest jurisdictions typically have greater resources and institutional capacity than smaller urban areas or rural regions. The enforcement patterns observed in these primary cities likely represent the optimal implementation scenario for each country, with smaller municipalities potentially facing even greater challenges in consistent code enforcement due to more limited technical and financial resources. This methodological consideration suggests that the enforcement gaps identified may be more pronounced when considering nationwide implementation.

**Figure 45 // Enforcement of Building Energy Codes by Income Group in Practice**

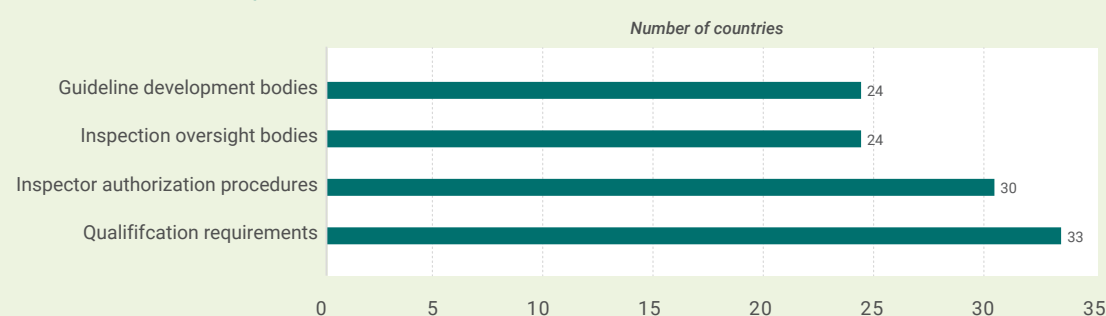


Source: Building Energy Codes Global Dataset, World Bank Group.

## 5.2 Enforcement Systems

Beyond technical requirements, 33 out of 88 countries in the dataset include at least one critical measure in their BECs to strengthen enforcement and compliance. These measures range from specifying procedures to authorize third-party inspectors, defining the professional qualifications required for their registration, to establishing independent bodies responsible for developing guidelines, standards, or codes of conduct for inspectors (Figure 46). Some countries go further by creating supervisory bodies to oversee inspections, ensuring they are conducted appropriately and without conflicts of interest. However, the majority of BECs lack such provisions, highlighting gaps in enforcement mechanisms that could undermine their effectiveness.

**Figure 46 // Third-Party Enforcement Mechanisms**

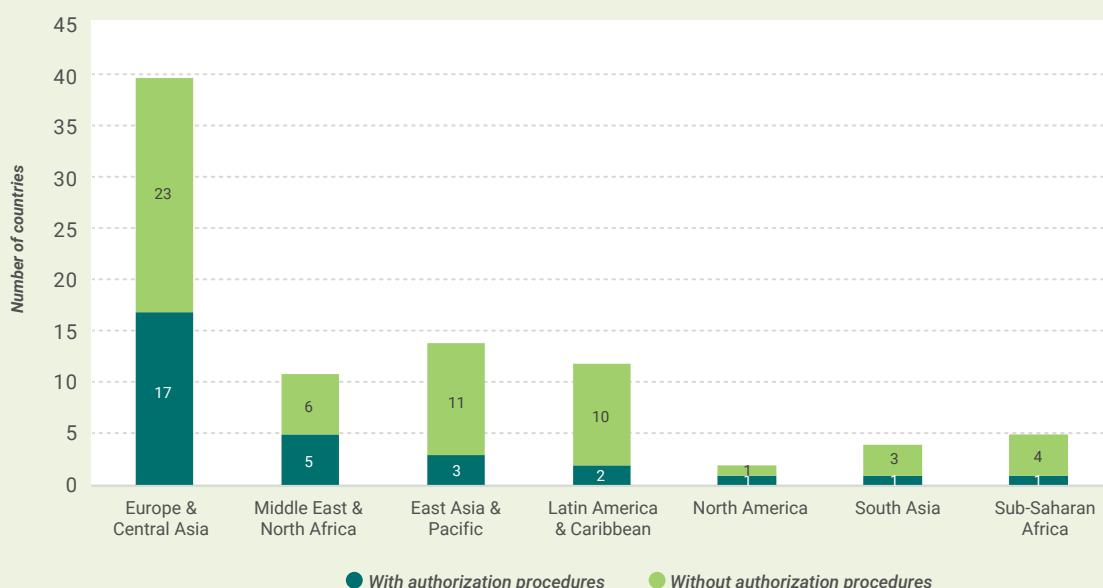


Source: Building Energy Codes Global Dataset, World Bank Group.

**Authorization procedures for third-party inspectors:** Clear procedures for authorizing third-party inspectors serve as a foundational element of effective BEC enforcement. These procedures establish the formal process through which qualified professionals can become authorized inspectors, ensuring consistent standards while maintaining transparency and accountability. Well-designed authorization procedures help prevent conflicts of interest and maintain professional standards, directly affecting the quality and reliability of code enforcement. Governance models for these procedures vary significantly—for instance, in the United States, the authority to allow third-party inspectors is typically delegated to state or local jurisdictions rather than managed at the federal level. Where such allowances exist, these local authorities generally implement robust procedures governing inspector qualification, authorization, and oversight. This decentralized approach allows for adaptation to local building practices while maintaining necessary quality standards.

Analysis of authorization procedures across 88 countries reveals significant regional and economic disparities. While 29 countries have established formal procedures, these are heavily concentrated in Europe and Central Asia (18 countries) and high-income economies (Figure 47). The data shows successful implementation in several lower-middle-income countries like Pakistan and Uzbekistan, demonstrating that effective authorization systems are achievable across economic contexts. However, the complete absence of such procedures in most of Sub-Saharan Africa highlights a critical gap in enforcement infrastructure.

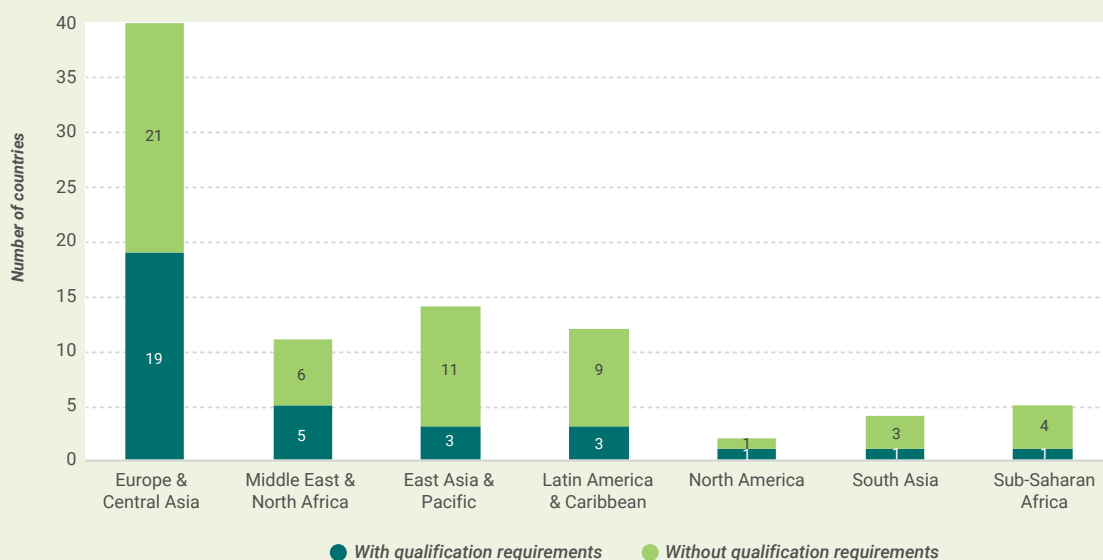
**Figure 47 // Countries with Authorization Procedures for Third-party Inspectors - by Region**



Source: Building Energy Codes Global Dataset, World Bank Group.

**Professional qualification requirements:** Professional qualification requirements for inspectors establish the minimum technical competency needed for effective code enforcement. These standards ensure inspectors possess the necessary knowledge and skills to verify compliance with increasingly complex building energy requirements. By standardizing inspector qualifications, these requirements create a professional framework that supports consistent enforcement while building market capacity for energy-efficient construction.

**Figure 48 // Countries with Professional Qualification Requirements for Building Inspectors - by Region**

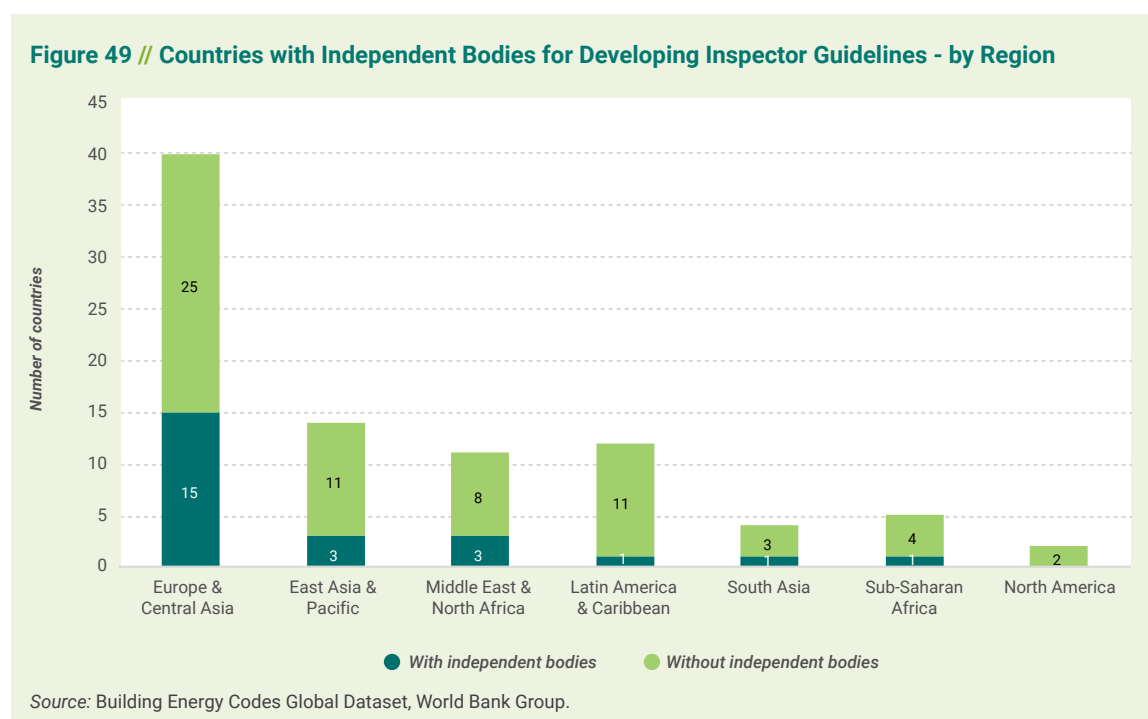


Source: Building Energy Codes Global Dataset, World Bank Group.



The dataset shows that 31 countries have established specific qualification requirements, with notable adoption patterns across development levels (Figure 48). Europe leads with 19 countries maintaining clear requirements, while emerging economies like Costa Rica and Paraguay demonstrating successful implementation in developing markets. In the United States, inspector qualifications vary by state, with many relying on certification from organizations like the International Code Council (ICC), ensuring a standardized technical framework despite decentralized governance. Interestingly, several countries including Rwanda have implemented qualification requirements without corresponding authorization procedures, suggesting qualification standards often precede more comprehensive enforcement frameworks. This pattern provides insights for countries beginning to develop enforcement systems.

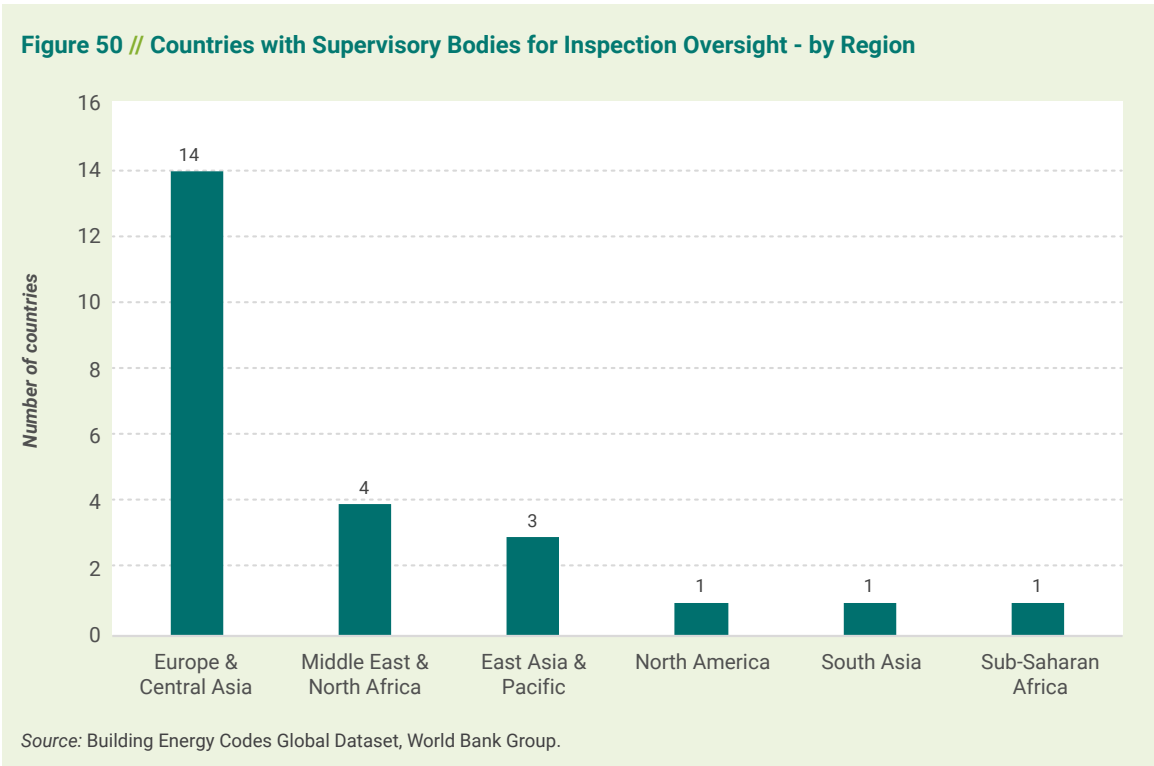
**Independent guideline development bodies:** Independent bodies charged with developing inspector guidelines and standards play a crucial role in maintaining enforcement quality over time. These organizations provide technical expertise for updating requirements, standardizing procedures, and addressing emerging challenges. Their independence helps ensure guidelines reflect technical best practices rather than political or commercial interests, while providing a mechanism for incorporating market feedback and technological advances.



The data reveals that 28 countries have established such bodies, showing strong correlation with overall enforcement effectiveness. High-income countries dominate adoption, with 16 maintaining independent guideline bodies (Figure 49). However, successful examples from upper-middle-income countries like Kazakhstan and Paraguay demonstrate these institutions can function effectively in developing markets. The concentration in Europe (15 countries) suggests regional cooperation may support successful implementation, providing lessons for other regions considering similar frameworks.

**Supervisory bodies for inspection oversight:** Supervisory bodies ensure inspection quality by monitoring third-party inspector performance and preventing conflicts of interest. These oversight mechanisms are essential for maintaining enforcement integrity and public trust in the inspection system. Through

systematic monitoring and evaluation, supervisory bodies can identify implementation challenges, standardize practices, and support continuous improvement in enforcement effectiveness.



Analysis shows that 27 countries have established supervisory bodies, with the strongest representation in high-income nations (18 countries). The regional distribution reveals concentrated adoption in Europe and Central Asia (13 countries), while other regions show limited implementation (Figure 50). Notably, several countries with otherwise comprehensive enforcement systems lack supervisory bodies, suggesting these oversight mechanisms often represent a final step in enforcement system development. The data indicates that supervisory bodies require significant institutional capacity, explaining their limited adoption in lower-income countries.

These enforcement mechanisms form the foundation for implementing specific technical requirements, with passive design elements representing one of the most critical areas for verification. The data reveals distinct patterns in how countries approach enforcement of passive design requirements, from basic envelope calculations to comprehensive performance verification. Understanding these patterns provides crucial insights for strengthening code implementation and achieving actual energy savings in buildings.

### Recommendations for policy makers

**Establish clear authorization frameworks** for third-party inspectors with standardized qualification requirements that balance technical expertise with practical experience. These authorization frameworks should include transparent selection criteria, standardized testing protocols, and regular performance reviews to maintain quality and integrity in the inspection system. Professional qualification requirements should specify both technical knowledge and field experience appropriate to the complexity of building energy systems being evaluated, with ongoing education requirements to address evolving technologies and standards.

**Create independent guideline bodies** responsible for developing and regularly updating inspector guidelines and technical standards. These entities should include balanced representation from both public and private sectors to ensure practical applicability while maintaining regulatory integrity. Guidelines should be tailored to different building types and market segments, with clear inspection protocols that address both compliance documentation and field verification. Supervisory bodies should be established with clear mandates for oversight of inspection quality, conflict resolution, and continuous improvement of enforcement practices. These oversight mechanisms should include both systematic reviews of inspector performance and random verification checks to ensure consistent application of requirements across different projects and jurisdictions.

**Integrate enforcement systems** into existing building control processes rather than creating parallel mechanisms. This integration allows for more efficient use of limited resources while promoting consistent application of both structural and energy requirements. Enforcement systems should take a staged approach to implementation, beginning with simple verification of critical requirements before expanding to more comprehensive assessment as market capacity and institutional expertise develop. Digital tools can significantly enhance enforcement effectiveness, from streamlined documentation systems to automated compliance checking and field inspection support. Policy makers should invest in these technologies while maintaining appropriate oversight and complementary field verification to address areas where visual inspection remains necessary. Through these comprehensive enforcement frameworks, policy makers can bridge the gap between well-designed technical requirements and actual building energy performance, ensuring that policy objectives translate into measurable energy savings and emissions reductions.

## 5.3 Enforcement of Passive Design Requirements

The analysis in this section examines mechanisms and tools that support the enforcement of passive design requirements across different jurisdictions. It is important to note that these mechanisms represent different approaches to facilitate compliance verification rather than comprehensive measures of enforcement effectiveness. The absence of specific tools like checklists or verification protocols does not necessarily indicate that passive design requirements are not being enforced, as jurisdictions employ diverse approaches based on their regulatory structures, institutional capacities, and implementation frameworks.

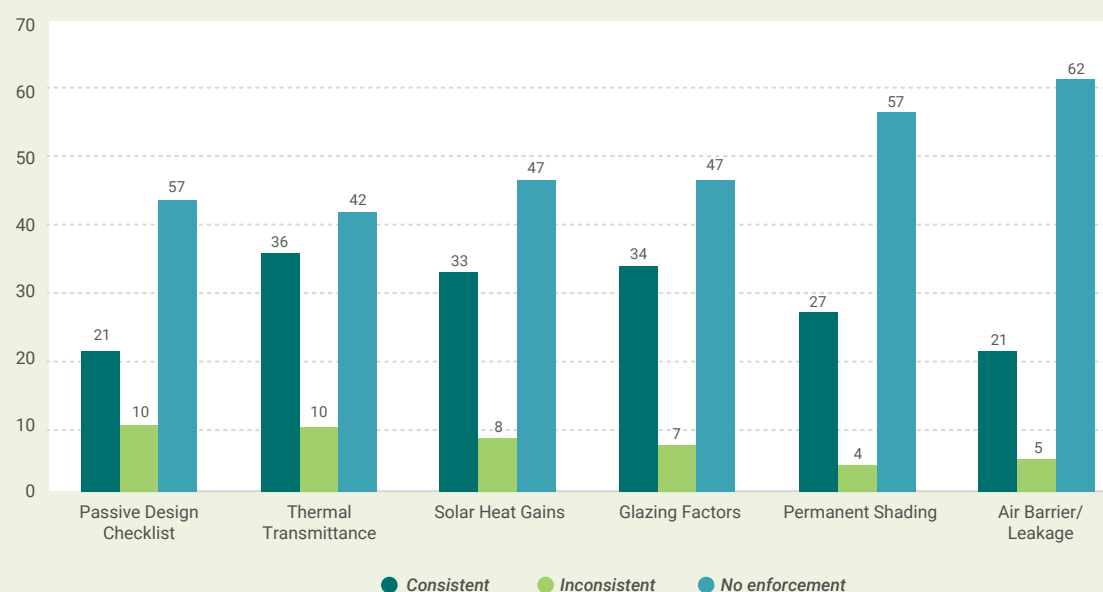
Well-developed regulatory systems may rely on specialized personnel with extensive training and expertise rather than formalized checklists. In such contexts, enforcement may occur through professional certification systems, integrated plan review processes, or sophisticated inspection protocols that address multiple code requirements simultaneously. Other jurisdictions may implement specialized tools to support consistent verification across different administrative levels or to build capacity in markets with emerging expertise in energy efficiency.

The data presented explores these supporting mechanisms while recognizing that actual enforcement occurs within broader regulatory frameworks that include permitting processes, plan reviews, and on-site inspections. These tools represent different approaches to translating technical requirements into verifiable practices, providing insights into how jurisdictions support compliance rather than definitive measures of enforcement effectiveness. The variations in support tools reflect differences in regulatory priorities, implementation approaches, and market development stages across the surveyed countries.

The technical requirements governing air movement, solar radiation control, and thermal transfer form the quantitative backbone of building energy efficiency, translating design principles into measurable performance metrics. While individual building components like roofs and walls form the physical elements of passive design, it is the careful calculation and control of heat flows, air movement, and solar gains that determine their effectiveness. These technical requirements—from air barrier specifications to solar heat gain calculations—provide the measurable standards that transform good design intentions into actual energy performance (Figure 51).

The strategic importance of these technical requirements has grown with our understanding of building physics and climate change impacts. Air barrier specifications significantly affect infiltration losses, which represent a major source of heating and cooling energy waste in buildings. Solar heat gain controls have become particularly crucial in increasingly warming climates, where managing solar radiation can substantially reduce cooling demands. Well-designed fenestration systems serve multiple functions, managing both heat flows and natural daylight levels to optimize overall building energy performance. Together, these technical requirements create a framework for achieving high-performance buildings that remain comfortable and efficient across changing climate conditions, while providing clear, measurable targets for both designers and regulators (Annex 2).

**Figure 51 // Building Envelope Requirements - Limited Levels of Enforcement**



Source: Building Energy Codes Global Dataset, World Bank Group.

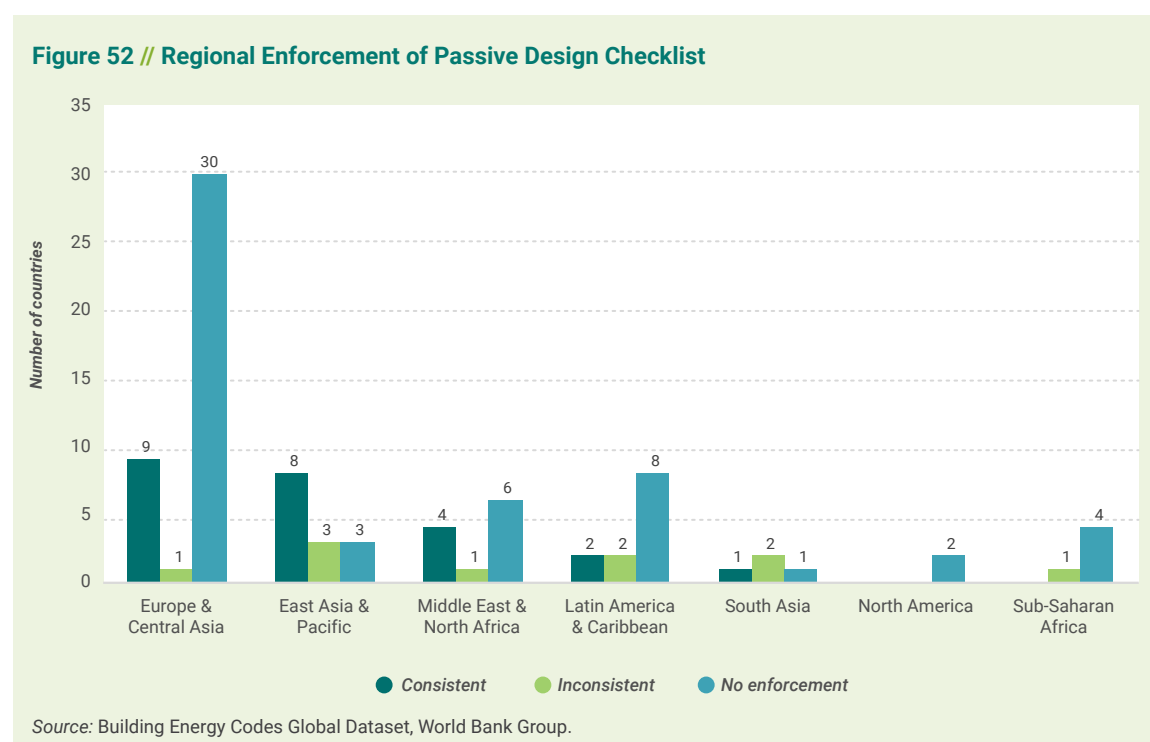
### 5.3.1 PASSIVE DESIGN CHECKLIST

#### Why it matters

Passive design checklists serve as crucial quality control tools in building energy efficiency, ensuring systematic implementation of foundational energy-saving strategies during the design phase. These checklists verify key elements like building orientation, thermal mass placement, natural ventilation pathways, and solar control features before construction begins. Without proper verification of these elements, buildings risk missing opportunities for passive energy savings that are extremely costly or impossible to

retrofit later. The importance of these checklists is particularly critical in rapidly urbanizing regions, where early design decisions will affect energy consumption patterns for decades. Proper implementation of passive strategies can significantly reduce heating and cooling energy needs through optimized solar gain in winter, shading in summer, and natural ventilation—but these benefits are only achieved when systematically verified through comprehensive checklists during the design phase.

## Analysis from Building Energy Codes Global Dataset



Analysis of passive design checklist enforcement across 88 countries reveals significant regional disparities, with Europe and Central Asia leading in adoption - 8 countries consistently enforce these checklists and 1 country (Ireland) shows inconsistent enforcement (Figure 52). This aligns with the region's mature building regulatory frameworks and early adoption of energy efficiency measures. East Asia and Pacific follows with 8 countries showing consistent and 3 showing inconsistent enforcement, reflecting varied institutional capacities across the region. The Middle East and North Africa and Latin America and Caribbean regions show limited adoption, despite the critical importance of passive design in their predominantly hot climates.

The economic dimension is evident in enforcement patterns, with high-income countries showing stronger implementation. However, several examples demonstrate that effective enforcement is achievable across economic contexts—India, as a lower-middle-income country, maintains consistent enforcement, while Viet Nam has successfully implemented these checklists. This suggests that while resource constraints influence enforcement capacity, they need not prevent effective implementation. Notably, 57 countries (65 percent of those surveyed) have no passive design enforcement mechanisms, highlighting a significant gap in building energy efficiency verification. This gap is particularly concerning in rapidly urbanizing regions where early-stage passive design decisions have long-term impacts on building energy performance.



The data also shows interesting climatic patterns—countries in extreme climates (both hot and cold) generally show higher adoption rates of passive design checklists, reflecting the increased importance of passive strategies in managing significant heating or cooling loads. For instance, several countries in extremely hot climates like Singapore and the United Arab Emirates maintain consistent enforcement, while Nordic countries like Norway also demonstrate strong implementation. However, many countries in similar climatic conditions lack enforcement mechanisms, suggesting opportunities for regional knowledge sharing and capacity building.

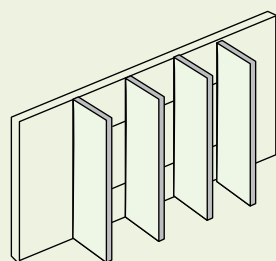
### 5.3.2 SHADING

#### Why it matters

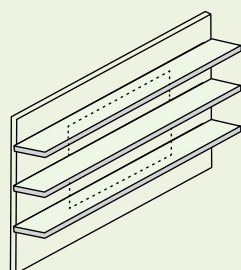
External shading devices function as the building's first line of defense against excessive solar heat gain, directly influencing both energy consumption and indoor comfort. Properly designed external shading substantially reduces solar heat gain while maintaining essential view and daylight access. Unlike other thermal control measures that require ongoing energy inputs, shading devices provide immediate heat reduction without operational costs. Their effectiveness varies significantly by climate and design—horizontal shading devices prove particularly valuable in tropical regions for reducing cooling energy demand, while in temperate zones, adjustable systems allow for seasonal optimization of solar gains. When integrated early in the design process, shading not only improves energy performance but can also reduce initial HVAC system costs through lower peak cooling loads. BECs typically address shading through both prescriptive and performance paths. These regulations typically specify different types of shading solutions based on facade orientation: horizontal devices for south facades, vertical fins for east and west facades, and combined systems for exposed facades in hot climates (Figure 53).

**Figure 53 // Types of Shading Approaches**

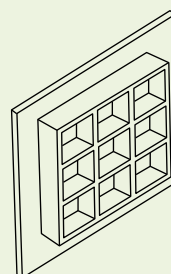
*Vertical Shading*



*Horizontal Shading*



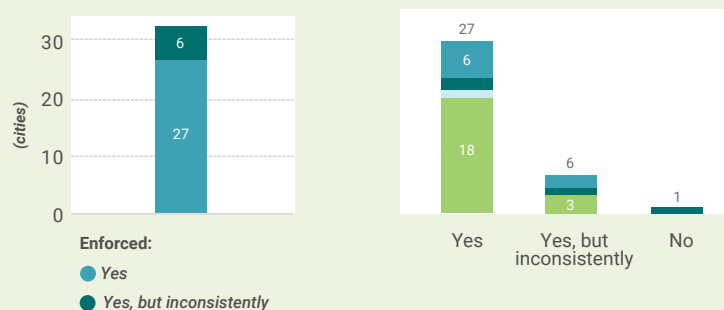
*Horizontal & Vertical Shading*



Source: [www.fairconditioning.org](http://www.fairconditioning.org).

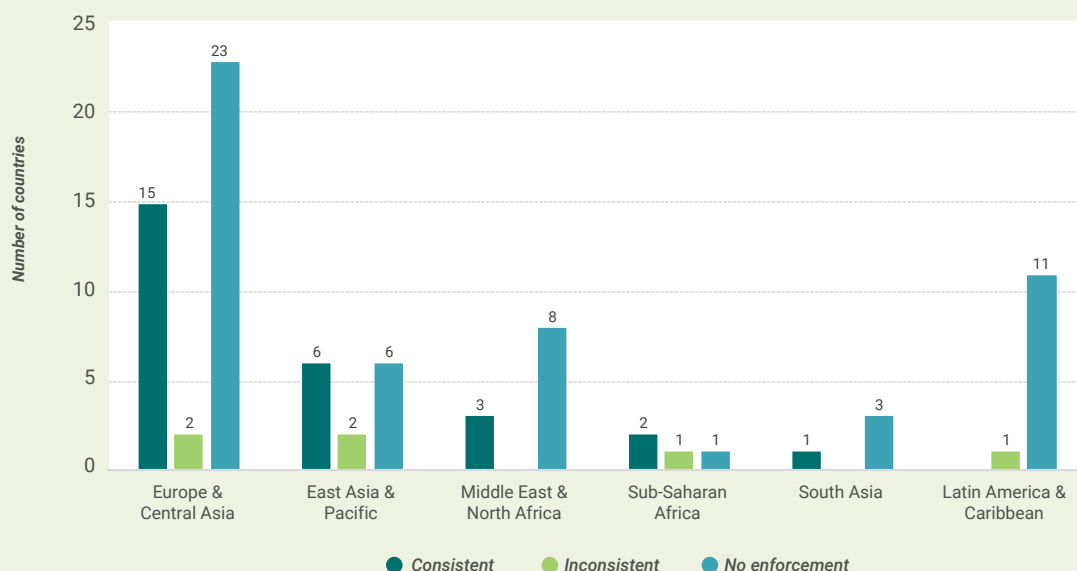
#### Analysis from Building Energy Codes Global Dataset

The global dataset reveals that permanent shading requirements are most prevalent in regions where solar heat gain management is crucial year-round (Figure 54). Among the 19 cities in mixed climate zones, 8 enforce permanent shading practices. Similarly, 8 out of 22 cities in warm climates and 7 out of 18 cities in extremely hot regions have implemented such requirements. This distribution suggests that regions with consistent cooling needs are more likely to mandate permanent shading solutions.

**Figure 54 // Enforcement Consistency of Permanent Shading Requirements**


Source: Building Energy Codes Global Dataset, World Bank Group.

The enforcement patterns show interesting economic and regional variations (Figure 55). While some countries report consistent implementation, others indicate varying levels of enforcement. Ecuador, Japan, the Netherlands, Luxembourg, Nigeria, and Malaysia report inconsistent enforcement of shading requirements. Notably, Rwanda, India, and the Philippines—all low to lower-middle-income countries—have successfully implemented and consistently enforce permanent shading requirements, demonstrating that effective solar control strategies are achievable regardless of economic status.

**Figure 55 // Regional Enforcement of Permanent Shading Requirements**


Source: Building Energy Codes Global Dataset, World Bank Group.

However, the relatively limited adoption of permanent shading requirements globally can be attributed to several factors. First, permanent shading presents a trade-off between summer heat reduction and winter solar gains—while fixed overhangs effectively block high summer sun, they can also obstruct beneficial winter sunlight, potentially increasing heating energy demands in climates with significant seasonal temperature variations. This makes permanent shading more suitable for climates with consistent year-round cooling needs. Second, permanent shading can reduce natural daylight penetration, potentially increasing reliance on artificial lighting and associated energy consumption. This complexity highlights the need for

climate-specific and carefully calculated shading solutions that balance solar heat gain, natural lighting, and overall energy performance throughout the year.

### BOX 8. Understanding Air Leakage in Building Energy Performance

Air leakage refers to the uncontrolled movement of air through gaps and cracks in the building envelope—the physical barrier between conditioned and unconditioned spaces. This movement occurs through various pathways including joints, seams, penetrations, and connections in walls, roofs, windows, and foundations. Understanding and controlling air leakage is crucial for building energy efficiency, as unwanted air infiltration can significantly affect heating and cooling loads, indoor air quality, and moisture control. The primary defense against air leakage is the air barrier system—building materials or assemblies specifically designed to be continuous throughout the building envelope, capable of withstanding mechanical forces, relatively impermeable to air flow, and durable for the expected lifetime of the building. The measurement and quantification of air leakage typically employs several key metrics. The Air Permeability Rate, measured in  $\text{m}^3/(\text{h m}^2)$  at a reference pressure (typically 50 Pascals), represents air flow per hour per square meter of envelope area, with lower values indicating better airtightness. Air Changes per Hour ( $\text{ACH}_{50}$ ), another crucial metric, represents how many times the entire volume of air in a building is replaced per hour at 50 Pascals pressure difference. The Passive House standard sets a stringent target of  $\leq 0.6 \text{ ACH}_{50}$ , while modern energy codes typically allow 3–5  $\text{ACH}_{50}$ , and conventional buildings often range from 5–7  $\text{ACH}_{50}$ .

BECs increasingly specify maximum allowable air leakage rates based on building type, climate zone, and construction category, recognizing that effective air barrier systems are essential for energy efficiency.

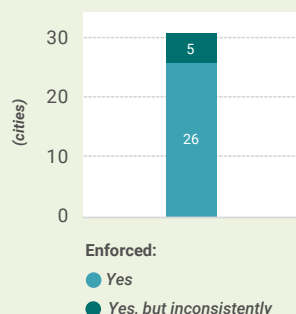
## 5.3.3 AIR LEAKAGE

### Why it matters

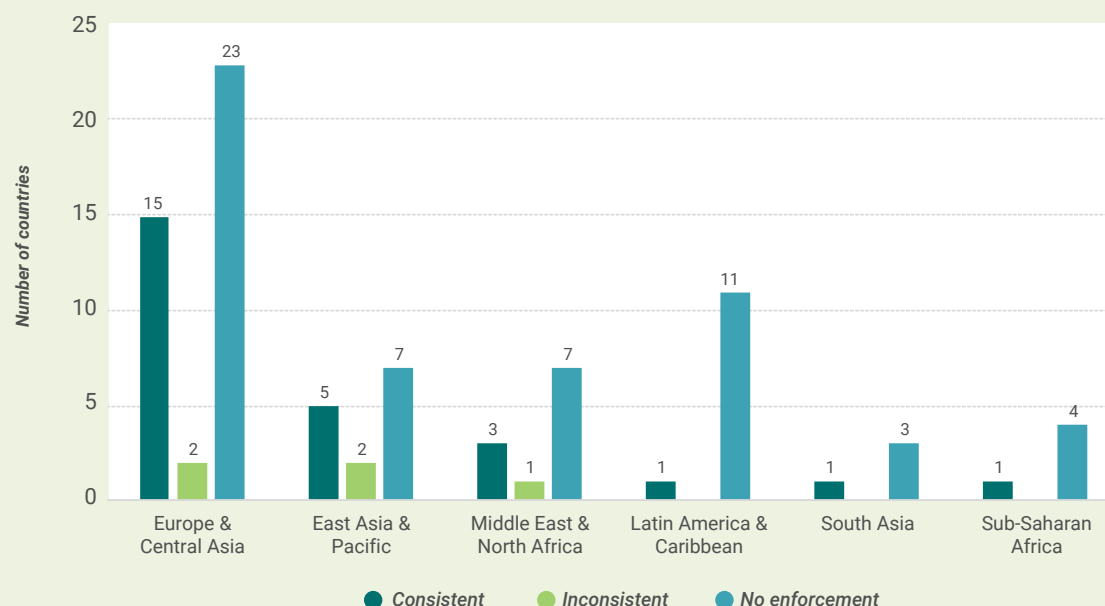
Controlling air leakage is essential for maintaining energy efficiency and indoor comfort, as it can account for up to 25 percent of the energy used for heating and cooling in homes and up to 40 percent in older office buildings in colder climates.<sup>40</sup> Reducing air leakage helps a building retain conditioned air, thereby decreasing the need for heating and cooling, lowering energy costs, and reducing GHG emissions. Additionally, airtight buildings improve indoor air quality by filtering out airborne particles more effectively, reducing particulate concentrations by approximately 70 percent compared to conventional buildings.<sup>41</sup> This reduction in particles benefits occupants' health by limiting the entry of allergens and pollutants.

### Analysis from Building Energy Codes Global Dataset

Experts from 31 cities affirmed that there was some enforcement on air leakage, air barrier, or air infiltration (Figure 56). In particular, out of 26 cities in our dataset, 21 have specific maximum air leakage requirements. The most stringent standards appear in cold climate zones, with Latvia and Iceland leading in terms of airtightness requirements (Figure 57). Finland follows with similarly strict standards, reflecting the importance of air barrier control in cold climates. Among cool climate countries, Ireland has established clear airtightness standards as part of its BEC. In extremely hot climate zones, only Bahrain and the United Arab Emirates have incorporated specific air leakage limits in their regulations, though with more relaxed requirements reflecting their different climatic challenges. In the hot climate zone, Pakistan stands out for including air leakage in its BEC, though it uses a performance-based approach without specifying maximum rates.

**Figure 56 // Enforcement Consistency of Air Leakage, Barriers, and Infiltration**


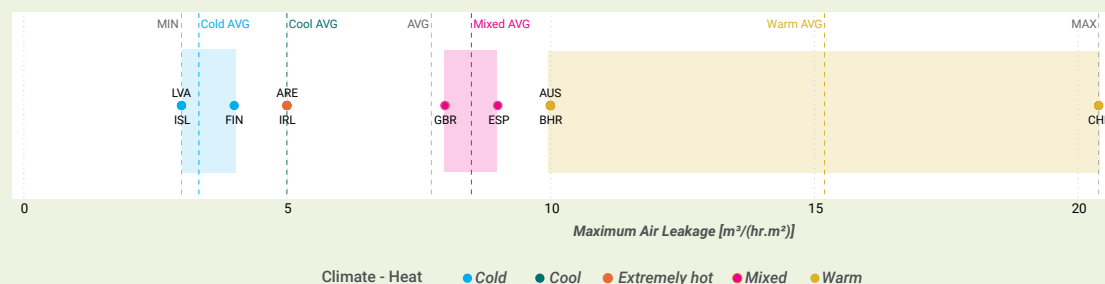
Source: Building Energy Codes Global Dataset, World Bank Group.

**Figure 57 // Regional Enforcement of Air Barriers, Leakages and Infiltrations Requirements**


Source: Building Energy Codes Global Dataset, World Bank Group.

In mixed climate zones, our dataset shows that both the UK and Spain have established specific air leakage limits, though with more moderate requirements than cold climate regions. In warm climate zones, Australia and Chile have incorporated air leakage standards into their BECs, with Chile setting notably less stringent requirements (Figure 58). The variation in standards reflects different approaches to building envelope control—while warmer regions often rely on natural ventilation for cooling, the growing prevalence of AC suggests a need to reconsider airtightness requirements even in these climates.

This pattern points to an important opportunity: while some countries have demonstrated the benefits of air leakage requirements, many nations across cold, cool, hot, and extremely hot climate zones have yet to introduce such standards. Our analysis shows that managing air infiltration through building codes can be an effective strategy for improving energy efficiency and occupant comfort, regardless of climate zone. The experience of countries that have implemented these requirements makes a compelling case for wider adoption of air leakage standards as part of comprehensive building energy efficiency strategies.

**Figure 58 // Maximum Air Leakage Requirements (Residential)**

Source: Building Energy Codes Global Dataset, World Bank Group.

### 5.3.4 THERMAL TRANSMITTANCE

#### Why it matters

Thermal transmittance verification serves as a core element in BEC enforcement, directly affecting both energy consumption and construction quality. Without proper verification, theoretical U-values specified in design may not translate into actual performance due to issues like thermal bridging, inadequate insulation installation, or substitution of materials that compromise envelope efficiency.

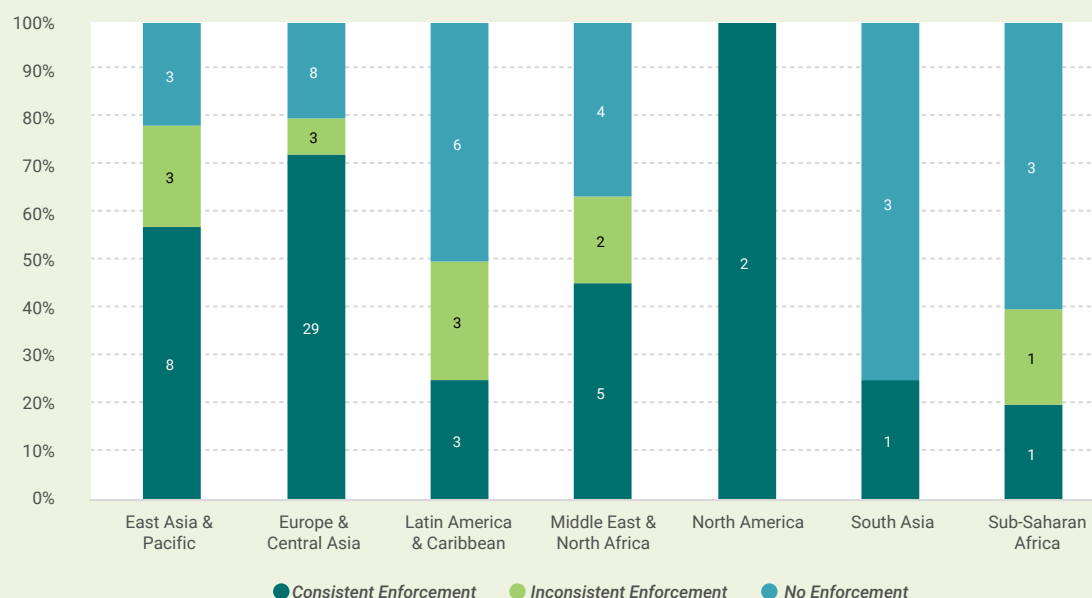
Moreover, thermal transmittance verification safeguards the economic investment in energy efficiency measures. When thermal performance is inadequately verified, the actual energy savings from building envelope improvements often fall significantly short of design predictions. This gap between design and reality particularly affects cooling-dominated climates, where proper verification of thermal barriers proves crucial for managing cooling loads.

The complexity of modern building envelopes makes systematic verification essential. Contemporary construction often combines multiple materials and assembly methods, creating numerous potential paths for heat transfer. Verification protocols help ensure these complex assemblies perform as intended, while enabling building officials to identify and address common failure points in thermal performance. This systematic approach to thermal verification becomes particularly critical as BECs adopt more stringent performance requirements to meet climate commitments.

#### Analysis from Building Energy Codes Global Dataset

The analysis of thermal transmittance and insulation calculation requirements across 88 countries reveals significant patterns in adoption and enforcement consistency. Among the surveyed countries, 56 have implemented these requirements, with 49 demonstrating consistent enforcement and 12 reporting inconsistent implementation. This relatively high adoption rate suggests widespread recognition of thermal performance calculations as a fundamental component of building energy efficiency regulation.

Regional analysis shows strong concentration in Europe and Central Asia, where 29 out of 40 countries have established thermal transmittance requirements (Figure 59). This high adoption rate reflects the region's long-standing focus on building energy efficiency, particularly through the EU's regulatory framework. East Asia and Pacific shows moderate adoption with 8 out of 14 countries implementing requirements, while Latin America and the Caribbean demonstrates more limited uptake with 3 out of 12 countries. The Middle East and North Africa region presents an interesting pattern—despite high cooling

**Figure 59 // Regional Enforcement of Thermal Transmittance**

Source: Building Energy Codes Global Dataset, World Bank Group.

demands, only 5 out of 11 countries have established thermal calculation requirements, suggesting a potential gap in regulatory frameworks where they might be most needed.

Economic capacity shows clear influence on implementation, though with notable exceptions. Among high-income countries, 34 out of 47 have established requirements, with 31 showing consistent enforcement. Upper-middle-income countries demonstrate strong adoption with 15 out of 22 implementing requirements, though several, including Serbia, Malaysia, and Albania, report inconsistent enforcement. Lower-middle-income countries show more limited but still significant adoption—6 out of 17 have established requirements, with Viet Nam, India, and Morocco demonstrating consistent enforcement. Rwanda, as the only low-income country in the dataset, has implemented requirements but reports inconsistent enforcement.

Climate patterns reveal interesting adoption trends. Countries in extremely hot climates show varied approaches—8 out of 18 countries have implemented requirements, with Singapore, Bahrain, and Kuwait maintaining consistent enforcement. Cold climate regions demonstrate strong adoption, with 5 out of 7 countries implementing requirements. This pattern suggests that while thermal transmittance calculations are valuable across climate zones, implementation success may depend more on institutional capacity than climatic conditions.

### 5.3.5 GLAZING AND SOLAR HEAT GAIN COEFFICIENT REQUIREMENTS

#### Why it matters

Windows and skylights represent critical points of heat transfer in buildings, significantly affecting both energy consumption and occupant comfort. Unlike opaque envelope elements, glazing systems involve multiple performance characteristics—from thermal transmittance to solar heat gain—that must be calculated and verified holistically. The complexity of modern glazing assemblies, often combining multiple



glass layers, coatings, and framing systems, makes systematic calculation essential. Without proper calculations of solar heat gain and glazing performance, even well-designed systems may fail to deliver their intended benefits, leading to increased energy consumption and compromised indoor environmental quality.

The Solar Heat Gain Coefficient (SHGC)—which measures the fraction of solar radiation admitted through a window—becomes particularly crucial as cooling demand increases globally. Proper window specifications with optimized SHGC values can significantly reduce cooling loads while maintaining natural light and views. Climate-specific fenestration standards are particularly effective, as they ensure optimal performance across different weather conditions while providing flexibility through both prescriptive and performance-based compliance approaches.

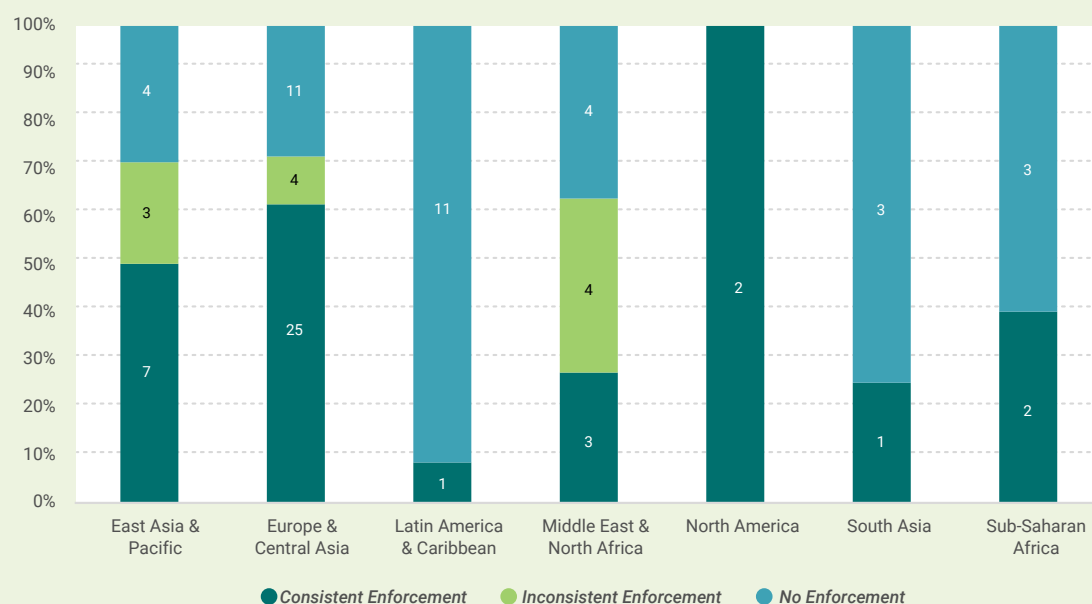
### Analysis from Building Energy Codes Global Dataset

The implementation of glazing and solar heat gain requirements shows significant variation across the surveyed countries. Among the 88 countries analyzed, 52 are enforcing glazing verification requirements. For solar heat gain calculations, 49 countries demonstrate consistent enforcement in their building codes, while 11 countries report inconsistent enforcement.

The geographic distribution reveals strong concentration in Europe and Central Asia, where 25 countries maintain glazing verification requirements. East Asia and Pacific follows with 7 countries implementing requirements, while Latin America and Caribbean shows more limited adoption with only Peru reporting consistent enforcement. The Middle East and North Africa region demonstrates moderate coverage with 3 countries enforcing requirements.

The data shows interesting patterns in adoption across economic contexts. While high-income countries show higher adoption rates (28 out of 47 for glazing requirements), successful implementation exists

**Figure 60 // Regional Enforcement of Glazing Requirements**



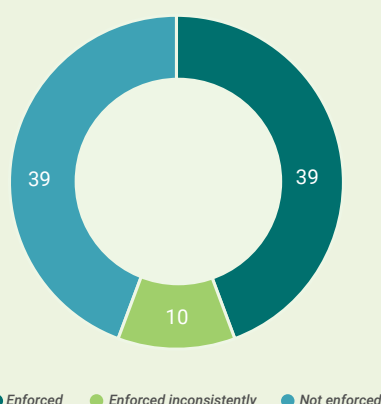
Source: Building Energy Codes Global Dataset, World Bank Group.

across economic categories. Among upper-middle-income countries, 10 out of 22 maintain glazing verification requirements, while 7 out of 17 lower-middle-income countries have implemented requirements. Rwanda stands out as the only low-income country with glazing verification requirements, demonstrating that effective implementation is achievable despite resource constraints.

Of the 88 countries analyzed, 39 demonstrate consistent enforcement of SHGC requirements, representing a significant proportion of countries with established BECs. However, 10 countries report inconsistent enforcement of these requirements, highlighting ongoing challenges in implementation. The remaining 39 countries have not yet implemented SHGC requirements in their BECs, suggesting considerable opportunity for expanding coverage of these important thermal performance standards.

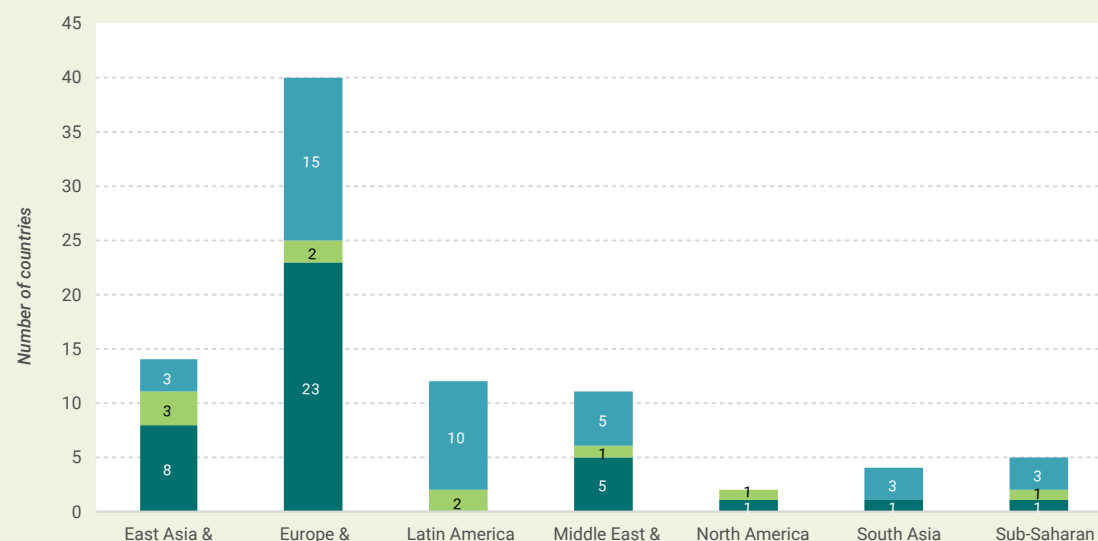
The enforcement of solar heat gain calculation requirements differs markedly across regions, with Europe and Central Asia leading with 25 countries consistently verifying compliance. East Asia and Pacific follows

**Figure 61 // Enforcement of Solar Heat Gain Calculation Requirements across Cities**



Source: Building Energy Codes Global Dataset, World Bank Group.

**Figure 62 // Solar Heat Gain Calculations by Region**



Source: Building Energy Codes Global Dataset, World Bank Group.

with 7 countries maintaining effective verification systems, while the Middle East and North Africa shows limited enforcement with only 4 countries despite their cooling-dominated climates. Latin America and Caribbean shows no countries with consistent enforcement, while in Sub-Saharan Africa, only South Africa maintains consistent verification, creating a concerning gap in rapidly urbanizing regions where cooling demands are projected to increase substantially. These regional disparities in enforcement capacity directly affect building energy performance outcomes, influenced by factors including technical resources, economic constraints, verification infrastructure, and the prioritization of climate-specific requirements in regulatory frameworks.

### BOX 9. Rising Temperatures, Rising Challenges: The Building Sector's Cooling Crisis

The unprecedented rise in global temperatures has transformed cooling from a comfort consideration into a critical infrastructure and public health challenge. The World Meteorological Organization confirms that 2023 was the warmest year on record globally, with unprecedented marine heatwaves and widespread extreme temperatures. The summer of 2023 saw record-breaking heat across multiple continents, with cities worldwide experiencing temperatures well above historic averages, straining both power grids and human adaptability. These new climatic conditions have made cooling in buildings one of the fastest-growing energy end-uses globally.

The new reality of persistent extreme heat makes BECs increasingly crucial as the primary regulatory tool for managing cooling demand before it becomes locked into building design. As regions previously focused on heating needs now face regular cooling demands, BECs must evolve to address this shifting thermal challenge. The traditional distinction between 'heating-dominated' and 'cooling-dominated' climates is blurring, requiring more sophisticated approaches to building thermal performance.

BECs worldwide are adapting to address this challenge. Hot climate regions are developing comprehensive requirements that combine solar heat gain limits, envelope sealing, and insulation standards. These requirements recognize that managing cooling loads requires an integrated approach to building design. However, many rapidly urbanizing regions with significant cooling needs still lack basic requirements for solar control or thermal performance, risking decades of excessive cooling energy use in new construction.

The challenge extends beyond individual building performance to broader infrastructure resilience. As cooling demands surge during increasingly frequent and intense heat waves, peak electricity loads strain power grids, particularly in regions with limited infrastructure. BECs can help manage these peaks through requirements for passive cooling strategies, thermal mass utilization, and equipment efficiency standards. These measures become especially critical in urban areas where heat island effects intensify cooling needs.

The growing cooling challenge demands a fundamental shift in how BECs approach thermal comfort. Future codes must address both heating and cooling demands across all climate zones, with particular attention to resilience during extreme heat events. This evolution requires rethinking traditional approaches to building design and creating more climate-responsive regulatory frameworks that can help buildings maintain livable conditions even during unprecedented heat waves.

## Recommendations for policy makers

**Establish a progressive passive design verification framework.** BECs should integrate a tiered verification system for passive design compliance, aligning with local climate zones and market capacity. Initial requirements should focus on fundamental elements like building orientation and solar control, progressively expanding to complex strategies such as thermal mass optimization and natural ventilation. Differentiated requirements based on building type and scale should be adopted, ensuring larger

commercial projects adhere to more comprehensive passive design measures. Singapore's approach demonstrates the effectiveness of scalable passive design mandates within existing approval processes.

**Implement quantifiable technical requirements and verification protocols.** Passive design regulations must be grounded in climate analysis and energy modeling, defining clear performance thresholds. Standards should specify minimum shading coefficients by facade orientation, ventilation opening ratios relative to floor area, and other quantifiable criteria. Verification should be standardized through consistent calculation methodologies, supported by documentation demonstrating how passive strategies integrate with mechanical systems. Germany's model of integrated performance verification serves as a best practice, ensuring that passive strategies contribute meaningfully to overall building efficiency.

**Strengthen professional certification and training program.** Effective implementation requires specialized expertise in passive design verification. Governments should establish accreditation programs that blend theoretical training with practical assessments, similar to Germany's energy efficiency expert certification. Continuous professional development should be mandatory for inspectors, designers, and builders, ensuring alignment with evolving passive design technologies. Detailed technical guidelines must provide real-world application examples, helping practitioners bridge the gap between compliance requirements and implementation.

**Mandate post-occupancy performance monitoring and feedback mechanisms.** Ensuring long-term effectiveness of passive design mandates requires systematic evaluation of real-world building performance. Policy frameworks should include post-occupancy assessments to collect data on energy consumption, thermal comfort, and system integration. This data should feed into regular review cycles, ensuring that checklist updates reflect documented successes and challenges across different climate zones and building types. Integrating performance monitoring with emerging passive technologies will maintain practical yet ambitious regulatory standards.

**Develop zoning-based shading requirements** with early integration into approval. Rather than applying uniform shading standards, policy makers should adopt zoning-specific shading mandates based on urban density and street orientation. High-density areas with significant inter-building shading may require different measures compared to open suburban developments. Integrating shading compliance into initial planning approvals, as seen in India's ECBC, ensures that solar envelope guidelines influence early-stage design, preventing costly post-design modifications. Performance verification should leverage simulation-based compliance protocols, setting solar exposure and daylight autonomy targets rather than relying solely on prescriptive device dimensions.

**Enforce thermal transmittance verification and support market readiness.** Thermal transmittance regulations should be implemented with clear verification protocols that align with technical capacities. Simplified calculation methods should be mandated for common assemblies before transitioning to more complex performance assessments. Regulatory frameworks must focus on thermal bridges, insulation quality, and envelope airtightness, supported by standardized assessment tools. Market readiness must parallel regulatory advancement through technical training, certification programs, and testing facilities, ensuring material and installation standards evolve in tandem with regulatory stringency.

**BOX 10. Understanding Solar Heat Gain and SHGC**

Solar heat gain refers to the increase in thermal energy that occurs when sunlight enters a building directly through windows or is absorbed by other building envelope components (like walls and roofs) and transmitted indoors. In passive design, understanding and managing solar heat gain is crucial as it can either be beneficial (reducing heating needs in cold climates) or detrimental (increasing cooling loads in hot climates). The ability to measure and control this solar heat transmission is essential for effective building design and energy efficiency. The Solar Heat Gain Coefficient (SHGC) serves as the primary metric for quantifying this phenomenon. Expressed as a number between 0 and 1, SHGC indicates how well a building component transmits solar heat. A high SHGC (closer to 1) means more solar heat transmission, while a low SHGC (closer to 0) indicates that less solar heat passes through. For instance, a window with an SHGC of 0.85 allows about 85% of available solar heat to pass through, while one with an SHGC of 0.25 only permits 25% transmission.

The optimal SHGC varies significantly based on climate conditions. In cold climates, higher SHGC values (0.50–0.85) are typically preferred to maximize free solar heating during winter months. Conversely, hot climates benefit from lower SHGC values (0.25–0.40) to minimize unwanted heat gain and reduce cooling loads. Mixed climates often require a balanced approach, combining moderate SHGC values with seasonal shading strategies. This metric has become an essential tool for architects, engineers, and regulators in specifying appropriate building components and design strategies to optimize energy efficiency while maintaining occupant comfort across different climate zones.

## 5.4 Enforcement of Space Heating and Cooling Requirements

The analysis of HVAC and water heating enforcement mechanisms across 88 countries reveals sophisticated patterns in regulatory oversight. The data tracks four distinct enforcement mechanisms: HVAC plans, heating/cooling demand calculations, equipment and controls efficiency verification for both HVAC systems, and water heating equipment verification. Among the surveyed countries, 53 have implemented at least one enforcement mechanism, with 32 countries maintaining comprehensive oversight through all four mechanisms—demonstrating the most robust approach to enforcement.

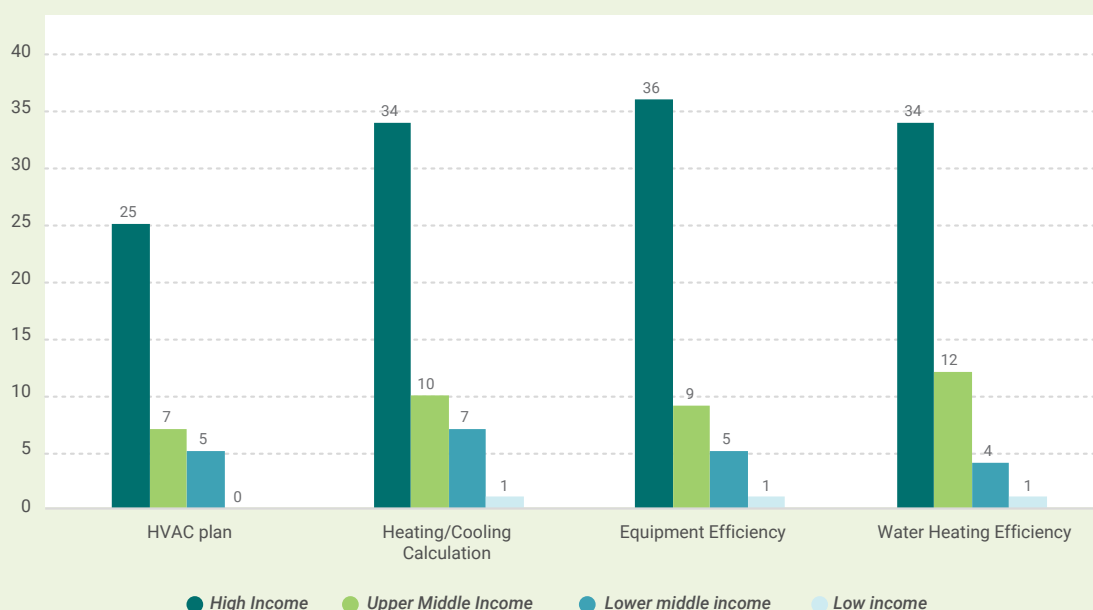
### Analysis from Building Energy Codes Global Dataset

The data reveals significant variation in enforcement of HVAC and water heating requirements across 88 countries, with a clear pattern in comprehensiveness of enforcement mechanisms. While 53 countries have implemented at least one form of enforcement mechanism—HVAC plans, heating/cooling demand calculations, equipment efficiency verification, or water heating standards—only 32 countries consistently enforce all four mechanisms. This suggests that while many jurisdictions recognize the importance of HVAC and water heating regulation, maintaining comprehensive enforcement remains challenging.

Regional patterns emerge strongly in the data, with Europe and Central Asia showing the most robust enforcement frameworks. Within this region, countries like Austria, France, Lithuania, Romania, Spain, and the United Kingdom demonstrate consistent enforcement across all mechanisms. In contrast, even some high-income European nations like the Netherlands report inconsistent enforcement across all four mechanisms, highlighting that economic capacity alone does not guarantee effective implementation. East Asia and Pacific shows mixed success, with countries like Australia, Japan, and Thailand maintaining comprehensive enforcement, while others report inconsistent implementation or limited coverage.

Enforcement patterns correlate strongly with economic development, though with notable exceptions (Figure 63). Among high-income countries, 27 have implemented three or more enforcement mechanisms, with nations like Canada, Qatar, and the United States maintaining consistent verification across all areas. However, several middle-income countries demonstrate that effective enforcement is achievable despite resource constraints. India stands out as a lower-middle-income country successfully implementing all four mechanisms consistently, while Thailand, as an upper-middle-income nation, shows similar success. This suggests that while economic capacity influences enforcement capability, it need not limit the establishment of effective oversight frameworks.

**Figure 63 // Enforcement of HVAC and Water Heating Mechanisms - by Income Group**



Source: Building Energy Codes Global Dataset, World Bank Group.

Climate zones appear to influence enforcement priorities, particularly regarding heating and cooling demand calculations. Countries in cold and mixed climates typically maintain more comprehensive enforcement mechanisms, likely reflecting the critical nature of heating systems in these regions. However, several countries in extremely hot climates, such as Qatar, Bahrain, and the United Arab Emirates, have also implemented comprehensive enforcement frameworks, recognizing the importance of proper HVAC system verification in cooling-dominated climates. This indicates that effective enforcement frameworks can be adapted to different climatic contexts while maintaining rigorous oversight of critical systems.

The consistency of enforcement reveals important implementation challenges that transcend economic and geographic boundaries. Even among countries with all four mechanisms in place, several report inconsistent applications in various areas. The Philippines and Tunisia exemplify this challenge in lower-middle-income contexts, where all four mechanisms exist but face consistency challenges. This pattern suggests that establishing enforcement mechanisms, while crucial, must be accompanied by adequate resources and institutional capacity to ensure consistent application.



## BOX 11. National Cooling Action Plans: From Policy to Implementation

As global temperatures rise and cooling demand surges, National Cooling Action Plans (NCAPs) have emerged as critical policy instruments to balance growing cooling needs with climate commitments. More than 40 countries have adopted NCAPs, with another 25 in development as of 2023. These plans serve as cross-ministerial frameworks to coordinate sustainable cooling efforts, enhance access to cooling, and reduce emissions. However, moving from policy design to effective implementation presents unique challenges in different national contexts.

Cambodia's 2022 NCAP exemplifies how rapidly developing economies can integrate cooling considerations into their climate agenda. As one of Southeast Asia's fastest-growing economies, Cambodia faces increasing cooling demand driven by rapid urbanization and rising incomes. The country's NCAP emerged from a recognition that uncontrolled growth in conventional cooling would conflict with its climate commitments. The plan successfully integrated passive cooling strategies into building guidelines and aligned with Cambodia's updated nationally determined contribution (NDC), helping unlock climate finance. The implementation framework focuses on harmonizing building sector regulations with environmental standards while building technical capacity. The plan creates clear links between cooling efficiency, refrigerant management, and Cambodia's broader climate goals, making it easier to access dedicated funding streams for implementation.

India's 2019 NCAP stands out for its comprehensive scope and market transformation approach. With cooling demand projected to grow 20-fold by 2037 and space cooling alone expected to consume more than half of peak power supply by 2050, India's plan was pioneering in its ambition. The World Bank identified potential market opportunities of US\$1.6 trillion and the capacity to create 3.7 million jobs through the plan's implementation. However, India's complex federal structure presents unique challenges, requiring careful coordination between central and state authorities. The diverse market conditions across states and the need for standards harmonization have necessitated a flexible implementation approach, while the significant informal sector poses ongoing enforcement challenges.

Kenya's 2022 NCAP demonstrates how African nations can address both access to cooling and emissions reduction. As East Africa's largest economy, Kenya faces growing cooling demands in both urban and rural settings, particularly for food cold chains and space cooling. The plan's innovative approach to refrigerant transition projects savings of 3.1 million tons CO<sub>2</sub>e by 2050 through mandating equipment using only medium- and low-GWP refrigerants from 2025 onwards. The plan provides regulatory certainty to the market while advancing both energy efficiency and refrigerant transition objectives through coordinated policy action.

Viet Nam's implementation approach demonstrates how cooling can be effectively mainstreamed into national regulatory frameworks. The country established a comprehensive decree that integrates cooling considerations into its broader climate strategy while providing clear mandates for different government agencies. Under Decree No. 06/2022/ND-CP, Viet Nam mandates GHG emissions reporting from large cold-chain establishments and commercial buildings, including airports, offices, hotels, and malls. The Ministry of Construction maintains the GHG inventory for commercial and public buildings with total energy consumption exceeding 1,000 tons of oil equivalent. This systematic approach enables tracking of cooling-related emissions while creating accountability for reduction targets.

The experience of these countries shows that while developing an NCAP is an important first step, success ultimately depends on addressing implementation challenges through sustained institutional commitment, adequate resources, and effective coordination mechanisms. Successful NCAPs share several common elements: clear institutional frameworks with defined responsibilities, integration with broader climate and development strategies, specific timelines and measurable targets, dedicated funding mechanisms, strong stakeholder engagement processes, and regular monitoring and reporting frameworks.

## Recommendations for policy makers

**Equipment Testing Infrastructure** The data reveals a critical gap in ability to verify actual equipment performance, even in countries with comprehensive enforcement frameworks. Policy makers should establish regional testing facilities that can serve multiple jurisdictions, enabling verification of actual versus rated performance for HVAC and water heating equipment. The networked approach would make advanced testing capabilities accessible to countries that cannot individually support such facilities, following successful examples in East Asia where countries share verification infrastructure.

### BOX 12. Traditional Cooling Wisdom: From Ancient Practice to Modern Building Codes

Passive cooling techniques, developed over the millennia, demonstrate sophisticated understanding of building physics and climate response that holds valuable lessons for modern BECs. Notable examples from architectural history illustrate this deep knowledge: Persian wind catchers (badgirs) created sophisticated natural ventilation systems as early as 3000 BCE; thick-walled adobe construction in desert climates managed heat flow through thermal mass; and courtyard designs across Mediterranean and Middle Eastern architectures balanced solar gain with natural ventilation. These traditional solutions evolved to work seamlessly with local climate conditions and available materials, maintaining comfort without mechanical systems.

These historical approaches relied on several fundamental principles that remain relevant for modern BECs. Natural ventilation through strategic opening placement and wind capture creates air movement without mechanical assistance. Thermal mass, utilizing dense materials like stone or earth, helps regulate temperature by absorbing heat during the day and releasing it at night. Solar control through careful orientation and shading prevents unwanted heat gain, while evaporative cooling and earth coupling provide natural cooling in appropriate climates. Each of these strategies demonstrates sophisticated understanding of building physics that modern codes can quantify and standardize.

Several countries have successfully translated these traditional principles into modern building energy requirements. Egypt's Residential Energy Efficiency Building Code (EREBC) provides specific metrics for cross-ventilation and solar shading based on traditional cooling strategies. India's Energy Conservation Building Code (ECBC) combines traditional passive design principles with modern performance requirements, particularly in its provisions for naturally ventilated spaces. Nigeria's building code quantifies natural ventilation requirements while preserving traditional cooling approaches, and South Africa's SANS 10400-XA establishes performance criteria for passive design elements.

However, incorporating these traditional approaches into modern building codes faces several challenges. Many regions lack comprehensive local climate data needed to validate performance requirements. Resource constraints often limit enforcement capabilities, particularly in developing economies where a significant portion of construction occurs in the informal sector. There is also an ongoing challenge of balancing traditional methods with modern building practices and materials, especially when initial costs may be higher for certain passive design elements.

The future of BECs lies in better integration of passive cooling principles through several emerging approaches. Performance-based requirements can allow traditional solutions while ensuring measurable outcomes. Climate-specific standards reflect local conditions and traditional practices, while hybrid approaches combine time-tested passive strategies with modern technologies. As global temperatures rise and cooling demands increase, the integration of passive cooling into building codes becomes increasingly crucial. These traditional principles, when translated into modern technical requirements, offer proven strategies for reducing cooling energy demand while maintaining cultural appropriateness and economic feasibility.

**Performance Monitoring Frameworks** Beyond initial verification, the data shows few countries have established systematic monitoring of actual HVAC and water heating system performance. Policy makers should develop frameworks for ongoing performance verification, particularly for larger systems, using automated monitoring systems that can flag significant deviations from design performance. This addresses the current enforcement gap between initial compliance and actual operational efficiency.

## 5.5 Enforcement of Lighting Requirements and Controls

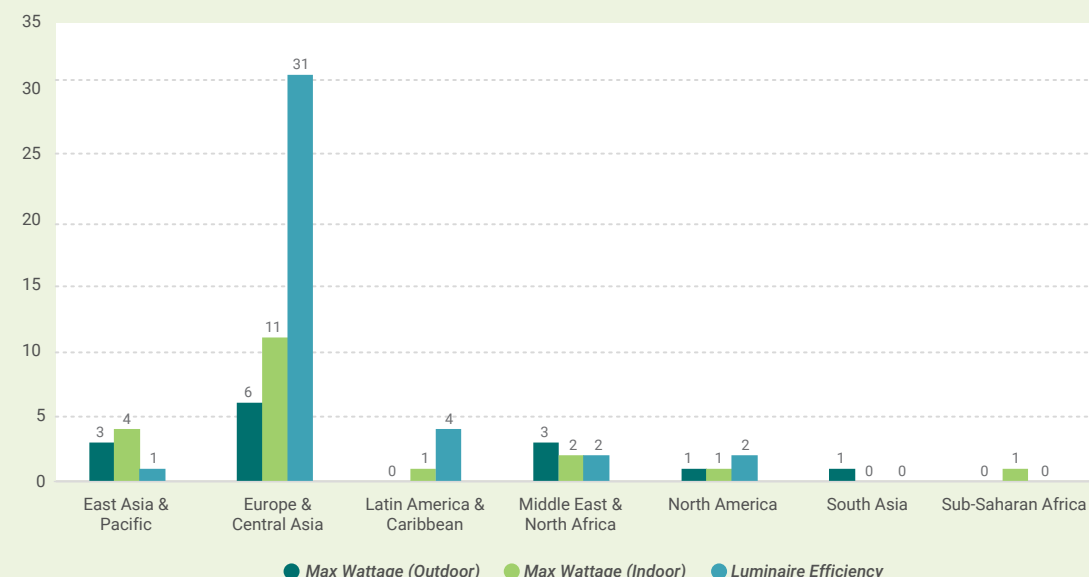
Lighting enforcement serves as a critical element in building energy efficiency, linking technical requirements with measurable performance outcomes that directly affect both energy consumption and occupant well-being. Unlike other building systems where performance verification can involve complex interactions, lighting offers relatively straightforward enforcement opportunities through clear metrics and established testing protocols. The verification of lighting requirements—from power density limits to luminaire efficacy—provides immediate feedback on compliance while enabling systematic improvement in building energy performance. Proper enforcement becomes particularly crucial as lighting technology rapidly evolves, requiring mechanisms that can adapt to improving efficiency standards while maintaining consistent verification of basic performance requirements. Furthermore, since lighting directly affects occupant comfort and productivity while remaining a significant contributor to building energy consumption, effective enforcement of lighting requirements delivers both immediate energy savings and tangible benefits to building users.

### Analysis from Building Energy Codes Global Dataset

The analysis of lighting enforcement mechanisms across the surveyed countries reveals distinct patterns in both coverage and technical stringency. Among the 88 countries studied, 51 have implemented at least one form of lighting enforcement requirement, demonstrating broad recognition of lighting's role in building energy performance. The enforcement mechanisms focus on three key areas: outdoor lighting allowances (15 countries), indoor lighting allowances (27 countries), and specific luminary efficacy requirements (38 countries) (Figure 64).

The regional distribution shows strong concentration in Europe and Central Asia, with 31 out of 40 countries maintaining lighting enforcement requirements. This high adoption rate reflects the influence of EU directives, particularly evident in the consistent luminary efficacy requirement of 65 lm/W across most EU member states. From among the 5 countries of Sub-Saharan Africa, 3 countries (Nigeria, Rwanda, and South Africa) have reported implementing lighting requirements. In East Asia and Pacific 6 out of 14 countries have implemented enforcement mechanisms, while Latin America and Caribbean shows more limited adoption with 5 out of 12 countries. The Middle East and North Africa region demonstrates moderate coverage with 3 out of 11 countries implementing requirements.

Indoor lighting allowances show the highest adoption rate among enforcement mechanisms, with 27 countries implementing specific requirements. This preference for regulating indoor lighting likely reflects both its significant impact on building energy consumption and the relative ease of verification compared to outdoor lighting systems. Comprehensive enforcement covering both indoor and outdoor lighting is less common, with only 13 countries implementing both requirements. Austria, Australia, Canada, China, Croatia, Denmark, Latvia, Malta, the Philippines, Slovenia, Spain, Thailand, and the United Arab Emirates demonstrate this more complete approach to lighting regulation.

**Figure 64 // Lighting Enforcement Mechanisms - By Region**

Source: Building Energy Codes Global Dataset, World Bank Group.

The economic analysis reveals that while high-income countries show higher adoption rates (34 out of 47 implementing at least one enforcement mechanism), several middle- and lower-income countries have established robust requirements. Among upper-middle-income countries, 10 out of 22 maintain enforcement mechanisms, while 6 out of 17 lower-middle-income countries have implemented requirements. Rwanda, as the only low-income country in the dataset, demonstrates that meaningful lighting enforcement is achievable even with limited resources.

The variation in enforcement approaches suggests different regulatory priorities and implementation capabilities. Some countries focus exclusively on luminaire efficacy requirements, viewing them as more straightforward to verify than wattage allowances. Others maintain comprehensive requirements covering both power limits and minimum efficacy standards. This diversity in approach indicates that effective lighting enforcement can be achieved through multiple pathways, allowing countries to adapt requirements to their specific regulatory capacity and market conditions.

## Recommendations for policy makers

**Tiered lighting power density requirements:** BECs should establish maximum lighting power density (LPD) requirements that reflect both technical potential and market readiness. While high-income countries with established LED markets and technical capacity can implement more stringent requirements, developing markets should begin with more achievable targets based on locally available technologies and implementation capability. The data shows countries successfully adopting this tiered approach—for instance, several East Asian nations like Japan and Korea maintain advanced requirements for commercial buildings, while emerging economies in Southeast Asia have established initial standards that can be progressively strengthened. These requirements should be structured by major space types rather than detailed space-by-space classifications in emerging markets, with provisions for progressive tightening as market capacity develops.

**Phased control system implementation:** Mandate control requirements based on market and enforcement capacity. All countries should begin with basic manual switching and scheduled shutoff requirements for larger buildings. As markets mature, introduce daylight-responsive controls for perimeter zones (within 5 m of windows) and occupancy sensors for enclosed spaces smaller than 50 m<sup>2</sup>. Advanced economies can further require networked controls with continuous dimming and energy monitoring for buildings exceeding 5,000 m<sup>2</sup>. This staged approach allows markets to develop technical capacity while delivering immediate energy savings.

**Market-appropriate verification systems:** Scale verification requirements to match institutional capacity. Basic requirements should include documentation of installed lighting power and control systems. For buildings over 1,000 m<sup>2</sup>, require illuminance measurements at completion to verify compliance with minimum lighting levels (typically 300–500 lux for work areas). Countries with strong enforcement mechanisms can add requirements for post-occupancy verification at 100-hour and 2,000-hour intervals, focusing on both energy consumption and maintained illuminance levels.

**Technology adoption framework:** Establish minimum luminaire efficacy requirements that reflect market availability—starting at 70–80 lm/W in developing markets and increasing to 100+ lm/W in advanced economies. Include provisions for local testing and certification to support market development. Phase out inefficient technologies gradually, with clear timelines that allow supply chains to adapt. For retrofits, set realistic energy reduction targets (25–40 percent depending on existing systems) that can be achieved with locally available technologies and expertise.

### BOX 13. Adapting Building Energy Codes for Climate Resilience: Global Approaches

Countries worldwide are transforming their BECs to address the dual challenges of climate change adaptation and energy efficiency. This evolution reflects a growing understanding that buildings must be designed not only to minimize energy use but also to remain resilient and functional under changing climatic conditions, particularly rising temperatures and extreme weather events.

#### Temperature Resilience and Thermal Adaptation

Viet Nam's National Technical Regulation on Energy Efficiency Buildings (QCVN 09:2017/BXD) exemplifies comprehensive climate-adaptive requirements. The code mandates specific technical measures for climate resilience, including stringent SHGCs of 0.3 for windows in hot climate zones, combined with minimum natural ventilation requirements calculated at 5% of total floor area. External shading devices must provide at least 50% shading during peak summer hours, while thermal mass requirements specify minimum wall thicknesses of 220 mm for heavyweight construction. These requirements work in concert with sophisticated occupancy-based cooling controls that continuously adjust temperature setpoints based on outdoor conditions.

Greece's Building Energy Performance Regulation (KENAK) has established Mediterranean-specific requirements that reflect the region's particular challenges. The regulation requires external shading systems with seasonal adjustment capabilities, mandating 70% shading in summer while limiting winter shading to 30% to optimize solar gain. Ventilation systems must be designed for night cooling with substantial air changes of 6 ACH, and external surfaces must maintain high solar reflectance indices above 0.85, demonstrating an integrated approach to climate adaptation.

#### Extreme Weather Resilience Integration

The Philippines' Green Building Code demonstrates how extreme weather resilience can be integrated with energy efficiency requirements. The code specifies comprehensive window performance standards that address both thermal and structural resilience, requiring U-values below 5.0 W/m<sup>2</sup>K while simultaneously maintaining impact resistance sufficient for wind speeds up to 250 km/h. Emergency power systems must be sized to maintain essential services for 72 hours during extreme weather events, with minimum energy efficiency ratings established for all backup systems.

**BOX 13 (cont.)**

Bangladesh's Building Construction Rules represent a sophisticated integration of flood resilience with energy efficiency measures. The code requires floor elevations to be set at least 1.5 m above the highest recorded flood level, while simultaneously mandating natural ventilation designed to maintain air speeds between 0.15–0.25 m/s for comfort and efficiency. Thermal mass requirements specify minimum time lags of 8 hours for wall assemblies, creating a comprehensive approach to both immediate and long-term climate challenges.

**Implementation Mechanisms and Enforcement**

Implementation frameworks have evolved to match the sophistication of technical requirements. Indonesia's Green Building Code pioneered a progressive compliance system that phases in requirements over five years, moving from basic passive design strategies to comprehensive resilience requirements. The system is supported by a digital compliance platform that automates calculations and verification processes, while local authorities maintain dedicated green building units with certified assessors, ensuring consistent evaluation and enforcement.

Mexico's IECC-Mexico has established a robust implementation framework centered on performance-based compliance paths with specific resilience metrics. The system incorporates mandatory third-party verification for larger buildings and maintains a digital building passport system that tracks both performance and adaptation measures over time. This approach allows municipalities to develop locally appropriate adaptation requirements while maintaining national standards.

Portugal's Regulamento de Desempenho Energético dos Edifícios de Habitação (REH) implementation system demonstrates how climate vulnerability can be systematically addressed through building codes. The system requires regular climate vulnerability assessments based on standardized future scenarios, coupled with mandatory reporting of projected energy performance under various climate conditions. Buildings must update their adaptation plans every five years, with independent verification of climate adaptation measures by certified assessors.

The evolution of BECs to address climate adaptation demonstrates the increasing sophistication of regulatory approaches worldwide. Success requires clear, measurable technical requirements, phased implementation allowing market adaptation, robust verification systems, sustainable financing models, and regular updates based on performance data and changing climate conditions. This comprehensive approach provides a model for future code development, particularly in regions facing significant climate risks.

## 5.6 Post-Construction Design Compliance

Post-construction verification represents the critical bridge between design intent and operational performance, ensuring that energy efficiency requirements translate into actual building energy savings. Unlike design-stage reviews or material specifications, post-construction verification directly addresses the quality and effectiveness of energy efficiency measures as implemented. Our analysis of 88 countries reveals three primary verification mechanisms—as-built energy verification, visual/walkthrough inspections, and energy audits—each serving distinct but complementary roles in ensuring building energy performance. While as-built verification confirms compliance with approved plans and specifications, visual inspections enable direct observation of installation quality, and energy audits assess actual operational performance. The data shows significant variation in adoption and implementation of these mechanisms, reflecting different approaches to balancing verification effectiveness with practical feasibility across diverse economic and institutional contexts (Figure 65).



**Figure 65 // Distribution of Post-Construction Verification Mechanisms across Countries**



Source: Building Energy Codes Global Dataset, World Bank Group.

## As-Built Energy Verification

As-built energy verification represents a critical pillar of effective BEC enforcement, serving as the essential on-site inspection process that confirms constructed buildings meet their approved energy performance requirements. This verification stage is fundamental to any meaningful enforcement system, as without these inspections, there can be little certainty that code requirements have actually been implemented in practice. Unlike theoretical document reviews, as-built verification directly assesses the physical implementation of energy efficiency measures through on-site inspections comparing actual construction to approved plans.

Our analysis of 88 countries reveals a significant enforcement gap: only 35 countries have implemented systematic as-built verification for energy requirements, with just 23 achieving consistent implementation. This means that a majority of surveyed countries lack this fundamental enforcement mechanism, raising serious questions about actual compliance levels in these jurisdictions. Without verification that constructed buildings match approved plans, energy efficiency requirements may exist primarily on paper rather than in practice. The geographic distribution reveals concentrated adoption in Europe and Central Asia (20 countries), with varying success rates. High-income countries like Finland, Greece, and Israel demonstrate consistent enforcement, while several upper-middle-income nations like Serbia and Bulgaria report implementation challenges. The data shows as-built verification typically precedes other mechanisms—all 14 countries with energy audit requirements also maintain as-built verification, suggesting it serves as a foundation for comprehensive verification frameworks.

## Visual/Walkthrough Inspection

While as-built energy verification typically involves a formal, systematic process of comparing constructed buildings against approved energy documentation and plans, visual/walkthrough inspections represent a more targeted, qualitative assessment method focusing on specific energy features that may not be captured in standard verification processes. These inspections complement rather than replace formal as-built verification.

This hands-on verification method allows inspectors to identify issues that might not be apparent in documentation reviews or performance tests—from missing insulation and thermal bridging to improper equipment installation and control system implementation. The immediate nature of visual inspections enables correction of problems before they become hidden behind finishes or buried in building systems. This verification step proves particularly valuable for elements that affect long-term performance but become inaccessible after construction completion, such as envelope air barriers or mechanical system components.

This focused inspection approach shows a more modest but focused adoption, with 22 countries implementing requirements. Among these, 14 maintain consistent enforcement. Several patterns emerge: most countries (18) combine visual inspections with as-built verification, suggesting complementary roles. The data reveals successful implementation across economic contexts—lower-middle-income countries like Viet Nam and Tunisia maintain effective visual inspection programs alongside high-income nations like Sweden and Israel. This suggests that specialized inspections can provide a valuable complement to formal verification systems, particularly for critical energy features that require qualitative assessment beyond simple documentation checks. Countries that maintain both mechanisms demonstrate a more robust approach to ensuring that energy efficiency measures are not only present but properly implemented to achieve their intended performance.

## Energy Audit

Energy audits serve as comprehensive evaluations of actual building energy performance, providing detailed analysis of energy consumption patterns, system operation, and improvement opportunities. It is important to note that energy audits typically occur post-occupancy, following a period of building operations, and thus extend beyond the traditional scope and timeline of building code enforcement. While most building code verification processes conclude at occupancy certification, energy audits examine how building systems work together under real operating conditions across seasons and usage patterns. This holistic assessment identifies both technical issues and operational practices that affect energy efficiency, while establishing baseline performance data for ongoing optimization. Energy audits prove particularly valuable for verifying that complex building systems achieve their intended performance targets and for identifying opportunities to enhance efficiency through operational improvements or targeted upgrades. Energy audits show the most selective adoption, with 14 countries implementing requirements and 10 achieving consistent enforcement. The data reveals a clear correlation with institutional capacity—12 of the 14 countries with audit requirements are high-income nations, with Tunisia and India being notable exceptions. European countries dominate implementation, with Latvia, Romania, and Denmark demonstrating successful programs. The geographic concentration suggests energy audits often represent a more advanced stage of verification framework development, typically built upon established as-built verification and inspection systems.

## Recommendations for policy makers

**Staged implementation strategy:** Policy makers should develop verification frameworks that match institutional capacity and market readiness. Begin with fundamental visual inspections focusing on easily verifiable elements like insulation installation and equipment specifications. As capacity develops, expand to more comprehensive as-built verification incorporating performance testing and detailed documentation review. Energy audits can be introduced later as market sophistication and verification capabilities mature. This staged approach allows both regulatory agencies and industry to develop necessary expertise while maintaining effective oversight.

**Resource optimization and capacity building:** Design verification systems that maximize impact within available resources. For jurisdictions with limited capacity, focus visual inspections on critical energy efficiency elements that significantly affect performance. Develop standardized inspection protocols and documentation requirements that can be effectively implemented by available staff. Create training programs for inspectors and auditors that build systematic verification expertise while maintaining consistent standards. Consider risk-based approaches that concentrate verification resources on larger or more complex projects while maintaining basic oversight of smaller buildings.

**Market support and technical infrastructure:** Establish clear technical guidelines and support systems that enable effective verification. Develop standardized protocols for different building types and sizes that provide practical guidance while ensuring consistent evaluation. Create compliance tools and documentation templates that streamline the verification process for both regulators and building teams. Build networks of qualified professionals through certification programs and continuing education requirements. Consider partnerships with professional organizations and educational institutions to expand verification capacity while maintaining quality standards.

**Integration with existing systems:** Incorporate energy efficiency verification into established building control processes rather than creating parallel systems. Align documentation requirements and inspection timing with existing construction oversight to minimize additional burden on both regulators and building teams. Develop digital platforms that integrate energy efficiency verification with other building

approvals and documentation. Create clear procedures for addressing non-compliance that work within existing enforcement frameworks while maintaining focus on achieving intended performance outcomes.

## 5.7 Retrofitting and Disclosure Standards

Retrofitting, disclosure, and retro-commissioning standards represent important policy mechanisms for addressing building energy efficiency, though it is important to note that these requirements often function as companion policies rather than traditional elements of BECs. While conventional building codes primarily govern new construction and major renovations, retrofitting mandates, disclosure requirements, and retro-commissioning standards typically operate through separate regulatory frameworks that extend beyond standard code purview. Retrofitting standards establish specific energy performance improvements required when existing buildings undergo renovations, while disclosure mechanisms make energy performance visible to market participants through certificates, ratings, or energy consumption reporting. Retro-commissioning standards complement these approaches by requiring periodic assessment and optimization of building systems to ensure they operate at peak efficiency throughout the building's lifecycle. These companion policies can be significantly strengthened when well-coordinated with BECs through provisions like metering requirements, equipment replacement standards, and documentation procedures.

The effectiveness of retrofitting, disclosure, and retro-commissioning policies depends on their integration with broader building regulatory systems. BECs can support these companion policies by establishing baseline technical requirements, standardized calculation methodologies, and verification protocols that create a consistent framework for evaluating both new and existing buildings. This coordination is particularly important for ensuring that retrofitting standards and disclosure requirements can be effectively implemented through existing administrative structures rather than requiring entirely new enforcement mechanisms. Similarly, retro-commissioning standards benefit from alignment with code-based performance metrics and documentation requirements to ensure consistent evaluation methodologies and improvement targets.

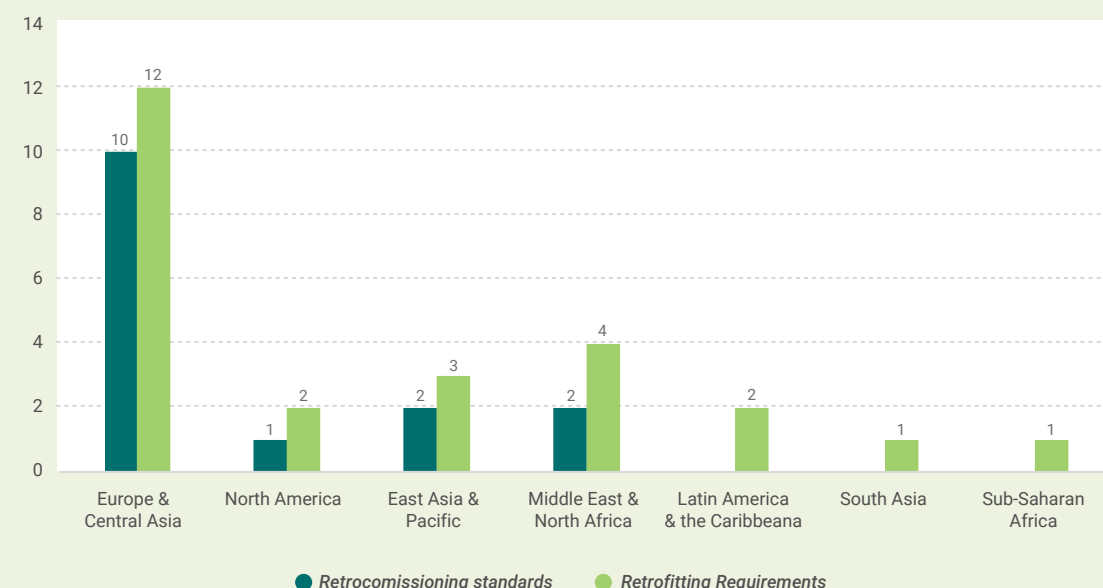
### 5.7.1 ENFORCEMENT OF RETRO-COMMISSIONING AND RETROFITTING STANDARDS

The enforcement of retro-commissioning and retrofitting standards remains uneven globally, with a clear divide between high-income and developing nations. While some high-income and upper-middle-income countries have established enforcement mechanisms, many others lack mandatory compliance frameworks, relying instead on voluntary adoption or market-driven efforts.

#### Enforcement of Retro-commissioning Standards

The data indicates that retro-commissioning enforcement is relatively limited, with only a few countries actively implementing compliance measures. Australia, Bahrain, Bulgaria, Finland, Italy, Latvia, the Netherlands, Romania, Sweden, Tunisia, and the United States have dedicated enforcement mechanisms, while most other jurisdictions lack mandatory enforcement.

A regional breakdown reveals that Europe and Central Asia leads in enforcing retro-commissioning, particularly within the EU's regulatory framework, which emphasizes continuous monitoring and optimization of building systems. North America, particularly the United States, also integrates retro-commissioning into BECs, requiring compliance during major renovations or performance audits (Figure 66).

**Figure 66 // Regional Distribution of Retro-commissioning Standards and Retrofitting Requirements**

Source: Building Energy Codes Global Dataset, World Bank Group.

In contrast, South Asia, Sub-Saharan Africa, and Latin America show very low enforcement levels, likely due to limited institutional capacity, funding constraints, and weak regulatory frameworks. Notably, some high-income countries—including Canada, Japan, Germany, and France—do not enforce retro-commissioning, suggesting that they rely on voluntary compliance or market-driven initiatives rather than strict mandates.

Overall, retro-commissioning enforcement remains in its early stages globally, but it represents an important tool for enhancing building energy efficiency. Countries with low adoption may benefit from structured capacity-building programs, financial support, and technical assistance to develop robust enforcement mechanisms.

### Enforcement of Retrofitting Requirements

The enforcement of retrofitting requirements is more widespread than retro-commissioning enforcement, particularly in Europe and Central Asia, North America, and parts of the Middle East and North Africa. Countries such as Australia, Bahrain, Belgium, Chile, China, Cyprus, Finland, Georgia, Kuwait, Latvia, Luxembourg, Moldova, the Netherlands, Romania, Saudi Arabia, Slovenia, Tunisia, the United States, and Rwanda actively enforce retrofitting measures to ensure energy efficiency upgrades in existing buildings.

Europe and Central Asia leads in retrofitting enforcement, with many EU countries aligning their policies with the European Green Deal and stringent building energy performance regulations (Figure 66). The availability of financial incentives and government-backed retrofit programs has contributed to strong enforcement rates. North America, particularly the United States, also enforces retrofitting measures through state-level energy efficiency mandates and city-driven climate action plans.

Among upper-middle-income countries, China and Bulgaria stand out for enforcing retrofitting requirements. China's large-scale building renovation programs are central to its carbon reduction strategy, while

Bulgaria enforces retrofits through EU-supported energy efficiency initiatives. Additionally, some Middle Eastern nations, including Saudi Arabia, Bahrain, and Kuwait, enforce retrofitting standards, reflecting a growing focus on energy conservation in high-energy-demand regions.

In contrast, South Asia, Sub-Saharan Africa, and most of Latin America show very low enforcement of retrofitting requirements, due to financial and institutional barriers, as well as the absence of clear regulatory frameworks. Rwanda is a unique case, as the only low-income country enforcing retrofitting requirements, suggesting early policy leadership in Africa on energy-efficient building regulations.

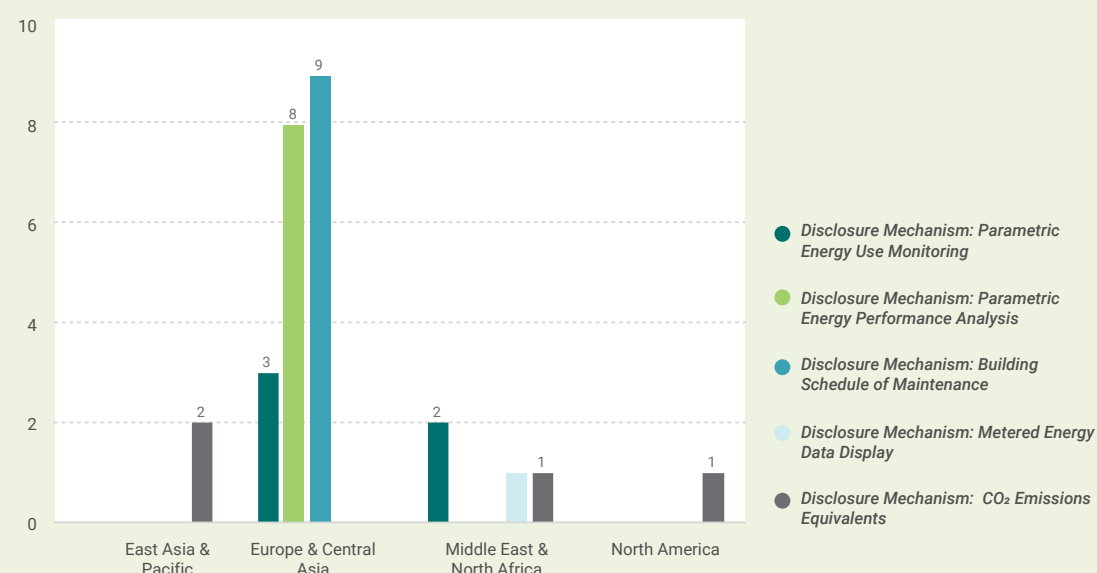
Despite broader enforcement of retrofitting requirements compared to retro-commissioning, significant regional and income-level disparities remain. Many developing nations lack the technical and financial infrastructure to enforce retrofitting mandates effectively. These countries would benefit from international financial support, incentive-driven programs, and stronger regulatory integration into BECs.

### Analysis from Building Energy Codes Global Dataset

The dataset reveals distinct regional patterns in building energy retrofitting and disclosure standards, closely tied to economic development levels and climate considerations (Figure 67). Europe leads globally in comprehensive adoption, with most EU nations implementing 3+ disclosure mechanisms and robust retrofitting requirements. Notable standouts like Denmark and Austria show consistent enforcement across multiple mechanisms, though even within Europe enforcement quality varies significantly. The Middle East and North Africa region displays a stark divide—Gulf states like Bahrain and Qatar have adopted comprehensive standards while lower-income countries show minimal requirements. Their retrofitting standards notably focus on cooling-specific measures, reflecting regional climate priorities.

East Asia presents perhaps the most varied landscape, with high-income jurisdictions like Australia implementing all five disclosure mechanisms consistently, while China shows comprehensive adoption but inconsistent enforcement. Most other Asian nations lack mandatory requirements entirely. The Americas

**Figure 67 // Availability of Disclosure Mechanisms across Regions**



Source: Building Energy Codes Global Dataset, World Bank Group.



similarly show a north-south divide—the United States implements comprehensive standards with consistent enforcement, while Latin American countries largely lack mandatory requirements, with only Chile and Panama showing partial adoption of disclosure standards.

Most concerning is the limited adoption across South Asia and Sub-Saharan Africa, where mandatory requirements are rare and enforcement is predominantly inconsistent where standards exist. Tunisia stands as a notable exception, with four disclosure mechanisms and consistent enforcement—an outlier in the African context. This regional disparity underscores the crucial link between institutional capacity and effective BEC implementation, suggesting targeted capacity building could help bridge the current gap between high and low-income regions. The correlation between climate zones and retrofitting priorities—heating in Europe, cooling in the Gulf—also highlights the importance of locally tailored approaches rather than one-size-fits-all standards.

## Recommendations for policy makers

**Adopt a staged implementation approach for disclosure mechanisms:** Policy makers should begin with basic energy monitoring requirements before advancing to more complex disclosures, such as CO<sub>2</sub> emissions reporting. The data demonstrates that this phased approach has been effective in jurisdictions with high compliance rates, including Australia and Denmark.

**Prioritize envelope improvements and air sealing for retrofitting standards:** Evidence suggests starting with these measures, which exhibit higher compliance rates, before mandating more capital-intensive actions like heating system replacements. This incremental approach fosters greater feasibility and adoption among stakeholders.

**Establish clear enforcement authority and mechanisms:** The data highlights a significant gap between the adoption and enforcement of standards. Policy makers should assign enforcement responsibilities to local building control authorities or dedicated environmental agencies, rather than relying on self-certification. Jurisdictions using authorized third-party inspectors with clear qualification requirements and supervisory frameworks achieve higher compliance rates.

**Standardize measurement and reporting protocols for disclosure requirements:** Jurisdictions with consistent enforcement often mandate specific methodologies for energy performance measurement and standardized formats for disclosure. Creating centralized databases for energy performance data enables improved monitoring, enforcement, and policy refinement while providing valuable insights for stakeholders.

**Implement disclosure requirements at points of sale or lease:** This strategy creates natural enforcement opportunities and market-driven incentives for compliance, leveraging transactional moments to reinforce standards.

**Address technical capacity constraints, particularly in developing economies:** Policy makers should establish dedicated training programs for building officials, energy auditors, and construction professionals to enhance implementation capacity. Simplified compliance paths for smaller projects, paired with rigorous requirements for large commercial buildings, have also shown success in multiple jurisdictions.

**Ensure regular review and updating of standards:** The most effective jurisdictions maintain systematic processes to incorporate new technologies and methods into their requirements, ensuring that standards remain relevant and effective over time.



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## 6. From Policy to Practice: Implementation Support

## 6.1 Support Mechanisms for Building Energy Code Implementation

The transformation of building energy efficiency through regulatory requirements depends critically on supporting mechanisms that enable and accelerate market adoption. Financial incentives, particularly in emerging markets and low-income regions, can offset the initial cost premiums of energy-efficient materials and technologies that often deter developers and building owners. These interventions become especially crucial when introducing new requirements like high-performance glazing or efficient HVAC systems, where market capacity may be limited and costs initially high.

Equally important but often overlooked is targeted support for local governments charged with code enforcement. Successful implementation frameworks recognize that municipal and local authorities require adequate resources, training, and technical assistance to effectively administer BECs. Countries with high compliance rates typically maintain robust programs that build enforcement capacity through standardized tools, training initiatives, and implementation resources tailored to local government needs. This support proves particularly crucial in federal systems or where enforcement responsibility is decentralized, as it ensures consistent application of requirements across different jurisdictions. Without adequate support for enforcement authorities, even well-designed codes and market incentives may fail to achieve their intended impact on building energy performance.

Technical resources play an equally vital role—design guides help professionals navigate new requirements, training programs build essential workforce skills, and equipment databases enable informed decision-making about compliant technologies. In resource-constrained environments, these support mechanisms can mean the difference between paper policies and actual market transformation. The strategic deployment of both financial and technical support creates pathways for different market segments to achieve compliance—from large commercial developers who might benefit from tax incentives to small contractors who need practical guidance and training.

**Table 3 // Examples of Financial Incentives by Country**

Country	Grants	Tax Credits	Rebates	Loans	Financial incentive examples
Armenia	✓			✓	Ameria Bank Renewable Energy Loans for businesses with an annual turnover of more than AMD 6 billion
Australia	✓			✓	Federal Grants for Solar Panels
Bangladesh					Bangladesh Bank green banking initiative
Finland	✓			✓	Motiva energy grants
Germany	✓	✓		✓	Federal subsidy for efficient buildings (Bundesförderung für effiziente Gebäude)
India	✓	✓	✓	✓	BSES Rajdhani Power Limited subsidy for light fixture replacement (switch to LED)
Ireland	✓	✓			<ul style="list-style-type: none"> <li>• Sustainable Energy Authority of Ireland (SEAI) Home energy upgrade loan scheme</li> <li>• SEAI Defective concrete blocks home energy upgrade grants</li> <li>• SEAI Vacant property refurbishment scheme home energy upgrade grant</li> </ul>

Table 3 (cont.)

Country	Grants	Tax Credits	Rebates	Loans	Financial incentive examples
Italy	✓	✓			<ul style="list-style-type: none"> <li>• Ecobonus (65%) tax break</li> <li>• Superbonus (110%) for energy efficiency improvements tax break</li> </ul>
Malta	✓	✓		✓	HSBC Bank fixed rate Energy Efficiency Loan to finance energy saving products and services for personal use
New Zealand	✓	✓	✓	✓	Low interest loans for energy efficiency (all banks)
Slovenia	✓			✓	<ul style="list-style-type: none"> <li>• Fixed interest rate credits for insulation</li> <li>• Fixed interest rate credits for HVAC</li> <li>• Subsidies for insulation</li> <li>• Subsidies for HVAC</li> </ul>
Canada	✓	✓	✓	✓	Toronto Green Standard (TGS) Development Charge Refund Program for verified Tier 2 or higher sustainable and high-performance development projects
Cyprus	✓	✓	✓	✓	Save – Upgrade Homes Grant Scheme for the energy upgrade of existing homes to achieve energy savings of at least 60%
Czechia	✓	✓		✓	New Green Savings Program (NGSP)
Netherlands	✓	✓	✓	✓	Investment Subsidy for Sustainable Energy and Energy Conservation (ISDE)
Mexico	✓	✓			Mexico City 'Ésta es tu Casa' subsidies
Moldova				✓	<ul style="list-style-type: none"> <li>• ESCO program for energy efficiency of public buildings</li> <li>• MoSEFF program for energy efficiency investments of private companies</li> <li>• MoREEFF program for residential energy efficiency investments</li> </ul>
Serbia	✓			✓	Energy improvement/rehabilitation of residential, multi-family buildings connected to district heating system– Public ESCO Project
Singapore	✓	✓			<ul style="list-style-type: none"> <li>• Bonus Gross Floor Area (GFA) Incentive Scheme</li> <li>• Green Mark Incentive Scheme</li> </ul>
Tunisia	✓		✓	✓	Investment bonus through Energy Transition Fund PROMO-ISOL offers rebates for roof insulation Loan programs from National Agency for Energy Management (ANME)
United States	✓	✓	✓	✓	Los Angeles Department of Water and Power (LADWP) Energy efficiency and water conservation rebates (Residential)
United Kingdom	✓	✓	✓	✓	<ul style="list-style-type: none"> <li>• Green Homes Grant</li> <li>• Boiler Upgrade Scheme (BUS)</li> </ul>

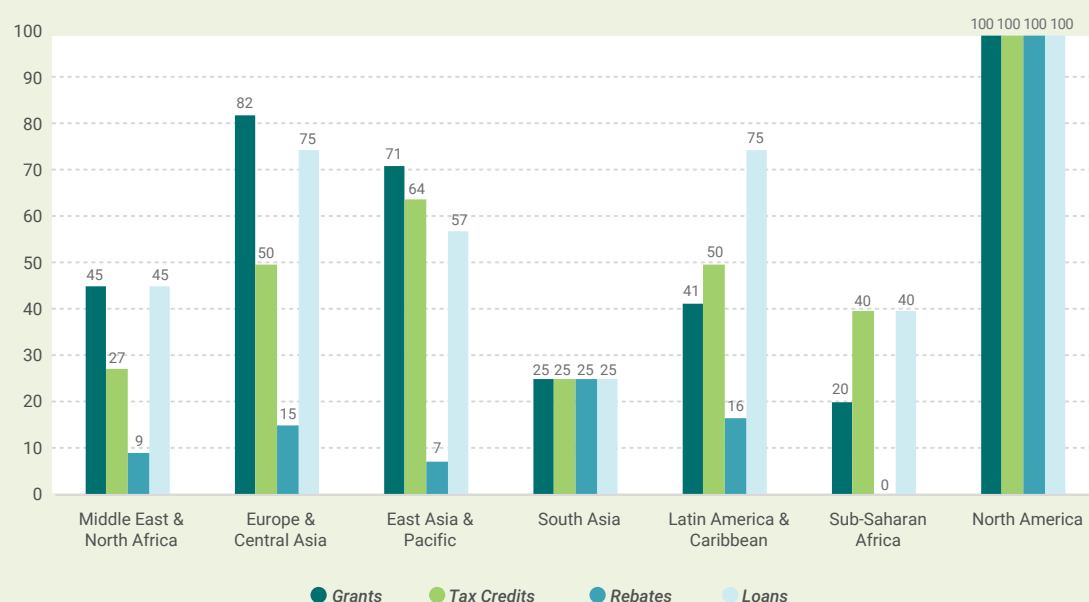
Source: Building Energy Codes Global Dataset, World Bank Group



## 6.1.1 FINANCIAL INCENTIVES

Financial incentives serve as crucial market transformation tools, bridging the gap between regulatory requirements and practical implementation of building energy efficiency measures. Unlike mandatory requirements that may face resistance due to cost concerns, well-designed incentive programs create positive market signals while addressing up-front cost barriers. The strategic value of financial incentives extends beyond individual projects—they help develop supply chains for energy-efficient materials and technologies, build workforce expertise in high-performance construction, and demonstrate the business case for exceeding minimum requirements. Incentives can be particularly effective during code transitions, helping markets adapt to new standards while maintaining construction activity. Four types of financial incentives are covered in the global dataset—grants, tax credits, rebates, and loans (Fig. 68).

**Figure 68 // Regional Distribution of Financial Incentives (% of Countries)**



Source: Building Energy Codes Global Dataset, World Bank Group.

**Figure 69 // Adoption of Financial Incentive Types by Income**



Source: Building Energy Codes Global Dataset, World Bank Group.

### 6.1.1.1 Financial incentives - Grants

#### *Why it matters*

Direct grant funding serves as a market transformation tool to encourage performance beyond minimum BEC requirements. Unlike tax credits or loans that offer delayed or repayable benefits, grants reduce capital costs at the point of decision-making, encouraging developers and building owners to exceed mandatory standards. This approach is particularly effective for advancing high-performance building practices in price-sensitive markets like affordable housing, where projects might otherwise only meet minimum code requirements. Grants can also support early adopters of advanced technologies and innovative solutions that help establish feasibility for future code improvements, while retrofit programs can accelerate improvements in existing buildings that may not be covered by current codes.

For resource-constrained public agencies, several approaches can help establish and maintain grant programs. Revenue from carbon taxes or environmental fees can be earmarked for energy efficiency grants, creating a sustainable funding source. Partnerships with multilateral development banks and climate funds can provide initial capital, while revolving funds that capture and reinvest energy cost savings can sustain long-term grant availability. Some jurisdictions have successfully implemented small surcharges on utility bills or building permits to fund grant programs, spreading costs across the sector while generating dedicated resources for efficiency improvements. Additionally, public-private partnerships where utilities or energy service companies co-fund grants can expand program reach without relying solely on public resources.

#### *Analysis from Building Energy Codes Global Dataset*

Of the 88 countries analyzed, 57 have implemented energy efficiency grant programs that complement their BECs. Europe and Central Asia shows the strongest adoption, with 33 countries implementing programs that typically target above-code performance and building retrofits (Figure 68). For example, the UK's Public Sector Decarbonization Scheme (PSDS) supports public buildings in achieving performance levels well beyond minimum code requirements through deep energy retrofits and low-carbon heating systems. Most grant programs across the EU focus on either driving market transformation toward higher performance standards or supporting energy efficiency improvements in existing buildings not covered by current codes. The East Asia and Pacific region demonstrates significant grant adoption with 10 countries, ranging from high-income nations like Japan, Singapore, and Australia to upper-middle-income countries like China and Thailand, and lower-middle-income countries like Viet Nam and Myanmar (Figure 69). This diverse economic representation suggests grants can be effectively implemented across different income levels. Singapore's Green Mark Incentive Scheme for Existing Buildings (GMIS-EB) and Australia's New South Wales Environmental Upgrade Program demonstrate how grants can be structured to target specific building sectors and efficiency improvements.

Latin America shows moderate adoption with 5 countries implementing grant programs—Argentina, Mexico, Chile, Peru, and Uruguay. In North America, both the United States and Canada maintain grant programs. The US Weatherization Assistance Program (WAP) specifically targets low-income households, while California's Energy Conservation Assistance Act (ECAA) program provides grants to public facilities. The Middle East and North Africa region has limited representation with 5 countries (Algeria, Tunisia, the Islamic Republic of Iran, Malta, and Qatar), while South Asia and Sub-Saharan Africa show the lowest adoption with only India and Nigeria, respectively, having grant programs.

The income-level distribution is particularly revealing: while high-income countries dominate grant programs, several upper-middle-income countries (including China, Thailand, Türkiye, and Argentina) and



lower-middle-income countries (Viet Nam, Myanmar, Kyrgyz Republic, Algeria, the Islamic Republic of Iran, India, and Nigeria) have successfully implemented grant schemes, demonstrating that resource constraints need not prevent grant program implementation.

### 6.1.1.2. Financial Incentives - tax credits

#### *Why it matters*

Tax credits represent a strategic fiscal tool for incentivizing building energy efficiency by directly reducing tax liability rather than just taxable income, providing a more powerful financial stimulus than tax deductions. This mechanism proves particularly effective for commercial buildings and large-scale developments where tax planning plays a crucial role in investment decisions. The structure of tax credits—typically calculated as a percentage of eligible energy efficiency investments—allows governments to precisely target specific technologies or performance levels without direct budgetary outlays. For instance, a 30 percent tax credit for high-performance envelope systems or a scaled credit based on achieved energy savings creates clear market signals while maintaining fiscal predictability. Unlike grants that require immediate government expenditure, tax credits defer fiscal impact to tax filing periods, allowing for better budget management while still providing investors with quantifiable financial benefits that can be incorporated into project planning and return calculations.

#### *Analysis From Building Energy Codes Global Dataset*

Of the countries analyzed, 43 have implemented tax credits to promote energy efficiency improvements beyond code requirements and support building retrofits, showing distinct regional and economic patterns. Europe and Central Asia demonstrates the strongest adoption with 20 countries implementing tax credit schemes, including EU member states from Sweden to Portugal, and several Central Asian countries like Kazakhstan and Uzbekistan. Within this region, these incentive programs span diverse climate zones, from cold climates (Latvia, Lithuania, Sweden) to mixed climates (France, Netherlands, UK) and warm climates (Portugal, Cyprus). France's MaPrimeRénov tax credit scheme specifically targets residential building renovations to achieve performance levels exceeding minimum requirements, while Italy's Ecobonus provides tax deductions for comprehensive energy efficiency improvements in existing buildings that go beyond basic code standards.

The East Asia and Pacific region shows significant adoption with 9 countries, ranging from high-income nations like Japan, Singapore, and Hong Kong SAR, China to upper-middle-income countries like Malaysia and Indonesia, and lower-middle-income countries like Viet Nam, Myanmar, and the Philippines. This diverse representation indicates tax credits can be effectively implemented across different income levels. Singapore's Building Retrofit Energy Efficiency Financing (BREEF)<sup>42</sup> scheme exemplifies how tax incentives can be structured to encourage commercial building retrofits, while Japan's Home Renovation Tax Credit demonstrates residential sector targeting.

Latin America shows moderate adoption with 6 countries implementing tax credit programs—Argentina, Colombia, Mexico, Paraguay, and Uruguay. In North America, both the United States and Canada maintain substantial tax credit schemes. The US Commercial Buildings Tax Deduction (Section 179D)<sup>43</sup> provides incentives for commercial building efficiency improvements, while various residential energy efficiency tax credits support homeowner investments in energy-saving improvements. The Middle East and North Africa region has limited representation with just 3 countries (Tunisia, the Islamic Republic of Iran, and Malta), while South Asia and Sub-Saharan Africa show the lowest adoption with only India and South Africa, respectively, having tax credit programs.

The income-level analysis reveals interesting patterns: while high-income countries dominate (25 countries) with comprehensive tax credit schemes, there is notable representation from upper-middle-income countries (10 countries, including Malaysia, Colombia, and South Africa) and lower-middle-income countries (8 countries, including Viet Nam, the Philippines, and India). This distribution suggests that while economic capacity influences the ability to offer tax credits, it is not an absolute barrier to implementation.

#### BOX 14. South Africa's Section 12L Energy Efficiency Tax Incentive: A Market-Based Approach to Building Energy Efficiency

South Africa introduced Section 12L of the Income Tax Act as a comprehensive financial incentive to promote energy efficiency across its economy, including the buildings sector. The program, which became effective in November 2013 and was enhanced in March 2015, represents an innovative approach to encouraging energy conservation through tax policy.

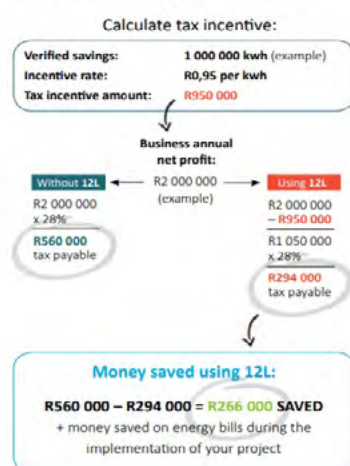
The incentive operates by offering building owners and businesses a tax deduction of 95 cents per kilowatt-hour of verified energy savings, increased from the initial rate of 45 cents/kWh (Figure 70). This deduction applies to demonstrated energy savings across all energy sources, making it particularly attractive for commercial and industrial building owners looking to implement comprehensive energy efficiency measures.

What makes this program particularly noteworthy is its robust verification mechanism. To qualify for the incentive, building owners must follow a stringent technical process overseen by the South African National Energy Development Institute (SANEDI). This process begins with establishing an energy baseline through a certified measurement and verification professional (CMVP) working under a SANAS-accredited body. The baseline determines what the energy consumption would have been without efficiency improvements, providing a clear benchmark against which to measure savings.

Figure 70 // Section 12L Energy Efficiency Tax Incentive Scheme

##### Example of 12L savings

A business could save **R266 000** on its annual tax by saving **1 million kilowatt hours of energy**. See how in the example below, which can be used to calculate your own project's savings estimate:



Source: South African National Energy Development Institute.

After a decade of implementation (2013–2023), the program has demonstrated remarkable success both in environmental and economic terms. SANEDI's data shows total energy savings of 27.6 TWh and GHG emission reductions of 26.7 tons. The program has generated gross tax rebates of R 22.6 billion, demonstrating substantial financial benefits for participating businesses.

#### BOX 14 (cont.)

A particularly significant outcome has been the program's impact on job creation, an unexpected benefit in a country grappling with high unemployment rates. According to SANEDI's Job Impact Report, the initiative has created at least 449 direct jobs, contributing an estimated R 136 million annually to the economy. Notably, 98% of these positions were filled by South Africans, with 60% being black employees, primarily within energy-services companies implementing efficiency projects.

The implementation structure remains thorough, requiring several key steps: First, building owners must demonstrate qualifying energy savings initiatives, which can either be individual projects or bundled improvements across a facility. They must then engage with accredited verification bodies to perform measurements according to national standards (SANS50010). Following baseline approval by SANEDI, performance assessments are conducted to quantify actual energy savings, culminating in the issuance of an Energy Efficiency Tax Certificate.

Currently scheduled to run until December 2025, there are hopes for the program's extension, with particular emphasis on enhancing participation from small and medium enterprises. This case demonstrates how well-designed tax incentives can simultaneously address environmental concerns, promote energy efficiency, and generate significant socio-economic benefits, particularly in developing economies where initial capital costs often pose significant barriers to implementation.

### 6.1.1.3. Financial incentives - rebates

#### *Why it matters*

Rebates serve as an immediate financial tool for accelerating building energy efficiency by reducing up-front costs at the point of purchase or installation, making them particularly effective for addressing first-cost barriers that often impede energy efficiency investments. Unlike tax credits or deductions that require waiting until tax filing periods, rebates provide instant cost reduction, making them especially valuable for residential consumers and small businesses where immediate cash flow considerations often drive decision-making.

The structure of rebate programs—typically offering a fixed amount or percentage of qualified product or installation costs—provides clear, easily understood incentives that can rapidly transform market behavior. For example, a US\$200 rebate on high-efficiency heat pumps or a 25 percent reduction on insulation costs creates immediate price signals that influence purchasing decisions without requiring sophisticated financial planning. This immediacy makes rebates particularly effective for market transformation, especially in the residential sector where decision-makers may lack the tax liability or financial sophistication to fully use tax-based incentives. Additionally, rebates can be strategically structured to promote specific technologies or performance levels, allowing program administrators to rapidly respond to market conditions and technology evolution, while their point-of-sale implementation creates natural opportunities for consumer education and quality assurance through participating contractor networks.

#### *Analysis from Building Energy Codes Global Dataset*

The limited adoption of rebate programs to promote energy efficiency upgrades (but not code compliance)—with only 13 countries implementing them—presents an interesting contrast to the wider uptake of other financial mechanisms like grants and tax credits. While rebates offer immediate financial benefits at point of purchase, they may face unique implementation challenges, particularly related to administrative capacity and up-front funding requirements.

The geographic distribution shows a strong concentration in developed economies, with Europe and Central Asia leading through 6 countries including EU member states and the UK. France's 'Coup de pouce' program demonstrates effective residential targeting, offering immediate rebates up to €4000 for heating system replacements, while the Netherlands' Energy Investment Allowance (EIA) provides direct rebates for commercial building technologies. In North America, both countries maintain robust rebate programs—the US ENERGY STAR programs coordinate state and utility rebates ranging from US\$50–US\$1,000 for HVAC equipment, while Canada's Greener Homes initiative offers up to US\$5,000 in direct rebates for residential energy improvements.

The income-level distribution is particularly striking, with 11 of the 13 countries being high-income economies. This heavy skew suggests that immediate-payment incentive structures may present particular challenges for resource-constrained governments. However, successful examples exist in emerging economies—India's UJALA program demonstrates how rebates can be structured for energy-efficient appliances and lighting in resource-constrained contexts, while Argentina's residential sector rebates show potential for targeted programs in upper-middle-income countries.

While the current adoption of rebate programs is limited compared to other financial incentives, their concentration in developed economies and successful examples across different climate zones suggest potential for expanded implementation. Denmark's successful building renovation rebate scheme shows how programs can evolve to include both single-measure and comprehensive retrofit support, while the UK's Boiler Upgrade Scheme demonstrates technology-specific rebates to accelerate market transformation.

#### BOX 15. Targeted Incentives for Building Energy Efficiency: Tunisia's PROMO-ISOL Initiative

Tunisia's experience demonstrates how lower-middle-income countries can effectively implement financial incentives for building energy efficiency despite resource constraints. At the heart of Tunisia's approach is the PROMO-ISOL program, which specifically targets thermal insulation of roofs in individual housing units—both existing and new construction not covered by the country's thermal regulations. This focused approach addresses a significant market gap, targeting a substantial existing housing stock that requires energy efficiency improvements.

The financial framework operates through a carefully structured combination of direct incentives and favorable financing terms. The program provides investment bonuses through the Energy Transition Fund (FTE) of 8 dinars per square meter for existing housing and 6 dinars per square meter for new construction. These direct incentives are complemented by accessible bank loans with favorable conditions, including credit ceilings of 10,000 dinars and maximum repayment periods of 7 years. Interest rates are set at either the money market rate (TMM) or 4% (whichever is lower), making financing accessible to a broader range of households. To ensure program sustainability and participant commitment, beneficiaries must contribute to financing through a modest self-financing component covering technical inspection costs).

Implementation success relies heavily on strong institutional coordination between Tunisia's energy, housing, and finance ministries, with the [National Agency for Energy Management](#) (ANME) serving as the primary implementation body. This coordinated approach has enabled effective program delivery while maintaining quality standards through standardized energy audit protocols and robust verification systems. The program's emphasis on market development has been particularly noteworthy, supporting the growth of local manufacturing capacity for energy-efficient materials while building technical expertise through professional certification programs.

**BOX 15 (cont.)**

The impact has been significant—the program has facilitated thermal insulation improvements in thousands of residential buildings, achieving substantial energy savings in participating properties. The program’s targeting strategy has proven particularly effective, addressing both new constructions outside existing thermal regulations and the vast stock of existing housing that requires energy efficiency improvements. Beyond direct energy savings, the program has catalyzed the development of a local energy efficiency services market, with certified contractors and installers now operating in the sector.

The program’s success stems from several key design elements: a clear focus on roof insulation where energy savings potential is highest, carefully calibrated financial incentives that make investments attractive while requiring participant commitment, and strong quality assurance systems that maintain performance standards. The initiative demonstrates how targeted intervention in a specific building component (roof insulation) can serve as an effective entry point for broader market transformation in building energy efficiency (Mediterranean Investment Facility 2022).

Recent developments have focused on expanding the program’s scope while maintaining its successful core elements. The program continues to evolve, with current initiatives focusing on enhancing monitoring and verification systems while developing new financing mechanisms for larger-scale projects. These developments suggest potential pathways for other developing economies seeking to establish effective building energy efficiency financing programs.

**6.1.1.4. Financial incentives - loans*****Why it matters***

Loans function as a financing mechanism for building energy efficiency by addressing up-front cost barriers while enabling repayment through energy savings over time. Unlike direct incentives such as grants or rebates that require public funding, loan programs can leverage private capital and create revolving funding mechanisms that support ongoing market development. The structure of loan programs—through interest rate subsidies, credit guarantees, or specialized terms—enables governments to support larger-scale investments than possible through direct incentives. For instance, green mortgages offering preferential rates for energy-efficient homes or commercial building retrofit loans with extended tenors tied to energy performance create financing streams while building market capacity. This mechanism serves comprehensive retrofits and new construction where project costs exceed grant or rebate program limits, while the ability to match loan terms to projected energy savings addresses traditional lending barriers. Loan programs can also stimulate private sector participation by demonstrating the creditworthiness of energy efficiency investments and establishing standardized approaches to project evaluation and risk assessment, contributing to the integration of energy efficiency financing in conventional lending markets.

***Analysis from Building Energy Codes Global Dataset***

The widespread adoption of loan programs for building energy efficiency—with 57 countries implementing various lending mechanisms—demonstrates the versatility of this financial instrument across different economic and climate contexts (Figure 71). The geographic distribution reveals strong representation across regions, with Europe and Central Asia leading through 30 countries, spanning from Nordic nations (Norway, Finland, Sweden) to Mediterranean countries (Spain, Greece) and Central Asian states (Kazakhstan, Uzbekistan). This regional concentration has fostered the development of diverse loan models, from Germany’s KfW programs<sup>44</sup> offering preferential rates for energy-efficient construction and retrofits to Estonia’s KredEx scheme<sup>45</sup> combining loan guarantees with technical assistance.

The East Asia and Pacific region shows substantial adoption with 8 countries implementing loan programs, ranging from high-income nations (Japan, Australia, New Zealand) to upper-middle-income economies (China, Thailand) and lower-middle-income countries (Viet Nam, the Philippines, Myanmar). This economic diversity has produced approaches like Japan's Flat 35 program<sup>46</sup> which demonstrates how green mortgages can be integrated into mainstream housing finance.

The income-level distribution reveals broader adoption across economic categories compared to other financial incentives: while high-income countries (33) lead in implementation, there is substantial representation from upper-middle-income (15) and lower-middle-income countries (9). This pattern suggests that loan programs can be effectively structured across different economic contexts. For instance, Viet Nam's energy efficiency loan program<sup>47</sup> demonstrates how credit lines can be combined with technical assistance in developing markets, while France's zero-interest eco-loans show how advanced economies can use interest rate subsidies to accelerate retrofits.

#### BOX 16. Mexico's Integration of Green Financing with Housing Policy

Mexico's approach to green building incentives demonstrates how middle-income countries can effectively integrate sustainability objectives with social housing programs. The country's Green Mortgage Program (Hipoteca Verde)<sup>a</sup>, launched by the National Housing Fund for Workers (INFONAVIT) in 2007, has become one of Latin America's most successful examples of scaling green building through financial incentives. The program's significance lies in its innovative approach to addressing both environmental and social objectives through housing finance mechanisms.

The program offers supplemental credit of up to 20% above standard mortgage amounts for homes incorporating eco-technologies that reduce energy and water consumption. What distinguishes this approach is its careful calibration of financial incentives with household economics—the additional monthly mortgage payment is deliberately structured to be lower than the projected utility bill savings, making the program financially attractive to homeowners. This alignment between environmental objectives and household economics has proven crucial for widespread adoption in a middle-income context.

Initially voluntary, the program became mandatory for all INFONAVIT mortgages in 2011, demonstrating how incentive programs can evolve into broader market requirements once proven successful. The technologies supported include solar water heaters, energy-efficient lighting systems, water-saving fixtures, and thermal insulation. By 2020, the program had financed over 3 million green mortgages, with documented average reductions of 20% in energy consumption and 38% in water consumption for participating households.

The program's success stems from several key design elements. First, it leverages existing mortgage infrastructure rather than creating new delivery mechanisms. Second, it focuses on specific, verifiable technologies with proven cost-benefit ratios. Third, it includes robust verification systems to ensure installed technologies deliver promised savings. The program has also catalyzed broader market transformation, stimulating local manufacturing of energy-efficient technologies and creating new jobs in green construction.

Recent evaluations suggest the program has reduced annual CO<sub>2</sub> emissions by approximately 1.2 million tons while generating average monthly utility savings of US\$17–25 per household. These documented benefits have helped secure continued political support and funding, enabling the program to achieve significant scale despite changes in government administration.

a. World Habitat. (2016). *Green Mortgage: Mexico's Path to Sustainable Housing*.



## Recommendations for policy makers

**Performance-based grants.** Grants should be structured progressively, offering higher funding levels for buildings achieving superior energy performance, following models like Singapore's Green Mark Incentive Scheme (GMIS). Distinct market segments should be targeted by providing larger grants for affordable housing and small commercial buildings, where access to capital is a greater challenge. Sustainable funding sources should be established through environmental surcharges on building permits, as demonstrated by Tokyo's Green Building Program. Partnerships with climate funds and development banks should be leveraged to create revolving funding pools that reinvest energy cost savings. Administrative processes should be streamlined through standardized cost benchmarks and simplified application procedures to increase participation while ensuring accountability.

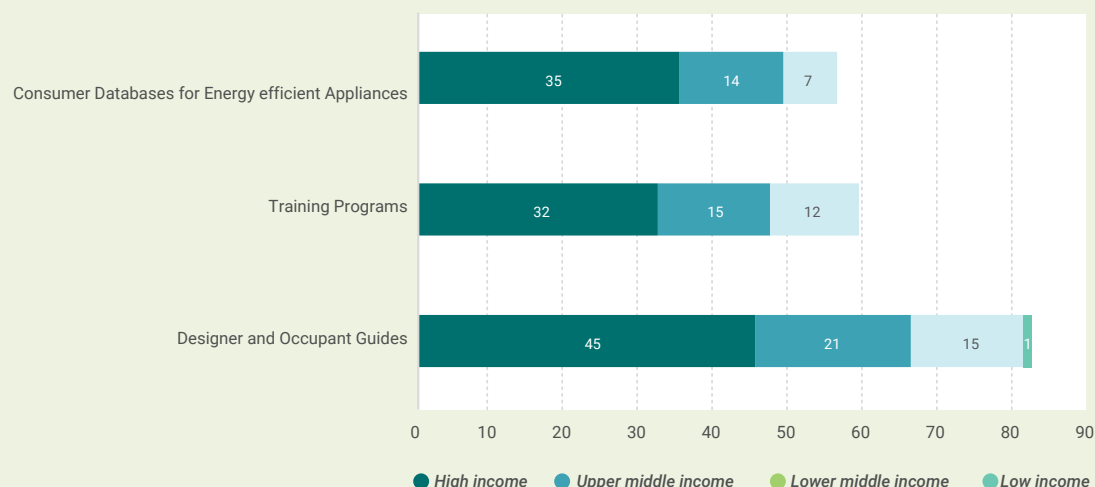
**Tiered tax credits.** Tax credits should be structured with performance-based tiers that incentivize higher energy savings, similar to France's MaPrimeRénov. Sector-specific tax credit structures should provide enhanced incentives for small buildings and affordable housing while maintaining base-level support for larger commercial projects. Targeted energy efficiency measures should be prioritized where verification is straightforward and energy savings are most reliable. Monitoring and evaluation systems should be implemented, balancing digital verification platforms for advanced markets with simpler compliance mechanisms like spot-checking in resource-constrained contexts.

**Scalable rebate programs.** Rebates should be designed to provide immediate financial benefits while encouraging deeper energy efficiency upgrades. The 'Coup de pouce' model in France demonstrates effective tiering, offering higher incentives for comprehensive retrofits while maintaining base support for single-measure improvements. High-impact, easy-to-verify technologies such as insulation, efficient HVAC systems, and smart controls should be prioritized, following India's UJALA program. Efficient rebate delivery should be integrated into existing point-of-sale systems through partnerships with retailers and contractors, as seen in the ENERGY STAR rebate model. Long-term funding stability should be ensured through utility-driven programs, revolving funds, and climate finance mechanisms.

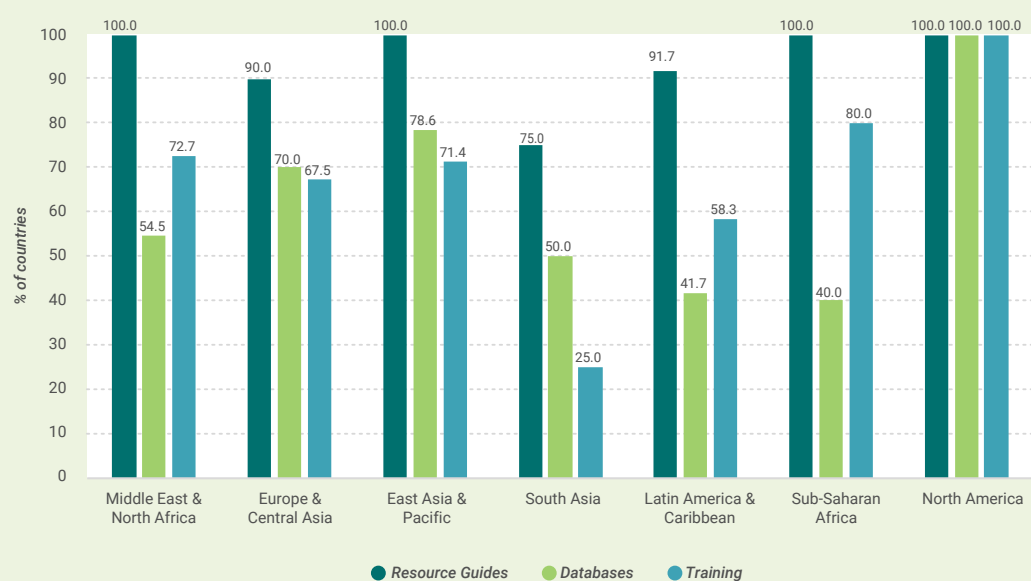
**Low-risk energy efficiency loans.** Loan programs should include risk-mitigation measures to encourage private-sector participation. Credit guarantees should be combined with clear technical standards, as in Germany's KfW program, to make energy efficiency loans attractive to commercial banks. Standardized technical criteria and simplified approval processes should be adopted, as demonstrated by France's eco-loan program, to reduce administrative barriers. In emerging markets, guarantee structures covering a portion of loan values for proven efficiency technologies should be introduced first, with gradual expansion to more complex retrofits as market capacity grows. Technical assistance programs should be integrated into loan offerings, as seen in Germany and India, to ensure that financed projects deliver intended energy savings.

## 6.2 Technical Resources

Besides financial incentives, countries are adopting innovative approaches to ensure widespread awareness of building codes, helping experts and developers become familiar with the compliance requirements. Based on data from the global dataset, three major pillars emerge as the most commonly used strategies: designer and occupant guides, consumer databases for energy-efficient appliances, and targeted training programs.

**Figure 71 // Technical Resources to Support Energy Efficiency Compliance and Adoption**


Source: Building Energy Codes Global Dataset, World Bank Group.

**Figure 72 // Regional Distribution of Technical Resources for Builders (% of Countries)**


Source: Building Energy Codes Global Dataset, World Bank Group.

## 6.2.1 TECHNICAL RESOURCES - DESIGNER AND OCCUPANT GUIDES

### Why it matters

Designer and occupant guides serve as practical tools for translating building energy efficiency requirements into implementable actions while reducing barriers to adoption. Unlike regulatory documents, these guides provide specific, actionable information tailored to different user groups, enabling informed decision-making throughout the building lifecycle. The structure of these resources—from detailed technical manuals for designers to simplified operational guides for occupants—supports consistent

implementation of energy efficiency measures while reducing compliance costs. For instance, design guides incorporating climate-specific solutions with performance calculations and construction details enable architects and engineers to efficiently integrate efficiency measures into their projects, while occupant guides linking behavior patterns to energy consumption help building users optimize operational performance. These resources also function as market development tools by establishing common technical language and performance expectations across the building sector, facilitating knowledge transfer between projects and supporting the standardization of energy-efficient building practices. Additionally, well-structured guides can reduce the technical assistance burden on regulatory agencies by providing clear, standardized solutions to common design and operational challenges.

### Analysis from Building Energy Codes Global Dataset

The near-universal adoption of designer and occupant guides (83 out of 88 countries) highlights their fundamental role in translating complex BECs into practical implementation guidance. Only five countries in the dataset—Bangladesh, Iceland, Poland, Ukraine, and Venezuela—lack these resources, with four of these also showing limited adoption of other technical support mechanisms.

This widespread implementation across economic contexts and regions reflects several key factors (Figure 72). First, guides represent a relatively low-cost, high-impact approach to supporting code compliance—they can be developed once and distributed widely through digital platforms, making them particularly attractive for resource-constrained environments. Second, these guides serve multiple critical functions: they help design professionals understand technical requirements during the planning phase, support contractors during construction, and assist building operators in maintaining energy-efficient operations. Third, they create standardized understanding across the building sector, reducing interpretation errors and improving compliance rates.

The evolution of these guides also demonstrates market maturity—high-income countries like Singapore and Germany maintain sophisticated technical libraries with detailed performance specifications and calculation methodologies, while emerging economies often start with basic compliance guides before expanding to more comprehensive resources. This adaptability makes guides particularly valuable as foundational elements of BEC implementation, explaining their near-universal adoption even in markets with limited regulatory capacity.

## 6.2.2 TECHNICAL RESOURCES - CONSUMER DATABASES FOR ENERGY-EFFICIENT APPLIANCES

### Why it matters

Consumer databases for energy-efficient appliances function as market transparency tools that bridge information gaps between manufacturers, retailers, and end-users. Unlike simple product labels, these databases provide detailed performance data, enabling quantitative comparison of energy consumption, efficiency ratings, and lifecycle costs across product categories. The structure of these databases—incorporating standardized test results, performance metrics, and cost data—enables informed decision-making while supporting market competition based on energy performance. For instance, databases linking annual energy consumption with operating costs and efficiency ratings allow consumers to evaluate lifetime economic benefits, while providing retailers and procurement officers with verified technical data for product selection. These platforms also serve as market monitoring tools by tracking the evolution of product efficiency levels and establishing performance benchmarks that inform policy development. Additionally, comprehensive product databases support enforcement of minimum energy performance

standards by providing verified compliance data, while enabling program administrators to identify opportunities for raising performance requirements based on market availability.

### Analysis from Building Energy Codes Global Dataset

The adoption of consumer databases for energy-efficient appliances spans 56 countries, demonstrating the role of information systems in market transformation. The geographic distribution shows significant concentration in Europe and Central Asia with 28 countries implementing such databases, from Nordic countries (Norway, Finland, Sweden) to Central European nations (Germany, Austria) and emerging economies (Kazakhstan, Moldova) (Fig. 72). The EU's approach through the European Product Registry for Energy Labelling (EPREL)<sup>48</sup> database provides a comprehensive model, integrating product information across national markets while enabling consumer access through standardized interfaces.

East Asia and Pacific represents the second-largest concentration with 10 countries maintaining appliance databases, ranging from high-income nations (Japan, Singapore, Australia) to emerging economies (China, Thailand, Indonesia). This region demonstrates diverse approaches to database implementation—Australia's Energy Rating product database<sup>49</sup> provides detailed comparative tools and running cost calculators, while Singapore's NEA database<sup>50</sup> integrates with their mandatory energy labeling scheme. Japan's Top Runner database<sup>51</sup> stands out for its integration of market transformation targets with consumer information.

The income-level distribution reveals significant variation in implementation: high-income countries (35) show the highest adoption, followed by upper-middle-income (14) and lower-middle-income countries (7). This pattern reflects the technical and administrative requirements of maintaining comprehensive product databases. The lower implementation rates in developing regions point to opportunities for expanding market transparency tools, particularly as these regions experience rapid growth in appliance markets and building energy consumption. However, successful examples from emerging economies demonstrate adaptable approaches—including India's BEE Star Label<sup>52</sup> database.

## 6.2.3 TECHNICAL RESOURCES - TRAINING PROGRAMS

### Why it matters

Training programs for building sector professionals serve as market development tools by establishing consistent technical knowledge and practical implementation skills. Unlike general construction training, these programs focus specifically on energy efficiency requirements, system integration, and performance verification methods. The structure of these programs enables systematic skill development—from basic energy calculations to advanced building systems optimization. For example, HVAC design courses combine load calculation methods with equipment selection criteria, while building envelope training connects thermal performance requirements with proper installation techniques. These programs support quality assurance by creating common technical understanding between designers, contractors, and building operators. Additionally, training programs facilitate the adoption of new technologies and methods by providing practical experience with installation and commissioning procedures, while establishing standard approaches to system optimization and performance verification.

### Analysis from Building Energy Codes Global Dataset

The implementation of training programs for building sector professionals spans 59 countries, indicating broad recognition of capacity-building needs for energy efficiency implementation. The geographic

distribution shows concentrated adoption in Europe and Central Asia with 27 countries implementing structured training programs. The Czech Republic's comprehensive system demonstrates effective integration of theoretical and practical training, while Bulgaria shows through its Build Up<sup>53</sup> program that training programs can be adapted for markets transitioning to higher efficiency standards.

East Asia and Pacific shows significant engagement with 10 countries implementing training programs. Indonesia's tiered training system provides a model for developing markets, offering basic courses for general contractors while maintaining advanced programs for specialists. Malaysia's building sector training integrates energy efficiency with broader green building skills, while New Zealand's program demonstrates effective coordination between vocational institutions and industry bodies.

The income-level distribution reveals implementation across economic categories: high-income (32 countries), upper-middle-income (15 countries), and lower-middle-income (12 countries). This spread shows how training programs can be adapted to different market contexts. Kenya's focus on practical workshops for contractors and installers demonstrates effective approaches for resource-constrained markets, while Chile's professional certification program shows how training can support market transformation in middle-income contexts.

## Recommendations for policy makers

**Comprehensive designer and occupant guides.** Technical guides should be structured in a three-tier system covering basic compliance, detailed design solutions, and advanced performance options. Hong Kong's design manual provides an effective model, offering fundamental requirements in Part 1, technical solutions in Part 2, and integrated system approaches in Part 3. For new and resource-constrained markets, foundational guides should focus on common building types and essential compliance requirements before expanding to more complex systems. Standardized calculation methods and worked examples should be included to directly support compliance verification.

**Digital platforms and continuous updates.** Centralized online platforms should be developed for the distribution of technical guides, with standardized templates for updates and revisions to ensure consistency. Germany's online building professional portal demonstrates effective integration of core documents, calculation tools, and regular technical updates. In regions with limited internet access, offline-accessible core documents should be prioritized while maintaining online platforms for supplementary resources and real-time updates.

**Industry integration and practitioner feedback.** Guide development should involve direct engagement with building professionals and industry bodies to ensure relevance. Australia's approach links technical documentation directly to professional certification requirements, while Singapore incorporates practitioner feedback through annual review cycles. Technical committees with rotating industry representation should be established to maintain practical applicability, and systematic processes for collecting and incorporating field implementation experiences should be put in place to refine technical guidance.

**Market support tools for implementation.** Complementary tools such as standard design templates, specification clauses, and compliance checklists should be developed in alignment with guide requirements. A technical support function, similar to Hong Kong's model of query response systems, should be created to assist with implementation. In emerging markets, the focus should initially be on addressing common design and construction challenges through basic support tools before expanding to advanced assistance systems.

**Accessible and standardized consumer appliance databases.** Product databases should be designed with user-friendly interfaces and standardized data templates. The EU's EPREL system demonstrates a multi-tier approach, offering detailed technical data for regulators and simplified interfaces for consumers. Emerging markets should start with core product categories and essential efficiency metrics before expanding to detailed specifications. Mobile-responsive platforms with offline access capabilities should be developed to ensure broad market reach.

**Data verification and quality assurance.** Systematic verification protocols should be implemented to maintain database accuracy, as demonstrated by Australia's Energy Rating system, which integrates test reports with market surveillance data. Clear product registration and update procedures should be established, with automated checks for data consistency. In resource-constrained markets, verification efforts should focus on high-impact product categories while gradually building capacity for comprehensive monitoring.

**Retailer integration and market accessibility.** Retailers should be provided with tools to integrate database information into their sales platforms. Singapore's approach of offering standardized API access and downloadable datasets supports market adoption. Standardized product comparison tools should be developed to enable retailers to incorporate efficiency data into their systems. In developing markets, basic product listing tools aligned with existing retail practices should be prioritized while building long-term capacity for digital integration.

## 6.3 Digital Toolkits

Beyond the technical resources, building agencies provide additional technical tools to facilitate code implementation and enhance compliance. These tools have become increasingly important for translating complex requirements into practical implementation.

**Algeria's RETA** (software for Algerian Thermal Regulation)<sup>54</sup> offers a particularly instructive example of how digital tools can address specific implementation challenges. Developed by the Center for Renewable Energy Development (CDER) in 2016, RETA emerged as a response to two critical barriers in Algeria's building energy efficiency framework: the absence of a regulatory enforcement body and the lack of operational tools for design offices to implement technical requirements.

The tool's development was driven by Algeria's distinctive energy context—residential energy consumption accounts for 31 percent of total final energy consumption (as of 2022), significantly higher than the global average of 25 percent. While Algeria established thermal regulations for new buildings in 1999, aiming to reduce heating and cooling energy consumption by 30 percent, implementation remained limited until RETA's introduction. The software provides comprehensive functionality that enables practitioners to perform thermal insulation calculations, evaluate heat loss in building components, and reference standardized energy performance values. Users can model detailed building components and size heating systems based on specific thermal comfort requirements. These capabilities make complex regulatory requirements more accessible to practitioners while standardizing calculation methods across projects.

RETA's significance extends beyond its technical capabilities—it represents a successful approach to democratizing complex regulatory requirements through free, accessible tools. The software has become widely used, demonstrating how digital tools can bridge the gap between regulatory frameworks and practical implementation, particularly in contexts where enforcement mechanisms may be limited.



**Singapore's** Green Mark (GM) system demonstrates how digital tools can systematically evolve to support code implementation while driving market transformation. Introduced in 2005 by the Building and Construction Authority (BCA), GM serves as a comprehensive green building certification framework, continuously refined to integrate technological advancements and implementation insights. It now covers new and existing buildings, user-centric spaces, and district-level developments, ensuring relevance across various built environments.

A defining feature of GM is its progressive evolution, with major updates approximately every 4–6 years. The latest iteration, Green Mark 2021, replaces previous versions such as GM NRB:2015 (Non-Residential Buildings) and GM RB:2016 (Residential Buildings), incorporating advanced requirements in decarbonization, smart building operations, climate-responsive design, and occupant well-being. Its integrated assessment approach evaluates projects across five key dimensions: climate-responsive design, building energy performance, resource stewardship, smart and healthy building features, and advanced green strategies, providing clear guidance for industry practitioners while supporting broader sustainability goals.

The system has also introduced more sophisticated requirements, including Building Information Modeling (BIM) integration, enhanced water management strategies, and advanced building analytics. A particularly robust feature is its verification process, which includes multiple checkpoints from application to assessment. Higher-tier certifications (GoldPLUS and Platinum) require 12 months of verified energy consumption data, ensuring that certified buildings deliver measurable environmental benefits. The program's impact is evident, growing from 17 certified projects in 2005 to over 3,125 in 2020, with GM-certified buildings consistently outperforming conventional buildings in energy efficiency.

Singapore's Green Mark system highlights how clear technical requirements, practical implementation pathways, and stringent verification measures can drive market transformation. By maintaining regular updates while ensuring consistency in core standards, GM has helped build a competitive green building market while continuously raising sustainability benchmarks.

**Hong Kong's** Comprehensive Environmental Performance Assessment Scheme (CEPAS)<sup>55</sup> represents a sophisticated approach to technical support tools. Developed and maintained by the Buildings Department, CEPAS provides specialized assessment software and technical calculators designed specifically for high-rise buildings in hot-humid climates. The system includes an intelligent assessment engine that automatically validates input data against regulatory requirements, calculates performance scores, and generates compliance reports. CEPAS pioneered innovative features like its 'Built Asset Performance' module that helps practitioners evaluate both design-stage and operational energy performance. The tool employs a comprehensive framework covering energy use, thermal comfort, ventilation performance, and building systems efficiency, with specific calculation methodologies for Hong Kong's unique climate conditions and building typologies.

**The Czech Republic's** 'New Green Savings' (Nová zelená úsporám) program<sup>56</sup> demonstrates how technical tools can be integrated with financial incentives to enhance code implementation. The program's online platform provides calculation tools that help professionals evaluate energy savings potential and verify compliance with performance requirements. A distinctive feature is its modular approach—the platform includes specialized calculators for different building types and renovation measures, from simple envelope improvements to comprehensive retrofits. The program's technical support system includes an energy assessment calculator that provides instant feedback on proposed measures' impact on energy performance certificates, helping practitioners optimize their designs. These tools are complemented by a comprehensive database of approved materials and technologies, streamlining the specification process while ensuring compliance.



## 7. The Missing Parts/ Gaps Toward the Paris Agreement

As the global community strives to meet the ambitious targets of the Paris Agreement, the building sector stands at a critical juncture. Buildings currently account for a significant portion of global energy consumption and emissions, and their performance will play a crucial role in determining our success in mitigating climate change. While progress has been made in developing and implementing BECs, significant gaps remain in their coverage, enforcement, and effectiveness. These gaps must be addressed to ensure that the building sector contributes to the global effort to reduce emissions and build resilience. This section identifies the key areas where these gaps exist and highlights the urgent need for targeted interventions to close them, thereby paving the way for a more sustainable and climate-resilient built environment.

## 7.1 The Scale of the Challenge

The Paris Agreement demands a 37 percent reduction in building energy intensity from 2015 levels by 2030, yet current progress falls significantly short. In 2023 alone, 2.55 billion square meters of new floor space was built without energy requirements—equivalent to building a new city the size of Paris every week. Analysis of BECs across 88 countries reveals not just policy gaps, but fundamental challenges in market transformation, technical capacity, and implementation systems that must be addressed to achieve Paris Agreement objectives.

The urgency of addressing these gaps is amplified by unprecedented urbanization rates. According to the United Nations, 68 percent of the world's population will live in urban areas by 2050, driving massive construction activity particularly in regions currently lacking effective BECs. Nearly 70 percent of global building stock that will exist in 2050 is yet to be built, making the gaps in current regulatory frameworks particularly critical for long-term climate impacts.

## 7.2 Geographic and Coverage Gaps

The most fundamental gap lies in limited global adoption of BECs. The dataset's 88 countries represent only 45 percent of nations globally, with critical gaps in rapidly urbanizing regions. The regional disparities are stark—Europe shows near-universal adoption with 40 countries having unified BECs, while Sub-Saharan Africa has only two countries with comprehensive requirements despite rapid urban growth. South Asia's limited representation, with only four countries having established requirements, raises serious concerns about future construction impacts.

## 7.3 Technical and Performance Gaps

Even where codes exist, implementation gaps persist. Of the 88 studied countries, only 71 have mandatory requirements, though it is important to note that even these mandatory codes often have limited scope, exempting certain building types or sectors from compliance. Beyond these coverage limitations, just 52 countries demonstrate consistent enforcement of their existing requirements. This enforcement gap is particularly pronounced in lower-middle-income countries, where resource constraints often limit inspection and verification capabilities. Current BECs show significant technical limitations that hinder their effectiveness in reducing emissions. Among the studied countries, only 36 have established heating system standards, while 52 include AC efficiency requirements. This incomplete coverage of major energy systems becomes particularly problematic given rising global temperatures and increasing cooling demands.

The stringency of requirements varies widely even among countries with similar climates, suggesting many codes are not optimized for maximum energy savings. The most critical technical gap concerns existing buildings—only 16 countries have established retrofit requirements, despite existing buildings constituting the majority of 2050 building stock in developed regions. The IEA estimates that to achieve Paris Agreement goals, the rate of energy-efficient building retrofits needs to triple from current levels.

## 7.4 Economic and Market Infrastructure Gaps

The distribution of effective BECs reveals stark economic disparities. While high-income countries show near-universal adoption with comprehensive requirements, representation drops significantly among upper-middle-income (22 countries) and lower-middle-income nations (17 countries). Only Rwanda, among low-income countries, has implemented comprehensive requirements. This disparity becomes particularly concerning as climate projections indicate that the majority of new construction will occur in developing economies over the next three decades.

The infrastructure gap extends far beyond code adoption to fundamental market readiness. Many developing countries lack the essential supply chain components needed for effective implementation. This includes underdeveloped networks of qualified designers and architects, limited availability of high-performance building materials and equipment, insufficient numbers of skilled installation contractors, and inadequate testing and certification infrastructure. These supply chain gaps cannot be addressed simply through regulation—they require time for market development and capacity building. Without adequate suppliers, products, and skilled professionals, even well-designed codes face severe implementation challenges. The World Bank estimates that developing countries will need to invest approximately US\$1.5 trillion annually in sustainable infrastructure to meet climate goals, yet current investment falls far short of addressing these fundamental market development needs<sup>57</sup>.

## 7.5 Climate Resilience and Future Readiness Gaps

Most current BECs fail to adequately address climate resilience and adaptation. As global temperatures rise and extreme weather events become more frequent, buildings must be designed not only for energy efficiency but also for resilience to changing climate conditions. However, few existing codes incorporate requirements for passive survivability, natural cooling, or extreme weather resilience.

This gap becomes particularly critical in rapidly urbanizing regions with hot climates, where cooling demands are projected to triple by 2050. Without integrated requirements for passive design strategies and climate adaptation, buildings risk becoming increasingly dependent on energy-intensive mechanical cooling, potentially offsetting efficiency gains in other areas.

## 7.6 Implementation Support Gaps

The analysis reveals significant gaps in the support systems needed to achieve Paris Agreement targets through BECs. While 76 percent of countries with codes maintain technical resource programs, only 43 percent offer financial incentives for compliance. This lack of comprehensive support mechanisms particularly affects developing economies, where higher up-front costs for energy-efficient construction often prevent code compliance.



Furthermore, many countries lack the professional training and certification programs needed to ensure the effective implementation of energy efficiency requirements. According to the **IEA**, scaling up Paris-aligned efficiency measures in the building sector will require a significant expansion of the skilled workforce, including insulation installers, HVAC specialists, and energy auditors. However, current training capacities are insufficient to meet this demand, creating a critical gap in the workforce needed to support global energy efficiency goals.<sup>58</sup>

## 7.7 Analysis of Experts' Surveys Reveals Enforcement Difficulties

Experts have reported that introducing and enforcing energy efficiency codes is challenging due to a combination of institutional, economic, cultural, and regulatory barriers that vary across different contexts. A common issue reported is the lack of **sufficient institutional capacity**. Agencies responsible for enforcement often do not have the necessary human resources, equipment, or access to private experts, such as building energy auditors, which limits their ability to effectively oversee compliance. **Economic barriers** are another significant challenge, particularly in countries with older building stock, where retrofitting to meet efficient standards can be prohibitively expensive. Additionally, the **high cost of construction** and the up-front investment required for energy-efficient technologies deter widespread adoption.

**Cultural and political** factors also play a role. In many places, energy efficiency codes are relatively new, requiring a cultural shift in both the construction industry and public attitudes. This shift often relies on strong political will, which is not always present. Without this support, implementation efforts can stall, particularly in contexts where energy efficiency is not seen as an immediate priority.

**Resource constraints** further complicate enforcement. Many countries lack the time and resources needed to implement these policies effectively. Often, the required combination of financial, technical, and institutional resources is not available. This is compounded by flaws in policy design, where the connection between policy actions and their desired outcomes is indirect, with multiple intervening factors complicating enforcement.

**Weak regulatory frameworks** exacerbate the problem. In some cases, laws are overly general and fail to define specific mechanisms for compliance, making enforcement nearly impossible. For instance, setting ambitious standards and goals without clear pathways for achievement leaves policies ineffective. Lastly, the coordination required among various stakeholders, such as government agencies, private sector actors, and local communities, is a major hurdle. **Inconsistent collaboration** often leads to delays and gaps in implementation.



## 8. Considerations for Policy Makers



The success of BECs extends far beyond their technical requirements—it hinges on creating comprehensive frameworks that address institutional structures, market readiness, and implementation capacity. The experiences documented across 88 countries reveal that effective implementation requires careful calibration of regulatory ambition with practical feasibility, supported by robust enforcement mechanisms and market development programs. Even well-designed codes can fall short of their potential without appropriate institutional frameworks, technical capacity, and market support systems.

Our analysis reveals three critical dimensions that policy makers must consider. First, the institutional framework must align energy efficiency objectives with existing building regulation systems while providing clear authority and accountability for enforcement. Singapore's experience demonstrates how energy requirements can be effectively integrated into established building control processes, creating streamlined compliance pathways for developers and builders. Second, market readiness assessment proves crucial—policy ambition must match industry capabilities and potential for growth. China's phased implementation approach shows how requirements can be gradually enhanced as market capacity develops, starting with larger cities or specific building types before expanding coverage. Third, resource allocation decisions fundamentally affect implementation success. Rwanda's experience demonstrates how limited resources can be effectively focused by starting with basic, enforceable requirements in major urban areas before expanding scope and complexity.

These dimensions provide a framework for policy makers to develop implementation strategies that reflect local conditions while maintaining progress toward energy efficiency goals. Successful implementation requires sustained commitment to capacity building across multiple stakeholders—from building officials and design professionals to contractors and building operators. The evidence from various jurisdictions consistently shows that investing in foundational capacity before enforcement proves more effective than attempting to drive compliance through regulations alone.

## 8.1 Strategic Implementation Framework

Successful implementation begins with integrating energy codes into existing building regulation systems rather than creating parallel processes. Singapore's approach demonstrates how energy requirements can be seamlessly incorporated into established building control systems, creating efficient processes for developers and builders. Policy makers must evaluate their current regulatory landscape and understand relationships between different levels of government involved in building regulation. Germany's experience shows how national frameworks can effectively coexist with local implementation, providing consistency while enabling regional adaptation.

Market readiness assessment is crucial for successful implementation. Policy makers must realistically evaluate their construction industry's capabilities and potential for growth. China's experience demonstrates how phased implementation allows markets to develop necessary capabilities gradually, starting with larger cities or specific building types. This approach gives the industry time to build capacity while maintaining momentum. The availability of materials, technologies, and skilled professionals significantly influences implementation success, as demonstrated by Korea's successful coupling of code requirements with industry development programs.

Resource allocation decisions fundamentally affect implementation success. Rwanda's experience shows how limited resources can be effectively focused by starting with basic, enforceable requirements in major urban areas before expanding scope and complexity. When planning implementation timelines, evidence from successful implementations consistently shows the value of prioritizing capacity building

before enforcement. This includes investing in training programs for building officials, design professionals, and construction industry stakeholders, as demonstrated by India's ECBC implementation and China's tiered city-level rollouts.

## 8.2 Implementation Process

The implementation process should follow a methodical progression aligned with institutional capacity and market readiness. The initial phase focuses on establishing basic institutional frameworks and clear compliance pathways, including inspection protocols, documentation requirements, and official training. Singapore's early implementation demonstrates how strong institutional foundations enable effective technical requirements later.

Technical requirements should be introduced strategically based on local climate conditions and market capacity. Gulf Cooperation Council countries show how envelope requirements often prove most critical initially in hot climates, while temperate regions might prioritize heating system efficiency. The progression of technical requirements should align with verification capability. Lighting standards often provide an effective starting point, combining clear specifications with straightforward verification procedures. Malaysia's experience demonstrates how success with basic lighting requirements builds confidence for more complex HVAC standards.

As market capacity develops, requirements can expand to cover more complex building systems. HVAC requirements typically demand more sophisticated testing facilities and professional expertise. India's phased implementation of its ECBC shows how technical requirements can expand as market infrastructure develops, including establishing testing laboratories, certification programs, and professional training systems.

## 8.3 Support Systems and Market Development

Successful implementation relies heavily on comprehensive support mechanisms. Technical support is particularly crucial in early stages, with countries like Australia and Singapore demonstrating the value of establishing technical assistance networks early. This includes developing design guidelines, compliance tools, and training programs. For countries with existing codes, specialized support for new requirements and emerging technologies becomes important.

Financial incentives play varying roles depending on market maturity. Emerging markets often focus on offsetting initial compliance costs and encouraging early adopters, while mature markets typically use targeted incentives to drive innovation and support ambitious performance targets. Successful programs often combine multiple incentive types—tax benefits, grants, low-interest loans, and rebates—tailored to different market segments.

## 8.4 Future Preparedness and Forward-Looking Requirements

BECs must evolve systematically to address emerging challenges while maintaining implementation feasibility. The analysis reveals that successful jurisdictions are incorporating forward-looking elements into

their regulatory frameworks, particularly around climate adaptation, technological integration, and market transformation. This proactive approach enables BECs to remain relevant and effective as both climate conditions and building technologies continue to evolve.

Technological integration and digital transformation represent key dimensions of future-ready building codes. Singapore's Green Mark scheme demonstrates successful integration of smart building requirements into its code framework, mandating building management systems for larger buildings that can monitor and optimize energy consumption in real time. The EU's Energy Performance of Buildings Directive provides a model for promoting technological advancement by requiring all new buildings to be 'smart-ready', with capabilities for automated energy management and grid interaction. In terms of renewable energy integration, Germany's building codes now include specific requirements for solar-ready roofs in new construction, while California has mandated solar panels on most new homes. These requirements, coupled with provisions for energy storage and grid interaction, create a comprehensive approach to building energy systems.

Climate resilience and adaptation have become increasingly critical considerations. Japan's building codes offer a compelling example of how to integrate both energy efficiency and climate resilience concerns, with specific requirements for structural resilience, natural ventilation, and passive cooling. These requirements have proven their value during extreme weather events, with newer buildings maintaining livable conditions even during power outages. France's updated building regulations demonstrate how codes can address urban heat challenges through requirements for external shading, cool roofs, and natural ventilation in new construction. The Netherlands provides another instructive example, combining flood resilience requirements with energy efficiency measures, including elevated ground floors in flood-prone areas while maintaining strict envelope performance requirements.

The increasing importance of grid interaction and distributed energy resources requires BECs to expand beyond traditional efficiency metrics. California's Title 24 energy code demonstrates how these elements can be incorporated systematically, with requirements for solar readiness, battery storage provisions, and demand response capabilities that position buildings as active participants in the broader energy system. Digital enforcement systems must similarly evolve to leverage new technologies. Singapore's comprehensive digital building control system shows how technology can streamline enforcement while improving compliance rates, particularly valuable for emerging economies establishing digital foundations early.

Market transformation pathways must be embedded in code frameworks to ensure long-term effectiveness. Denmark's building regulations exemplify this approach by announcing future requirements several years in advance, allowing markets to prepare while maintaining predictable progress toward climate goals. This forward-signaling helps drive innovation and investment in energy-efficient solutions while providing certainty for market participants. Perhaps most critically, BECs must maintain sufficient flexibility to address unforeseen challenges while providing clear, enforceable requirements. Sweden's building code structure offers a model for this approach, combining mandatory performance requirements with flexible compliance pathways that encourage innovation while maintaining regulatory certainty.

## 8.5 Addressing the Retrofit Challenge

The retrofit challenge represents one of the most significant opportunities for achieving energy efficiency goals yet remains largely unaddressed in most jurisdictions. With only 16 high-income countries currently maintaining retrofit requirements, developing appropriate strategies for existing buildings is crucial. Policy

makers must create distinct approaches for retrofits that differ from new construction requirements while maintaining meaningful impact on building energy performance.

Successful retrofit policies require a multifaceted approach. The EU's experience demonstrates the value of combining technical requirements with financial incentives—Germany's KfW program and France's MaPrimeRénov scheme show how public funding can accelerate retrofit adoption while maintaining high performance standards. For developing economies, simpler assessment tools and staged retrofit requirements, as demonstrated by Mexico's Hipoteca Verde program, can make implementation more feasible.

Implementation should focus on trigger points where retrofits are most cost-effective and least disruptive. This includes major renovations, property transfers, and equipment replacement cycles. Singapore's Green Mark Retrofit scheme demonstrates how requirements can be tailored to different building types and renovation scopes while maintaining clear performance targets. Additionally, policy makers should establish clear metrics for retrofit performance that balance ambition with practical feasibility—Ireland's approach of requiring specific energy performance improvements during substantial renovations provides a replicable model.





## 9. Conclusions

## 9.1 Key Findings

The analysis of BECs across 88 countries reveals critical patterns in adoption, implementation, and effectiveness that directly inform policy development. Comprehensive code coverage remains limited—while 71 countries have mandatory requirements, only 52 demonstrate consistent enforcement. This enforcement gap significantly undermines potential energy savings, with inconsistent implementation reducing actual savings by 60–70 percent compared to technical potential.

Climate conditions strongly influence both code adoption and technical requirements. Countries in cold and mixed climates show the most comprehensive requirements, particularly for envelope performance and heating systems. However, many hot climate regions lack adequate cooling efficiency standards despite facing rapidly growing cooling demands. This misalignment between climate challenges and regulatory responses represents a significant gap in global building energy efficiency.

Economic capacity influences but does not fully determine BEC adoption patterns. While high-income countries show higher adoption rates (44 out of 47 having codes), several lower-middle-income countries have established basic regulatory frameworks. Rwanda, as the only low-income country in our dataset with building energy requirements, demonstrates that initial code development is possible with limited resources. While our dataset measures the existence of codes, their technical stringency, sectoral coverage, and reported enforcement mechanisms, additional research examining actual energy savings and market transformation outcomes would help better understand success factors across different economic contexts.

Technical requirements show significant variation in coverage and stringency. Space cooling emerges as the most widely regulated aspect (52 countries), followed by lighting (41 countries), while only 36 countries have established heating system standards. This incomplete coverage of major energy systems limits code effectiveness. More critically, only 16 countries have established requirements for existing building retrofits, despite existing buildings constituting the majority of 2050 building stock in developed regions.

Support mechanisms are crucial for implementation success. Countries combining technical requirements with comprehensive support systems show significantly higher compliance rates. The data reveals that 76 percent of countries with effective codes maintain robust technical resource programs, while 43 percent offer financial incentives. However, many countries, particularly in developing regions, lack essential support infrastructure like testing facilities, professional certification programs, and compliance tools.

Market readiness emerges as a fundamental determinant of implementation success. Countries that align technical requirements with market capacity show higher compliance rates and more consistent enforcement. The progression from basic prescriptive requirements to performance-based standards requires systematic development of market infrastructure, including testing facilities, professional expertise, and verification capabilities.

Future challenges emerge primarily in code coverage and enforcement effectiveness. The analysis reveals significant gaps in enforcement mechanisms, with only 33 out of 88 countries including critical measures like third-party inspector qualifications and oversight bodies. Technical infrastructure for compliance verification varies widely, particularly for complex requirements like building envelope and HVAC system performance. These gaps in coverage and verification capabilities threaten long-term code effectiveness as building energy efficiency requirements become increasingly stringent to meet climate commitments.



## 9.2 Pathways for Progress

**The Coverage Imperative:** With 2.55 billion square meters of new floor space built without energy requirements in 2023, expanding code coverage represents an urgent priority. Success stories from diverse contexts—from Rwanda’s implementation in resource-constrained environments to China’s tiered city approach—demonstrate that progress is possible across different economic contexts. Regional cooperation, particularly in rapidly urbanizing areas, offers promising models for expanding coverage efficiently.

**The Enforcement Evolution:** Analysis shows enforcement effectiveness, rather than code stringency, determines success. The 52 countries demonstrating consistent enforcement share common elements—clear compliance pathways, systematic verification procedures, and robust support mechanisms. These experiences provide replicable models for strengthening enforcement globally.

**The Technology Bridge:** Countries are bridging traditional divides between prescriptive and performance-based approaches through technology integration. Singapore’s digital building control system and Estonia’s performance-based framework show how technology can enhance both compliance and verification while reducing administrative burdens.

## 9.3 The Path Forward

Meeting Paris Agreement targets requires unprecedented transformation of the building sector. Success requires parallel progress on three fronts: expanding coverage to regions currently lacking requirements, strengthening enforcement in jurisdictions with existing codes, and developing retrofit requirements for existing buildings. The experiences documented in this analysis demonstrate that while challenges are significant, proven solutions exist across different contexts.

The urgency for action has never been greater. By 2030, global housing needs will grow by more than 77 billion square meters of floor space. The decisions made today about building energy efficiency will shape emissions trajectories for decades. However, this unprecedented construction boom also presents an opportunity to reshape the built environment for a low-carbon future.

The path forward must balance ambition with practicality through strategic implementation pathways that reflect local conditions while maintaining clear progress toward climate goals. Emerging markets should focus on establishing foundational elements—creating basic but mandatory requirements for larger buildings in major urban centers while systematically developing the necessary market infrastructure. These jurisdictions need clear roadmaps that align code development with growth in technical capacity and enforcement capabilities, particularly focusing on requirements that can be effectively verified with limited resources.

Transitioning economies face the challenge of strengthening existing frameworks while expanding their scope and effectiveness. These countries should implement regular code update cycles that progressively increase stringency while maintaining achievable compliance pathways. The focus should be on developing sophisticated enforcement systems, including digital compliance tools and automated verification processes, while expanding requirements to address both new construction and existing buildings.

Advanced economies must lead the transition toward next-generation BECs that drive market transformation toward net-zero performance. This includes developing innovative enforcement approaches that leverage data analytics and automated compliance verification, while creating mechanisms for regional

knowledge sharing and capacity building. These jurisdictions should also pioneer new approaches to existing building requirements, creating replicable models for achieving deep energy savings in standing stock.

Across all contexts, success depends on creating self-sustaining implementation frameworks that align policy requirements with market capacity. This means establishing dedicated funding streams for enforcement, developing professional certification programs for building officials and practitioners, and creating systematic processes for code updates that respond to market evolution and technology advancement. While implementation velocities will vary based on local conditions, all jurisdictions must establish concrete action plans with clear accountability for achieving full code implementation and enforcement. The focus must shift from policy adoption to creating lasting market transformation that delivers measurable reductions in building energy consumption and emissions.

## Endnotes

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- <sup>42</sup> <https://www1.bca.gov.sg/buildsg/sustainability/green-mark-incentive-schemes/building-retrofit-energy-efficiency-financing-brief-scheme>
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- <sup>47</sup> <https://projects.worldbank.org/en/projects-operations/project-detail/P164938>
- <sup>48</sup> <https://eprel.org/>
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# Annexes

## Annex 1. Countries in the Building Energy Codes Global Dataset: Regional, Climate Zone, and Income Level Breakdown

Country	City covered	Region	Climate Zone	Income Level
Albania	Tirana	Europe and Central Asia	Warm, Humid	Upper-middle
Algeria	Algiers	Middle East and North Africa	Warm, Humid	Lower-middle
Argentina	Buenos Aires	Latin America and Caribbean	Warm, Humid	Upper-middle
Armenia	Yerevan	Europe and Central Asia	Mixed, Humid	Upper-middle
Australia	Melbourne	East Asia and Pacific	Warm, Humid	High
Austria	Vienna	Europe and Central Asia	Mixed, Humid	High
Bahrain	Manama	Middle East and North Africa	Extremely hot, Dry	High
Bangladesh	Dhaka	South Asia	Extremely hot, Humid	Lower-middle
Belgium	Brussels	Europe and Central Asia	Mixed, Humid	High
Brunei Darussalam	Bandar Seri Begwan	East Asia and Pacific	Extremely hot, Humid	High
Bulgaria	Sofia	Europe and Central Asia	Mixed, Humid	Upper-middle
Canada	Toronto	North America	Cool, Humid	High
Chile	Santiago	Latin America and Caribbean	Warm, Dry	High
China	Beijing	East Asia and Pacific	Mixed, Humid	Upper-middle
Colombia	Bogota	Latin America and Caribbean	Warm, Humid	Upper-middle
Costa Rica	San Jose	Latin America and Caribbean	Hot, Humid	Upper-middle
Croatia	Zagreb	Europe and Central Asia	Mixed, Humid	High
Cyprus	Nicosia	Europe and Central Asia	Hot, Humid	High
Czechia	Prague	Europe and Central Asia	Cool, Humid	High
Denmark	Copenhagen	Europe and Central Asia	Cool, Humid	High
Ecuador	Quito	Latin America & Caribbean	Warm, Humid	Upper-middle
El Salvador	San Salvador	Latin America and Caribbean	Extremely hot, Humid	Upper-middle
Estonia	Tallinn	Europe and Central Asia	Cold, Humid	High
Finland	Helsinki	Europe and Central Asia	Cold, Humid	High
France	Paris	Europe and Central Asia	Mixed, Humid	High
Georgia	Tbilisi	Europe and Central Asia	Mixed, Humid	Upper-middle
Germany	Berlin	Europe and Central Asia	Cool, Humid	High
Ghana	Accra	Sub-Saharan Africa	Extremely hot, Dry	Lower-middle
Greece	Athens	Europe and Central Asia	Mixed, Humid	High



Country	City covered	Region	Climate Zone	Income Level
Hong Kong SAR, China	Hong Kong	East Asia and Pacific	Hot, Humid	High
Hungary	Budapest	Europe and Central Asia	Cool, Humid	High
Iceland	Reykjavík	Europe and Central Asia	Cold, Humid	High
India	Mumbai	South Asia	Very hot, Dry	Lower-middle
Indonesia	Jakarta	East Asia and Pacific	Extremely hot, Humid	Upper-middle
Iran, Islamic Rep.	Tehran	Middle East and North Africa	Warm, Dry	Lower-middle
Ireland	Dublin	Europe and Central Asia	Cool, Humid	High
Israel	Jerusalem	Middle East & North Africa	Warm, Humid	High
Italy	Rome	Europe and Central Asia	Warm, Humid	High
Japan	Tokyo	East Asia and Pacific	Warm, Humid	High
Kazakhstan	Almaty	Europe and Central Asia	Cool, Humid	Upper-middle
Kenya	Nairobi	Sub-Saharan Africa	Warm, Marine	Lower-middle
Korea, Rep.	Seoul	East Asia and Pacific	Mixed, Humid	High
Kuwait	Kuwait	Middle East & North Africa	Extremely hot, Dry	High
Kyrgyz Republic	Bishkek	Europe and Central Asia	Mixed, Humid	Lower-middle
Latvia	Riga	Europe and Central Asia	Cold, Humid	High
Lithuania	Vilnius	Europe and Central Asia	Cold, Humid	High
Luxembourg	Luxembourg	Europe and Central Asia	Cool, Humid	High
Malaysia	Kuala Lumpur	East Asia and Pacific	Extremely hot, Humid	Upper-middle
Malta	Valletta	Middle East and North Africa	Warm, Humid	High
Mexico	Mexico City	Latin America and Caribbean	Warm, Humid	Upper-middle
Moldova	Chişinău	Europe and Central Asia	Cool, Humid	Upper-middle
Montenegro	Podgorica	Europe and Central Asia	Warm, Humid	Upper-middle
Morocco	Rabat	Middle East and North Africa	Warm, Humid	Lower-middle
Myanmar	Naipyidó	East Asia and Pacific	Extremely hot, Humid	Lower-middle
Netherlands	Amsterdam	Europe and Central Asia	Mixed, Humid	High
New Zealand	Wellington	East Asia and Pacific	Warm, Humid	High
Nigeria	Lagos	Sub-Saharan Africa	Extremely hot, Humid	Lower-middle
Norway	Oslo	Europe and Central Asia	Cold, Humid	High
Pakistan	Islamabad	South Asia	Hot, Humid	Lower-middle
Panama	Panama City	Latin America and Caribbean	Extremely hot, Humid	High
Paraguay	Asunción	Latin America and Caribbean	Hot, Humid	Upper-middle

Country	City covered	Region	Climate Zone	Income Level
Peru	Lima	Latin America and Caribbean	Hot, Dry	Upper-middle
Philippines	Manila	East Asia and Pacific	Extremely hot, Humid	Lower-middle
Poland	Warsaw	Europe and Central Asia	Cool, Humid	High
Portugal	Lisboa	Europe and Central Asia	Warm, Humid	High
Qatar	Doha	Middle East and North Africa	Extremely hot, Dry	High
Romania	Bucharest	Europe and Central Asia	Mixed, Humid	High
Rwanda	Kigali	Sub-Saharan Africa	Hot, Humid	Low
Saudi Arabia	Riyadh	Middle East and North Africa	Very hot, Dry	High
Serbia	Belgrade	Europe and Central Asia	Mixed, Humid	Upper-middle
Singapore	Singapore	East Asia and Pacific	Extremely hot, Humid	High
Slovak Republic	Bratislava	Europe and Central Asia	Mixed, Humid	High
Slovenia	Ljubljana	Europe and Central Asia	Mixed, Humid	High
South Africa	Pretoria	Sub-Saharan Africa	Warm, Humid	Upper-middle
Spain	Madrid	Europe and Central Asia	Mixed, Dry	High
Sri Lanka	Colombo	South Asia	Extremely hot, Humid	Lower-middle
Sweden	Stockholm	Europe and Central Asia	Cold, Humid	High
Thailand	Bangkok	East Asia & Pacific	Extremely hot, Humid	Upper-middle
Tunisia	Tunis	Middle East and North Africa	Hot, Humid	Lower-middle
Türkiye	Istanbul	Europe and Central Asia	Warm, Humid	Upper-middle
Ukraine	Kyiv	Europe and Central Asia	Cool, Humid	Lower-middle
United Arab Emirates	Dubai	Middle East and North Africa	Extremely hot, Dry	High
United Kingdom	London	Europe and Central Asia	Mixed, Humid	High
United States	Los Angeles	North America	Warm, Marine	High
Uruguay	Montevideo	Latin America and Caribbean	Warm, Humid	High
Uzbekistan	Tashkent	Europe and Central Asia	Mixed, Humid	Lower-middle
Venezuela, RB	Caracas	Latin America and Caribbean	Very hot, Humid	
Viet Nam	Hanoi	East Asia and Pacific	Extremely hot, Humid	Lower-middle

Source: Building Energy Codes Global Dataset, World Bank Group.

## Annex 2. HVAC and Water Heating Enforcement Mechanisms

Country	HVAC Plan	Heating / Cooling Demand Calculations	Efficiency of Heating and Cooling Equipment and Controls	Efficiency of Water Heating Equipment and Controls
Albania	✓	þ	þ	þ
Argentina	..	..	✓	✓
Australia	✓	✓	✓	✓
Austria	✓	✓	✓	✓
Bahrain	þ	þ	þ	þ
Belgium	..	✓	✓	✓
Brunei Darussalam	..	..	þ	..
Bulgaria	þ	✓	✓	✓
Canada	✓	✓	✓	✓
China	þ	✓	✓	✓
Czechia	..	✓	✓	✓
Denmark	✓	✓	✓	✓
Ecuador	..	..	..	þ
Estonia	✓	✓	✓	✓
Finland	✓	✓	✓	✓
France	✓	✓	✓	✓
Germany	..	✓	✓	✓
Greece	..	✓	✓	þ
Hong Kong SAR, China	..	..	✓	..
Hungary	..	✓	..	..
India	✓	✓	✓	✓
Indonesia	✓	✓	✓	..
Ireland	þ	✓	✓	✓
Israel	✓	✓	✓	✓
Italy	..	✓	✓	✓
Japan	✓	✓	✓	✓
Kazakhstan	..	No	✓	..
Kenya	..	..	..	þ
Korea, Rep.	✓	✓	þ	✓
Kuwait	✓	✓	✓	..

Country	HVAC Plan	Heating / Cooling Demand Calculations	Efficiency of Heating and Cooling Equipment and Controls	Efficiency of Water Heating Equipment and Controls
Latvia	..	✓	✓	✓
Lithuania	✓	✓	✓	✓
Luxembourg	..	✓	✓	✓
Malaysia	..	✓	þ	þ
Mexico	✓	..	✓	þ
Montenegro	..	✓	✓	✓
Morocco	..	✓	..	..
Netherlands	þ	þ	þ	þ
New Zealand	✓	..	þ	þ
Nigeria	..	þ	þ	..
Norway	..	✓	✓	✓
Pakistan	þ	þ	þ	..
Peru	þ	✓	þ	þ
Philippines	þ	þ	þ	þ
Portugal	þ	✓	✓	✓
Qatar	✓	✓	✓	✓
Romania	✓	✓	✓	✓
Rwanda	..	þ	þ	þ
Serbia	..	þ	..	..
Singapore	..	✓	✓	✓
Slovak Republic	þ	✓	✓	✓
South Africa	..	..	..	✓
Spain	✓	✓	✓	✓
Sri Lanka	✓	þ	..	..
Sweden	✓	þ	✓	✓
Thailand	✓	✓	✓	✓
Tunisia	✓	þ	þ	þ
Türkiye	..	..	..	✓
United Arab Emirates	✓	✓	þ	✓
United Kingdom	✓	✓	✓	✓
United States	✓	✓	✓	✓
Uruguay	..	..	..	✓

Source: Building Energy Codes Global Dataset, World Bank Group.

Note: ✓ Enforced; þ Enforced inconsistently.

## Annex 3. Lighting Enforcement Mechanisms

Country	Maximum Wattage or Lighting Allowances (Outdoor)	Maximum Wattage or Lighting Allowances (Indoor)	Luminary Efficacy (lm/W)
Algeria	..	✓	..
Argentina	..	..	150
Australia	✓	✓	..
Austria	✓	✓	65*
Bahrain	✓	..	150
Belgium	..	..	65*
Bulgaria	..	..	65
Canada	✓	✓	100
China	✓	✓	..
Croatia	✓	✓	65*
Cyprus	..	..	65*
Czechia	..	✓	65*
Denmark	✓	✓	65*
Ecuador	..	✓	..
El Salvador	..	..	60
Estonia	..	..	65*
Finland	..	✓	65*
France	..	..	65*
Georgia	..	✓	..
Germany	..	..	65*
Greece	..	✓	60
Hungary	..	..	65*
Indonesia	..	✓	75
Ireland	..	..	65*
Italy	..	..	65*
Kazakhstan	..	..	55
Kuwait	..	✓	..
Latvia	✓	✓	65*
Lithuania	..	..	150
Luxembourg	..	..	65*
Malta	✓	✓	65*
Netherlands	..	..	65*

Country	Maximum Wattage or Lighting Allowances (Outdoor)	Maximum Wattage or Lighting Allowances (Indoor)	Luminary Efficacy (lm/W)
Nigeria	..	✓	..
Pakistan	✓	..	..
Peru	..	..	100
Philippines	✓	✓	..
Poland	..	✓	65*
Portugal	..	..	65*
Romania	..	..	65*
Rwanda	..	✓	..
Singapore	..	✓	..
Slovak Republic	..	..	65*
Slovenia	✓	✓	65*
South Africa	..	..	..
Spain	✓	✓	65*
Sweden	..	..	65*
Thailand	✓	✓	..
Türkiye	..	✓	..
Ukraine	..	..	75
United Arab Emirates	✓	✓	..
United Kingdom	..	✓	75
United States	..	..	45
Venezuela, RB	..	..	45

Source: Building Energy Codes Global Dataset, World Bank Group.

\* For EU countries, the luminaire efficacy is standardized in accordance with the Energy Performance of Buildings Directive (EPBD) requirements