Mapping Energy Efficiency:

A Global Dataset on Building Code Effectiveness and Compliance

METHODOLOGY NOTE

THE WORLD BANK
Development Economics • Global Indicators

KnowledgeFORChange

The World Bank 1818 H Street NW Washington DC 20433 Telephone 202-473-1000

www.worldbank.org

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Acronyms

AC	Air Conditioning
BEC	Building Energy Code
COP	Coefficient of Performance
DR	Desk Research
EER	Energy Efficiency Ratio (see also: SEER)
EF	Energy Factor
IEA	International Energy Agency
HVAC	Heating, Ventilation, and Air Conditioning
lm	Lumen
OTTV	Overall Thermal Transfer Value
RTTV	Roof Thermal Transfer Value
SA	Survey Answers
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
Wh	Watt-hour

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1.0 Background

1.1 Conceptual Framework

The UNEP estimates that by 2030 the energy intensity per square meter of the global building sector needs to improve on average by 35 percent to meet global climate goals set forth in the Paris Agreement.[1] Despite this, only 30 countries have referenced building energy codes as part of their Nationally Determined Contributions (NDCs) under the Paris Agreement on Climate Change, which entered into force in November of 2016. Although the building sector energy intensity has improved by roughly 1.5 percent per year, its net Greenhouse Gas (GHG) emissions are still increasing, because these improvements are offset by the growth in global floor area, which is expanding by 2.3 percent year on year globally. Even though advanced building energy codes can reduce a building's energy consumption by up to 70 percent, the adoption of these codes and standards has been slow and uneven globally.

This dataset covers 88 countries that have adopted and made mandatory a building energy code or building energy efficiency standards in at least one city. Among these, there is wide variation in the stringency and applicability of the codes (minimum performance standards, coverage, and types of buildings affected).

1.2 Objectives

This project aims to address this issue through its two main objectives.

First, by creating a primary dataset on building energy code standards, coverage and compliance levels, we will finally have a database of accurate and up-to-date information on building energy codes and standards across a large set of economies. Although organizations such as the International Energy Agency (IEA) publish country profiles and energy efficiency policies, a dataset using standardized definitions and common metrics across economies has not yet been developed. There is also very limited cross-country data on the actual enforcement of building energy codes, and levels of compliance. This project has therefore surveyed experts and relevant firms to evaluate the substantive enforcement of minimum energy performance standards through disclosure and compliance-checking mechanisms to make more meaningful comparisons between cities and countries.

Second, through the creation of a benchmarking tool, progress can be measured toward energy policy and emissions reduction goals through adoption and enforcement of building energy codes. A single dataset with harmonized and standardized metrics to evaluate building energy codes across countries would allow researchers, statisticians, and data scientists to apply the analytical approaches needed to generate a meaningful cost–benefit analysis as well as projected outcomes sought through the adoption of given codes and standards.

1.3 Approach to data collection

1.3.1 DATA COLLECTION METHODOLOGY

The project employed a multi-phase data collection methodology, engaging a diverse array of stakeholders ranging from architects and engineers to construction sector professionals. This engagement is facilitated through an online questionnaire available in five languages and a downloadable MS Word document, designed to invite global participation. This methodology benefits from the vast experience of the Development Economics Global Indicators Group (DECIG) in collecting detailed annual data on regulations, including those related to building control.

1.3.2 QUESTIONNAIRE AND EXPERT CONSULTATIONS

The online questionnaire played a crucial role in the data collection process, engaging experts across various fields such as architecture, engineering, environmental consulting, building surveying, and academia. This approach was designed to ensure a comprehensive and varied collection of data, enhancing the dataset's overall quality and relevance. The survey was made available in both a digital format and as a downloadable Word document, facilitating easy access for contributors from different backgrounds and with different preferences.

Experts were specifically queried about mandatory minimum energy performance standards, to gather detailed information on this critical aspect of building energy efficiency. Notably, most experts who responded to the questionnaire were from the private sector. This fact highlights the significant involvement of private sector professionals in addressing building energy efficiency issues, underscoring the private market demand for energy efficiency in buildings, and showcasing the alignment between both private and public sectors in advancing this crucial agenda. The collection of diverse insights from individuals primarily operating in the private sector enriches the dataset, providing a balanced perspective on the depth of implementation of building energy efficiency standards and typical challenges to enforcement. This inclusion of a broad range of experts ensures that the dataset not only serves academic and policy-making purposes but is also grounded in practical, real-world applications and experiences.

1.3.3 DESK RESEARCH AND ANALYSIS

Desk research formed a foundational component of the data collection strategy for The Global Dataset on Building Energy Efficiency Code Effectiveness and Compliance project. This initial phase focused on a detailed analysis of national standards related to building energy efficiency. Recognizing the significant within-country variations—particularly those arising from different

climate zones—a methodical approach was adopted to ensure the relevance and accuracy of the data collected.

To account for these variations, the analysis team selected for detailed analysis one city per country, considering various factors, such as prevailing building demand, and population growth, and prominence (consequently the capital city was often chosen). This selection was also based on the city's climate zone, aiming to reflect the mandatory standards that are most relevant to most urban areas within that country. This approach allowed for a nuanced understanding of how national standards translate into local requirements, accommodating the diversity of climate conditions that can affect building energy efficiency.

Following the selection of cities, the team then cross-referenced these with the cities included in the survey phase of the project. This step was crucial to ensure consistency between the desk research findings and the survey data. By aligning the cities surveyed with those studied during the desk research phase, the project ensured that the dataset would offer a coherent and comprehensive overview of building energy efficiency codes and standards, directly correlating with the specific climate zones of major cities.

By integrating national standards analysis with climate-specific considerations, the project offers valuable insights into how different regions address the challenges and opportunities of energy-efficient building practices.

1.3.4 NATIONAL BUILDING ENERGY CODES AND INDIVIDUAL STANDARDS

In cases where countries lacked unified building energy codes, the research explored individual standards that contribute to energy efficiency. This investigation was crucial for understanding the regulatory landscape in countries with decentralized or nonuniform energy efficiency regulations. By consulting experts to clarify ambiguities and access vital regulatory information, the project ensured the accuracy and completeness of its dataset, even in challenging regulatory environments.

1.3.5 A CITY-LEVEL ANALYSIS

While the project's analysis acknowledges that many of the examined building energy codes and standards operate on a national level, the dataset specifically references one city per country. This focused approach is adopted due to the recognition that, in several instances, building energy codes 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 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.

1.3.6 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 dataset provides data at the city level rather than the country level due to significant geographic and climate differences that can exist within single 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'.[2] This approach and the specific classification it represents are also widely recognized and utilized in academic research,[3],[4] reflecting a common methodology for analyzing and addressing climatic impacts on building design and energy efficiency.

2.0 **Methodology**

2.1 Overview of dataset: breakdown of variables

2.1.1 OVERVIEW OF BUILDING ENERGY CODES AND STANDARDS

This section contains detailed information on the existence and characteristics of the building energy code (BEC) in each city. Tables 2.1.1.1 to 2.1.3.10 detail the variables covered by the dataset.

The indicators are the fruit of both desk research (DR) and survey answers (SA). The approach to data collection methodology is detailed in section 1.3. The section reveals the type of building code adopted by the city and makes note of its overall approach. A prescriptive building code is focused on providing detailed standards for passive design and for building equipment, whereas a performance-based code generally mandates a minimum performance level, or introduces a points-based system where tradeoffs between building components are permitted as long as an overall minimum performance level is attained. Similarly, building energy codes may vary in terms of the types of structures and buildings covered—or exempted—as well as by the types of projects that trigger enforcement. In some jurisdictions only new buildings must comply with the code while in others significant alterations, change of occupancy and renovation projects also require building energy efficiency compliance.

Table 2.1.1.1 // Overview of Building Energy Codes and Standards

Indicator	Code	Details	Source*
Existence of Unified BEC	BEC-INFO-01	A "Yes" indicates that there is a known unified Building Energy Code (BEC).	SA, DR
Unified BEC name	BEC-INFO-02	The name of the code.	SA, DR
BEC or Standard Jurisdiction	BEC-INFO-03	Type of jurisdiction: national, state or provincial level, or local or city level.	SA, DR
BEC or Standard Approach	BEC-INFO-04	Categorical variable with three options: - Performance-based: a points-based system mandating an overall minimum energy performance of the building but not mandating specific standards for each component. - Prescriptive: detailed standards for passive design and for HVAC and lighting equipment, appliances, and systems. - Combination of the two.	SA
Primary Energy Performance Requirements	BEC-INFO-05	Indicates whether Primary Energy Performance Requirements are explicitly stated in the BEC.	DR
Building project types covered			
Partial Score	BEC-PROJ-01	Indicates how many of the following indicators are covered.	SA
New buildings	BEC-PROJ-02	A "Yes" indicates that the type of building-related project is covered by the known BEC.	SA
Renovations	BEC-PROJ-03		
Additions	BEC-PROJ-04		
Alterations	BEC-PROJ-05		
Repair Projects	BEC-PROJ-06		
Change of Occupancy	BEC-PROJ-07		
Buildings exempted in practice			
Partial Score	BEC-EXEM-01	Indicates how many of the following indicators are covered.	SA
Retail	BEC-EXEM-02	A "Yes" indicates that the type of building is exempted from the BEC requirements in practice.	SA
Office Buildings	BEC-EXEM-03		
Public Services	BEC-EXEM-04		
Medical Services	BEC-EXEM-05		
Education	BEC-EXEM-06		
Warehouse	BEC-EXEM-07		
Entertainment	BEC-EXEM-08		
Single Houses	BEC-EXEM-09		
Townhouses	BEC-EXEM-10		
Apartment Buildings	BEC-EXEM-11		
Movable Dwellings	BEC-EXEM-12		

**DR=Desk Research; SA= Survey Answers*

2.1.2 OVERVIEW OF ENFORCEMENT & COMPLIANCE

This part of the dataset measures the enforcement of mechanisms of building energy codes—and compliance—subdivided into the preconstruction, postconstruction, and retrofit enforcement requirements. This section also covers retro-commissioning and energy performance disclosure, offering a panoramic view of the varied dimensions of energy code enforcement. The dataset records substantive enforcement of BEC as reported by local experts, including by third-party professionals. In addition, the section covers compliance of design with energy efficiency requirements in the preconstruction phase, building plan review components, postconstruction compliance requirements as well as retrofitting, recommissioning and energy performance disclosure requirements. Finally, the dataset also records availability of financial incentives and resources provided to construction professionals to improve adoption of energy efficiency measures.

a. Enforcement overview

Table 2.1.2.1 // Enforcement indicators

Indicator	Code	Details	Source
BEC enforced in practice	ENF-INFO-01	Indicates the enforcement status with three options: - Yes: consistent and full enforcement. - Yes, but inconsistently or partially: enforcement that may not be uniform or comprehensive. - No: no active enforcement of the BEC.	SA
Year BEC First Enforced	ENF-INFO-02	The year the known unified BEC was first enforced.	SA, DR
Third-party enforcement system			
Partial Score	ENF-AUTH-01	Indicates how many of the following indicators are covered.	SA
Authorization procedure	ENF-AUTH-02	- Yes: the BEC describes the procedure to authorize third-party inspectors. - No: it does not.	SA
Professional Qualifications	ENF-AUTH-03	- Yes: the BEC describes the professional qualifications required to register as a third-party inspector. - No: it does not.	
Independent Body	ENF-AUTH-04	- Yes: the BEC establishes an independent body charged with developing guidelines, standards and/or codes of conduct for third-party inspectors. - No: it does not.	
Supervisory Body	ENF-AUTH-05	- Yes: the BEC establishes a supervisory body to ensure third-party inspections are conducted appropriately and without conflict of interest. - No: it does not.	

b. Preconstruction Enforcement & Compliance

Local building control authorities may require that energy efficiency requirements are incorporated into the building design even before the construction process can begin This section of the dataset examines what components are reviewed for building permit approvals. The compliance pathways are evaluated to determine how compliance is verified with a partial score assessing how comprehensive the review and approval process is for the city. In more advanced

jurisdictions, energy use modeling may be required, while in others building plans are reviewed to ensure that minimum requirements are met.

Table 2.1.2.2 // Preconstruction enforcement indicators

Indicator	Code	Details	Source
Preconstruction Design Compliance (Building Permit)	ENF-PERM-01	- Yes: the city mandates proof of design compliance with green building codes before issuing a building permit. - No: it does not.	SA
Design Compliance Components			
Partial Score	ENF-PERM-02	Indicates how many of the following indicators are covered.	SA
Checklist of passive design features	ENF-PERM-03	- Yes: the component is considered before issuing a building permit. - Yes, but inconsistently: the component is inconsistently considered before issuing a building permit. - No: the component is not considered before issuing a building permit.	SA
Energy Verification Worksheets	ENF-PERM-04		
Energy Models	ENF-PERM-05		
Commissioning Plans	ENF-PERM-06		
HVAC Plans	ENF-PERM-07		
Lighting Plans and Schedules	ENF-PERM-08		
Building Plan Review Components			
Partial Score	ENF-REVW-01	Indicates how many of the following indicators are covered.	SA
Thermal transmittance or insulation calculations for building envelope	ENF-REVW-02	- Yes: the component is reviewed as part of the building plan. - Yes, but inconsistently: the component is inconsistently reviewed as part of the building plan. - No: the component is not part of the building plan or is not reviewed.	SA
Solar heat gain calculations for building envelope	ENF-REVW-03		
Glazing factors for fenestration	ENF-REVW-04		
Heating/Cooling demand calculation	ENF-REVW-05		
Daylighting and orientation	ENF-REVW-06		
Permanent shading	ENF-REVW-07		
Air barrier, air leakage, or air infiltration	ENF-REVW-08		
Efficiency of Heating/Cooling equipment and controls	ENF-REVW-09		
Efficiency of Water Heating equipment and controls	ENF-REVW-10		
Efficiency of lighting fixtures and controls	ENF-REVW-11		
Insulation and heat traps	ENF-REVW-12		

c. Postconstruction Enforcement & Compliance

This section of the dataset examines if certain practices, including as-built energy verification, visual/walkthrough inspections, and energy audits, are mandated by law and enforced in practice. These inspection practices are meant to provide a postconstruction verification to determine if they were constructed in accordance with the approved building plans as well as to determine if the actual energy performance matches the minimum requirements of the equipment installed in the building.

Table 2.1.2.3 // Postconstruction enforcement indicators

Indicator	Code	Details	Source
Postconstruction Design Compliance (Occupancy)	ENF-POST-01	This binary variable determines whether cities require proof of green building code compliance as a prerequisite for occupation permit issuance or occupancy authorization.	SA
Postconstruction Design Compliance Components in Practice			
Partial Score	ENF-POST-02	Indicates how many of the following indicators are covered.	SA
As-built Energy Verification or Compliance	ENF-POST-03	- Yes: the component is considered for authorizing occupancy. - Yes, but inconsistently: the component is inconsistently considered for authorizing occupancy. - No: the component is not considered for authorizing occupancy.	SA
Visual / Walkthrough Inspection	ENF-POST-04		
Energy Audit	ENF-POST-05		

d. Retrofitting, Retro-commissioning, and Energy Performance Disclosure

Retrofitting offers the opportunity to improve the efficiency level of existing buildings. The dataset examines what retrofitting requirements are mandated by law, and what disclosure mechanisms are in place to ensure transparency with regard to energy use and energy performance levels.

As building occupants incur significant energy-related costs, disclosure of the energy performance can encourage or deter a potential occupant's willingness to acquire or rent a building or unit. The dataset assesses the type of disclosure mechanisms enforced in practice including metering data, parametric analysis which measures the gap between actual and predicted performance, or the disclosure of the history of building maintenance as an alternative pathway. In the most advanced jurisdictions, actual CO2 emission equivalent can be estimated allowing for precise comparisons between buildings.

Additionally, the type and quality of materials impacts factors such as thermal transmittance through a building element, thus affecting the overall efficiency of the building envelope. Building material production is also a major source of CO2 emissions, in particular the manufacture of cement, steel and aluminum. Some regulatory frameworks are incorporating "whole life carbon" approaches to encourage recycling materials or at least to account for the embodied carbon and energy footprint of materials used to construct new buildings.

Table 2.1.2.4 // Retrofitting and disclosure standards

Indicator	Code	Details	Source
Retro Commissioning Standards	ENF-RETR-01	Assesses the existence of standards for retro-commissioning.	SA
Retrofitting Requirements	ENF-RETR-02	Assesses the existence of legal requirements for retrofitting existing buildings to improve energy efficiency.	SA
Public Disclosure of Energy Performance	ENF-DISC-01	Ascertains if there are mandates for the public disclosure of a building's energy performance.	SA
Energy Performance: Public Disclosure Mechanisms			
Partial Score	ENF-DISC-02	Indicates how many of the following indicators are covered.	SA
Parametric Energy Use Monitoring	ENF-DISC-03	- Yes: the mechanism is part of the disclosure system. - Yes, but inconsistently: the mechanism is part of the disclosure system, but inconsistently. - No: the mechanism is not part of the disclosure system.	SA
Parametric Energy Performance Analysis	ENF-DISC-04		
Building Schedule of Maintenance	ENF-DISC-05		
Metered Energy Data Display	ENF-DISC-06		
CO2 Emissions Equivalent	ENF-DISC-07		
Requirements on Construction Materials			
Partial Score	ENF-MATR-01	Indicates how many of the following indicators are covered.	SA
Energy Efficiency Ratings	ENF-MATR-02	- Yes: construction materials are subject to the mechanism. - Yes, but inconsistently: the requirements on construction materials are inconsistently enforced. - No: the mechanism is not enforced on construction materials.	SA
Mandatory Labeling	ENF-MATR-03		
Mandatory Laboratory Testing	ENF-MATR-04		
Mandatory Independent Certification	ENF-MATR-05		

e. Resources to facilitate compliance

Ensuring the availability of resources is essential in facilitating compliance with building energy efficiency measures. Comprehensive guides for both designers and occupants serve as blueprints, fostering understanding and implementation of energy-saving practices from inception to daily usage. Consumer databases offering information on energy-efficient appliances empower individuals to make informed choices, amplifying the impact of energy-efficient upgrades. Equally crucial are training programs, equipping professionals with the skills to integrate energy-saving technologies effectively. Financial incentives such as grants, tax credits, rebates, and loans

provide the necessary financial support, incentivizing adoption of energy-efficient solutions by mitigating initial investment costs. Together, these resources form a robust framework, essential for achieving widespread adoption of energy-efficient practices, thereby reducing carbon footprint and promoting sustainable development.

Table 2.1.2.5 // Resources offered to encourage compliance or improvements in energy efficiency

Indicator	Code	Details	Source
Resources to Facilitate Compliance			
Partial Score	RES-FACI-01	Indicates how many of the following indicators are covered.	SA
Designer and Occupant Guides	RES-FACI-02	- Yes: the resource is available. - Yes, but inconsistently: indicates inconsistent availability of the resource. - No: the resource is not available.	SA
Consumer Databases for Energy-Efficient Appliances	RES-FACI-03		
Training Programs	RES-FACI-04		
Financial Incentives			
Partial Score	RES-FINA-01	Indicates how many of the following indicators are covered.	SA
Grants	RES-FINA-02	- Yes: a financial incentive is available. - Yes, but inconsistently: indicates inconsistent availability of the financial incentive. - No: no financial incentive is available.	SA
Tax Credits	RES-FINA-03		
Rebates	RES-FINA-04		
Loans	RES-FINA-05		

2.1.3 ENERGY EFFICIENCY DESIGN AND TECHNOLOGY REQUIREMENT INDICATORS: BREAKDOWN OF VARIABLES

The stringency level of an economy may be assessed based on the:

- Kind of design or technology covered by requirements; for example, in addition to improving the energy efficiency of a heating technology, transitioning to electrical appliances, and phasing out fuel technologies is crucial to reduce heating-related CO2 emissions;
- Existence of enforcement mechanisms associated with a given technology; and
- Gap between the minimum level of performance mandated in the economy and common reference standards in peer countries.

The most widely adopted requirements are adequate metrics for stringency. Therefore, the dataset incorporates some of the most common standards for both passive design (building envelope, roofs, floors, windows, skylights) as well as equipment commonly found in buildings for thermal comfort or illumination (HVAC—space cooling, space and water heating—and lighting).

This section comprises a snapshot of passive design requirements and equipment requirements by economy, as well as a summary of the most common and relevant quantitative requirements.

Table 2.1.3.1 // Energy Efficiency Requirement indicators

Section	Requirements	Code
2.1.3.a	Passive design requirements	REQ-PAS- XX
2.1.3.b	Equipment requirements	
2.1.3.b.i	HVAC and Water Heating	REQ-HVAC-XX
2.1.3.b.ii	Lighting	REQ-LIGH-XX
2.1.3.c	Performance requirements	

The indicators utilize data from both desk research (DR) and survey answers (SA). The approach to data collection methodology is detailed in section 1.3.

a. Passive design requirements

Building should be designed to reduce the use of energy. For example, the design should incorporate the use of natural ventilation and natural light. In addition, minimum performance standards of building equipment should be mandated in order to ensure that lighting, mechanical ventilation, and heating or air-conditioning systems use energy-efficient technology.

With 40 percent of the world's homes requiring space heating (IEA[5]) and cooling being the fastest-growing energy demand in buildings (IEA2[6]), it is critical for regulatory frameworks to target building design features that reduce the need for artificial cooling and heating to the extent possible. This approach aims to adapt the design, structure, and materials of a building to the local climate and environment and to maintain thermal comfort without relying exclusively on mechanical systems. Better passive design reduces or eliminates the need for additional heating or cooling, depending on the building's location.

Table 2.1.3.2 // Passive design indicators: overview

Indicator	Code	Details	Source
Coverage			
Passive design coverage	REQ-PAS-01	A "Yes" indicates that the BEC mandates requirements for any type of new building (residential, commercial, etc.) with respect to one or several of the following passive design features: maximum U-values, maximum solar heat gain coefficient, maximum air leakage.	DR
Passive Design Enforcement			
Partial Score	REQ-PAS-02	Indicates how many of the following indicators are covered.	SA
Checklist of passive design	REQ-PAS-03	- Yes: the component is considered for enforcement. - Yes, but inconsistently: the component is inconsistently considered for enforcement. - No: the component is not considered for enforcement.	SA
Thermal transmittance or insulation calculations for building envelope	REQ-PAS-04		
Solar heat gain calculations for building envelope	REQ-PAS-05		
Glazing factors for fenestration	REQ-PAS-06		
Permanent shading	REQ-PAS-07		
Air barrier, air leakage or air infiltration	REQ-PAS-08		
Stringency			
Passive design requirements	REQ-PAS-XX	A subset of 28 indicators for a variety of passive designs. See Table 2.1.3.3 for breakdown.	DR

The coverage indicators reflect the extent to which a city has incorporated energy efficiency design requirements into its codes and standards. Even when the city's requirements do not match the specific quantitative indicator retained for the dataset, they may be recognized as covering passive design. Other thermal transmittance indicators such as Residential Thermal Transfer Value or Overall Thermal Transfer Value, which only a small sample of countries use, were excluded from the dataset. However, for the countries adopting them, U-values are still included in the list of design categories covered by the code.

Table 2.1.3.3 // Passive design requirements

Indicator	Unit	Code	Details
Maximum U-values	$W/m^2.K$	REQ-PAS-XX	Indicate thermal transmittance through a building envelope element. The lower the more stringent. See Table 2.1.3.4 for breakdown.
Maximum Solar Heat Gain Coefficient (SHGC)	%	REQ-PAS-22	A "Yes" indicates that there is a Maximum Solar Heat Gain Coefficient requirement.
		REQ-PAS-23	SHGC requirement for residential buildings.
		REQ-PAS-24	SHGC requirement for commercial buildings.
Maximum air leakage	$m^3/hr*m^2$	REQ-PAS-25	Indicates the maximum volume of air that can leak through a building envelope (element). The lower the more stringent. A "Yes" indicates that there is a Maximum air leakage requirement.
		REQ-PAS-26	Maximum air leakage requirement for residential buildings.
		REQ-PAS-27	Maximum air leakage requirement for commercial buildings.
Natural Ventilation	m^3/hr	REQ-PAS-28	Indicates the process of renewing indoor air without using mechanical systems.

U-values reflect thermal transmittance through an element of the building envelope. The most relevant building envelope elements are external walls, roofs, and floors. Analysis of other components, such as windows, doors, or skylights, uncovered larger disparities, making stringency comparison more difficult. They are nevertheless still covered in the dataset.

Table 2.1.3.4 // U-values breakdown

Building part covered by U-value	Code	Details
General Coverage	REQ-PAS-09	A "Yes" indicates that at least one building part is covered by U-value requirements.
Roofs	REQ-PAS-10	U-value requirement for residential building roofs.
	REQ-PAS-11	U-value requirement for commercial building roofs.
Floors	REQ-PAS-12	U-value requirement for residential building floors.
	REQ-PAS-13	U-value requirement for commercial building floors.
External walls	REQ-PAS-14	U-value requirement for residential building external walls.
	REQ-PAS-15	U-value requirement for commercial building external walls.

Table 2.1.3.4 // U-values breakdown (cont.)

Building part covered by U-value	Code	Details
Doors	REQ-PAS-16	U-value requirement for residential building doors.
	REQ-PAS-17	U-value requirement for commercial building doors.
Windows	REQ-PAS-18	A "Yes" indicates that there are requirements for residential building windows.
	REQ-PAS-19	A "Yes" indicates that there are requirements for commercial building windows.
Skylights	REQ-PAS-20	A "Yes" indicates that there are requirements for residential building skylights.
	REQ-PAS-21	A "Yes" indicates that there are requirements for commercial building skylights.

b. Technology requirements

In the realm of energy efficiency, rules and enforcement around Heating, Ventilation, and Air Conditioning (HVAC) systems, as well as water heating, are crucial for sustainable building practices worldwide. This section covers how countries regulate and enforce standards for heating, cooling, water heating systems and lighting. The dataset records the coverage of various components, how they are enforced, and how stringent current performance requirements are.

In this section, some European countries that are members of the European Union are mandated to follow the European Ecodesign Directive requirements. Unless a country expresses specific requirements in its code, the dataset provides the European required value. An asterisk (*) indicates that the datapoint corresponds to a European requirement.

i. HVAC and Water Heating

Measuring HVAC and water heating standards is important as these systems account for a significant portion of energy consumption in buildings, often constituting the largest share of energy use.

Table 2.1.3.5 // HVAC and Water heating indicators: overview

Indicator	Code	Details	Source
Coverage			
Space heating coverage	REQ-HVAC-01	A "Yes" indicates that the BEC mandates requirements for fossil fuel boilers and/or furnaces, electrical boilers and/or furnaces, or heat pumps in heating mode.	DR
Water heating coverage	REQ-HVAC-02	A "Yes" indicates that the BEC mandates requirements for water heating.	DR
Space cooling coverage	REQ-HVAC-03	A "Yes" indicates that the BEC mandates requirements for AC systems, heat pumps in cooling mode, or fans.	DR
HVAC and Water Heating Enforcement Mechanisms			
Partial Score	REQ-HVAC-04	Indicates how many of the following indicators are covered.	SA
HVAC Plan	REQ-HVAC-05	- Yes: the component is considered for enforcement. - Yes, but inconsistently: the component is inconsistently considered for enforcement. - No: the component is not considered for enforcement.	SA
Heating/cooling demand calculations	REQ-HVAC-06		
Efficiency of heating and cooling equipment and controls	REQ-HVAC-07		
Efficiency of water heating equipment and controls	REQ-HVAC-08		
Stringency			
Space heating technology requirements	REQ-HVAC-XX	A subset of 13 quantitative and coverage indicators for a variety of space heating technologies. See table 2.1.3.6 for break down.	DR
Water heating technology requirements		A subset of six quantitative and coverage indicators for a variety of water heating technologies. See table 2.1.3.7 for breakdown.	DR
Space cooling technology requirements		A subset of seven quantitative indicators for a variety of space cooling technologies. See table 2.1.3.8 for breakdown.	DR

» *Space and water heating*

According to the International Energy Agency (IEA) almost half of the energy consumption in buildings globally is due to space and water heating, and 40 percent of households require space heating worldwide at least part of the year due to climatic conditions.Fossil fuel-based heating systems remain prevalent globally, even in advanced economies. Gas boilers and furnaces still dominate new equipment sales in various markets.[7] In addition to improving energy efficiency, transitioning to electrical appliances, and phasing out fuel technologies is crucial to reduce heating-related CO2 emissions.

Table 2.1.3.6 // Space heating technology quantitative requirements

Technology	Indicator	Unit	Code	Details
Fossil Fuel Boiler / Furnace	Coverage		REQ-HVAC-09	A "Yes" indicates that fossil fuel burners and/or furnaces are subject to efficiency requirements.
Fossil fuel boiler	Energy Efficiency		REQ-HVAC-10 REQ-HVAC-11	Ratio of the useful heat output to the total energy input. The higher the more stringent.
Fossil fuel furnace	Energy Efficiency		REQ-HVAC-12 REQ-HVAC-13	Ratio of the useful heat output to the total energy input. The higher the more stringent.
Electrical Boiler/ Furnace	Coverage		REQ-HVAC-14	A "Yes" indicates that electrical burners and/or furnaces are subject to efficiency requirements.
Electrical Boiler	Energy efficiency		REQ-HVAC-15 REQ-HVAC-16	Ratio of the useful heat output to the total energy input. The higher the more stringent.
Electrical furnace	Energy efficiency		REQ-HVAC-17 REQ-HVAC-18	Ratio of the useful heat output to the total energy input. The higher the more stringent.
Heat pump	Coverage	Wh/Wh	REQ-HVAC-19	A "Yes" indicates that heat pumps are subject to efficiency requirements.
Heat pump	Coefficient of Performance (COP)		REQ-HVAC-20 REQ-HVAC-21	Ratio of the useful heat output to the total energy input. The higher the more stringent.

Table 2.1.3.7 // Water heating technology requirements

Technology	Indicator	Unit	Code	Details
Fossil fuel water heater	Coverage		REQ-HVAC-22	A "Yes" indicates that fossil fuel water heaters are subject to efficiency requirements.
Fossil fuel water heater	Energy Factor (EF)		REQ-HVAC-23 REQ-HVAC-24	Reflects the overall efficiency of a water heater. The higher the more stringent. Both residential and commercial buildings are covered.
Electric water heater	Coverage		REQ-HVAC-25	A "Yes" indicates that fossil fuel water heaters are subject to efficiency requirements.
Electric water heater	Energy Factor (EF)		REQ-HVAC-26 REQ-HVAC-27	Reflects the overall efficiency of a water heater. The higher the more stringent. Both residential and commercial buildings are covered.

Air-conditioning and mechanical ventilation systems account for a fifth of total electricity use in buildings worldwide and are the fastest growing end-use of energy in buildings. According to the IEA, globally, the overwhelming majority of air-conditioning equipment in use today globally are split systems. In order for buildings to improve their energy efficiency however, more efficient AC technologies including ductless systems, and heat pumps need to replace outdated equipment.

Table 2.1.3.8 // Stringency subindicators: space cooling

Technology	Indicator	Unit	Code	Details
Central AC system	Coverage		REQ-HVAC-28	A "Yes" indicates that Central AC systems are subject to efficiency requirements in terms of Energy Efficiency Ratio (EER) or Seasonal Energy Efficiency Ratio (SEER).
Central AC system	EER	Wh/Wh	REQ-HVAC-29	Ratio of the cooling capacity to the total energy input. The higher the more stringent. Both residential and commercial buildings are covered.
			REQ-HVAC-30	
Split AC system	Coverage		REQ-HVAC-31	A "Yes" indicates that Split AC systems are subject to efficiency requirements in terms of Energy Efficiency Ratio (EER) or Seasonal Energy Efficiency Ratio (SEER).
Split AC system	EER	Wh/Wh	REQ-HVAC-32	Ratio of the cooling capacity to the total energy input. The higher the more stringent. Applies to residential buildings.
Split AC system	EER	Wh/Wh	REQ-HVAC-33	Ratio of the cooling capacity to the total energy input. The higher the more stringent. Applies to commercial buildings.
Heat pump	Coverage		REQ-HVAC-34	A "Yes" indicates that heat pumps in cooling mode are subject to efficiency requirements.
Fan	Coverage		REQ-HVAC-35	A "Yes" indicates that fans are subject to efficiency requirements in terms of fan horsepower or efficiency rate.

Energy Efficiency Ratios (EER) can be expressed in Wh/Wh or Btu/Wh. The dataset units are in Wh/Wh as it is the most prevalent unit internationally. Some economies resort to measurement in refrigeration tons (RT), which can equally be converted. Some countries also have requirements for the Seasonal Energy Efficiency Ratio (SEER): the ratio of the cooling capacity to the total energy input for a representative range of temperature points. Therefore, its measurement for the same appliance varies from one economy to another, making cross-country comparison difficult. For this reason the dataset does not include SEER values.

ii. Lighting

As advancements in lighting technology continue to evolve, measuring standards becomes essential for keeping regulations up-to-date and aligned with industry innovations. In addition, the dataset covers maximum allowable power levels and minimum efficacy requirements, the two most common lighting requirements for energy efficiency.

Table 2.1.3.9 // Lighting indicators: overview

Indicator	Code	Details	Source
Coverage			
Lighting coverage	REQ-LIGH-01	A "Yes" indicates that the BEC mandates requirements for lighting systems.	DR
Enforcement			
Lighting enforcement mechanisms	REQ-LIGH-02	Indicates how many of the following indicators are covered: Lighting Plans and Schedules (ENF-PERM-08, see Table 2.1.2.2), Efficiency of lighting fixtures and controls (ENF-REVW-11, see Table 2.1.2.2).	SA
Stringency			
Lighting technology requirements	REQ-LIGH-XX	A subset of three indicators for lighting technologies. See table 2.1.3.10 for breakdown.	DR

Table 2.1.3.10 // Stringency subindicators: Lighting

Indicator	Unit	Code	Details
Maximum Wattage or Lighting Allowances (Outdoor)		REQ-LIGH-03	As wattage reflects power, a limit on wattage allowance leads to energy savings. The lower the more stringent.
Maximum Wattage or Lighting Allowances (Indoor)		REQ-LIGH-04	
Luminary Efficacy	lm/W	REQ-LIGH-05	Indicates ratio of lighting output (in lumens) to power input (in watts). The higher the more stringent.

ENDNOTES

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