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Minimum Energy Performance Standards for Non-Residential Buildings

EU requirements and national implementation

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Executive Summary

To meet European and national climate targets, EU Member States must transition their building stock to zero-emissions by 2050. This entails shifting heating systems to renewable energy sources and improving the building's energy efficiency through thermal retrofits. Retrofitting buildings, for example with insulation, offers several benefits, including reduced heating costs, decreased dependence on fossil fuel imports, enhanced comfort, and improved health.

In December 2023, the EU agreed a revision to the European Performance of Buildings Directive (EPBD) which introduces "Minimum Energy Performance Standards" (MEPS) for non-residential buildings. Under the revised EPBD, 16% of the worst-performing non-residential buildings will need to be renovated by 2030 and 26% by 2033.

Non-residential buildings include schools, hospitals, offices and shops. They account for 30% of the total floor area in the EU-27 and 34% of the final energy demand for heating and hot water.[1] However, their renovation rate in the EU with 0.5% per year is even lower than for residential buildings with 1.0 % per year.[2]

Successful strategies for renovating non-residential buildings

This study explores how MEPS have already been successful in many countries and regions, and offers a practical guide to their implementation to achieve the 2030 target in EU Member States. Inspired by 15 different countries and regions, the study examines examples where MEPS have been rolled-out. It shows options on designing MEPS, including data gathering and indicator choices, and different approaches to defining "worst performing" buildings. The study then explores the application of MEPS on non-residential buildings in Germany and concludes that the instrument can lead to significant emission and energy savings.

The benefits of MEPS include:

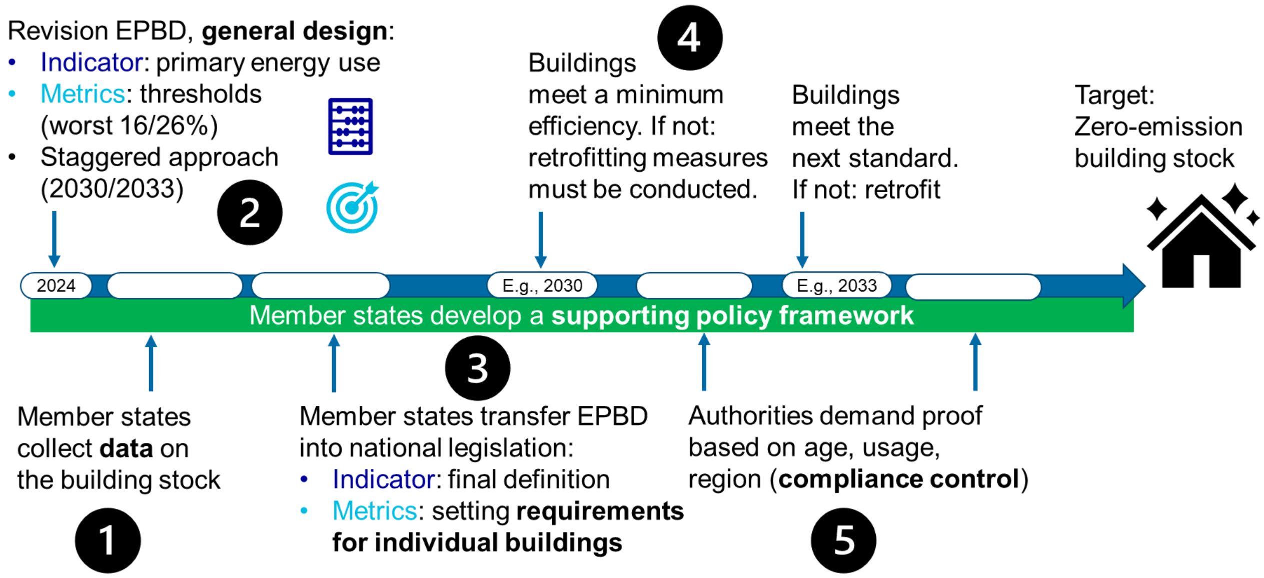
- Prioritising the "worst-performing" buildings first since these have the greatest energy saving potential and thermal retrofits are most economical here
- Avoiding stranded investments in renovations which are not suitable for a zero-emission building stock
- Ensuring deep renovations that improve energy efficiency
- Planning certainty for owners, investors and small businesses
- Lower energy bills

A step-by-step guide to implementation

The report offers a step-by-step guide for national policymakers to help them set up a successful renovation programme for their worst-performing non-residential buildings. Figure 1 illustrates the steps:

[1] Kranzl et al. (2022).
[2] Allianz Research (2022) based on European Commission. Directorate General for Energy. et al. (2019).

Figure 1: Step-by-step guide for Member States implementing MEPS under a revised EPBD



Source: Öko-Institut

Step 1: Collect data on the non-residential building stock

- Map the type of buildings are there in a country as a basis for determining which buildings MEPS should apply to.
- Gather data: number of buildings, floor area and energy use of different categories of non-residential buildings. Reliable data is key to the implementation of MEPS, it can help define useful thresholds for setting requirements as well as categories for different property types with similar usage patterns.
- A sample survey can provide representative data cost efficiently. Geospatial data should be available in all Member States as a result the EU INSPIRE Directive. This data can be a basis for the sample survey as it provides the sampling frame for drawing representative data.
- In parallel, develop a central building database to facilitate enforcement of MEPS and to track progress on achieving targets.

Step 2: Determine how MEPS are defined

- Decide how MEPS are measured. This can influence the choice of policy e.g. an indicator based on primary energy or emissions encourages fuel switch, while an indicator based on final/useful energy demand favours energy efficiency measures such as insulation.
- Define what type of energy use is relevant to comply with MEPS. Is it actual, metered energy use or a calculated demand based on the technical characteristics of a building? This will determine whether building owners can meet the requirement by retrofitting the building, by replacing heating systems with renewable heating, by changing behaviour, by adopting low-cost measures, etc. It will also determine how costly and easy it is to assess compliance.

Step 3: Define requirements for individual buildings

- The energy demand of non-residential buildings varies greatly e.g. a hospital uses energy very differently to an office building. If we are to tackle the worst 16% of buildings, how can we fairly account for this heterogeneity? This study suggests three different approaches, outlined below.

- The study recommends first identifying the share of buildings in terms of heated floor space, and then taking the worst 16%. This is a better indicator than the number of buildings because it avoids giving a lot of weight to smaller buildings with lower total energy consumption.

1. **Approach – define a threshold per building use category**: 1) define categories of buildings; 2) for each category, rank the buildings according to the indicator (e.g. primary energy use in kWh/m^{2}a) using the database established; 3) determine a threshold at which MEPS apply, representing the worst 16% of that category.
2. **Approach – reference building**: 1) compare each individual building to its corresponding virtual reference building (with the same location, geometry, usage category etc.). 2) calculate the ratio and rank the ratio from low (highly efficient buildings that need less energy than their reference building) to high (low efficiency buildings that need more energy than their reference building); 3) determine a threshold at which MEPS apply, representing the worst 16%.
3. **Approach – component-related requirements**. This approach can be used in different ways: owners could demonstrate that the components of their building (e.g. the thickness of wall insulation) comply with a minimum standard by a deadline. Or, owners could be required to implement specific measures in their Energy Performance Certificates or a renovation roadmap. Alternatively, owners could complete a minimum number of measures from a predetermined list within a timeframe. In this case, the 16% threshold is not applicable, but Member States can define criteria for buildings that are likely to be worst performing (e.g. construction year, usage, retrofitting history).

Step 4: Building owners demonstrate that their properties meet the standards

- Energy Performance Certificates could outline the energy use of a building, but they can be costly and there may be a lack of certified energy consultants.
- There are some other options:
  - Require owners to complete a certain number of measures from a pre-defined list
  - Owners complete a questionnaire on building characteristics, energy related information
  - Flexible approach that accepts different forms of proof

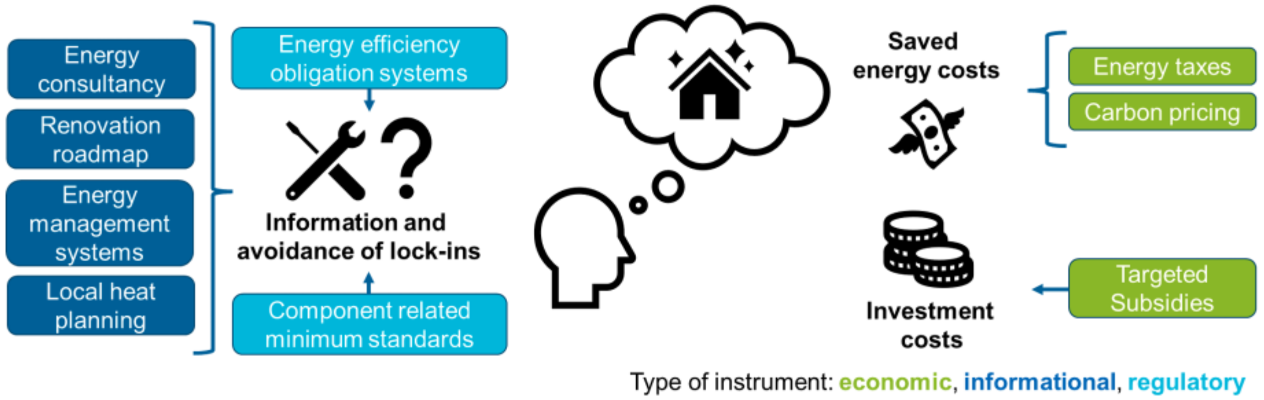
Step 5: Authorities check if each building meets the requirements

- Identify buildings likely to be worst-performing buildings using a set of criteria, e.g. construction year, location, size, renovation status, usage category. The owners must 'clear their buildings' from the list, or comply.
- If not compliant, different options are suggested, such as prohibitions on use or rental, cooperation with banks (credit granting is conditional on fulfilment of requirements), penalty payments (which should incentivise investments without overburdening owners, while also considering how tenants may be affected), naming and shaming.

A supporting policy framework is important

To ensure the acceptance and effectiveness of MEPS, it is crucial to develop a supporting policy framework that assists building owners in implementing retrofit measures. This framework can encompass various components as shown in Figure 2, including adjustments of energy prices (such as taxes or carbon pricing), targeted subsidies, energy consultancy services with renovation roadmaps, energy management systems, local heat planning, energy efficiency obligation systems, and minimum standards related to building components (e.g., rooftop).

Figure 2: A supporting policy framework for MEPS induced retrofits is important



Source: Öko-Institut

Case-study Germany

Germany serves as an exemplary case study as the data available from the research database on non-residential buildings is comparatively good. We have undertaken the task of translating portions of the worst-performing building stock into specific requirements for individual buildings. Our calculations consider primary and useful energy demand, yielding noteworthy findings:

- Threshold values for the "worst 15%" vary by usage category, ranging from 94 kWh/m²/year for offices to 921 kWh/m²/year for sports facilities in terms of primary energy demand.
- The "worst 15%" exhibit a primary energy demand of more than 180% of their corresponding reference building.

Building upon this structural data and the derived threshold values, we have conducted a model-based estimation to assess the potential impact of various EPBD revisions in Germany. Introducing MEPS for non-residential buildings in Germany can save up to 5 Mt of emissions per year in 2030 if the ambitions required in the EPBD are strongly exceeded. The result of the trialogue is close to the General Approach of the council, which is estimated to have a mitigating effect of up to 2 Mt of emissions per year in 2030 in Germany. MEPS for non-residential buildings can contribute substantially to achieving national climate targets in the building sector.

1 Introduction

The decarbonization of the buildings sector is a key priority for achieving climate neutrality in the EU by 2050 and for reducing the dependency on fossil fuel imports. A key driver of the transition of the buildings sector could be Minimum Energy Performance Standards (MEPS). This instrument requires building owners to increase the efficiency of their buildings if the building's energy demand exceeds a defined maximum. It thereby aims to induce retrofits of the most inefficient and therefore called "worst performing buildings".

Previous studies have shown a variety of benefits related to the introduction of MEPS schemes (Sunderland and Jahn 2021; Sunderland and Santini 2020; Braungardt et al. 2022):

- setting priorities by addressing the worst performing buildings first, which have the greatest energy saving potential,
- ensuring deep thermal retrofits and avoiding lock-in-effects of unambitious renovations,
- decreasing the investor-user-dilemma for retrofits of rented buildings,
- increasing planning certainty for owners, investors and craft business,
- decreasing energy poverty and
- improving the potential use of renewable energy heating systems by lowering the flow temperature in efficient buildings.

MEPS for non-residential buildings are part of the revision of the Energy Performance of Buildings Directive (EPBD). Non-residential buildings compromise all types of buildings which are primarily used for purposes other than residential living such as offices, hospitals, industrial facilities or supermarkets. This subsector makes up a relevant share of the building stock in the EU-27 accounting for 30 % of the total floor area and 34% of final energy demand for heating (Kranzl et al. 2022).

While earlier studies primarily focused on the role of MEPS in residential buildings, this report delves into the specific implications of MEPS for non-residential buildings. The energy demand and efficiency of non-residential buildings differs a lot depending on their usage, cubature[3], thermal insulation, degree of mechanization and heating behavior. This heterogeneity makes it more complex to identify the worst performing non-residential buildings and implement a MEPS-scheme addressing them.

This study aims to provide guidance for Member States who are faced with the challenge of implementing a MEPS-scheme for non-residential buildings. The overarching process of revising the EPBD is described in Chapter 2. It also gives an overview about a general procedure on how Member States can implement MEPS. Chapter 3 provides an overview of existing schemes for non-residential buildings, design options and lessons learned. In Chapter 4 we analyze key aspects for implementing MEPS and propose three approaches to address the heterogeneity of the non-residential building stock. As a case-study, we take a deeper look on Germany in Chapter 5 because good data on the characteristics of the buildings stock are available here. On the one hand we derive threshold-values for Germany. On the other hand, we estimate the impact of different MEPS-designs for Germany using a bottom-up modelling approach. Chapter 6 draws conclusions.

[3] Ratio of useful floor area and volume of a building.

2 Background

The concept of establishing minimum standards for building efficiency is not a new one. It has traditionally been applied for two reasons. Firstly, for new constructions, where only buildings meeting specific energy performance criteria are granted construction permits. Secondly, during major retrofit projects, such as comprehensive rooftop renovations, where building owners are required to incorporate a designated level of insulation. In the 2018 revision of the Energy Performance of Buildings Directive (EPBD), these standards are referred to as "minimum energy requirements" (Article 6). Notably, these requirements are conditional, meaning they apply only under certain circumstances, such as new construction or significant retrofitting.

In contrast, Minimum Energy Performance Standards (MEPS), both in the process of revising the EPBD and as referred to in this study, are unconditional. This implies that owners of existing buildings must take proactive steps to ensure that their properties achieve defined efficiency levels by specific deadlines.

This Chapter provides an overview of the proposals for MEPS being considered within the current process of revising the EPBD. Once an updated version of the EPBD incorporating MEPS is adopted, Member States will be responsible for implementing these standards nationally. We will outline a general procedure for how this implementation process can be carried out.

2.1 Discussed proposals for MEPS in the EPBD

The Energy Performance of Buildings Directive (EPBD) is currently under revision in the context of the European Renovation Wave Strategy, the RePowerEU strategy and the European Green Deal. In order to meet the European climate targets for 2030 the efforts of Member States for renovating their building stocks need to be strengthened (European Commission 2021a).

For the adoption of the revised EPBD, the European Commission, the European Parliament and the European Council must reach an agreement within the so-called “trilogue”. This process is now concluded. The institutions agree on the concept of Minimum Energy Performance Standards (MEPS) for non-residential buildings in form of time-related efficiency requirement. This report was mainly written before the trialogue. We therefore refer to the different positions published before the trialogue. Those differ in terms of fulfillment dates and minimum ambition levels, which are expressed through thresholds representing different proportions of the worst-performing building stock in 2020 as shown in Table 2.[4] Table 1 compares the definition of efficiency classes in the positions. The positions of the negotiating parties as well as the result of the trialogue read as follows:[5]

- The agreement of the trialogue, reached at 8th December 2023, is close to the General Approach of the Council, but slightly more ambitious. The 16% energetically worst performing buildings need to be retrofitted until 2030 and the worst 26% until 2033.[6]
- The European Commission (2021b) published its proposal on 15th December 2021, foreseeing MEPS for non-residential buildings with the energy performance classes F and E in 2027 and 2030, respectively (Art. 9 par. 1). The definition of energy classes is shown in

[4] Example for understanding the approach: A buildings stock consists of 100.000 buildings. They get ranked and sorted according to their efficiency. The required efficiency by a 15 %-threshold is the efficiency of the 15.000th least efficient building. All buildings which consume more energy have to be retrofitted until they meet this efficiency level – until a defined date.

[5] See also Sunderland (2023).

[6] European Commission (2023).

Table 1. It is referring to classes of the current building stock sorted by efficiency. Class G reflects the 15 % least energy efficient buildings. Class A represents “zero emissions buildings” (ZEB). We assume that this represents the top 10% most efficient buildings.[7] The remaining efficiency classes B to F reflect an “even bandwidth distribution”[8] (Art. 16 par. 2). In order for all buildings to reach class F, the worst 15% of existing buildings need to be retrofitted. For class E, the worst 30% are affected.

- The Council of the European Union (2022) published its General Approach on 21st October 2022. Instead of defining efficiency classes which represent shares of the stock, the shares are defined directly in terms of thresholds. The 15% energetically worst performing buildings need to be retrofitted until 2030 and the worst 25% until 2034 (Art. 9 par. 1).
- The plenary vote on the position of the European Parliament (2023) took place on 14th March 2023. Similar to the Commission’s proposal, efficiency classes are defined as shown in Table 1: G reflects the worst 15% and F to A have an “even bandwidth distribution”[9] (Art. 16, par. 2). As shown in Table 2 the worst 29% would have to be retrofitted in order reach class E by 2027 and the worst 43% by 2030 in order to reach class D (Art. 9, par. 1).

Table 1: Definition of efficiency classes

Efficiency class (worst … %)	G	F	E	D	C	B	A
Commission	0-15%	16-30%	31-45%	46%-60%	61%-75%	76%-90%	ZEB: 91%-100%
Parliament	0-15%	16%-29%	30-43%	44%-58%	59%-72%	73%-86%	87%-100%

Sources: European Commission (2021b), European Parliament (2023)

[7] In the Commission’s proposal the ZEB-standard for offices in continental climate is defined as less than 85 kWh primary energy use per m² and year. For Germany, this is already reached by 53% of the office buildings (analysis based on Hörner et al. (2022)). We therefore use a more ambitious definition, also introduced by BPIE (2022).
[8] (100%-15%-10%)/5=15% per efficiency class
[9] (100%-15%)/6=14,2% per efficiency class

Table 2: Requirements in positions and agreement of the trilogue

Target efficiency class (worst % to be retrofitted)	2027	2030	2033	2034
Agreement in the trialogue		16%	26%	
Commission	F (15%)	E (30%)		
Council		15%		25%
Parliament	E (29%)	D (43%)		

Sources: European Commission (2021b), Council of the European Union (2022), European Parliament (2023), European Commission (2023)

In all three positions, primary energy use in kWh per m^2 and year serves as the key indicator for overall energy efficiency (Art. 16, par. 1). The Parliament's position also allows Member States to consider indicators related to final energy use and associated carbon footprint. Furthermore, all three positions call for increasing ambition levels over time to ensure the transformation of building stocks into zero-emissions building stocks (Art. 9, par. 1).

The position of the Parliament is the most ambitious with regards to timeline and efficiency classes. The proposal of the Commission and the General Approach of the Council are similar in terms of efficiency levels (15% and 30% vs. 15% and 25%), but the timeline of the Commission’s proposal is more ambitious (2027 and 2030 instead of 2030 and 2034).

2.2 General procedure for implementation

gives an overview about the steps and key aspects in implementing a MEPS scheme. The lessons learned from existing schemes in Chapter 3.2 and 3.3 refer to the key aspects depicted in bold letters in the figure. Additionally, the structure of Chapter 4 corresponds to the steps shown in Figure 3, as indicated by the section numbers within the magnifying glass icons.

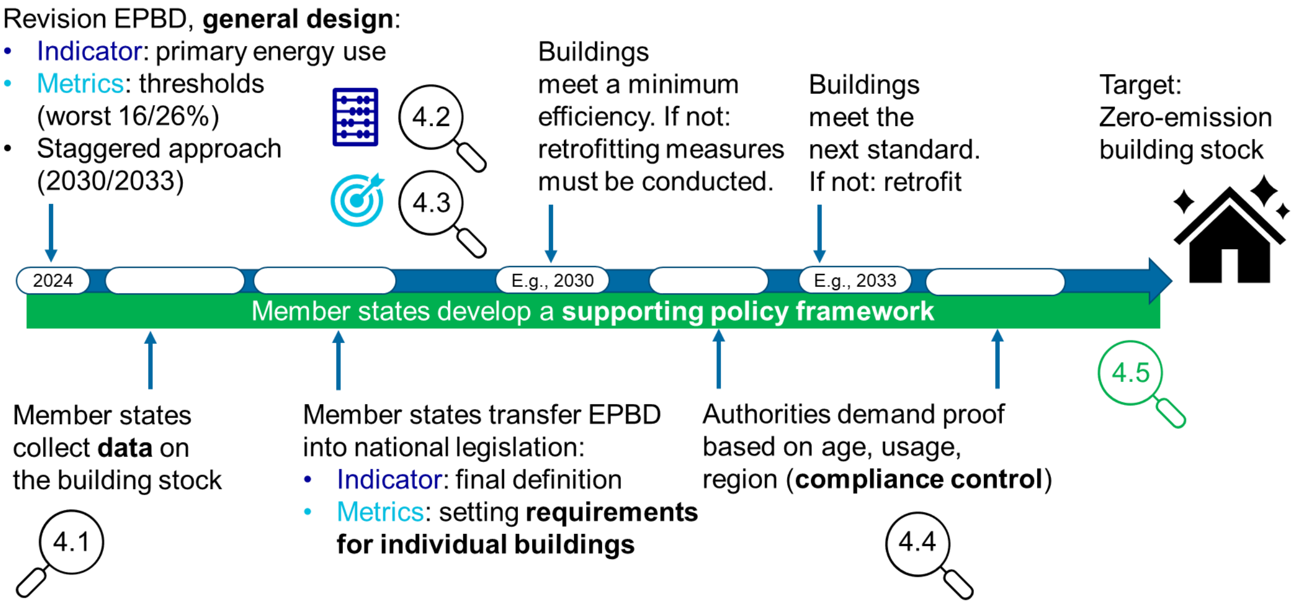
The revision of the EPBD marks the starting point of the flow chart in 2024. The directive determines the general design and minimum ambition level of MEPS, featuring unconditional thresholds ("worst 16/26%") with a staggered approach (until 2030/2033), with primary energy use as the main indicator. Member states are tasked with translating this general design into requirements for individual buildings, which necessitates the collection and analysis of representative data, as discussed in Chapter 4.1.

The EPBD focuses on primary energy use as main indicator. Member states must decide whether they apply operational or asset rating (metered consumption vs. calculated demand). Moreover, additional indicators can be employed for steering the effect of MEPS, as elaborated in Chapter 4.2. Non-residential buildings differ a lot in their energy demand depending on their usage category. Chapter 4.3 presents three approaches on how Member States can define thresholds taking this heterogeneity into account.

Once the MEPS scheme is designed and enacted, building owners are obligated to meet the established requirements until the first compliance cycle, such as in 2030. Authorities must develop an efficient compliance control procedure, as detailed in Chapter 4.4. This may involve prioritizing buildings likely to be worst performing, based on criteria such as age, usage and geographic region.

Concurrently, it is important for acceptance and feasibility that Member States develop a supporting policy framework for thermal retrofits. Chapter 4.5 outlines what this can include: economic incentives like subsidies or carbon pricing, as well as informational instruments such as renovation passports and Energy Performance Certificates.

Figure 3: Possible general procedure for implementing a MEPS scheme

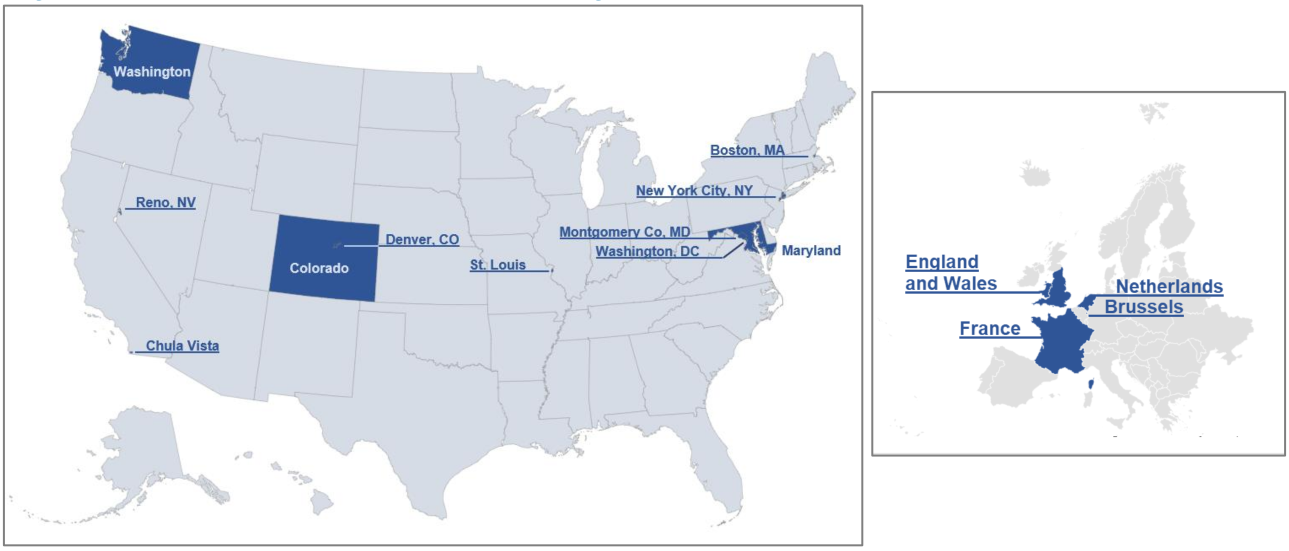


Source: Figure by Öko-Institut

3 Existing MEPS for non-residential buildings

MEPS for non-residential buildings are not a new instrument. They have been established in various national jurisdictions in the EU, the UK and the US, as shown in Figure 4 (Sunderland and Santini 2020; IMT 2023). This section provides an overview of existing MEPS schemes for non-residential buildings and a comparative analysis of key design options. The summary of lessons learned from existing schemes provides a basis for the recommendations in this report and may assist policy makers in implementing new MEPS schemes (see Chapter 3.3).

Figure 4: MEPS for non-residential buildings



Sources: Figure by Öko-Institut based on information from Sunderland and Santini (2020) and IMT (2023)

3.1 Overview

Table 3 shows the main characteristics of the MEPS schemes on non-residential buildings in Europe and the US. Further information on the schemes can be found in the country fact sheets in the annex. Most MEPS schemes in the US apply to larger buildings with a floor area exceeding a defined threshold. Thresholds range from buildings with 20,000 sq. ft. (1,858 m^2) or larger (e.g., Boston, Chula Vista) to buildings with 50,000 sq. ft. (4,645 m^2) or larger (Colorado). Most schemes cover all commercial and multi-family buildings exceeding the defined floor area threshold. Others also include municipal buildings.

Table 3: Existing MEPS-schemes on non-residential buildings in Europe and the US

Country	Introduced	Coverage	Approach	Timeline and ambition
		Europe		
England and Wales	2016	Privately rented buildings (residential and non-residential)	One time-related threshold based on EPC[10] level	2018: EPC E (Score on energy running costs between 39 and 45 out of 100)

[10] Energy Performance Certificate.

Netherlands	2018	Office Buildings	One time-related threshold based on EPC level	2023: EPC C (225 kWh/m²a primary energy consumption)
France	2019	Large commercial Buildings	Time-related efficiency targets per building	2030: reduction by 40% 2040: reduction by 50% 2050: reduction by 60%
Brussels (Belgium)	2021	All non-residential and residential buildings	Five-yearly enforcement dates for defined technical measures	2030: start of five yearly enforcement dates 2050: EPC C (100 kWh/m²a primary energy consumption)
United States				
Boston, Massa-chussets	2021	All municipal, commercial and multifamily buildings above 20,000 sq. ft of 15 residential units[11]	Target set by building type on emission intensity basis. Opt-in option: 50% reduction by 2030 and 100% by 2050 (base year: 2005) Buildings must meet their targets annually starting in 2025; targets are adapted every 5 years. Buildings can also opt into a “glide path” target achieving 50% emissions reduction by 2030 and 100% by 2050 using a 2005 or later baseline Renewable energy credits may be used to offset emissions from electricity consumption	
Chula Vista, California	2021	Municipal, commercial, institutional,and multifamily buildings 20,000 sq. ft. or larger	Requirement for high performance buildings (HPB): ENERGY STAR[12] Score ≥ 80 (out of 100); or be ENERGY STAR certified; or be LEED[13] Existing Building Certified for 3 of the 5 preceding years. non-residential buildings and Multifamily buildings with significant owner-paid energy use must either (1) achieve a minimum EUI[14] improvement or (2) complete an Energy Audit and Retrocommissioning and meet a smaller mandatory minimum improvement by the end of the next compliance cycle (every five years beginning 2023 for buildings ≥ 50,000 sq. ft. and 2026 for buildings ≥ 20,000 sq. ft)	

[11] Also multiple buildings on the same parcels totalling 20,000 sq. ft. or 15 or more units in size.
[12] Certification scheme for buildings (ENERGY STAR 2023b).
[13] Green building rating system by the Leadership in Energy and Environmental Design (U.S. Green Building Council 2023).
[14] Energy use intensity

Colorado	2021	Public, commercial, institutional, and multifamily buildings 50,000 sq. ft. or larger	Standards must achieve a GHG emissions reduction of 7% from 2021 levels by 2026 and 20% from 2021 levels by 2030. Process for determining standards for 2030 to 2050 foreseen. Compliance cycles are every four years, beginning in 2026 and going through 2050.
Denver, Colorado	2021	All commercial and multifamily buildings ≥ 25,000 sq. f	Threshold for site EUI standard based on occupancy type by the year 2030. Buildings are required to meet interim performance targets in 2024 and 2027 to ensure progress toward the final, 2030 standard. Interim targets are determined according to the building's "trajectory" from its baseline site EUI performance in 2019 to the final site EUI standard for its property type
Federal Building Performance Standard	2022	Federal agency's buildings	30% (by total building area) of each Federal agency's buildings must eliminate all Scope 1 emissions — on-site fossil fuel use — by 2030. Further targets for years 2038 and 2045 for the percentage of buildings that every agency must electrify will be set no later than 2028.
Maryland	2022	Public, commercial, institutional, and multifamily buildings ≥ 35,000 s	Existing buildings over 35,000 square feet achieve a 20% reduction in net direct greenhouse gas emissions by January 1, 2030, as compared with 2025 levels for average buildings of similar construction; and net–zero direct greenhouse gas emissions on or before January 1, 2040
Montgomery County, Maryland	2022	Public, commercial, institutional, and multifamily buildings ≥ 25,000 sq. ft	The specifics have to determined yet.
New York City	2019	All commercial and multifamily buildings > 25,000 sq. ft	Targets for CO_2-intensity for on-site emissions, first compliance cycle in 2024, increasingly stringent targets every five years.
St. Louis, Missouri	2020	Municipal, commercial, institutional, and multifamily buildings 50,000 sq. ft. or larger	Standards to be set no lower than the 65th percentile by property type, so that at least 65% of the buildings of the property type have a higher EUI. New performance standards issued at the end of each compliance cycle.

Washington State	2019	Commercial buildings (non-residential) 50,000 sq. ft. or larger 2031: Multifamily buildings ≥ 20,000 sq. ft. and commercial buildings 20,000 sq. ft. to 49,999 sq.	EUI targets must be no greater than the average energy use intensity for the building's occupancy type with adjustments for unique energy-using features. EUI targets initially based on ASHRAE standard 100– 2018. Proposed rules set first target at 15% below average EUI for building type.
Washington DC	2018	Jan 1, 2021: Privately owned buildings ≥ 50,000 sq. ft. District-owned buildings ≥ 10,000 sq. ft. Jan. 1, 2027: All privately owned buildings ≥ 25,000 sq. ft. Jan. 1, 2033: All privately owned buildings≥ 10,000 sq. ft.	For buildings that are eligible for an ENERGY STAR score, the building energy performance standard shall be no lower than the District median ENERGY STAR score for buildings of each property type. New performance standards issued every six years. Campus-wide standards for educational campuses and hospitals

Sources: Collection by Öko-Institut based on Sunderland and Santini (2020) and IMT (2023)

3.2 Comparison of design options

The existing MEPS schemes for non-residential buildings described in the previous section use different design options. The following key features are relevant to the design of MEPS schemes. We structure them according to the identified steps shown in Figure 3 and relate the findings to future MEPS schemes under the EPBD.

General Design

- **Coverage of building segments:** Several of the existing schemes only address a subset of non-residential buildings, where the selection criteria differ: In the Netherlands, only office buildings are covered. In England and Wales, all privately rented buildings, residential and non-residential, are covered. In the United States, most MEPS schemes are limited to larger buildings.
- **Staged approach vs. one-time threshold:** Many schemes define multiple thresholds with increasing levels of ambition over time (e.g., France with a staggered percentage reduction in final energy consumption from 2030 to 2050). Other schemes use only one threshold and do not define future requirements. This is the case for the MEPS scheme for office buildings in the Netherlands. Most schemes in the US use multiple compliance cycles with increasing targets.

- **Ambition of approaches:** The ambition of the approaches depends on the defined threshold values, as well as the status of the building stock at the time when MEPS come into force. In the Netherlands, it is estimated that 10 % of the office buildings did not meet the requirement when the scheme was adopted, while 35 % did not have the mandatory energy label.
- **Performance metrics:** Different performance metrics can be used to evaluate the energy performance of the buildings covered in the scheme. These include measured final energy consumption (e.g. France), calculated energy demand, energy running costs (England and Wales) and CO_2-emissions (e.g. Boston). In the US, many schemes use on-site energy consumption and the United States Environmental Protection Agency (2022b)does not recommend subtracting renewable energy from total energy use to avoid that buildings meet the compliance criteria solely be using renewable energies.

The agreement of the trialogue for the revision of the EPBD already provides a framework for the general design of MEPS: a staged approach (2030 and 2033) and the coverage of defined share of the worst performing non-residential buildings (16% and 26%). Nevertheless, Member States retain the flexibility to prioritize specific building segments or increase the level of ambition. In the EPBD primary energy use is discussed as main indicator for defining the thresholds. However, a Member State could define alternative metrics for individual buildings, provided that they are consistent with the overall threshold criteria.

Data Acquisition

- **Use of utility data:** In some schemes in the US, utilities are encouraged or mandated to provide data on the energy consumption of buildings to support reporting requirements. In these cases, utility data is entered directly into the Energy Star Portfolio Manager through spreadsheets or web interfaces (United States Environmental Protection Agency 2021).
- **Ensure high quality of data:** High-quality data is essential for successful MEPS. Linking the schemes to existing benchmarking can help to make use of existing methods for quality control.

Existing schemes are not bound by pre-defined coverage criteria, such as the “worst 16%” as agreed on in the revision of the EPBD. Consequently, metrics could be established based on existing, well-established benchmarks. This flexibility applies also to MEPS under the EPBD. Member States are only required to translate the overarching thresholds (“worst 16%”) into requirements for individual buildings to demonstrate compliance with the mandated building coverage. A representative data base is therefore essential.

Requirements for individual buildings

- **Connection to existing benchmarking schemes:** Many schemes use existing benchmarking and transparency schemes for defining threshold values. In the Netherlands, for example, the national scheme for Energy Performance Certificates is used. In the United States, MEPS schemes are typically based on the energy star rating system. Other approaches require relative reductions in energy demand at the individual building level (e.g. France and some schemes in the US).

- **Different thresholds for different building types:** Most MEPS-schemes in the US define different thresholds for over 80 different building types. The building types are grouped into categories with staggered deadlines.
- **Flexible pathways vs. fixed metrics:** The MEPS scheme in Washington DC allows building owners to choose between different compliance pathways, giving them the possibility to select an option that works best for their buildings. For each building, the choice of pathway must be submitted and approved by the authority responsible for the scheme (Building Innovation Hub 2023a).
- **Exemptions:** Most of the existing schemes include several exceptions. Often, the MEPS scheme is only applied for building with a minimum of used floor space. For example, in the Netherlands, buildings with an office use of less than 50 % or 100 m² do not have to meet the requirements. Also, listed buildings for monument protection or buildings that are to be demolished are not affected. Several schemes include a maximum payback period for the retrofit measures that would be necessary to meet the requirement (e.g. the Netherlands 10 years or England and Wales 7 years). The market value of a building can also be considered. in England and Wales, the measures may not reduce it more than 5 %).

The energy demand of non-residential buildings can vary considerably depending on their use. Defining different thresholds for different homogeneous building types addresses this problem. We return to this tried and tested approach in Chapter 4.3.1. Linking MEPS requirements for individual buildings to existing benchmarks can help building owners to understand what is expected of them. Exempting several usage categories can reduce the complexity of a scheme.

Regulatory Compliance

- **Development of reporting requirements:** Many schemes link their reporting requirements to existing benchmarking and use existing tools such as the Energy Star Portfolio Manager.
- **Penalties for non-compliance:** Schemes vary in terms of what happens in the event of non-compliance. In the Netherlands, office buildings cannot be further used if the threshold is not met. In the US, many schemes foresee Alternative Compliance Payments. These payments can be based on the level of non-compliance (i.e. a fixed payment per ton of CO2 above the threshold). Alternative compliance payments can also be linked to building size (e.g. Euro per square meter) or to the assessed value of the property. Most schemes also foresee fines for building owners who do not comply with reporting requirements.
- **Split of fines between building owners and tenants:** In some schemes, the alternative compliance payments can be partially passed on to tenants, thus (partially) shifting the responsibility for compliance to the users of the building. While this may encourage energy savings by optimizing energy usage patterns, a full pass-through would neglect the important role of investment in building retrofits. Such options are only applicable to schemes that use indicators based on measured consumption (i.e. not calculated energy demand based on building characteristics).

The positions discussed for revising the EPBD leave the decision on the consequences of non-compliance to the Member States. Existing schemes vary in their severity, ranging from fines to bans on use. In Chapter 4.4 we take up on both approaches.

Supporting policy framework

- **Combination with funding schemes:** To support building owners and to encourage early compliance, MEPS can be combined with funding schemes. For example, the Washington State MEPS scheme includes an early compliance incentive program, where building owners can receive a performance-based incentive totaling 85 cents per square foot (approximately EUR 8.5/m²).
- **Support tools and information for building owners:** Support tools can help building owners to manage the data needed to benchmark their building portfolios and demonstrate proof of compliance with the MEPS. In the US, the Energy Star Portfolio Manager provided by the Environmental Protection Agency (EPA) is a free-to-use tool that helps building owners to manage their energy-related building data. Free training material as well as regular webinars and a help desk are offered by the EPA to support users. The tool can also be used to define reporting templates, which building owners can use to prove compliance (ENERGY STAR 2023a).
- **Technical assistance for building owners:** Jurisdictions implementing MEPS schemes may establish platforms to provide coordinated information on building retrofit measures and compliance requirements and respond to questions by building owners. Examples include the Washington DC Building Innovation Hub (2023b)or the St. Louis Building Energy Improvement Board (2023), a nine-member board appointed by the mayor. In addition, the United States Environmental Protection Agency (2022a)provides comprehensive information and support for jurisdictions implementing MEPS schemes.
- **Use of revenues from fines/alternative compliance payments:** The revenues can be used to support building owners with financial constraints in retrofitting their buildings to meet the MEPS (United States Environmental Protection Agency 2022b).

Member states should accompany the introduction of a MEPS scheme with supporting policies. These can include both financial and technical measures (see also Chapter 4.5).

3.3 Lessons learned

The analysis of existing MEPS schemes for non-residential buildings provides insights for the future introduction of MEPS in the EU Member States. The following subsection summarizes key learnings for each stage of the introduction of MEPS (see Figure 3).

General design and requirements for individual buildings

The definition of metrics, targets and compliance cycles are essential steps in the definition of MEPS schemes.

Regarding the metrics, it is helpful to connect metrics to existing transparency and benchmarking tools, such as Energy Performance Certificates, so that existing databases and interfaces can be used. In the case of the US MEPS schemes, most schemes use metered on-site energy use or on-site CO_2-emissions, indicators that are also used in the Energy Star Portfolio Manager and Energy Star rating.

For building owners, simple requirements help them to understand what is expected of them, thereby increasing compliance. In addition, from the possibility to choose between different compliance pathways increases flexibility for building owners.[15] However, it is important to ensure that all compliance pathways are aligned with national long-term targets. Also, a high number of exemptions increases the complexity for owners and reduces the potential savings of MEPS, leaving a higher burden on the targeted building owners.

Nevertheless, when introducing MEPS schemes for non-residential building, it may be helpful to limit the scope to buildings with certain characteristics. In the US, most schemes are limited to larger buildings, and some schemes allow for exemptions for buildings with small heated floor area or at risk of financial hardship.

For the EU, where in some countries data availability is a challenge and Energy Performance Certificates are not fully digitised and sometimes not reliable, it may be helpful to start with a scheme limited to certain building categories (such as the one in the Netherlands for office buildings) before implementing a full MEPS scheme as foreseen in the EPBD.

When setting requirements and compliance cycles, it is important to allow sufficient time to inform building owners, to establish reporting requirements and leave time for building owners to conduct necessary retrofit measures if buildings fall below the threshold.

Compliance cycles should include the full timeframe until full decarbonisation in 2050, with regular sub-targets in line with the path towards decarbonisation. Providing a clear pathway can prevent building owners from creating lock-ins by conducting retrofit measures that are inconsistent with requirements beyond the current compliance cycle. Sub-targets should be consistent with existing national strategies and targets for the buildings sector.

Data basis: collection of representative data on the non-residential building stock

Access to reliable data on the non-residential building stock is key to the implementation of MEPS. Data are essential not only to define useful thresholds for setting requirements, but also to define categories for different property types with similar usage patterns.

The MEPS schemes in the US benefit from the availability of data on the non-residential building stock provided by the Commercial Buildings Energy Consumption Survey (CBECS), which is conducted periodically since 1979 (US Energy Information Administration 2023). The survey combines information provided voluntarily by building owners with building-specific data from energy utilities to increase the reliability of the data.

There are no EU-wide surveys for non-residential buildings. It is therefore essential for Member States to collect information on key statistics on the number, floor area and energy use of different categories of non-residential buildings.

Compliance: Reporting requirements

MEPS schemes need a framework for communicating with building owners and for managing the data they provide. In the US, many MEPS schemes benefit from the availability of existing classification schemes and tools for non-residential building under the Energy Star Portfolio

[15] Example: Either the change of a heating system and the decrease of carbon emissions or the exchange of windows and a decrease of heating demand are accepted proofs.

Manager, as well as from building owners' prior experience with existing benchmarking and transparency schemes.

For countries with no or insufficient benchmarking and transparency schemes, it is essential to define and implement such schemes and to provide information and support to building owners covered by the schemes.

In addition to implementing a MEPS scheme, it is important to develop the necessary management tools and foresee staff for compliance control:

- Collect and manage contact information of and for building owners
- Establish a system for tracking and managing correspondence, including enforcement notices
- Exploit possibilities to connect information collected from building owners with utility data to ease continuous monitoring.

Compliance control and fines for non-compliance

Relevant consequences of non-compliance increase the impact. Fines or alternative compliance payments should be a relevant amount compared to the cost of achieving compliance through retrofit measures in order to incentivise compliance. When designing the nature of fines/payments, it is important to take into account the national regulatory framework for passing them on to tenants. Full pass-through is likely to limit the impact of a MEPS scheme. Instead of fines or payments, other consequences may be considered, such as restrictions on the ability to use or rent the building.

With appropriate consequences for non-compliance, banks can play an important role in promoting efficiency measures. This is because buildings that do not meet the compliance criteria lose value even before the end of the compliance cycle. In the Netherlands, where rental bans are foreseen if the addressed office buildings do not achieve the set requirements, banks played a major role in informing their clients and even stopped giving loans, if owners do not take efforts in meeting the efficiency targets. Nevertheless, in July 2023 59 % of the offices met the MEPS, 10 % had a label D or worse, and 31 % did not even have an energy label (Rijksdienst voor Ondernemend Nederland 2023).

Supporting policy framework

Stakeholder involvement is highlighted as an important factor for the success of MEPS in the US experience. Both during the planning and implementation of MEPS schemes, as well as after their adoption, stakeholder involvement is essential for better understanding the needs of building owners and to ensure adequate support for building owners (United States Environmental Protection Agency 2022b)

The social impact of MEPS schemes needs to be considered from the very beginning, where creating an advisory board with representatives of different stakeholder groups including social welfare associations can help to identify relevant needs early in the process. For example, targeted funding schemes can provide targeted support for the types of buildings or owners that are most affected by MEPS.

4 Implementation of MEPS

Based on our examination of existing schemes, this Chapter offers recommendations for EU Member States on the implementation of MEPS, with the key aspects highlighted in Figure 3. Firstly, we describe the situation in the EU regarding data bases for defining thresholds of a MEPS scheme. Secondly, we discuss the impact of different indicators which can be chosen to steer a MEPS scheme. Thirdly, we explain two approaches to derive thresholds for a heterogenous non-residential building stock: On the one hand, different thresholds could be defined per use category, and on the other hand, a reference building approach could be chosen. Fourth, we provide information on options for monitoring compliance and consequences of non-compliance. Fifth, we describe ideas for a supporting policy framework around MEPS.

4.1 Data Acquisition

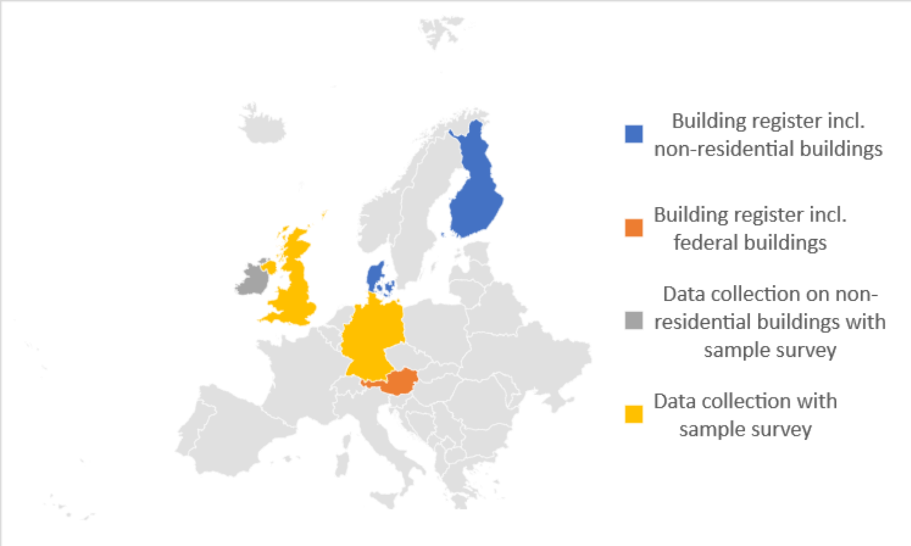
The Council and Parliament EPBD drafts propose that the basis for setting the thresholds for MEPS "shall be established on the basis of the non-residential building stock on 1 January 2020, based on available information and, where appropriate, on statistical sampling." (Art. 9, par. 1). This section provides an overview of available data for this task.

Information about the European non-residential building stock is scarce

In the EU, population and household censuses are coordinated by Eurostat about every 10 years. However, these censuses only cover residential buildings and do not include non-residential buildings. Eurostat data on non-residential buildings are limited to the number of building permits (useful floor area) starting from 2005, with variations among EU Member States. In 2016 the EU Building Stock Observatory (BSO) was established as part of the „Clean Energy for all Europeans"-package, but the primary data source and its statistical quality remain unclear.

Figure 5 gives an overview about existing data on non-residential buildings, which can possibly be used to determine thresholds for MEPS. Building registers exist e.g., in Austria, Denmark and Finland, which in the latter two include structural data on the non-residential building stock in addition to the residential buildings stock, but in Austria only non-residential buildings that belong to the Federal Government. Ireland and UK commissioned primary data collections to research the non-residential building stock with different sampling concepts and data coverage, none of both can be considered representative samples.

Figure 5: Overview about existing data on non-residential buildings



Source: Figure by Öko-Institut and IWU

Data on the energy-related quality of non-residential buildings are collected in databases of Energy Performance Certificates (EPC) in most EU Member States. However, EPCs are primarily issued for new buildings and specific occasions, such as re-sales or re-lettings [Art. 12, 1 (a), EPBD 2018], they neither represent a statistically representative sample nor do they cover the non-residential building stock completely.

As of now, most EU Member States lack statistically valid data on the energy-related and structural characteristics of non-residential buildings like number or floor space, making it challenging to assess their properties and align them with climate policy goals. The planned renovation obligations associated with MEPS, however, require such a database in order to determine the segment of worst performing buildings in a legally secure manner.

In addition to reliable and current data on the structure, data on the energy-related quality of the building stocks are also required. This is of great political importance, because it also examines the adequate supply of housing for the people. Of course, the census could be extended to the non-residential building stock. This would result in high costs for statistical offices.

However, the increasing importance of climate protection also requires better data on building stocks, above all, data on the energy-related quality. After all, building stocks are one of the largest sources of greenhouse gases. Although the EPC exists for assessing the energy performance of buildings, there is hardly any statistically reliable data on the status and dynamics of the energy-relevant condition in the building stock in the EU Member States. As mentioned above, today's EPC databases don't help with this either.

Thus, if a MEPS regime is based on EPCs, a statistically valid database would have to be generated at first and be updated regularly. It would involve a great deal of effort and considerable costs of several thousand euros per EPC.

A sample survey can provide representative data cost efficiently

A sample survey with a highly simplified methodology for assessing the energy-related quality of a building can be a cost-effective alternative for ensuring sufficient data quality. It can be conducted with less time and especially costs. In Germany, this was exemplified in the dataNWG project (Hörner et al. 2021). Statistically valid data on structural features and energy-related properties of non-residential buildings were collected in a representative sample survey, from which unbiased statements about the entire stock can be derived.

The crucial prerequisite for this was that geospatial data derived from the German cadastre (ALKIS) has been available in digital form since 2015. This means, that each building is represented in the cadastre by its building footprint, which represents its geometry, and a building coordinate, which indicates its location. After the end of the implementation phase of the EU INSPIRE Directive at the end of 2021, data of similar quality will be available in all EU Member States. This provides a sampling frame that allows a representative sample to be drawn and data to be collected in every EU Member State's non-residential building stock in a sample survey. Monitoring non-residential building stocks in the EU Member States on a regular basis is within reach.

The sample survey on the German non-residential building stock was conducted in three stages: screening, interview (by phone or online) and on-site inspection. From survey stage to survey stage, increasingly detailed structural and energy-related data were recorded, while the sample size decreased from 100,000 building footprints in screening to approximately 6,000 non-residential buildings in the interview phase and approximately 460 non-residential buildings in on-site data acquisitions by certified energy consultants. With 35 characteristics from the interviews, a simplified energy demand calculation can be carried out with the help of the Dynamic ISO Building Simulator (DIBS) developed in the project (Bischof 2022). The measured energy consumption was also recorded on site, from which a calibration data set for energy demand calculations was developed.

The data from the sample survey can be used to determine threshold-values as presented in Chapter 5.1. When using the data for calibration of a MEPS scheme the proof of compliance of the individual buildings must be provided using the same indicator and the same method of calculation.

In addition, a central building database or a building register appears to be necessary alongside the implementation of MEPS. All buildings with their relevant data should be recorded in a building database in compliance with data protection regulations. In addition to facilitating enforcement of MEPS[16], the database would enable policy makers to compare and evaluate the status of target achievement in the building stock.

However, such data collection takes time. In order not to delay the roadmap for the introduction of MEPS, preparations for the surveys should start immediately, independently from the process of revising the EPBD. Given the urgency of climate change mitigation, especially in the existing building stock, good data are needed anyway to identify the barriers to building modernization and to govern the transformation of the non-residential building stock. This is in the interest of all EU Member States.

4.2 Choice of indicator

A MEPS-scheme defines a minimum energy performance standard. If buildings fall below this standard, the owners are obliged to conduct measures to achieve the required efficiency. Which measures are applicable depends on the chosen indicator. In other words: The choice of indicator determines the steering effect of a MEPS scheme on renovation activities. In this chapter, we first outline which indicators encourage either a fuel switch or an increase in efficiency (e.g., with thermal

[16] E.g. by making it possible to inform building owners who are presumably obliged to renovate or to proof they already comply with the requirements

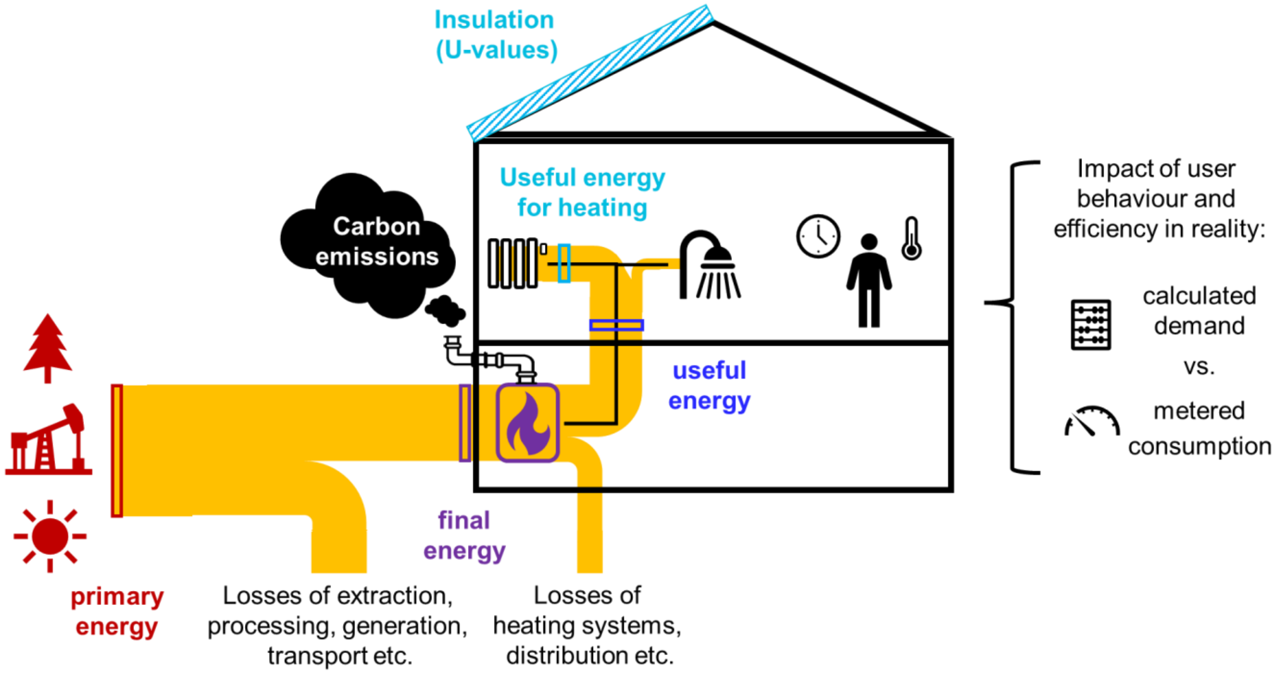
insulation). Another question regarding the indicator is whether it reflects actual user behaviour. Second, we discuss the pros and cons of calculated demand and metered consumption.

The revised EPBD focusses on area-specific primary energy use as an indicator[17], which is one of the most comprehensive indicators for assessing the energy performance of buildings. Of course, there are alternative choices of indicators. It is important to consider the implications of defining indicators such as the effort involved for building owners to meet requirements and for authorities to monitor compliance for a large number of buildings.

4.2.1 Fuel switch vs. efficiency of the building shell

Figure 6 illustrates the different types of energy use, which differ regarding their balancing space / boundary (e.g., inside/outside the building). This section follows the energy flow in yellow starting from the inside of the building and explains the different indicators and their steering effect on a MEPS scheme. Table 4 summarizes which measures building owners can conduct to increase their efficiency for the different indicators.

Figure 6: Which indicator addresses which components of a building?



Source: Öko-Institut

The useful energy demand for space heating is determined by the geometry and thermal resistance of the building envelope (insulation, U-values) as well as user behaviour in terms of heating hours and temperature. This also influences the demand for hot water. Both energy demands add up to the useful energy demand for space heating and hot water. This type of energy use does not include any losses in the energy demand but is the starting point for the flowchart.

17 Art. 9 par. 1 of the revised EPBD names “primary or final energy use” as main indicators for MEPS. Member states can also define operational carbon emissions as additional indicator (Art. 9 par. 3).

If a MEPS scheme uses the indicator useful energy demand for space heating or directly addresses the characteristics of the building envelope (U-values) owners can only meeth the requirement by improving the thermal resistance of their building by retrofitting building shell components.

The useful energy demand is covered by the heating system (e.g., boiler with fossil oil or gas, heat pump etc.). The final energy demand is greater than the useful energy demand because it includes the losses of the heat distribution system (heat exchangers, heat storage, heating pipes, radiators) and the efficiency of the heating system. Final energy is the type of energy that owners pay for in their energy bills. If building owners must comply with a threshold based on final energy use, on the one hand, they can reduce losses in the heat distribution system with low-cost measures (hydraulic balancing, pipe insulation, smart thermostats etc.). On the other hand, installing a more efficient boiler decreases losses by converting the energy carrier into heat.

The amount of carbon emissions is calculated by multiplying emission factors to the final energy demand. Primary energy is calculated similarly, by multiplying primary energy factors to the final energy demand. A MEPS scheme with either of these as an indicator will potentially cause building owners to change the energy carrier of their heating system (fuel switch) from fossil fuels with relatively high carbon and primary energy factors to renewable systems only.

Primary energy demand is higher than the final energy demand because it includes all other losses along the process chain from the primary source (e.g., extraction of crude oil, tree in the forest) to the energy carrier entering the building (e.g., heating oil, wood pellets are filled into a storage in the basement). This includes steps such as extraction, refinement and transport or the generation of electricity.

As shown in Figure 6 building owners have more options for measures with higher aggregated indicators like primary energy use or carbon emissions. This increased flexibility may suit the differing optimization potentials of different individual buildings.

Table 4: Which indicator is addressed by which technical efficiency measures?

Indicator for MEPS-scheme	Possible technical efficiency measures	Steering effect of MEPS-scheme
Component-related requirements: U-values or lists of insulation measures	Insulation of building shell components (roof, walls, upper/lower ceiling, windows)	**Energy efficiency**: Lowering the energy demand of the building sector
Useful energy for heating and hot water	+ user profile (heating hours, temperature, water use)	
Final energy	+ low-cost measures for the efficiency of heating distribution systems (hydraulic balancing, insulation of pipes, smart thermostats etc.) + more efficient heating system (fossil or renewable)	
Primary energy, carbon emissions	+ fuel switch of heating system towards renewable energies	**Decarbonisation**: Phase-out of fossil fuels for heating

Source: Öko-Institut and IWU

The choice of indicator determines the impact of a MEPS scheme as shown in the right-hand column of Table 4. The measure with the most straightforward impact on the indicators primary energy and carbon emissions is replacing a fossil with a renewable heating system. A MEPS scheme with one of these indicators is likely to drive mainly the decarbonization of the building sector. This can lead to a high demand for renewable energy carriers like electricity or biomass and increase the pressure to decarbonize the energy sector and expand renewable energy sources. One example: The more heat pumps with poor efficiency are run, the more wind turbines need to be installed in order to meet the electricity demand. Furthermore, the energy bills of households could even rise.

Other indicators may be more likely to incentivise reductions in the energy demand, such as useful or final energy demand or component-related requirements like the thermal resistance of components (outlined in lists of possible insulation measures). Such indicators do not reward fuel switching but obligate building owners to increase the energy efficiency of the building envelope and reduce energy demand through insulation measures, thereby also reducing energy bills.

Primary energy use – and thus decarbonization – is likely to be the main indicators proscribed for MEPS under the revised EPBD. Nevertheless, Member States may add another indicator if they wish to have a different steering effect within their policy mix.

4.2.2 Operational vs. asset rating

In addition to the type of energy use (useful, final or primary) Member States also have to decide on the type of survey. There is a difference between operational and asset rating. Operational rating means metered consumption as it is to be paid for in energy bills. Asset rating means calculated demand, which is assessed using technical standards/norms. It is used for building permits to prove that a new building meets a minimum energy efficiency requirement. Both types of assessment affect on the one hand the steering effect of a MEPS scheme and on the other hand the practicability of its compliance. Table 5 compares their advantages and disadvantages.

Table 5: Comparison of operational and asset rating as indicator for a MEPS-scheme

Operational rating (metered consumption)		**Asset rating (calculated demand)**	
Advantage	**Disadvantage**	**Advantage**	**Disadvantage**
Reflects real energy use, energy costs and emissions.	Includes influences which are not building-related: user behaviour, outdoor temperature, vacancy.	Reflects building related aspects (geometry, thermal resistance of building shell, efficiency of heating system).	Characteristics of existing building envelopes are often unclear (U-values, efficiency). Results differ and are less justiciable.
Easy collectible number for buildings with defined metering points only for space heating. Can be	The energy use for heating is not collectible if different other types of energy use run over the	Energy consultants who are doing the asset rating can directly develop a renovation roadmap on	Assessment must be done by professional energy consultants: higher costs.[18]

[18] This is especially true for buildings with simple energy use, e.g. only space heating and warm water preparation like offices. The more complex the energy flows of a building gets, the less different are the costs between an energy performance certificate based on asset and operational rating. For very large

done by utilities or non-professionals.	same metering point (e.g., process heat).	how to comply with MEPS.	
Objective, justiciable number.	Large building complexes often have a lot of different metering points. Their scope is not always clear at first sight.		
Low-cost measures for optimizing existing heating systems are applicable.			

Source: Öko-Institut and IWU

In many Member States Energy Performance Certificates exist based on both asset and operational rating. It can be helpful for building owners and authorities to allow different approaches for different types of buildings. On the one hand, this may increase flexibility and make it easier to link a MEPS-scheme to existing energy performance benchmarks. On the other hand, it may also increase the complexity and provides loopholes.

4.3 Definition of requirements for individual buildings

Energy demand is a comprehensive indicator which includes the usage of the building. On the one hand, the energy demand of non-residential buildings varies greatly depending on their usage: A hospital differs significantly from an office building in terms of energy demand. On the other hand, a MEPS-scheme under the planned revision of the EPBD shall cover a fixed percentage of the worst performing buildings in every EU Member State. One option would be to interpret this literally: Imagine ranking all non-residential buildings by efficiency and setting a requirement that, e.g., the worst 16% need to improve to the next better efficiency class. This approach is unlikely to be feasible. Now, consider this fictional example: If a building stock consisted of 10% hospitals and 90% office buildings, very likely the above “worst 16%” requirement would mean, that all hospitals have to be retrofitted in a way that their energy use is as low as for offices buildings. On the one hand, such a requirement leads to retrofits which are not cost-efficient or even technically feasible. On the other hand, this comparison is unfair and penalises only certain usages.

Member states should avoid this and take into account the heterogeneity of non-residential buildings in a “fair” manner when breaking down the “worst 16%” into requirements for individual buildings. In this Chapter we discuss three approaches to achieve this: Thresholds per use category, a reference building approach and an approach with component-related requirements. All approaches are independent from the type of energy use (useful, final, primary) or carbon emissions and survey method (asset, operational rating).

When defining the threshold for the worst 16% of buildings, it is useful to identify the share of buildings in terms of heated floor space. An alternative would be to use the number of buildings.

building complexes finding and merging all metering points and extracting the energy used for space heating and warm water preparation is more elaborate or sometimes even not possible.

However, this would give much weight to small buildings, which in terms of total energy consumption are less relevant.

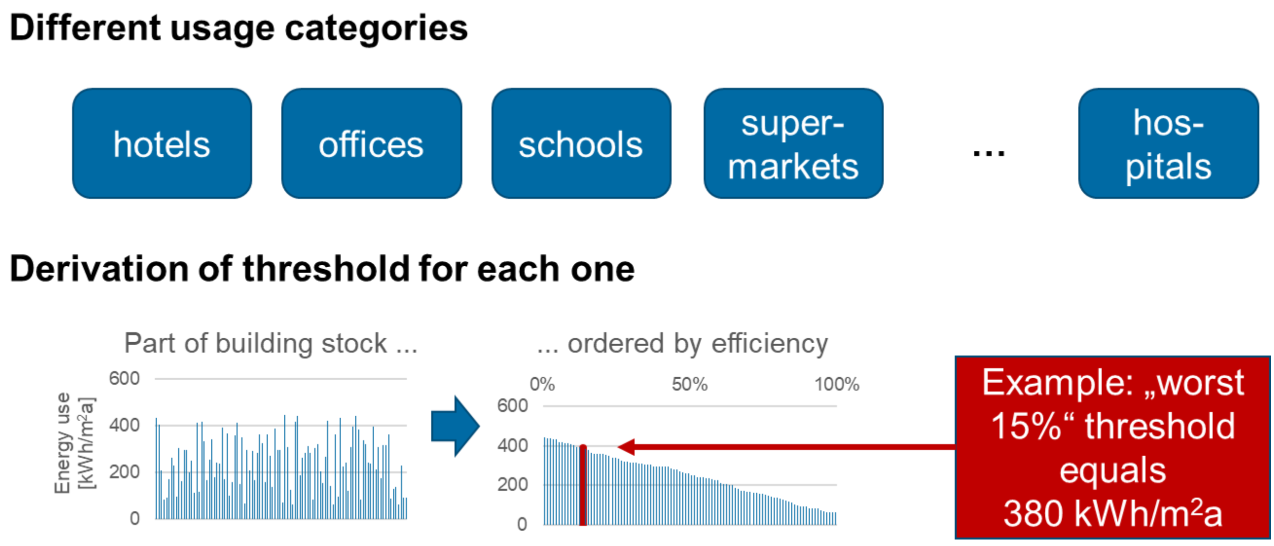
4.3.1 Thresholds per building use category

The energy demand of non-residential buildings with different usages cannot be fairly compared with each other. Figure 7 presents an approach to handle this problem:

1. Member States can define different categories of non-residential buildings with similar characteristics, mainly their usage (e.g., hotels, offices, schools etc.).
2. For each defined usage category, a building data basis is needed for the chosen indicator (e.g., primary energy use).
3. These data are ranked from high to low. A threshold-value can be determined (e.g., primary energy use in kWh/m²a) which is reflecting a share of building in the defined usage category (worst 16%).

Table 6 provides an overview of the arguments for and against this approach.

Figure 7: Thresholds per building use category



Source: Figure by Öko-Institut

Table 6: Pros and cons of defining thresholds per usage category

Advantages	Disadvantages
The heterogeneity of non-residential buildings is addressed "fairly".	Many different categories increase the complexity of the scheme.
Can be combined preferably with operational rating, see advantages in Table 5. E.g., utility data can be used as benchmark.	Other differences, such as the degree of mechanization, are not taken into account.

Easy understandable requirement and direct benchmark in absolute numbers (e.g., energy use in kWh/m²a).	

Source: Öko-Institut and IWU

Benchmarks per usage category are used in many of the existing schemes such as in the US based on utility data on metered consumption. The MEPS scheme of the Netherlands obligates only offices buildings – an isolated usage category.

4.3.2 Reference building approach

In this approach, the actual individual building is compared to a corresponding virtual reference building as illustrated in Figure 8. Both have the same basic aspects: location (heating days due to outdoor temperature), geometry (ratio of building shell surfaces and floor area) and usage category (expected consumption behaviour, mainly heating hours and indoor temperature). The energy related aspects are different: The reference building has predefined characteristics such as the type of heating system and set thermal transmittances (U-values) for each part of the building envelope which are more ambitious than many of the existing non-residential buildings. For any other technical equipment like ventilation or illumination that the actual building may have there is also a predefined reference version to compare with.

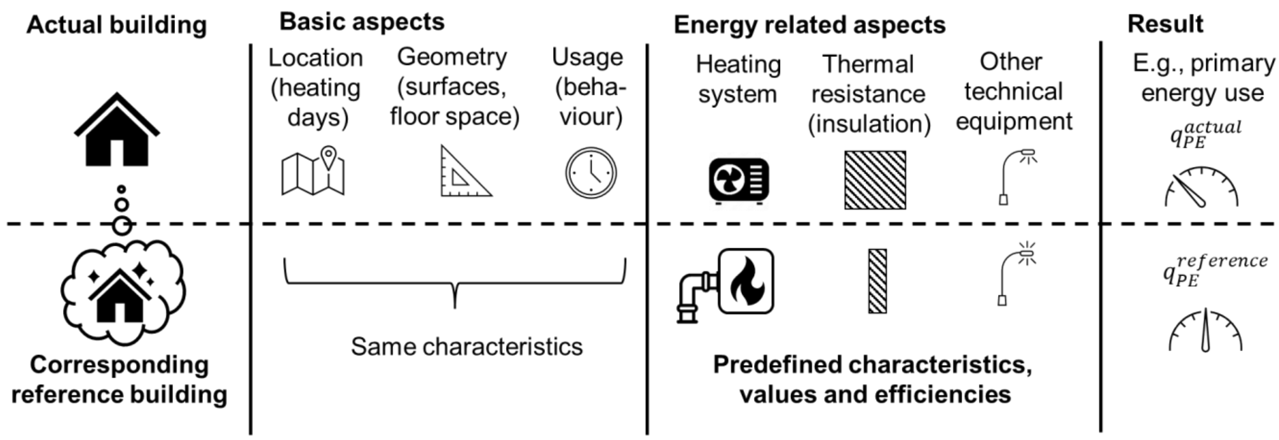
In the end, e.g., the primary energy use can be calculated for the actual building q_{PE}^{actual} and the reference building $q_{PE}^{reference}$. The ratio R_{PE} of actual and reference building

$$R_{PE} = \frac{q_{PE}^{actual}}{q_{PE}^{reference}}$$

gives a benchmark: e.g., the actual building has a primary energy use which is 200% of its reference building.

This benchmarking approach works also for all other types of indicators presented in Section 4.2. The procedure shown in Figure 8 describes an asset rating approach. But it can also be used for metered consumption if a corresponding benchmark is set as reference in the denominator in the above equation.

Figure 8: Reference building approach



Source: Figure by Öko-Institut

This approach is not new. For new buildings it was introduced in 2002 together with Energy Performance Certificates (EPC) (EPBD 2018 Art. 11 (1)). EPCs must contain minimum energy performance requirements in terms of benchmarking/reference values or minimum requirements against which the energy performance of a building can be assessed. In addition, the comparative methodology framework for identifying cost-optimal levels of energy performance requirements for buildings requires EU Member States to define reference buildings and to assess primary energy needs.

A translation of a threshold like "worst 16%" of the building stock into requirements for individual buildings could work as follows:

1. Based on a representative data basis calculations are made:
    a. the primary energy demand[19] for every building in the database
    b. and the primary energy demand for every corresponding reference building
2. The ratio R_{PE} of actual and reference building is calculated for every building
3. All ratios are ordered from low (highly efficient building which need less energy than their reference building) to high (poorly efficient building which need more energy than their reference building)
4. The value of the 16th percentile determines threshold-value "worst 16%": e.g., 200% or 2.0

In Section 5.1.1 we present results for this approach for Germany.

Table 7 summarizes advantages and disadvantages of the approach.

Table 7: Pros and cons of defining thresholds with a reference building approach

Advantages	Disadvantages
In countries where the reference building approach is implemented: Well-known approach for building permits for new buildings, EPCs and benchmarking (e.g., efficiency classes relevant for subsidies in Germany: "Effizienzhaus")	Complexity in countries where the approach is not implemented already.
The heterogeneity of non-residential buildings is addressed "fairly" because it is reflected in the user profile of every reference building.	
A single, uniform number decreases the complexity of the MEPS-scheme.	
Suitable for other types of benchmarks in the denominator of the ratio.	Mostly suitable within an asset rating approach giving EPCs. See disadvantages in Table 6.
The benchmark can be assessed with a time and cost-effective representative sample survey as described in Chapter4.1.	A representative data basis is needed.

[19] Or any other type of chosen indicator

Mixed usage in one building can be addressed.	

Source: Öko-Institut and IWU

This approach has not been applied so far. However, existing schemes also use relative benchmarking, mostly in combination with metered consumption: In France building owners must reach relative savings compared to a base year. This is also the case in many US states as compliance option. Benchmarking systems like Energy Star in the US or the EPC scheme in England and Wales give a score which also reflects the individual usage of a building and thereby the heterogeneity of the non-residential building stock.

4.3.3 Component-related requirements

This approach integrates renovation obligations for existing buildings with specific objectives, which are entailed in a pre-defined list of individual measures with component-related requirements (e.g., the thickness of an insulation of the wall). Building owners are required to implement a specified number of the listed measures within defined time intervals to comply with the MEPS scheme. This approach has already been established in the Brussels-Capital Region of Belgium. A minimum efficiency standard for all residential and non-residential buildings is to be achieved in five stages from 2030 to 2050. Compliance is determined based on recommendations from the Energy Performance Certificates (EPC), which are to be carried out as a matter of priority.

Component-related minimum standards can be designed in different ways (Braungardt et al. 2022):

- Owners must demonstrate that components of their building comply with a defined minimum quality/standard (e.g., U-values) by a designated deadline.
- Building owners may be obligated to implement specific measures proposed in the EPCs or a renovation roadmap.
- An alternative approach mandates that building owners complete a minimum number of measures from a predetermined list within a specified timeframe.[20]

This approach is not directly suited for the transfer of a stock related threshold (worst 16%) into requirements for individual buildings. However, Member States can define objective criterions for buildings which are very likely to be worst performing buildings according to the definition in a revised EPBD. These criterions can be: the year of construction, the usage and the question if relevant parts of the building envelope have already been retrofitted thermally since the construction. Based on representative data on the characteristics of the non-residential building stock, Member States can assess which combination of parameters warrants a threshold obligation like "the worst 16%".

Table 8: Pros and cons of defining thresholds with a component-related approach

Advantages	Disadvantages
Requirements are easy to understand for owners.	Not all measures achieve the same savings effect. There is therefore a risk that mainly simpler measures with lower savings potential will be implemented.

[20] See also Pehnt et al. (2021).

A list of conducted measures is an objective evidence of fulfilment, which is maybe easier to address by law than for example EPC-classes.	No direct transfer of thresholds of the building stock ("worst 16%") into requirements for individual buildings possible.
Staggered implementation of measures forces continuous renovation activity and continuous reduction of carbon emissions.	
By combining requirements with a renovation roadmap, lock-in effects can be avoided.	
Particularly in the case of buildings which are poor in terms of energy efficiency, individual measures with a view to achieving the achievable CO_2 emission reductions represent a simpler option for fulfilling obligations than achieving efficiency classes according to the current EPCs.	

Source: Öko-Institut, IWU and Braungardt et al. (2022)

4.4 Compliance

Member states that establish requirements for individual buildings must also implement a system for monitoring and control. In this chapter, we address key questions that policy makers should consider: How can building owners demonstrate that their properties meet the required standards (proof of compliance)? How can authorities efficiently ensure that building owners adhere to the established requirements (compliance control)? What action should be taken when building owners fail to meet MEPS requirements (consequences of non-compliance)?

4.4.1 Proof of compliance

In some regions, such as France and certain US states, MEPS are defined as **relative reduction targets** (e.g., reducing energy consumption by 30% compared to 2020 by 2030). Many existing MEPS schemes for non-residential buildings leverage pre-existing benchmarking systems, such as **classes of energy performance certificates (EPC)** in the Netherlands, Brussels, England, and Wales, or the Energy Star Rating system in many US states. This approach enhances the clarity and comprehensibility of MEPS schemes.

However, it's worth noting that in some countries, like Germany, there are no EPC-classes for non-residential buildings, which poses challenges for proof of compliance. The choice of the indicator for individual building requirements (as discussed in Chapter 4.2 and 4.3) significantly impacts the proof of compliance. For energy use indicators, an Energy Performance Certificate (EPC) is often the primary means of proof.

Herein lies a practical problem: creating an EPC for complex buildings can incur substantial costs, often reaching several thousand euros. In Germany, EPCs based on calculated energy demand (asset rating) can only be issued by certified energy consultants. This could lead to capacity constraints if a large number of EPCs need to be issued within a short timeframe. [21] EPCs based on metered consumption (operational rating) are more cost-effective for small buildings, but complex structures with multiple metering points can still result in high costs.

Alternative methods for proof of compliance include predefined lists of measures or a self-disclosure-based monitoring system. Pehnt et al. (2021) propose an approach based on a **predefined list of measures** (as discussed in Chapter 4.3.3). Building owners are required to complete a specific number of these measures by a set deadline (e.g., two measures by 2030, four measures by 2034). Examples of items on such a list include:

- Renewable Energy Fitness[22] (counts as two compliance measures)
- Insulation of external walls (counts as two compliance measures)
- Insulation of roof surfaces or top-floor ceilings
- Insulation of the thermal envelope boundary from below
- Replacement of windows and exterior doors (counts as two compliance measures)
- Replacement or installation of a ventilation system with heat recovery
- Replacement of the heating system (transition to renewable energy heating)
- Installation of digital systems for energy operation and consumption optimization
- Photovoltaic (PV) installation

This approach simplifies the proof of compliance, potentially done by a declaration by executive craftsmen. The predefined list can be expanded to include additional details on characteristics, such as insulation thickness or U-value and heating system efficiency.

Another option is a **simplified estimation based on self-disclosure**, where building owners complete an online questionnaire[23]. A similar approach is not new: Some European Union Member States, allow the EPC issuance for existing buildings without on-site data collection.[24] Gathering information on building characteristics like usage, construction year, monument protection status, etc., is straightforward for building owners. The energy-related questions in the questionnaire, referred to as monitoring variables, can be designed so that respondents with knowledge of their buildings can answer them without expertise in building physics or technology. Model input variables for energy calculations, such as component U-values and heat generator information, can be derived

[21] It is conceivable that only one cohort of the presumed worst performing buildings will be required to provide evidence, e.g., all thermally conditioned NRBs built before 1978, the year of the first heat protection ordinance. In Germany, this is about 1.146 million NRBs, of which about 30% have already been completely or partially modernized in terms of energy efficiency in the building envelope. This leaves about 800 thousand NRBs, for which evidence would have to be prepared in a relatively short period of one to two years, according to the currently proposed timetables for MEPS implementation. This is a daunting task, which is why it will be important to make the verification processes as lean as possible and as reliable as necessary.

[22] A building which is renewable ready is suitable to be heated with a low flow temperature, e.g. 55°C (Mellwig et al. 2021).

[23] This could work as for the representative sample survey on the German non-residential building stock in the project ENOB:dataNWG by (Hörner et al. 2022).

[24] In 6 EU-Member States, the issuance of EPCs in existing residential buildings is allowed without on-site data acquisition, just by evidence provided by the owners (Austria, Czech Republic, Estonia, Italy, Poland and Germany) (Arcipowska et al. 2014).

from typical construction era information available in literature related to EPC creation.[25] Additionally, standard weather and user data that adequately describe various building functions are available.[26] If a valid EPC corresponding to the current refurbishment status and based on calculated energy demand exists, data can be extracted from it.

Furthermore, Member States can adopt a compliance system that accepts different forms of proof. For instance, they can combine a calculated primary energy demand, as the primary indicator proven through an EPC, with a list of predefined measures. Combining options offers building owners greater **flexibility** in meeting their obligations.

4.4.2 Efficient compliance control by authorities

To achieve a high compliance rate, Member States must establish a robust monitoring system. This system should serve two primary purposes: Firstly, the compliance control by authorities: Authorities should conduct compliance checks, at least on a random basis, to ensure that building owners adhere to the Minimum Energy Performance Standards (MEPS). Secondly, raising awareness among building owners: It's essential to ensure that owners of potentially underperforming buildings are aware of their obligations under MEPS. Given the significant number of non-residential buildings, authorities must implement an efficient system with a focus on prioritizing those buildings most likely to be “worst performing buildings”.

One approach to identifying such buildings involves conducting a cluster analysis based on representative data. This analysis aims to answer the question: What objective criteria indicate that a building should be classified as "worst performing" and be subject to MEPS requirements? These criteria may include the year of construction, location, size, renovation status, and usage category. Consumption data from utilities can support this analysis but having a complete building register would be even more advantageous. The outcome of this analysis might reveal, for example, that all office buildings constructed before 1978 without thermal retrofitting are likely to be considered "worst performing" buildings.

Armed with this information and using cadastral data, authorities can contact owners of buildings suspected of being "worst performing." Owners can be asked to demonstrate that their buildings do

[25] Using the exterior wall, we present a more detailed example of how the questions about the insulation of the wall was formulated so that laymen could answer it. After a rough classification of the construction - solid exterior wall, lightweight construction, façade system - four pieces of information had to be collected:

1. Are these exterior walls wholly or partially covered with thermal insulation layers ...? In the case of the answer "don't know", we asked again with the hint that this information is important.
2. What proportion of these exterior walls is insulated? Answer options: the entire wall, part of it, do not know.
3. When was the thermal insulation layer predominantly applied? Possible answers: already at the time of construction of the building, only after the construction of the building, do not know.

4a. If the answers were "yes", "the entire wall", "already at the time of construction of the building", the next question was: "What is the predominant insulation thickness in cm?" If the respondent answered "don't know", he was asked for an estimate in cm in a second step. If the respondent did not know this either, classes of insulation thicknesses were offered as answer options in a third step: up to 2 cm, 3- 5 cm, 6 - 9 cm, ...

4b. If the answers were "yes", "part of it", "only after the construction of the building", the question was first about the proportion of the insulated area and then about the year in which the insulation had been installed. The proportion of area and the date were each collected in a three-stage process: exact proportion in percent, estimated proportion in percent, roughly estimated proportion in classes of percentage ranges or exact year, estimated year, rough period in annual classes.

[26] In Germany standard weather and user data are described in DIN V 18599-10:2018-09

not fall into this category. This can be accomplished through the provision of new or existing Energy Performance Certificates (EPCs). Alternatively, as an initial step, owners can complete a self-disclosure checklist, as described in Section 4.4.1. This checklist might include questions such as whether the exterior walls are insulated or if the heating system is older than 30 years.

If the checklist confirms that enough criteria are met positively, the building can be "cleared from the suspicion of being a worst performing" building (e.g., if windows and the boiler have been replaced). However, if too many criteria are not met, further evidence of compliance, such as an EPC, becomes necessary.

Implementing a monitoring system like this requires effort on the part of authorities. However, it also provides an opportunity for authorities to directly engage with building owners. This engagement can involve providing technical guidance, presenting a register of local craftsmen and energy consults and highlighting the financial, comfort, and health benefits of upgrading buildings. Additionally, the classification of a building as "suspected to be a worst performing building" can serve as a criterion for subsidizing informational measures, such as creating an EPC and a renovation plan, with higher funding rates.

4.4.3 Consequences for non-compliance

Efficiency measures are most cost-effective for buildings with a high potential for energy cost savings. When a Minimum Energy Performance Standards (MEPS) scheme is accompanied by instruments that provide owners with informational and financial assistance, in the best-case complying with regulatory requirements can transform into intrinsic motivation. Nevertheless, the effectiveness of a regulatory requirement like MEPS depends on proper compliance control and the imposition of consequences for non-compliance. These consequences should be proportionate to the effort required for compliance. The following options for addressing non-compliance are ranked in order of severity:

Prohibitions on use or rental, as applied in the Dutch MEPS scheme, can significantly increase compliance rates. However, enforcing prohibitions may burden owners and harm their business activities, potentially reducing acceptance of the MEPS scheme.

Cooperation with banks, as has been reported from the Dutch MEPS scheme also, to the extent that the granting of credit is made conditional on the fulfilment of MEPS requirements, can be a supportive and effective leverage in the event of non-compliance.

Penalty Payments provide another option. They can be escalated over time and offer a sufficient incentive for efficiency investments without overburdening owners. Member states must decide how to address the investor-user dilemma in rented buildings. For MEPS schemes using metered consumption-based indicators influenced by user behavior, dividing fines between tenants and landlords can be reasonable. If the MEPS indicator primarily addresses building characteristics (calculated demand, component-based values), tenants typically cannot influence compliance, and only owners should bear the fines.

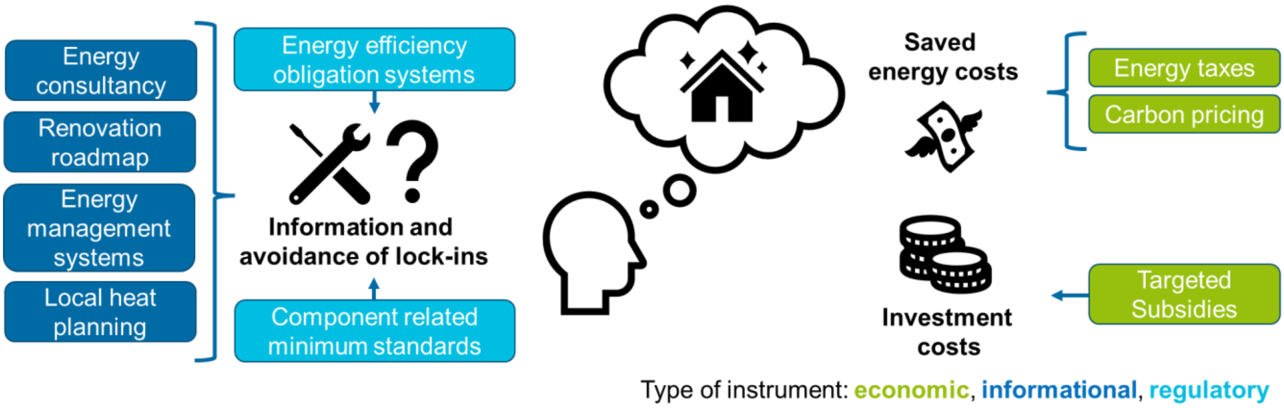
Revenues generated from penalty payments can be reinvested in MEPS-related initiatives, such as targeted subsidies for retrofits of worst-performing buildings and financially disadvantaged owners, possibly at higher subsidy rates. This approach resembles an earmarked "efficiency tax" targeting the building sector and can be administered through climate funds.

Public disclosure (“Naming and shaming”) is the mildest consequence for non-compliance. When a building register is established, the owners of worst-performing buildings can be made publicly visible. This strategy is utilized in the French MEPS scheme. The fear of negative publicity may motivate compliance. However, the effectiveness of this approach depends on societal values related to climate mitigation.

4.5 Supporting policy framework

MEPS can obligate owners of buildings with a poor energy efficiency to thermally retrofit. These measures are more likely to be conducted if building owners find themselves in a regulatory environment which supports their investment. It also gives owners the supportive feeling “that they are not alone” which is important for the public acceptance of MEPS. In this Chapter we give impulses on a supporting policy framework for MEPS, which are illustrated in Figure 9. We therefore differ between three types of policy instruments: economic, informational and regulatory.

Figure 9: Supporting policy framework for MEPS induced retrofits



Source: Figure by Öko-Institut

Economic instruments influence the payback time of investments in energy efficiency. One the one hand in their use phase: Saved energy costs are determined by the energy price. Any instrument which increases the price of fuels like *energy taxes* or *carbon pricing* decreases the payback time of investments in efficiency. Currently, a European emissions trading scheme pricing emissions is prepared for implementation (EU ETS 2) and many EU Member States already have national pricing mechanisms covering the building sector. If fuel switch is a compliance option for a MEPS scheme, the relationship between fossil and renewable energy price determines the economic efficiency in the use phase of the measure (e.g., fossil gas to electricity used in heat pumps). The price of target energy carrier is also influenced regulatory be energy taxes which can maybe lowered.

On the other hand, investment costs play a major role for the objective economic efficiency. Surveys show that high one-time investment costs are more relevant to owners than energy cost savings over time (Durth 2017; Stieß et al. 2010). Non-residential buildings differ a lot in their characteristics, possible efficiency measures and also regarding their type of ownership (e.g., big companies, small workshops, public authorities). *Targeted subsidies* are needed to overcome various financial barriers (e.g., higher funding rates for worst performing buildings and financially weak owners, funded loans for owners with reduced financial liquidity). The technical requirements on funded measures are also an option to avoid lock-in effects (e.g., poor thickness of insulation).

Also, funding of **informational instruments** can be a valuable support for building owners and reduce lock-ins. This includes *energy consultancy* to show building owners their technical options and associated benefits as well as inform them about possible subsidies. This can lead to energy performance certificated (status quo) linked with individual *renovation passports* (target). Many non-residential buildings are often held by a single owner (e.g., university campus, industrial site). For stakeholders like this a comprehensive climate protection concept and *energy management system* is useful to embed thermal retrofit measures in an overarching plan for reducing emissions. Informational instruments could be subsidized completely for worst performing buildings.

Bringing together MEPS and *local heat planning* can mobilize synergies on the district level like serial renovation or centralized heat supply. Managers for energy efficient district rehabilitation may support building owners implementing measures.

MEPS are already a **regulatory instrument** obligating building owners. The scheme itself can be designed in a way which does not need support of other regulatory instruments. Nevertheless, *component related minimum standards* can increase the impact of MEPS and protect building owners from lock-in effects. This includes technical standards for low-cost measures (e.g., hydraulic balancing), minimum thermal resistance (U-values) or minimum efficiency of heating systems (e.g., coefficient of performance of heat pumps). On the other hand, policy owners should not overregulate a MEPS scheme and leave flexibility in terms of conductible measures for building owners to comply with the obligations.

Energy efficiency obligation systems (EEOS) may form synergies with a MEPS scheme. This instrument is described in Article 8 and 9 of the European Energy Efficiency Directive (EED). In 2018 it was in force in 15 EU Member States (Fawcett et al. 2019). Member states can obligate actors like energy suppliers or grid operators to annually reduce their energy demand/sells by a defined percentage. To achieve this the obligated parties must conduct efficiency measures – partly the same ones that MEPS obligate building owners to do. As a result, EEOS can embed professional actors in the fulfillment of requirements by MEPS. This can help owners of buildings which are very close to a threshold-value (e.g., worst 15% in a MEPS scheme obligating the worst 16%). In these cases low-cost measures are initially sufficient like increasing the efficiency of the heat distribution system (e.g., insulation on heat pipes, lowering the flow temperature) or on the steering of consumption (e.g., smart thermostats, optimizing the heat curve of a boiler). Especially for buildings which.

5 Case-study Germany

In this Chapter we take a closer look to Germany to give further insights for the implementation of a MEPS-scheme under a revised EPBD. As the report was mainly written before the result of the trialogue on 8th December 2023, we refer our analysis in this Chapter to the positions of Commission, Parliament and Council. The final agreement on the EPBD is close the General Approach of the Council.[27] Firstly, we break down stock related thresholds of the General Approach ("worst 15/25%") to requirements for individual buildings. This gives an example for the two approaches described in Chapter 4.3.1 and 4.3.2. Secondly, we use the derived threshold-values and estimate the impact of MEPS on the German non-residential building stock using a bottom-up modelling approach.

5.1 Derivation of thresholds

For reasons of equal treatment of all EU Member States, it seems necessary to define equal percentages of the respective national non-residential building stock as worst performing building, e.g. 15% in a first stage in the council proposal. In order to be able to determine the threshold value of the key indicator, theoretically, the energy demand of the entire building stock would have to be known. However, this is not the case in virtually any EU Member State.

A full survey of the non-residential building stock as in the census is probably out of question for cost reasons. In our view, the only reasonable alternative for defining the threshold values on a scientifically sound basis is a representative sample survey of the required building data, such as dataNWG in Germany (cf. Section 4.1). Such a sample allows an unbiased estimation of population parameters from the sample and thus a reliable and valid determination of the thresholds for the non-residential building stock within the statistical uncertainty inherent in a sample.

5.1.1 Reference building approach

To find out which value of the main indicator defines the threshold to the 15 % or 25 %, respectively, worst performing buildings, a stock model of the non-residential building stock is generated exemplarily for Germany using the representative sample of the research database dataNWG. The non-residential buildings are sorted in ascending order of the main indicator's value. The threshold is defined by the indicator value exceeded by 15 % or 25 % of all non-residential building, respectively. Sorting by number of buildings leads to an overestimation of the impact of small buildings. In order to describe the entire stock, it seems therefore useful to include the floor area of the buildings into the procedure. Therefore, thresholds considering the thermally conditioned net floor area (tcNRA) have been determined also.

The sample buildings represent the whole non-residential building stock, their extrapolation factor[28] is well known. Therefore, a quantitative model can be generated from the sample. At 85% and 75% of the cumulative tcNFA, respectively, the threshold value of the performance indicator can be read. All non-residential buildings with R_{PE} > 1,843, that is 428.000 non-residential buildings with 405 million m² tcNRA, belong to the 15% worst performing buildings, with R_{PE} > 1,568 to the 25% worst performing buildings, that is 733.000 buildings with 676 million m².

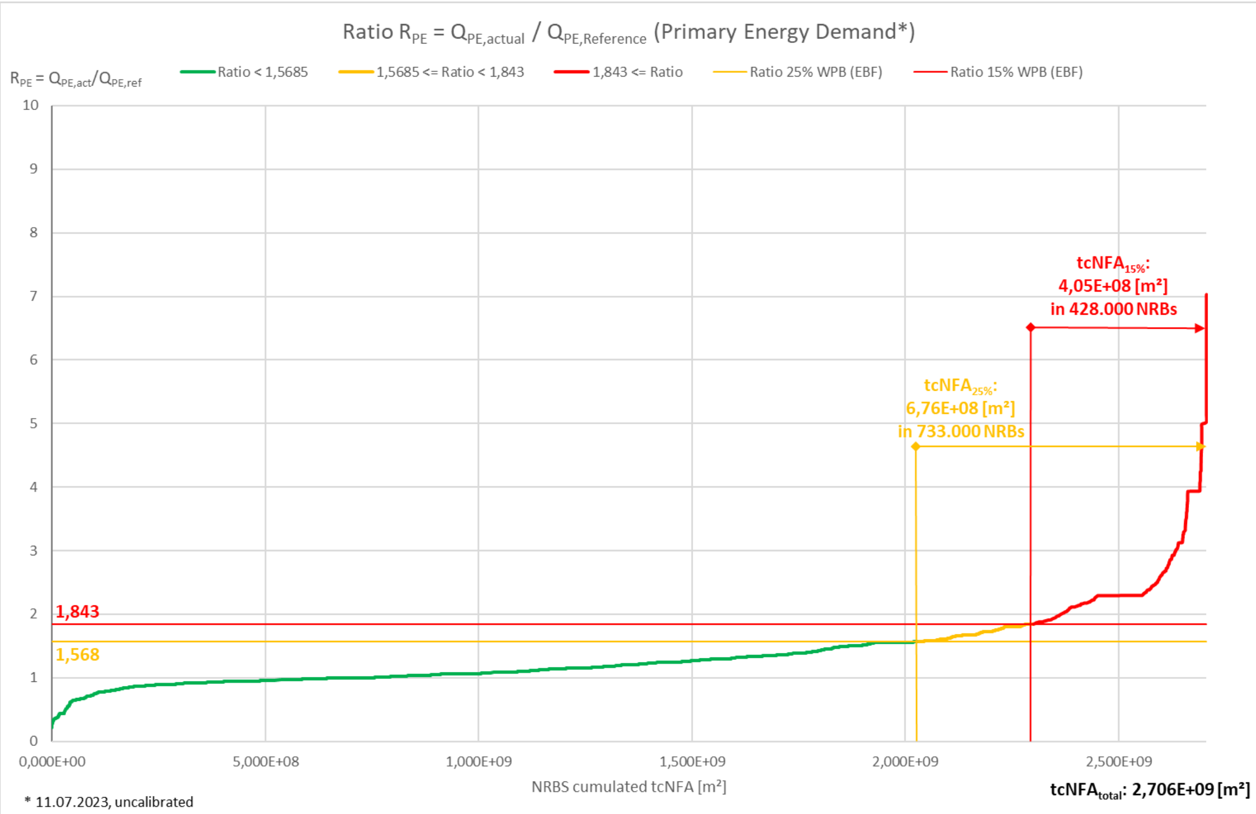
[27] Result of the trialogue: worst 16%/26% to be retrofitted by 2030/2033;
General Approach of the council: worst 15%/25% to be retrofitted by 2030/2034.

[28] The extrapolation factor of a non-residential building (NRB) in the sample gives the number of NRBs in the population that the sample NRB stands for. This is a necessary pre-requisite for a representative sample.

Figure 10 shows how the threshold values of the relevant performance indicator, in this case the ratio R_{PE} of the actual building's primary energy demand for space heating and domestic hot water over the reference building's demand (cf. Section 4.3.2), can be derived from data from a corresponding sample survey. The DIBS calculation results were sorted in ascending order of the ratio R_{PE}, tcNRA cumulated. The total tcNRA is 2,706 billion m².

At 85% and 75% of the cumulative tcNFA, respectively, the threshold value of the performance indicator can be read. All non-residential buildings with R_{PE} > 1,843, that is 428.000 non-residential buildings with 405 million m² tcNRA, belong to the 15% worst performing buildings, with R_{PE} > 1,568 to the 25% worst performing buildings, that is 733.000 buildings with 676 million m².

Figure 10: Example of the definition of thresholds from a representative sample



Source: Figure by IWU

Figure 10 shows that the MEPS regime turns out to be quite simple with regard to its requirements system. The fact that a hospital has different usage requirements than an office building is already taken into account by the characteristics of the reference building. The same applies to the different technical equipment of the buildings. The difference between the calculation only according to the number of buildings and the calculation taking into account the building area tcNRA is also significantly smaller compared to the approach per building usage category, because the building geometry is also included in the calculation accordingly.

Table 9: Threshold-values for the ratio R_{PE} in the reference building approach

Threshold values of the ratio R_{PE}	Worst 25% by number	Worst 15 % by number	Worst 25 % by tcNRA[29]	Worst 15 % by tcNRA
BEA-relevant non-residential buildings in total	**1.8**	**2.2**	**1.6**	**1.8**

Source: Calculations by IWU

Table 9 must be read as follows: In a regime that includes the floor area in the determination of the threshold values, e.g. any non-residential building, regardless of its use category, geometry or technical equipment, whose primary energy use exceeds that of the associated reference building by more than 1.6 times (highlighted yellow), is among the 25% worst performing buildings in the national building stock.

5.1.2 Threshold-values per usage category

Table 10 shows the result of a corresponding evaluation of the dataNWG non-residential buildings that are relevant under the German Building Energy Act (BEA)[30],differentiated according to building category The threshold values are calculated area-specific primary energy demands for space heating and domestic hot water in kWh per m² tcNRA and year, calibrated to measured consumption (cf. Section 4.2.2). Two things immediately stand out: Firstly, the threshold values are very different, depending on whether they have been determined according to the number of buildings or also taking into account the floor area of the buildings and secondly, values differ greatly depending on the category of use of the building.

The table must be read as follows: In a regime that includes the area in the determination of the threshold values, e.g. any office building that has a primary energy demand greater than 102 kWh/m² p.a. (highlighted yellow) is among the 25% worst performing buildings in the national building stock. If the thresholds were determined only according to the number of buildings, this threshold is 187 kWh/m²a (highlighted blue). Of course, the indicator values of general thresholds for the national stock and the ones for the individual building must be calculated using the same calculation method.

Table 10: Threshold-values for MEPS by building use category

MEPS in terms of calibrated specific primary energy demand Q_{PE} [kWh/m²$_{tcNRA}$a] by main building use categories	Worst 25% by number	Worst 15 % by number	Worst 25 % by tcNRA[31]	Worst 15 % by tcNRA
BEA-relevant non-residential buildings in total	**208**	**292**	**118**	**152**
1. Office, Administrative or Government Buildings	187	225	102	133
2. Buildings for Research and University Teaching	225	411	198	210

[29] thermally conditioned net floor area
[30] The Building Energy Act (Gebäudeenergiegesetz) is the national implementation of the EPBD in Germany.
[31] thermally conditioned net floor area

3. Buildings for Health and Care	142	170	143	214
4. School, Day Nursery and other Care Buildings	92	111	82	94
5. Buildings for Culture and Leisure	120	141	93	124
6. Sports Facilities	321	921	280	921
7. Buildings providing Boarding, Hotels, Restaurants or Catering	230	285	156	180
8. Production, Workshop, Warehouse or Operations	321	405	112	159
9. Trade Buildings	149	241	96	109
10. Technical and Utility Buildings (supply and disposal)	206	505	121	206
11. Transport Buildings	181	289	181	364

Source: Calculations by IWU

If the thresholds were set solely on the basis of the total building stock, as shown in the first row of the table, some use categories would be classified much less frequently as worst performing buildings than other use categories. This might cause problems in the implementation of such a simple MEPS regime.

It should be noted, however, that currently for some usage categories, the number of cases in the sample of dataNWG is quite low and therefore the statistical uncertainty is quite large. This must be taken into account in the interpretation of the current data and in future data acquisition.

5.1.3 Component-related requirements

As mentioned above, in this approach there is only qualitative criteria to define the subset of worst performing buildings, e.g. 15%. Of the 1.981 million non-residential buildings in Germany that are relevant under the BEA, 57.9% or 1.146 million were established before 1978, i.e. the year in which the first Thermal Protection Ordinance came into force in Germany. About 31% of these old buildings are already insulated on the outer wall, 77% in the roof or on the top floor ceiling and 22% on the basement ceiling. In addition, in about 78% of these old buildings, the windows have already been replaced at some point.

We might assume that only one renovation measure on a building component is sufficient to fulfil the renovation obligation in the first step, e.g. window renewal, then a maximum of 22% of the old buildings would remain that may not have undergone any subsequent optimisation measures on the building envelope. That's about 250 thousand, or about 13% of all BEA-relevant non-residential buildings. This very simple calculation may suffice to illustrate a possible approach to defining the subset of worst performing buildings.

5.2 Modelling the impact of MEPS

In this Chapter we compare the discussed positions of the three parties who are negotiating the revision of the EPBD as described in Chapter 2.1: European Commission, Council and Parliament. Firstly, we describe our bottom-up modelling approach for the estimation for the estimations. Secondly, we define the assessed scenarios and thirdly, discuss the results.

5.2.1 Methodological approach

The following section describes our modelling approach for estimating the impact of MEPS for the German non-residential building stock.

5.2.1.1 Building Stock Transformation Model (Building STar)

Our model represents a non-residential building typology with 11 building categories and 12 construction periods based on Hörner and Bischof (2022). With addition of data from Destatis (2022), BMWK (2022) and BDH (2021) a stock of all German non-residential buildings is assembled, which are thermally conditioned and addressed by the Buildings Energy Act (BEA). This includes both, buildings used in industry and commerce, trade, services[32].

As shown in

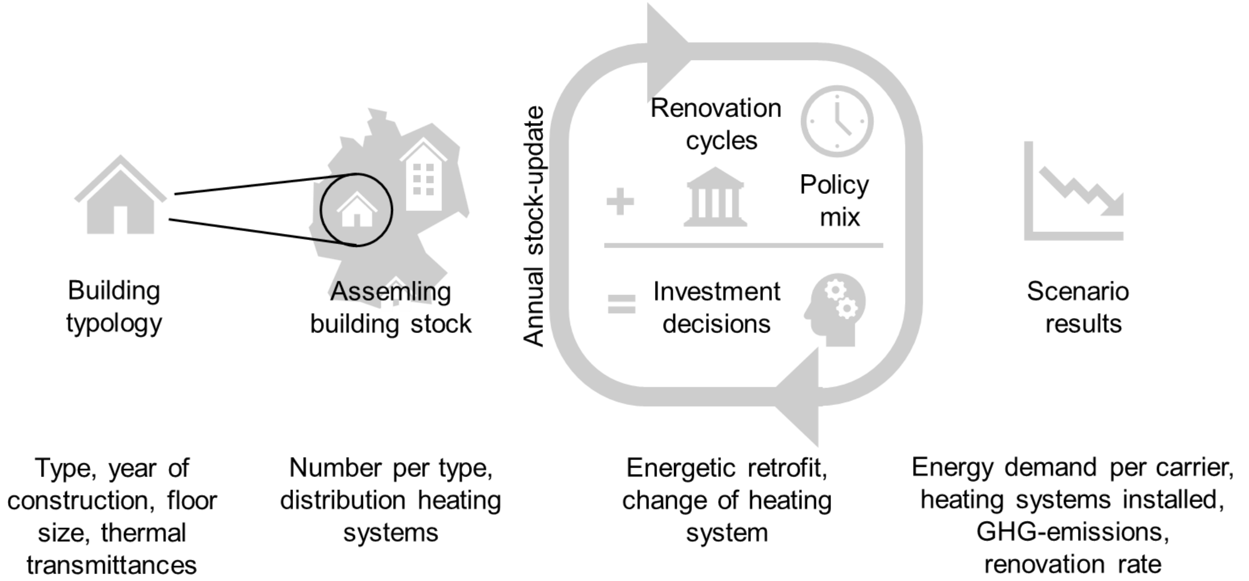
[32] The German Federal Climate Change Act (Klimaschutzgesetz; KSG) divides the emissions for space heating and warm water preparation for non-residential buildings into two sectors: Industry and commerce, trade and services (Gewerbe, Handel, Dienstleistung; GHD). Thus, most studies projecting carbon emission pathways follow this division, too. We, on the other hand, regard the non-residential buildings stock as a whole.

Figure 11, Building STar follows a stock-exchange approach: The building stock is updated annually considering investment decisions of building owners. These are influenced by endogenous dynamics like renovation cycles of building shell components as well as heating systems and exogenous inputs, which reflect the assumed policy-mix: e.g., MEPS or subsidies for heat pumps or thermal retrofits. The modelled investment decisions lead to thermal retrofits and changes of heating systems. These in turn shape the scenario results on indicators such as the development of the final energy consumption or the GHG-emissions.

The period from 2010 to 2019 is used for calibrating the model in terms of renovation rate and replacement rate of heating systems to values of Hörner and Bischof (2022). The final energy share per energy carrier is calibrated according to the official energy statistics. The total final energy consumption is calibrated to calculations with the Dynamic-ISO-Building-Simulator (DIBS) using representative data from IWU (Hörner et al. 2021; Bischof 2022). The total final energy consumption for space heating and warm water preparation of all BEA-relevant non-residential buildings including industrial ones is estimated to be 294 TWh/a in 2018[33] resulting in 45 Mt of CO_2-emissions.

[33] This number is different to the official energy statistics for 2020 by AG Energiebilanzen (2022) with 228 TWh/a or the “Energiedaten” by BMWK (2022) with 206 TWh/a. This is due to different calculation approaches: IWU has collected building specifics in a sample survey and calculated an energy consumption based on a building physics model. The energy balances with main input of Fraunhofer ISI are derived by a survey of workplaces (“Arbeitsstättenbefragung”) as basis. Also, Fraunhofer ISI uses the lower and IWU the upper calorific value. For reasons of consistency within this project we calibrated our model to the values of IWU.

Figure 11: Schematic modelling routine of Building STar



Source: Figure by Öko-Institut

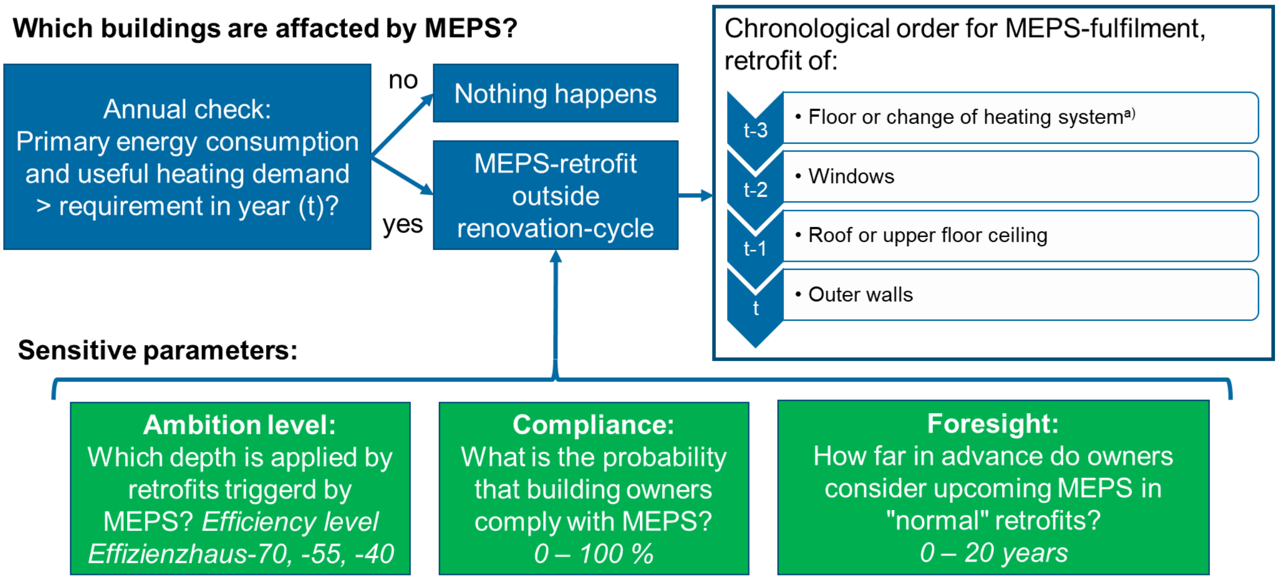
5.2.1.2 Investment behaviour faced with MEPS

The impact of MEPS on reducing the energy consumption is driven by the following key assumptions which are thus sensitive parameters:

- Compliance: What is the probability that building owners take efforts to meet the legal requirements?
- Ambition level: If building owners renovate due to MEPS – which retrofit depth is applied?
- Foresight: Even without MEPS building owners conduct thermal retrofits within the normal reinvestment cycle of building shell components. It would be advantageous, if these retrofits were conducted in a more ambitious manner that complies with future requirements of MEPS. How long in advance do building owners consider future thresholds within normal retrofits and thereby avoid lock-in effects?

These parameters are included in the modeling routine in Building STar, schematically shown in Figure 12. The procedure is as follows: Every year *t* it is checked if a building exceeds the maximum permissible value defined in the MEPS scheme. If it doesn't, nothing happens. If it does, a retrofit outside the renovation-cycle is induced. Therefore, in our modelling approach we assume that building owners at first aim to meet the standard with minimum financial effort and as late as possible. The chronological order of measures for MEPS-fulfilment in Figure 12 is derived by the investment costs. Building owners react in advance to the fulfilment date t: in year *t-3* the floor is insulated. If this is not enough, in year *t-2* the windows are replaced etc.

Figure 12: Schematic modelling routine for MEPS



a) Renewable heating systems have a lower primary energy factor than fossil ones. If primary energy use is the only indicator of a MEPS-scheme, it is often cheaper to change the heating system than to conduct a thermal retrofit. This option is reflected in the model.

Source: Figure by Öko-Institut

5.2.2 Definition of scenarios

As mentioned in Chapter 2.1, the three European institutions negotiating the revision of the EPBD have published their positions. These are represented in three different scenarios, which we compare to a reference scenario also described in this section.

5.2.2.1 MEPS-scenarios

Table 11 summarizes the positions of Council, Commission and the European Parliament. In our case-study Germany we assume that MEPS are only applied to buildings, which are thermally conditioned and fall under the regulations established by the Buildings Energy Act (Gebäudeenergiegesetz, GEG)[34]. We exempt buildings which are listed for monument/heritage protection – this accounts for around 6 % of the GEG-relevant non-residential buildings stock[35].

All three positions mention, that Member States shall ensure, that the transformation of the building stock is aligned to a defined pathway which sets milestones for 2040 and 2050. In 2050 the building stock shall consist of zero-emissions buildings (Art. 9, par. 1). This can be reached with MEPS, if the set thresholds are continued by Member States. This assumption is model-sensitive. Therefore, we created an additional scenario, in which we continued the ambition levels based on the proposal of the Commission from F (worst 15% shall be retrofitted) in 2027 to A (worst 90% shall be retrofitted) in 2045.[36]

[34] This is the case for all non-residential buildings, which are thermally conditioned for more than four months per year at a temperature higher than 12°C (§2 GEG)
[35] Hörner (2020).
[36] 2045 is the target year for climate neutrality in Germany (§3 KSG).

Table 11: Definition of assessed scenarios for MEPS

Scenario	Timeline for thresholds (worst …% must be retrofitted)	Indicator triggering MEPS
General Approach Council (1)	2030: 15 %, 2034: 25 %	Metered primary energy consumption
General Approach Council (2)	2030: 15 %, 2034: 25 %	Metered primary energy consumption, Calculated useful heating energy demand[37]
Proposal Commission (COM)	2027: F (15 %), 2030: E (30 %)	
Plenary vote EU Parliament	2027: E (30%), 2030: D (44 %)	
Target Continuation based on (COM)	2027: F (15%), 2030: E (30%), 2034: D (45%), 2038: C (60%), 2042: B (75%), 2045: A (90%)	

Source: Öko-Institut

All proposals for revising the EPBD leave the detailed design to the Member States which forces us to make several assumptions:

- “Primary energy use” is named as indicator for triggering MEPS in the General Approach of the council (Art 9, par. 1)[38] The other proposals also name primary energy use as key indicator for energy efficiency classes (Art 16, par. 1). We interpret it the indicator as metered primary energy consumption.
- Member states can establish additional indicators (Council, Art. 9 par. 3)[38]. We assume that this is done in all scenarios except for Council (1) by adding the indicator calculated useful heating energy demand. For fulfilling requirements on primary energy use, the change of the energy carrier is often the most cost-effective way. With the additional requirement of useful heating energy demand, building owners have to improve the energy efficiency of the building shell via thermal retrofits.

5.2.2.2 Reference scenario

Calculating the impact of retrofitting e.g., the worst 15% would give the so called “gross effect” of MEPS. But owners also renovate their buildings without MEPS – due to other political instruments or other reasons. In order to estimate the “net effect” of a political instrument such as MEPS, their impact has to be compared to a reference development (Schlomann et al. 2022). Our reference or “business-as-usual” scenario comprises the current policy mix (07/2023) without any MEPS.

The impact of MEPS as additional political instrument is calculated as follows:

$$\Delta FEC(t)_{MEPS} = FEC(t)_{MEPS} - FEC(t)_{Reference} \quad \text{and} \quad \Delta GHG(t)_{MEPS} = GHG(t)_{MEPS} - GHG(t)_{Reference}$$

[37] We defined useful heating energy demand as additional criterion. Our estimation took place before the finalization of the trialogue. The revised EPBD names “primary or final energy use” as main indicators for MEPS (Art. 9, par. 1). Member states can also define operational carbon emissions as additional indicator (Art. 9 par. 3). Thus, useful energy use is not possible as an additional indicator.

[38] Council of the European Union (2022).

With FEC(t) as final energy consumption in year t, MEPS as reference scenario plus MEPS, GHG(t) as greenhouse gas emissions in year t

The current policy mix (07/2023) in Germany includes the following main instruments addressing non-residential buildings:

- Minimum Energy Performance Standard for new buildings from 2022 (primary energy demand must be 55 % less than the reference building), ban for installing new boilers run on heating oil in all buildings from 2026 (Gebäudeenergiegesetz)
- For non-residential buildings with a floor area of >1000m^2 heated with natural gas the heating system has to be optimized including hydraulic balancing (EnSimiMaV)
- Economic incentives: Subsidies for deep thermal retrofits and heating systems based on renewable energies (Bundesförderung effiziente Gebäude), carbon pricing (Brennstoffemissionshandelsgesetz)

The impact of the high energy prices due to the Russian war on Ukraine is modelled by a slight decrease of the reinvestment cycle of natural gas boilers and reduced consumption due to energy saving behaviour.

5.2.3 Results

Our estimations on the impact of MEPS are compared to the reference scenario described in Section 5.2.2.2. The final energy consumption in the reference decreases by 30 % from 2020 to 2040. This is already rather ambitious compared to the projections of the non-residential building stock in other scenarios: minus 25 % by DENA (2021), minus 18 % (Reference) and minus 23 % (Target) by Prognos AG (2020). Reasons for the differences are a more ambitious policy-mix, higher fossil energy prices and a different data basis regarding the structure of the non-residential buildingS: We use representative data from dataNWG, which were only available since late 2022. The more buildings have already been retrofitted in the reference; the less buildings can be additionally retrofitted due to MEPS. On the one hand, a more ambitious reference scenario leads to a lower impact of MEPS. On the other hand, the reference scenario is only a projection, and the increase of efficiency may not be realized. MEPS, however, as a regulatory instrument ensure the thermal retrofits of the buildings, they address. They can fulfill the function of a “safety-net” towards the transition of the building sector.

We estimated the impact of the different MEPS-proposals before trialogue ended in December 2023. Its result is closest to our scenario Council (1) regarding thresholds, timeline and primary energy use as indicator.

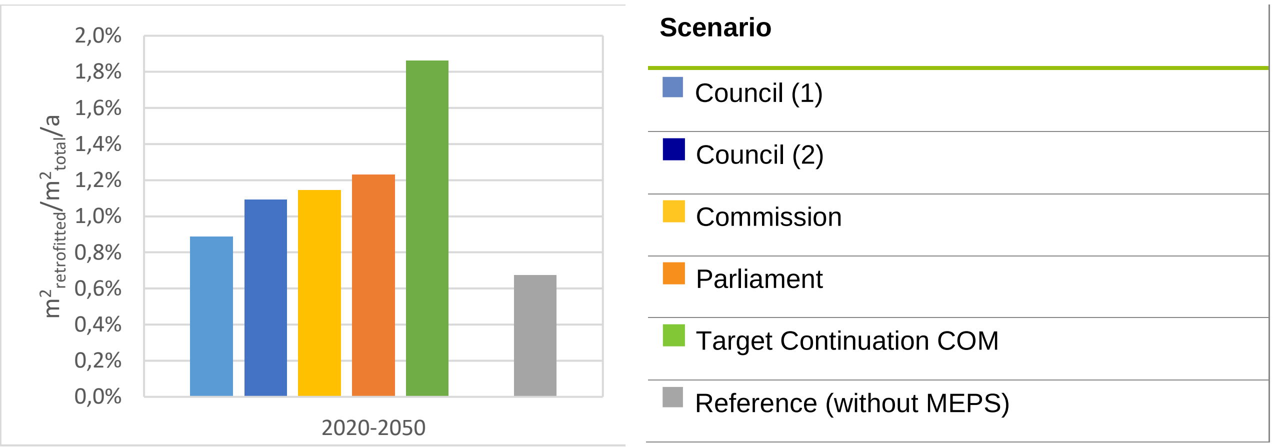
Added upon the reference, MEPS can reduce the final energy consumption and the GHG-emissions significantly. We observe the following:

Average annual retrofit rate (fully renovated equivalents, average from 2020 to 2050)

- MEPS induce retrofits which is expressed by an increased retrofit rate. In the reference scenario the average retrofit rate stays at a low level of 0.7%/a. We estimate that MEPS according to the positions of Commission and Parliament almost double the average retrofit rate with 1,1 and 1,2%/a.

- In the scenarios we do not continue MEPS after the first two steps, because the EPBD does not provide a clear pattern but leaves it to the Member States to further develop the instrument. This leads to rather low average retrofit rates for the whole period until 2050. However, in the scenario Target Continuation COM we continue the MEPS-requirements of proposal of the Commission until 2045, which results in a higher average retrofit rate of 1,9%/a, which is almost tripled compared to the reference.

Figure 13: Average annual retrofit rate



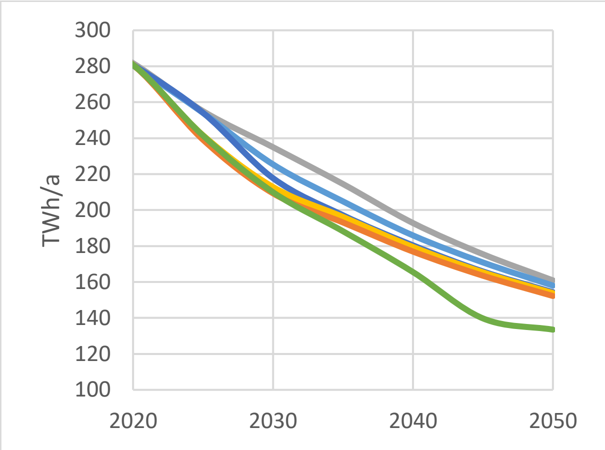
Source: Modeling results by Öko-Institut

Annual final energy consumption

- The dynamic of the final energy consumption for space heating and warm water preparation is directly linked to the annual retrofit rates: The year with the biggest savings corresponds with the fulfilment dates for MEPS (e.g., 2030 for Council).
- MEPS lead to a retrofit of the worst performing buildings until 2030 and 2034, respectively. This does not take place in the reference scenario. So the impact of MEPS as a difference between the MEPS scenarios (colored lines) and reference scenario (grey) is biggest around 2030. However, many of the worst performing buildings are also assumed to be retrofitted in the reference scenario over time, which decreases the relative difference between MEPS scenarios and the reference scenario. Especially, the last two steps after 2042 require deep thermal retrofits in order to achieve a ZEB-standard in terms of efficiency.
- The annual final energy consumption in 2050 differs between the scenarios. On the one hand, this is due to buildings, which are not retrofitted at all in the reference scenario. MEPS lead to a retrofit of these. On the other hand, MEPS decrease lock-in effects: building owners in the model know about future requirements (foresight) and conduct retrofit measures at once with an ambition level which will be sufficient to meet upcoming thresholds within a MEPS-regime.
- Council (1) and Council (2) have the same threshold and timeline but differ with respect to their indicators: Additionally, to primary energy use, Council (2) has an additional requirement (useful heating demand). This leads to more thermal retrofits because it can only be met by increasing the energy efficiency. In 2035, Council (2) reaches twice as many savings in final energy use than Council (1) compared to the difference to the reference. Council (1) has only primary energy demand as threshold, which prioritizes fuel switches and thus

decarbonization. Nevertheless, Council (2) reaches a higher reduction of emissions. This is because Council (2) addresses the worst 15%/25% in terms of primary and useful energy. In total more buildings than 15%/25% are obligated and thus more emissions saved.

Figure 14: Final energy consumption for heating and warm water in non-residential buildings



Scenario	MEPS induced savings in 2030
Council (1)	9.6 TWh/a
Council (2)	17.2 TWh/a
Commission	22.1 TWh/a
Parliament	25.7 TWh/a
Target Continuation COM	25.0 TWh/a
Reference (without MEPS)	-

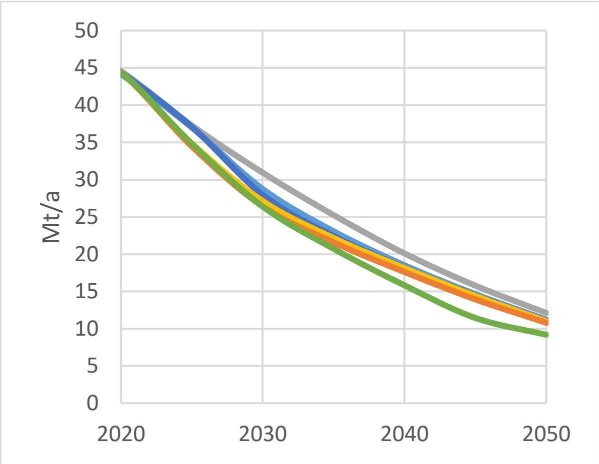
Source: Structural data by IWU, modeling results by Öko-Institut

Annual GHG-emissions

- The picture changes slightly when looking at emissions: In Council (1) the change of the heating system towards renewable energy is an option to fulfil MEPS with primary energy as single indicator. The light blue line comes closer to the dark blue line of Council (2) compared to the diagram showing the final energy consumption.
- We estimated the impact of the different MEPS-proposals before trialogue ended in December 2023. Its result is closest to Council (1) regarding thresholds, timeline and primary energy use as indicator.
- The savings of GHG-emissions compared to the reference scenario are highest around 2030 because MEPS lead to an almost complete retrofit of the worst performing buildings at an early time. The differences to the reference scenario after 2030 decrease over time because no additional requirements are set after 2034 and thus the reference is catching up. The annual emissions in 2050 are still around 2 Mt_{CO2}/a lower than in the reference. This means that there are still MEPS-induced retrofits of buildings, that have been modernized in the reference scenario.
- The emissions of the scenario "Target Continuation COM" are always lower than in the reference because the thresholds are continued until 90% of the building stock is retrofitted and reaches a ZEB-efficiency-standard in 2042.
- In 2030, we estimate that MEPS for non-residential buildings can save between 2.2 and 4.5 Mt_{CO2}/a. The climate target for 2030 for the building sector is defined in the German Climate Protection Act (Klimaschutzgesetz): the annual emissions need to be below 67 Mt_{CO2}/a. This target is projected to be missed by 12 Mt_{CO2}/a with the current policy mix in the projection

report ("Projektionsbericht") of the German government (Harthan et al. 2023) MEPS for non-residential buildings can play a key role for filling this gap.[39]

Figure 15: Annual GHG-emissions



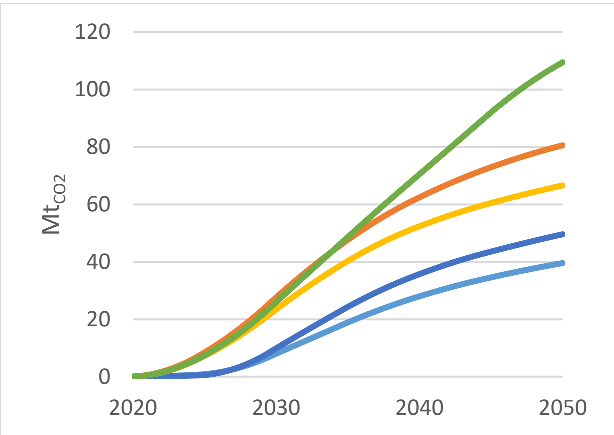
Scenario	MEPS induced savings in 2030
Council (1)	2.2 Mt/a
Council (2)	3.0 Mt/a
Commission	3.8 Mt/a
Parliament	4.5 Mt/a
Target Continuation COM	4.5 Mt/a
Reference (without MEPS)	-

Source: Structural data by IWU, modeling results by Öko-Institut

Accumulated GHG-savings

- For the mitigation of climate change the total amount of emissions is more relevant than the annual emissions. Furthermore, slight differences in annual emissions sum up over time. The graph at the right lower corner shows accumulated GHG-savings – the difference between the MEPS and the reference scenario in the annual emissions diagram, summed up over time.
- Time matters. Commission and Parliament set earlier thresholds and lead to accumulated emission savings which are much higher than the scenario of the Council.

Figure 16: Accumulated GHG-savings



Scenario	MEPS induced savings in 2030
Council (1)	8 Mt
Council (2)	10 Mt
Commission	23 Mt
Parliament	28 Mt
Target Continuation COM	26 Mt
Savings compared to a reference without MEPS	

[39] The building sector defined by the climate protection act does not include non-residential buildings used in industry. Our estimations of 3,1 to 6,5 Mt_{CO2}/a are not fully allocated in the buildings sector under the German Climate Protection Act but also in the industrial sector. The database we use does not differ between the sectors.

Source: Structural data by IWU, modeling results by Öko-Institut

Interpretation of results

The results related to the impact of Minimum Energy Performance Standards (MEPS) must be understood as potential upper limits. In practice, the actual effect of MEPS embedded within a broader policy mix is likely to be lower. This lower impact can be attributed to several key factors:

- Perfect Foresight Assumption: In our analysis, we assume that building owners have perfect foresight when making energy efficiency investment decisions. This means they are fully aware of future MEPS requirements. In reality, building owners may not always conduct ambitious energy-efficient measures when a component reaches its technical end of life.
- High Compliance Rate: Our analysis assumes a very high compliance rate with MEPS requirements, with minimal exemptions (except for monument protection) and no time delays. Real-world compliance rates may vary due to practical challenges and exemptions added by Member States.
- Higher Energy Consumption and Emissions: The building stock we consider in our analysis consumes about 30% more final energy and emits more greenhouse gases compared to the non-residential building stock described in energy balance data (see Footnote 33 in Chapter 5.2.1.1). Other projections calibrated with the energy balances automatically have less reduction potential.
- Policy Interactions: Our reference scenario assumes no other strong policy instruments that promote fuel switches, such as the revised German Buildings Energy Act (requirement to use 65% renewable heat for new heating systems). In a more comprehensive policy mix, the impact of MEPS can be reduced due to interactions with other policy instruments. This means that the same energy-saving actions may be counted towards multiple policy instruments, diminishing the impact allocated to MEPS.
- Lack of Analysis on Policy Instrument Interactions**:** We did not analyze how MEPS interacts with other policy instruments, such as subsidies for retrofit measures induced by MEPS. In such cases of overlapping instruments, a portion of the energy savings from the conducted retrofit measures needs to be attributed for example to the subsidy instrument (Fraunhofer ISI et al. 2020; Oeko-Institut et al. 2023).

6 Conclusions

Retrofitting worst performing buildings in the non-residential building stock offers a considerable improvement of economic efficiency and a substantial impact on reducing carbon emissions. However, despite these "low-hanging fruits" being readily available, they remain widely untapped within the current policy framework. The introduction of Minimum Energy Performance Standards (MEPS) provides an opportunity to drive the transition of the building sector – particularly in the light of the 2030 climate targets. Yet, the effectiveness of MEPS depends crucially on the specific design of the scheme.

In Chapter 3, we analyse existing MEPS-schemes for non-residential buildings. Most of them did not reach their first compliance cycle yet which limits the experiences. Still, these are key **lessons learned** we derive:

- A MEPS scheme depends on a data basis. On the one hand for setting meaningful thresholds. On the other hand, the same system could provide information for checking compliance. In both cases, collecting representative data and establishing a monitoring system takes time. Member states should start both processes as soon as possible.
- Requirements of a MEPS scheme must be easy to understand for building owners. It can be helpful to express the requirement based on existing benchmarks like Energy Performance Certificates. The extent of exemptions should be limited. Building owners must be provided with information – third parties like banks can play a major role in doing so.

Unlike residential buildings, non-residential buildings differ a lot depending on their usage: For example, a hospital will most likely have a higher area-specific energy demand for space heating than an office building. This leads to the key challenge designing a MEPS scheme for non-residential buildings: **How can the heterogeneity be addressed fairly?** Which are the worst performing buildings? In Chapter 4.3 we describe three approaches to this question: One option is to handle every usage category separately and define threshold-values for each category separately (worst e.g., 16% of hospitals, hotels, offices etc.). Another option is to define a uniform indicator across all usage categories. This can be done by comparing every individual building to a corresponding virtual building with reference characteristics. The ratio can be used in order to define the 16% worst performing buildings. A third approach is to provide a predefined list of component-based requirements, from which owners can choose which measures they want to apply.

Chapter 5 contains an **estimation of the impact** of different MEPS-schemes using a bottom-up modelling approach to analyse the significance of specific design elements:

- **MEPS can play a key role in achieving the 2030 climate** targets by reducing emissions from 2.2[40] and 4.5 Mt_{CO2} per year in 2030 in Germany. This reduction potential is relevant compared to official projections which indicate a gap to the 2030 target of 12 Mt_{CO2} per year for the buildings sector (Harthan et al. 2023)
- Our estimations are based on a comparison with a reference scenario. If the reality results in fewer retrofits than we assumed, the impact of MEPS increases. MEPS serves as a **safety net within a comprehensive policy mix**.

[40] The result of the trialogue is close to our scenario Council (1), which we estimate to mitigate 2.2 Mt_{CO2} per year in 2030. This value marks an upper limit due to the reasons explained at the end of Chapter 5.2.3.

- The impact of a MEPS scheme grows the more buildings it covers. The ambition is defined by the thresholds. The position of the Parliament sets a threshold for retrofitting the worst 43% buildings. This is more ambitious than the General Approach of the Council (targeting the worst 25%).
- **Time matters**: The climate stability degradation depends on the total amount of greenhouse gas emissions. This is reflected by yearly accumulated emissions. The sooner a MEPS establishes obligations to retrofit buildings, the more emissions can be saved.
- The **choice of the indicator** defines the steering effect of MEPS:
  - Indicators which consider the type of energy carrier, such as primary energy or carbon emissions, strengthen the decarbonization of the building sector
  - Indicators focussing on the energy efficiency of the building envelope, such as useful or final energy demand, promote deep retrofits and reduce energy consumption. This decreases e.g., the demand for electricity used in heat pumps and supports the decarbonization of the energy sector.
  - The indicator decides if consumption behaviour is included. This is the case for benchmarks based on metered consumption (operational rating). Component-related requirements or calculated demand (asset rating) only contain the physical building characteristics.
- The impact of MEPS increases when thresholds are progressively raised until the efficiency target level is reached (e.g., zero emission building). On the one hand because the level of ambition increases. On the other hand, this can **avoid lock-in-effects**: Building owners facing an investment decision at the end of a building component's lifespan are more inclined to opt for a comprehensive deep thermal retrofit, rather than implementing a renovation depth that does not align with future efficiency targets.

For any MEPS-scheme, Member States need to collect data on their non-residential building stock (see Chapter 4.1). Building owners should also be given some time between the communication of a law and its enforcement. With planned first compliance cycles in 2027 or 2030, it is evident: Member States should not waste time and start as soon as possible with **acquisition of representative data** on their non-residential building stock.

This report does not address possible exemptions or hardship rules. Reasonable criteria may include monument protection, vacant building, or those slated for demolition. In cases where owners have low financial capacities and face overload, targeted subsidies and a supportive policy framework may be more helpful than exempting them from obligations. This may help short-termly but leaves them burdened with high ongoing energy costs. Informational tools like Energy Performance Certificates and renovation roadmaps can assist owners. To keep a MEPS scheme simple, Member States may initially only cover several usage categories or exclude complicated and less relevant ones. However, keeping exemptions at a low level increases the scheme's potential impact.

Minimum Energy Performance Standards for non-residential buildings present both challenges and opportunities – for Member States striving to meet the 2030 climate and efficiency targets and for users of the worst-performing buildings. While obligations are burdensome initially, a MEPS scheme shines a spotlight on those grappling with high ongoing energy costs. When embedded within a policy framework that targetedly supports retrofitting, MEPS schemes can deliver benefits for the climate, the economy, and individuals alike.

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8 Annex: Factsheets for existing MEPS-schemes on non-residential buildings

The Netherlands

Introduced: 2018

Description of the scheme[41]

Coverage Office Buildings	**Approach** One time-related threshold
Exceptions • Office use is less than 50 % or 100 m² • Listed buildings (monument protection) • Planned to be demolished • Measures with a payback period over 10 years do not have to be implemented	**Threshold definition** Primary energy consumption from fossil fuels within Energy Performance Certificate (EPC)
Compliance control Local authorities decide about appropriate measures, fines, ban on renting or closure of the building	**Threshold timeline and value[42]** 1.1.2023: EPC C (225 kWh/m²a primary energy consumption from fossil fuels)

Lessons learned

positive[43]	negative[44]	other

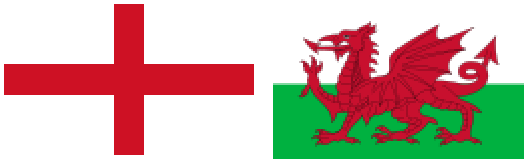
• Early announcement → Easy planning and staggered implementation
• Banks became very active → by alerting and advising their costumers → by adjusting financing conditions expecting non-compliance
	• Lack of compliance: Energy efficiency of office buildings (1st Jan. 2023):
	  • 55% EPC C or better
	  • 10% EPC D or worse
	  • 35% without energy label	

Summary

With 2023, all office buildings in the Netherlands must achieve an EPC C, which is expressed by a primary energy consumption from fossil fuels of 225 kWh/m^{2}a. If not, any required retrofit measures must be determined, or the local authorities step imposing consequences up to closure of the building. Early announcements of the MEPS (5 years in advance) helped to ease the process. Nevertheless, a lack of compliance is seen.

41 Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2018).
42 Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2020).
43 Sunderland and Santini (2020).
44 Rijksdienst voor Ondernemend Nederland (2023).

England and Wales



Introduced: 2016

Description of the scheme[45]

Coverage Privately rented buildings (residential and non-residential)	**Approach** One time-related threshold
Exceptions • Measures with a payback period over 7 years or an investment of more than £3,500 do not have to be implemented • The relevant energy efficiency improvements must not reduce the market value of the premises by more than 5%	**Threshold definition**[46] The EPC is expressed by a score from 1-100 assessing the buildings energy running costs. It is called SAP (Standard Assessment Procedure).
Compliance control ban of renting for landlords	**Threshold timeline and value** EPC E (SAP 39-54): • April 2018: for new tenancies • April 2020: for all tenancies

Lessons learned

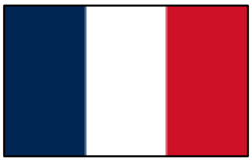
Positive[47]	**negative**[48]	**other**
• increase on the energy efficiency: plus 5 points on average at the SAP-score	• Lack of compliance → little reliable data → no obligation to update EPC • Not user-friendly: complex • many exceptions	

Summary

Since 2018, privately rented buildings must meet Energy Efficiency Standards. A minimum of EPC E must be provided, or it is no longer legal to rent out the building. Evaluations show that most building owners met the demands by minimal effort, while others invested in even higher efficiency standards. Compliance control turned out to be difficult, due to a poor data supply. The large extent of exemptions decreased the impact of the scheme.

[45] Department for Business, Energy and Industrial Strategy (2021).
[46] Eden District Council (2022).
[47] Department for Business, Energy and Industrial Strategy (2021).
[48] Sunderland and Santini (2020).

France



Introduced: 2019

Description of the scheme[49]

Coverage Large non-residential buildings with >1000m² floor area	**Approach** Time-related efficiency targets per building
Exceptions	**Threshold definition** Staggered percentual reduction of final energy consumption
Compliance control • mainly: “name and shame” • Buildings must be registered together with their energy consumption at a platform (“OPERAT”)[50] • not meeting the requirements may result in warnings or fines between 1500 and 7500€[51]	**Threshold timeline and value** • 2030: reduction by 40% • 2040: reduction by 50% • 2050: reduction by 60%

Lessons learned

positive	negative	other
• Provision of tools, databases and information before the enforcement	• A lack of data in the non-residential building sector ➔ hard to monitor and control policies	• Obligatory achievement logging on a national platform

Summary

Large non-residential buildings must follow a staggered percentual reduction of their final energy consumption, compared to 2010 or later. Starting with a reduction of 40% in 2030, a reduction of 60% must be reached in 2050. Each building owner or user must protocol their progress on an online platform to enable monitoring.

[49] Weiß et al. (2021).
[50] Ademe (2020).
[51] Kamenders et al. (2022).

Brussels-Capital (Belgium)

Introduced: 2021

Description of the scheme

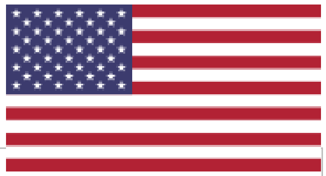
Coverage[52] All residential and non-residential buildings	**Approach** Building-specific measures, installed at five staged enforcement dates
Exceptions[53] Offices smaller than 500m²	**Threshold definition**[54] sectoral- and building-specific technical measures concerning sizing, insulation, partitioning etc.
Compliance control Public authorities have the power to perform monitoring at the points of sale or lease[14]	**Threshold timeline and value** • 2023: implementing decrees laying down measures and requirements to be achieved[13] • 2030: start of five yearly deadlines • 2050: target: minimum of EPC C (100 kWh/m²a primary energy consumption)[55]

Summary

In the Brussels-Capital Region, sectoral- and building-specific measures must be conducted on all residential and non-residential buildings. Therefore, 5 yearly enforcement dates are intended. A minimum of EPC C (<100kWh/m^{2}a primary energy consumption) for the whole building stock is targeted for 2050. At points of sale or lease, public authorities may monitor the retrofit achievements and thermal status of the building.

[52] Sunderland and Santini (2020).
[53] Bruxelles environnement (2022).
[54] Gouvernement de la Région de Bruxelles Capitale (2019).
[55] Kamenders et al. (2022).

USA



Description of the schemes (for details see Table 12)

<u>Coverage</u> • Individual MEPS schemes in a multitude of cities and states • Typically, large buildings, e.g. >20.000 sq ft	**<u>Approach</u>** • building size thresholds that reduce over time • building category thresholds that reduce over time

<u>Exceptions</u>	**<u>Threshold definition</u>**
	
	• Typically based on existing benchmarking and transparency approaches, different thresholds for more than 80 building types
	• Approach:
	  • Mostly: energy use intensity (EUI) and water use intensity (WUI)
	  → increased energy star rating or percentual reduction relative to baseline year
	  • some schemes: GHG intensity (kg_{CO2}/sq. ft)

<u>Compliance control</u>
 	
• Energy star rating is mandatory
  → Data is published online
  → Public display
• Shared responsibility
  → Owner and tenant responsible
  → portion of fee in case of non-compliance can be passed to tenant
	<u>Threshold timeline and value</u>
	
	• depending on scheme, see table 7
	• Staggered deadlines following (compliance cycle)

Lessons learned

positive	negative	other
Schemes profit existing data from long-term survey for non-residential buildings Connection to existing tools for benchmarking and transparency Direct data inputs by utility increase reliability		

Summary

There are existing MEPS in many cities and states all over the United States. While there is individual jurisdiction in every city or state, their MEPS are all based on the ENERGY STAR rating system that is based on data of Commercial Buildings Energy Consumption Surveys. The thresholds mostly concern energy consumption and are staggered by building size – starting with building with the largest floor area. An ENERGY STAR label is mandatory and all data is published online, which facilitates compliance control. In case of non-compliance, not only building owners are responsible, but fees can be passed partly to tenants. For details on the schemes see Table 7.

Table 12: Existing MEPS-schemes on non-residential buildings in the US

General information			
	Year of introduction	**Coverage**	**Metric**
Boston, Massachussets	2021	All municipal, commercial and multifamily buildings above 20,000 sq. ft of 15 residential units[56]	Annual GHG emissions per floor space
Chula Vista, California	2021	Municipal, commercial, institutional,and multifamily buildings 20,000 sq. ft. or larger	ENERGY STAR score or Weather Normalized Site EUI
Colorado	2021	Public, commercial, institutional, and multifamily buildings 50,000 sq. ft. or larger	To be determined (TBD)
Denver, Colorado	2021	All commercial and multifamily buildings ≥ 25,000 sq. f	Weather Normalized Site Energy Use Intensity (EUI) Deduction of energy produced from onsite or offsite solar from its measured site EUI is possible. Some alternative compliance pathways are possible
Federal Building Performance Standard	2022	Federal agency's buildings	MT CO2e/yr. The performance pathway is measured through annual scope 1 GHG emissions from fossil fuels combusted on-site
Maryland	2022	Public, commercial, institutional, and multifamily buildings ≥ 35,000 s	Onsite greenhouse gas (GHG)emissio
Montgomery County, Maryland	2022	Public, commercial, institutional, and multifamily buildings ≥ 25,000 sq. ft	Site energy use intensity (EUI)

[56] Also multiple buildings on the same parcels totaling 20,000 sq. ft. or 15 or more units in size.

New York City	2019	All commercial and multifamily buildings > 25,000 sq. ft	Annual GHG emissions per floor space
St. Louis, Missouri	2020	Municipal, commercial, institutional, and multifamily buildings 50,000 sq. ft. or larger	Site energy use intensity (EUI)
Washington State	2019	Commercial buildings (non-residential) 50,000 sq. ft. or larger 2031: Multifamily buildings ≥ 20,000 sq. ft. and commercial buildings 20,000 sq. ft. to 49,999 sq.	Weather-normalized Energy Use Intensity
Washington DC	2018	Jan 1, 2021: Privately owned buildings ≥ 50,000 sq. ft. District-owned buildings ≥ 10,000 sq. ft. Jan. 1, 2027: All privately owned buildings ≥ 25,000 sq. ft. Jan. 1, 2033: All privately owned buildings≥ 10,000 sq. ft.	ENERGY STAR score or an equivalent metric (source EUI for buildings ineligible for ENERGY STAR). Law directs department to assess a metric based on emissions by 2023
Performance targets/standards and compliance cycles			
Boston, Massa-chussets	Target set by building type on emission intensity basis. Opt-in option: 50% reduction by 2030 and 100% by 2050 (base year: 2005) Buildings must meet their targets annually starting in 2025; targets are adapted every 5 years. Buildings can also opt into a “glide path” target achieving 50% emissions reduction by 2030 and 100% by 2050 using a 2005 or later baseline Renewable energy credits may be used to offset emissions from electricity consumption		
Chula Vista, California	Requirement for high performance buildings (HPB): ENERGY STAR Score ≥ 80; or be ENERGY STAR certified; or be LEED Existing Building Certified for 3 of the 5 preceding years. non-residential buildings and Multifamily buildings with significant owner-paid energy use must either (1) achieve a minimum EUI improvement or (2) complete an Energy Audit and Retrocommissioning and meet a smaller mandatory minimum improvement by the end of the next compliance cycle (every five years beginning 2023 for buildings ≥ 50,000 sq. ft. and 2026 for buildings ≥ 20,000 sq. ft)		
Colorado	Tbd. Standards must achieve a GHG emissions reduction of 7% from 2021 levels by 2026 and 20% from 2021 levels by 2030. Process for determining standards for 2030 to 2050 foreseen. Compliance cycles are every four years, beginning in 2026 and going through 2050.		

Denver, Colorado	Threshold for site EUI standard based on occupancy type by the year 2030. Buildings are required to meet interim performance targets in 2024 and 2027 to ensure progress toward the final, 2030 standard. Interim targets are determined according to the building's "trajectory" from its baseline site EUI performance in 2019 to the final site EUI standard for its property type
Federal Building Performance Standard	30% (by total building area) of each Federal agency's buildings must eliminate all Scope 1 emissions — on-site fossil fuel use — by 2030. Further targets for years 2038 and 2045 for the percentage of buildings that every agency must electrify will be set no later than 2028.
Maryland	Existing buildings over 35,000 square feet achieve a 20% reduction in net direct greenhouse gas emissions by January 1, 2030, as compared with 2025 levels for average buildings of similar construction; and net–zero direct greenhouse gas emissions on or before January 1, 2040
Montgomery County, Maryland	To be determined.
New York City	Targets for CO2-intensity for on-site emissions, first compliance cycle in 2024, increasingly stringent targets every five years.
St. Louis, Missouri	Standards to be set no lower than the 65th percentile by property type, so that at least 65% of the buildings of the property type have a higher EUI. New performance standards issued at the end of each compliance cycle.
Washington State	EUI targets must be no greater than the average energy use intensity for the building's occupancy type with adjustments for unique energy-using features. EUI targets initially based on ASHRAE standar 100– 2018. Proposed rules set first target at 15% below average EUI for building type.
Washington DC	For buildings that are eligible for an ENERGY STAR score, the building energy performance standard shall be no lower than the District median ENERGY STAR score for buildings of each property type. New performance standards issued every six years. Campus-wide standards for educational campuses and hospitals
Exemptions	
Boston, Massa-chussets	Does not cover state, county, or federal buildings. Exemptions for newly constructed buildings, those with permits for demolition, and those facing specific financial distress
Chula Vista, California	The law does not apply to county, state, and federal buildings, Metropolitan Transit Service buildings, or buildings owned by the Chula Vista and Sweetwater School Districts.

	Properties meeting any of the following conditions are exempt from the performance standard requirements: • Properties that have been occupied less than 5 years • Properties in financial distress • Properties with a permit for demolition that have already commenced demolition work • Properties that have not been previously subject to the benchmarking requirement
Colorado	• storage facilities, stand-alone parking garages, airplane hangars that lack heating and cooling • Buildings where more than half of gross floor area is used for manufacturing, industrial, or agricultural purposes • Single family homes, duplexes, or triplexes
Denver, Colorado	To be determined.
Federal Building Performance Standard	To be determined.
Maryland	Single family homes, historic properties, manufacturing buildings and agricultural buildings
Montgomery County, Maryland	Single family homes, buildings where 10% or more of their total floor space is used for public assembly in a building without walls; warehousing; self-storage; or a use classified as manufacturing and industrial or transportation, communication, and utilities
New York City	• Industrial facility used for generating electric power or steam • City buildings • NYC Housing Authority buildings • Different types of residential buildings
St. Louis, Missouri	• Demolition permit issued or demolition is planned during the compliance cycle; • Financial hardship or if compliance would not be in public interest; • Primary use of building is industrial; • Property is communications infrastructure; • Property is owned by the state or federal government
Washington State	• Historic buildings do not need to meet any requirement that would compromise their historical integrity. • No Certificate of Occupancy for all 12 months prior to compliance date • Average occupancy less than 50% • Primary use of building is industrial • Primary use of building is agricultural • Building meets conditions of financial hardship
Washington DC	Requests for delay may be issues for all building types

	Penalties for non-compliance
Boston, Massa-chussets	Alternative Compliance Payment (ACP) of $234 per metric ton of CO2e per year; Cost review by the Review Board every 5 years; Funding goes into the Equitable Emissions Investment Fund.
Chula Vista, California	Non-compliance may result in a fine ranging from $750 - $2500 depending on building size.
Colorado	Civil penalty of up to $2000 for a first violation and up to $5,000 for each subsequent violation.
Denver, Colorado	Civil penalty of up to $0.70 per year for each required kBtu reduction that the owner's building failed to achieve in that year. If unpaid within 180 days the penalty becomes a lien on the property.
Federal Building Performance Standard	To be determined.
Maryland	To be determined.
Montgomery County, Maryland	To be determined.
New York City	Exceeding annual building emissions limit: Civil penalty of not more than an amount equal to the difference between the building emissions limit for such year and the reported building emissions for such year, multiplied by $268. Failure to file a report: Penalty no more than an amount equal to the gross floor area of such covered building, multiplied by $0.50, for each month that the violation is not corrected within the 12 months following the reporting deadline (more conditions); False statement: Fine of not more than $500,000 or imprisonment of no more than 30 days, or both, in addition to a civil penalty of not more than $5
St. Louis, Missouri	If data is not reported and an alternative compliance plan is not presented within 60 days of the compliance date, a fine between $1– $500 is issued for each day beyond the 60 days.
Washington State	Penalty up to $5,000 plus an amount based on the duration of any continuing violation. The additional amount for a continuing violation may not exceed a daily amount equal to $1 per gross square foot of floor area
Washington DC	Alternative compliance penalty determined per rules established by the DOEE; penalties collected pursuant to this provision shall be deposited into the Sustainable Energy Trust