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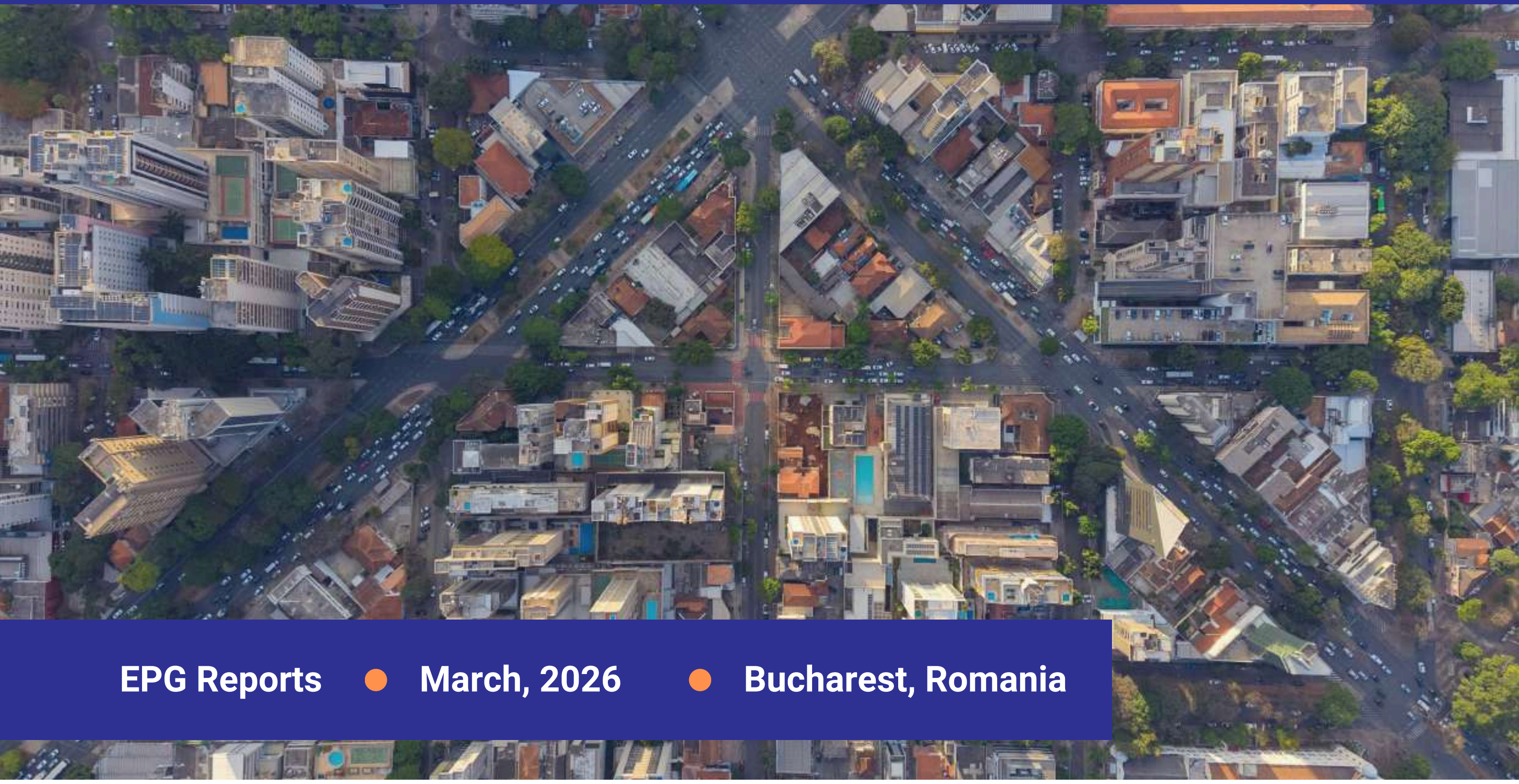

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Sustainability and Constraints in the Building Sector under the ZEB Requirements

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Title

Sustainability and Constraints in the Building Sector under the ZEB Requirements

A study by

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About EPG

EPG is an independent, non-profit think tank focused on energy and climate policy in Romania and the European Union. Founded in 2014, EPG operates as a policy research institute primarily financed through competitive grants, philanthropic organisations and, to a limited extent, private sector projects. EPG aims to promote an evidence-based dialogue on how to balance decarbonisation, economic competitiveness and social fairness, engaging decision-makers, industry, and the public.

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Key Findings

The ZEB standard, alongside the requirement for whole-life carbon accounting and disclosure for new buildings, represent a significant policy shift in how sustainability and development are approached within the sector. Drawing on these provisions introduced in the 2024 recast of the EPBD and the broader concept of sustainability, the study identifies key directions for future policy development. These include setting limits to the construction of new buildings against national and local carbon budgets; developing cross-sectoral municipal planning frameworks to enable ZEB compliance, particularly in dense urban areas; addressing demand through sufficiency-oriented measures and building public and stakeholder acceptance around such measures. These steps prove essential to improving the prospects of a sustainable building sector.

- **Establishing a framework to assess new construction against sectoral emissions** set out in the National Energy and Climate Plans, using national carbon budgets to identify material constraints and define a national "safe operating space" for life-cycle emissions in the built environment. In setting limits for buildings' life-cycle GWP, policymakers should move beyond simple area-based thresholds and adopt more nuanced, function-based approaches that reflect differences in building typologies, technical requirements, and their relative importance to human well-being.
- **Advancing cross-sectoral integrated planning to enable ZEB implementation, especially in dense urban areas.** Transitioning to ZEB requires coordinated actions between the building and the energy sectors, particularly at local level. This is only useful but necessary in dense urban areas, where ensuring ZEB compliance and the ban of on-site fossil fuels may be difficult to square, placing increased pressure on the centralised heating systems and electricity grids to decarbonise. In Romania, this strong dependence risks becoming a structural vulnerability. Long-standing infrastructure decline, outdated system designs and continued reliance on public subsidies have centralised heating &cooling systems currently ill-prepared to support ZEB-compliant new buildings.
- **Complementing the new building standards ZEB and embodied emissions policies with sufficiency measures.** Integrating sufficiency measures shows significant potential to reduce embodied emissions. Potential measures include stricter planning regulations where vacant buildings exist, systematic evaluation of reuse options before demolition or new construction, and limits on development on greenfield sites. Urban planning is a central leverage point for addressing these sufficiency measures. National or municipal databases of vacant and underused buildings, linked to spatial planning and housing strategies, would provide an important evidence base.
- **Tackling the political risks for national efficiency, circularity, and sufficiency policies.** Measures such as differentiated life-cycle emission thresholds or limits on new construction can challenge prevailing economic incentives, property rights expectations and urban development models. As a result, they may encounter political resistance from local authorities, developers and other stakeholders. To overcome these barriers, policymakers will need to combine regulatory measures with effective communication strategies and efforts to build public and stakeholder support.

Executive Summary

The European Union has developed an extensive body of legislation and guidance for achieving an energy efficient, sustainable, and decarbonised building stock by 2050. A central element in this policy framework is the shift from a sole focus on emissions generated during a building's operational phase to a more comprehensive accounting of emissions across its entire life-cycle, including those embedded in construction materials and processes (embodied emissions). This comprehensive approach is regulated in the Energy Performance of Buildings Directive (EPBD), through the provisions for new builds, specifically the Zero-Emission Building (ZEB) and the mandatory disclosure of Life-Cycle Global Warming Potential (GWP), which quantifies the amount of embodied emissions associated with a building throughout its life cycle.

This policy shift responds to a pressing challenge: the building sector is below the required trajectory for 2050 climate neutrality, and one the highest energy-consuming and largest emitters of carbon dioxide among all economic sectors. Globally, around half of all annually extracted raw materials are used for construction, and still heavily reliant on raw material input. Circular approaches, such as recovery of construction components, material reuse and recycle, are relatively underdeveloped practices, as are policies and regulatory mechanisms to incentivise and facilitate bringing abandoned material stocks to new life. Material dynamics, the scale of construction activities, and a prevalent linear model of consumption of construction material are mirrored in waste generation patterns, accounting for more than 38% of total waste generation across EU. At the same time, material demand is expected to continue growing, driven by urbanisation, rising living standards, and increased demand for housing. Expanding the supply of affordable housing through new construction is also high on the EU policy agenda.

Against this backdrop, this study examines the zero emission buildings definition and the calculation of whole life carbon for new buildings, situating these provisions within the broader concept and debates on sustainability and sustainable development. It argues that expanding the regulatory attention beyond operational energy efficiency to include circularity, RES and whole-life carbon impacts, these instruments redefine what constitutes a "sustainable" building. However, when these policies are embedded in wider urban development and economic growth dynamics, closely linked to social goals, housing provision, land values and investment dynamics, they also open up a broader space for reflection on the normative decisions and policy trade-offs that Member States must confront in aligning the building sector with a sustainability agenda.

The implementation of ZEB and the embodied carbon calculations for ZEB buildings, while necessary, is insufficient to address the full complexity of what a sustainable and decarbonised building sector entails. Sustainability has a political facet, too, and governments must consider not only how buildings can become more energy-efficient, but also which sectors along the building value chain should bear stronger regulatory responsibilities, how the costs of decarbonisation should be distributed, and under what circumstances new construction is necessary in the first place.

To strengthen the implementation of the EU policy framework, the study further identifies several levers for policy development at the national level. These include expanding spatial boundaries of assessment to set limits to the construction of ZEB buildings against national and local carbon budgets; developing cross-sectoral municipal planning frameworks to enable ZEB compliance, particularly in dense urban areas; addressing demand through sufficiency-oriented measures; and building public and stakeholder acceptance around such measures. These steps prove essential to improving the prospects of a sustainable building sector.

Sumar executiv

Uniunea Europeană a dezvoltat un cadru amplu de legislație și ghidaj pentru ca stocul de clădiri să devină unul eficient energetic, sustenabil și decarbonizat până în 2050. Un element central al acestui cadru de politici îl reprezintă trecerea de la o abordare concentrată exclusiv pe emisiile generate în faza de utilizare a clădirilor la o contabilizare mai cuprinzătoare a emisiilor pe întregul ciclu de viață al acestora, inclusiv a celor încorporate în materialele și procesele de construcție (emisiile încorporate). Această abordare este reflectată în Directiva privind performanța energetică a clădirilor (EPBD), prin prevederile aplicabile construcțiilor noi, în special conceptul de clădire cu emisii zero (Zero-Emission Building – ZEB) și obligația de raportare a potențialului de încălzire globală pe ciclul de viață (Life-Cycle Global Warming Potential – GWP), care cuantifică emisiile încorporate asociate unei clădiri pe întreaga durată a ciclului său de viață.

Această schimbare de politică răspunde unei provocări importante: sectorul clădirilor se situează sub traiectoria necesară pentru atingerea neutralității climatice până în 2050 și este unul dintre cei mai mari consumatori de energie și emițători de dioxid de carbon dintre sectoarele economiei. La nivel global, aproximativ jumătate din materiile prime extrase anual sunt utilizate în construcții, iar practicile actuale sunt dependente de utilizarea continuă a resurselor primare. Abordările circulare, precum recuperarea componentelor de construcție, reutilizarea și reciclarea materialelor, sunt încă relativ puțin dezvoltate, la fel ca politicile și mecanismele de reglementare menite să stimuleze și să faciliteze readucerea în circuit a stocurilor de materiale abandonate. Aceste dinamici, alături de amploarea activităților de construcție și de modelul predominant liniar de consum al materialelor, se reflectă și în generarea de deșeuri: activitățile de construcție și demolare reprezintă peste 38% din totalul deșeurilor generate în Uniunea Europeană. În același timp, este preconizată o continuă creștere a cererii de materiale de construcții, pe fondul urbanizării, al creșterii nivelului de trai și al cererii sporite de locuințe. Extinderea ofertei de locuințe accesibile prin construcții noi reprezintă, de asemenea, o prioritate importantă pe agenda politicilor europene.

În acest context, studiul de față analizează definiția clădirilor cu emisii zero și calculul carbonului pe întregul ciclu de viață pentru clădirile noi, plasând aceste prevederi în cadrul mai larg al conceptelor și dezbaterilor privind sustenabilitatea și dezvoltarea durabilă. Studiul argumentează că, prin extinderea atenției reglementărilor dincolo de eficiența energetică operațională către circularitate, utilizarea surselor regenerabile de energie (RES) și impactul emisiilor pe întregul ciclu de viață, aceste instrumente contribuie la redefinirea a ceea ce înseamnă o „clădire sustenabilă”. Totuși, atunci când aceste politici sunt integrate în dinamici mai ample de dezvoltare urbană și creștere economică, strâns legate de obiective sociale, de oferta de locuințe, de valorile terenurilor și de dinamica investițiilor, ele deschid și un spațiu mai amplu de reflecție asupra deciziilor normative și a compromisurilor de politică publică pe care statele membre trebuie să le abordeze pentru a alinia sectorul construcțiilor la o agendă de sustenabilitate.

Implementarea standardului ZEB și calculul emisiilor de carbon încorporate pentru aceste clădiri reprezintă pași necesari, dar insuficienți pentru a aborda întreaga complexitate a tranziției către un sector al construcțiilor sustenabil și decarbonizat. Sustenabilitatea are și o dimensiune politică: guvernele trebuie să decidă nu doar cum pot deveni clădirile mai eficiente energetic, ci și care sectoare din lanțul valoric al construcțiilor ar trebui să suporte responsabilități de reglementare mai stricte, cum ar trebui distribuite costurile decarbonizării și în ce condiții construcțiile noi sunt cu adevărat necesare.

Pentru a consolida eficacitatea implementării cadrului de politici al UE, studiul identifică, de asemenea, mai multe direcții de acțiune la nivel național. Acestea includ extinderea limitelor spațiale de evaluare pentru a corela construcția de clădiri ZEB cu bugetele de carbon naționale și locale; dezvoltarea unor cadre de planificare municipală intersectoriale care să faciliteze implementarea standardului ZEB, în special în zonele urbane dense; abordarea cererii prin măsuri orientate spre suficiență; și consolidarea acceptării publice și a implicării actorilor relevanți în jurul acestor măsuri. Împreună, aceste demersuri sunt esențiale pentru îmbunătățirea perspectivelor unui sector al construcțiilor sustenabil.

Contents

1. Introduction

The European Union has developed an extensive body of legislation and guidance regarding energy efficient, sustainable, and decarbonised buildings. The revised Energy Performance of Buildings Directive (EPBD), adopted in 2024, was the latest update of the directive as part of the broader European Green Deal, which aims to transform the EU's economy into a competitive, resource-efficient, and climate neutral economy by the mid-century.

The Directive tightens the energy performance requirements for both new and existing buildings and entrenches sustainability and circularity as guiding principles. This is most clearly reflected in the provisions for new builds through the concept of *zero-emission building* (ZEB) and the mandatory calculation and disclosure of life-cycle global warming potential (GWP) – the carbon emissions a building generates throughout its lifecycle. ZEBs are buildings designed and operated so that they produce no net greenhouse gas (GHG) emissions over a year. Therefore, ZEBs must use very little energy, which must come entirely from clean (i.e. zero-carbon) emissions sources.

ZEBs must achieve energy performance levels at least 10% higher than those required under the current nZEB standard. They must use no on-site fossil fuels and derive all energy from renewable sources, with solar PV panels mandatory on new non-residential roofs by 2027 and on residential ones by 2030. ZEB buildings must also support electric vehicle charging.

Member states must mandate calculation and disclosure of life cycle GWP (covering embodied carbon emissions in materials, construction works, utilisation, and decommissioning) in energy performance certificates (EPC), starting for larger/governmental buildings by 2028, and for all new buildings by 2030. By 2027, Member States will develop roadmaps for limit values on life-cycle emissions to apply from 2030 on. This applies to new ZEB buildings (public ones by 2028, all the others by 2030).

Circularity and sustainability in buildings are further embedded in the Construction Product Regulation (CPR), Ecodesign for Sustainable Products Regulation (ESPR), Waste Framework Directive (WFD), and the Level(s) Framework (the European framework for sustainable buildings), which include assessments and reporting conditions on sustainability indicators for construction products and building levels, respectively.

For some Member States, especially those with limited experience in policies addressing life-cycle emissions, the implementation of these legislative files represents a major regulatory and institutional overhaul (Energy Policy Group, 2024). Absent immediate direct benefits for the end-users, it often entails higher upfront costs for new buildings, driven by the green premium for low-carbon construction materials, as well as increased demand for specialised services of architects, engineers and construction companies. At the same time, the current urbanisation levels and projections for urban population, alongside demand for new buildings and built floor area, are expected to surge, primarily in urban areas (UNEP, 2024a).

Boosting affordable housing is high on the EU policy agenda (European Commission, 2025). Although buildings are responsible for approximately 33% of EU-wide energy-related emissions, the numbers are much higher in dense urban areas, where emissions associated with buildings can be at least twice as much, new construction ranking second (OECD, 2024) (Ramboll, 2023). In addition, building systems are embedded in complex interactions with the environment and with other socio-economic systems, such as energy and waste management, pulling resources for construction from surrounding areas and beyond, using them in the city and disposing of them outside of it (Goldstein & Rasmussen, 2017).

Sustainable and systemic approaches to new construction are therefore required to respond to increasing demand of new buildings and urban growth and, at the same time, limiting their embodied and operational GHG emissions.

Sustainable development is predicated on the idea of limits and the finiteness of natural systems and resources. The present study examines the concept of sustainability and its application to the buildings sector, under the latest EU regulatory framework. It analyses the definitions and requirements introduced by EPBD, with particular attention to how sustainability is framed and operationalised through the zero-emission building (ZEB) requirements and calculation of life cycle GHG emissions.

The study aims to identify regulatory gaps and flexibilities by focusing on the building level, with system boundaries and spatial boundaries, and promotes a holistic approach to assessment and decision-making for the provision of new buildings. It provides policy recommendations for the sector to remain within the limits of sustainability, drawing on facets of sustainability that have been more extensively used within the building sector, both in research and policy practice.

2. Background

The building sector is one of the highest energy-consuming sectors and one of the largest emitters of carbon dioxide among all economic sectors. Globally, around half of all annually extracted raw materials are used for construction. The production of these materials, notably cement, steel and aluminium, entails large energy requirements and environmental emissions along supply chains. Wiedenhofer, Streeck et al. (2024) estimate that more than two thirds of global material stocks are contained in buildings and transport infrastructure, with the majority stored in residential buildings. In regions experiencing population decline, 22% of material stocks in residential buildings remains unused due to building vacancy; and even in growing regions, 16% of material stocks hibernate as part of unoccupied dwellings.

Current building practices are still heavily reliant on new material inputs, and the *disassemble and reconstruct elsewhere* approach remains a nascent and underdeveloped practice, as are policies and regulatory mechanisms to incentivise and facilitate bringing abandoned material stocks to new life. These material dynamics, the scale of construction activities, and a prevalent linear model of consumption of construction material are mirrored in waste generation patterns. Construction and demolition account for more than 38% of total waste generation across EU (Eurostat, 2024).

Looking ahead, projections indicate that these challenges are likely to persist, and may even intensify in the coming decades. Firstly, material demand for construction is expected to keep rising, driven by demographic factors, such as population growth and urbanisation, as well as increasing living standards. As urban populations concentrate, cities will generate substantial demand for housing and infrastructure, reinforcing a sustained upward trajectory in construction volumes and material consumption. As such, in a business-as-usual scenario, global raw material use is projected to rise by 60% by 2060 (UNEP, 2024b). Total floor area is anticipated to increase in many countries worldwide, including in the EU, where projections show an increase of approximately 17% and 22% by 2050 and 2060, respectively – Chatterjee et al. (2025). This trend implies greater material use not only in absolute terms but also per person, intensifying pressures on resource efficiency.

This multifaceted challenge is particularly salient in light of the EU's commitments to reducing emissions and advancing a sustainable built environment. The gap between the sector's actual climate performance and the required decarbonisation pathways continues to widen, with key indicators (CO_2 emissions reductions, final energy consumption, the share of renewable energy, and investment in building renovation) remaining more than 40% off track relative to the desired trajectory. Overall, the European buildings and construction sector is not on track to achieve climate neutrality by 2050 (BPIE, 2024).

However, significant measures to advance the decarbonisation of the sector have been adopted in the EU through a comprehensive policy framework addressing the buildings and construction value chain. This framework requires intensified efforts to reduce emissions from the day-to-day use of buildings, including those from lighting, heating and cooling. It also introduces obligations to calculate and report emissions generated throughout the lifecycle of building materials – from extraction, manufacturing and transportation to installation, maintenance and end-of-life. The main policies impacting the construction of new buildings and emissions throughout the entire buildings' lifespan include:

- **Energy Performance of Buildings Directive (EPBD),** adopted in 2024. EPBD aims for a zero-emission building stock by 2050, establishes binding decarbonisation milestones for Member States, and provides a framework for the calculation of energy performance of buildings and minimum energy performance requirements for both new and existing buildings. EPBD also introduces the zero-emission buildings standard for new construction, and requires life-cycle global warming potential reporting for new buildings, although not specifically setting targets and requiring Member States to reduce whole-life carbon emissions (EU, 2024).
- **Energy Efficiency Directive (EED)** is the main overarching legislation aimed at improving energy efficiency across EU. The Directive sets an annual energy savings target of 1.5% for Member States and requires the renovation of at least 3% of the total floor area of publicly owned buildings each year. EED addresses heating and cooling and domestic hot water (EU, 2023).
- **Renewable Energy Directive (RED III**) promotes the integration of renewable energy sources into heating and cooling systems in buildings. It requires Member States to contribute to an indicative target of achieving a 49% share of renewable energy in buildings by 2030, while accelerating the deployment of renewable heating and cooling technologies (EU, 2023).
- **Level(s) Framework** is a voluntary framework of core indicators to assess and report on the sustainability performance of buildings throughout their life-cycle, from design to end-of-life. Importantly, Level(s) also considers other critical aspects of building performance, including GHG emissions, efficient use of water resources, health and well-being, climate adaptation and resilience, as well as cost and value, providing a more holistic approach to evaluating sustainable construction. Indicator 1.2 on life-cycle global warming potential lays the foundation for harmonised environmental assessment across the EU (EC, 2021).
- The revised **Construction Products Regulation (CPR**) (EU, 2024), linked to the **Ecodesign for Sustainable Products Regulation (ESPR)** (EU, 2024), aims to improve the sustainability and circularity of construction products. It establishes harmonised standards for assessing environmental performance, covering embodied carbon, circularity, resource efficiency, and decarbonisation, and requires manufacturers to report compliance via a Digital Product Passport. While the CPR sets no binding targets, it enhances transparency and comparability across the EU. It also addresses Green Public Procurement (GPP), encouraging the selection of products with lower life-cycle environmental impacts and supporting the sector's decarbonisation and circularity objectives.
- **Waste Framework Directive (WFD)** establishes the legal foundation for waste prevention and management in the EU, through the waste hierarchy (prevention, reuse, recycling), waste prevention and rules for end-of-waste status. With regard to the construction sector, the WFD established a Union-wide target of reusing or recycling at least 70% of construction and demolition waste (CDW) by 2020 (EU, 2008) (EU, 2025).

- **EU Taxonomy Regulation** establishes a framework for classifying environmentally sustainable economic activities. Activities are deemed sustainable if they make a substantial contribution to one or more environmental objectives, such as climate mitigation, circular economy, pollution prevention, water protection, or biodiversity. In construction, this includes investing in sustainable or circular products and materials to reduce emissions and increase the use of materials recovered from waste, by-products, or end-of-life products through recycling (EU, 2020).
- **The EU Emissions Trading System (EU-ETS)** is the main economic instrument influencing embodied carbon in the EU, covering electricity and heat generation, aviation sector, industrial manufacturing including construction materials such as steel, cement, glass, plastics, gypsum, and ceramics (EU, 2024). Thus, ETS indirectly targets embodied emissions in buildings construction and energy use. The recently introduced **ETS2** expands coverage to include fuel combustion in buildings, road transport, and certain additional sectors previously outside the scope of the ETS, with full implementation scheduled for 2027 (EC, 2023).

3. Sustainability and limits in construction

Views and definitions of sustainability, particularly with respect to triggering political actions and processes, differ despite a common core meaning that emphasises the weighing of needs against limitations. This shows in the way the concept has evolved and reflected in environmental policies over time.

At certain points, sustainability seemed to be an exhausted concept that has failed to deliver meaningful change and has subsequently been met by little political appetite. The concept's (re-) emergence in climate policies and actions as an organising framework bears the necessity of revisiting its constitutive feature of **ecological limits**, and of **(politically) reconciling these ecological limits with development**. The latter has much to do with the building sector, insofar as new construction is associated with growth, urban expansion, material consumption, hence with questions of how development can proceed within environmental limits.

A reference point in the concept's evolution is a three-pronged conception encompassing economy, society, and environment. Although cemented in academic and popular discourse, this conception has been insufficient in guiding environmental policies due to its ambiguity. However, despite this weakness, several models grew out from this tripartite definition with different frames of understanding and different policy responses. These approaches have retained the recognition of ecological limits while reframing environmental problems in the context of development as mainly a matter of inefficient resource use, which could be rectified through improved scientific understanding of ecological limits, technological innovation and more efficient management of resources.

Among these approaches, **Planetary Boundaries (PB)1** is one of the most influential variants of the notion of *limits at the planetary scale*, developed by Rockström et al. (2009) and Steffen et al. (2015). PB stresses the interdependence of biophysical processes, emphasising that "transgressing one may both shift the position of the other boundaries or cause them to be transgressed." PB is deemed to represent a basis for shifting environmental governance away from "sectoral analyses of limits to growth aimed at minimising negative externalities" towards estimating a "safe space" for human development, generally referred to as absolute boundaries.

3.1. Absolute and relative limits

There has been growing interest in understanding the boundaries of environmental limits as well as assessing sustainability against quantitative estimates of these limits, e.g. in different regions. Other sustainability approaches have also been developed, such as life-cycle assessments and policies on construction and buildings design (Kuittinen, 2023) (Binz & Jäger, 2024).

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[1] The Planetary Boundaries (PB) framework identifies nine critical Earth systems (like climate change, freshwater use, and biodiversity) that must stay within certain limits to maintain a stable environment.

There are two commonly used kinds of assessments of what counts as *a sustainable system*:

- *Absolute Environmental Sustainability Assessment* (AESA) is a methodology that determines if human activities (products, companies, systems) are sustainable by comparing their environmental impacts to the planet's carrying capacity (Planetary Boundaries,[2] e.g. scientifically derived carbon budgets), rather than comparing to a previous year or alternative course of action. A key component of AESA is the assigned share -- specific portion of the global budget/boundary allocated to the sector, activity, company, or product. AESA typically covers the entire life-cycle, including material extraction, manufacturing, use, and disposal. In AESA, the question is not whether a building or a sector performs better than another, but whether its total life-cycle emissions stay within a defined share of a finite emissions budget (Bjørn, et al., 2020).
- By contrast, *relative boundaries and relative sustainability assessments* (RESA) evaluate the sustainability of a system, such as a construction product or a building, by comparing it to a chosen reference, for example another product or a building. RESA is a method that typically uses Life-Cycle Assessment (LCA) to compare the environmental impacts of products, actions or systems against each other rather than against absolute planetary boundaries. As such, RESA identifies which of the available options has the lowest environmental burden (e.g., carbon emissions). However, while it offers quantitative comparisons of various options, RESA cannot determine if a product, process or system is actually "sustainable enough", that is, within nature's carrying capacity.

3.2. Ecological limits and normative limits

The ecological or bio-physical limits of sustainability refer, on the one hand, to the finite availability of a resource stock or flow, and on the other hand to the limited capacity of an ecological system to withstand perturbations while keeping its current state, as implied in the notion of Planetary Boundaries (PB). Indeed, the PB framework accounts for systems withstanding perturbations and remaining in their current state while being in a "safe operating space" in which development can continue.

However, when absolute environmental boundaries are seen from the viewpoint of values and preferences, they can be subject to politicised debates outside of the established scientific institutions and expert processes from which the ecological limits were derived. Such contestations do not necessarily rely on scientific evidence, but instead tend to be shaped by competing priorities, interests, and even unscientific information.

Therefore, environmental limits are often expressed in climate policies in terms of normative vocabularies, such as national carbon budgets and effort sharing mechanisms. These frameworks involve value-based decisions regarding equity, environmental justice, burden sharing, well-being differences, and the allocation of resources across sectors and value chains. At the EU level, a key example is the Effort Sharing Regulation (ESR) (EU, 2023), which

[2] The **Planetary Boundaries** (PB) framework identifies nine critical Earth systems (like climate change, freshwater use, and biodiversity) that must stay within certain limits to maintain a stable environment.

sets collective and national binding annual emissions reduction targets by the Member States. The national targets are negotiated among countries and are primarily based on economic capacity and ability to pay, rather than being distributed equally per country. Each Member State allocates annual emissions limits through their National Energy and Climate Plan (NECP). This approach sets a national emissions "budget" for the sectors buildings, transport, agriculture, waste, and small industries, ensuring that reductions occur in line with the EU's overall climate objectives.

Building on PB, a sustainability policy framework employed in France and currently advanced by IPCC for the building sector is the **SER** framework **(Sufficiency, Efficiency, Renewables),** which is structured around improving energy and materials intensity (efficiency), reducing the environmental impacts of the demand for energy and materials through renewables deployment, and avoiding unnecessary demand for energy and materials over the life-cycle of buildings and goods (sufficiency).

IPCC defines sufficiency policies as "measures and daily practices that avoid demand for energy, materials, land and water while delivering well-being for all within planetary boundaries." (IPCC, 2022). Sufficiency operates within the remaining carbon budget by defining a bounded space between two normative thresholds: an upper limit, set by principles of distributional equity and ecological constraints, and a lower limit, determined by the material requirements for ensuring decent living standards.

Applied to the building sector, sufficiency policies have proven important potential when complementing energy efficiency and renewable energy sources (RES) by reconciling trade-offs between social goals, such as affordable or social housing, and environmental concerns about the climate impact of new buildings (BPIE, Ramboll, 2024) (EEB, 2024).

The following sections explore how energy efficiency and the requirements for renewable energy sources in buildings, alongside sufficiency, can address the challenges of reducing CO_2 emissions and support sustainable transformation of the building sector through sustainable construction of low-emission buildings.

4. Operational versus embodied emissions

Emissions from the built environment can be split into operational and embodied emissions, depending on when and how they are generated. A building's carbon footprint over its lifespan is the sum of its operational plus embodied emissions. The operational emissions, i.e. those produced when using a building, are composed of direct emissions from fuel use in buildings (Scope 1) and indirect emissions from use of electricity and district heating (Scope 2). Embodied emissions (Scope 3) are those generated from the materials and construction processes throughout a building's entire life cycle.

Operational emissions

Operational emissions are associated with the energy consumption (operational energy) while the building is occupied. This includes energy required for the ongoing functioning and maintenance of a building, and released from sustaining comfortable indoor conditions, including by heating, cooling, ventilation, lighting, as well as the use of electrical appliances (cooking refrigeration appliances etc.). Early design decisions, such as the choice of building materials, insulation, orientation, and mechanical systems, significantly influence operational carbon, as do decisions made during renovations, including material upgrades and system replacements. As operational emissions have been dominating the building sector's carbon footprint, there is an extensive track record of EU policies and measures aimed at reducing them by setting performance requirements and standards that lower energy demand and improve efficiency.

Embodied emissions

In short, embodied emissions encompass the carbon footprint of construction materials, over their entire life-cycle. They include emissions generated during the extraction, production, transport, installation, maintenance, and eventual disposal or recycling of materials. Embodied carbon arises not only during the construction of new buildings but also during renovations and demolitions.

Embodied emissions have received less attention in EU building decarbonisation policy-making until the 2024 EPBD recast, under the assumption that emissions beyond operational energy use were negligible. However, research has shown that embodied emissions are significant and are becoming increasingly dominant as operational energy decreases due to energy efficiency measures (Röck, et al., 2020).

Energy performance standards prioritise minimising operational energy through high-performance insulation, efficient HVAC systems, and integrated renewable energy, and have been successful in lowering energy consumption during a building's use. However, achieving these performance levels often requires complex materials and technical systems that generate significant embodied emissions during production and installation. In other words, while operational energy savings reduce emissions in use, the production, transport, and installation of more complex materials and technical systems (e.g., high-performance façades, insulation, HVAC, renewable energy systems) generate extra emissions upfront, creating the so-called 'carbon spike' from initial production.

Consistent with projections regarding the trade-offs between operational and embodied carbon set out by Röck et al. (2020), recent research indicates that current energy performance standards, which place a strong emphasis on reducing operational emissions, are associated with increases in embodied carbon from construction materials and processes, averaging around 15%, based on representative residential and office building case studies.

Moreover, when nZEB definitions have been made more stringent, exceeding current EU benchmarks and targeting reductions in operational emissions of up to 80 %, embodied carbon emissions can rise further, reaching approximately 20 % (Kayaçetin & Hozatlı, 2024).

5. Energy efficiency and circularity: zero-emission buildings and embodied carbon

A step further from the current nZEB requirements, the ZEB buildings must achieve very high levels of energy efficiency and ensure that their energy demand is met by low-carbon energy sources. ZEB buildings must achieve annual primary energy use levels that are at least 10% lower than national nZEB thresholds and below the cost-optimal levels established in the most recent national calculations. In addition, operational greenhouse gas (GHG) emissions must comply with nationally defined limits.

EPBD places the ZEB standard within a broader EU legislative framework by linking it to other directives: the total annual primary energy must be covered from on-site or nearby RES, renewable energy communities (as defined by Renewable Energy Directive), efficient district heating and cooling systems (as required in the recast Energy Efficiency Directive).

The challenges for Member States in implementing ZEB include setting the energy demand thresholds while simultaneously banning on-site carbon emissions. This requires systems (heating, cooling, ventilation, lighting, and domestic hot water – DHW) to be powered exclusively by low carbon sources. This could prove difficult for buildings with no direct access to affordable, low-carbon energy, especially in urban and high-density contexts where on-site RES capacity may be limited. To meet this condition, though, the building's energy demand must be further diminished. Moreover, RES sources and energy storage solutions may see limitations to their widespread adoption, thus leading to greater reliance on centralised systems that are required to achieve decarbonisation by 2050 (Maduta, et al., 2025). Indeed, the adoption of ZEB criteria for the buildings stock will have to rely on the transition towards low-carbon, mostly electricity-based energy systems.

Apart from reducing energy demand through efficiency measures, which has been a long-standing priority in the EU legislation, the EPBD recast has mandated the assessment of embodied emissions for new, with the requirement to calculate the building's global warming potential (GWP) for new buildings along its full life cycle. By January 1, 2027, Member States must develop a roadmap for introducing limit values for the life-cycle GWP of new buildings and must set targets for new buildings from 2030, that feature a progressive downward trend. These targets in fact represent a series of limit values from 2030 followed by a lowering limit value for each subsequent moment – 2033, 2036, and so on.

5.1. System boundaries and emission balance boundaries

The concept of zero-emission building (ZEB) has been developed and applied in many countries in the last two decades, within and outside Europe, with some definitions entrenched in national laws and others merely conceptualised in scientific literature, including a few that consider the trade-offs between operational and embodied emissions. There is a noticeable common tendency to link on-site or nearby renewable energy sources (RES) to offsetting embodied emissions, whereby RES generation is assumed to both cover the building's energy demand and compensate for emissions arising over the building's life cycle (Þórólfsdóttir, et al., 2023) (Maduta, et al., 2023).

While EPBD requires life-cycle GHG to be calculated and disclosed, these emissions are not required to be counterbalanced or compensated to comply with the current ZEB requirements. As it stands, besides the calculation and disclosure of embodied emissions mandated for a ZEB building, these values themselves do not influence whether a building qualifies as a ZEB or not. Since ZEB focuses on strengthening the requirements for energy efficiency through mandatory numerical benchmarks for operational energy use and low-carbon energy supply, the system boundaries assigned to it are in fact limited to operational emission performance.

The EPBD limitation considers differing contexts and specific constraints faced by Member States concerning their national energy systems and electricity grids, and degree of RES adoption. Thus, the phrase zero emission building should be understood as rather 'operational net-zero' emission building, or 'zero operational emission building' (EEB, 2022). Operational net zero emissions reflect in the emissions balance during the operation stage of the building, which over a period of time, typically a year, ought to be zero.

The system boundary for embodied emissions follows the principle 'from cradle to grave', encompassing all significant greenhouse gas emissions associated with a building over its lifetime, thus wider than the one used for ZEB buildings assessments. Under the international standard EN 15978, life-cycle impacts are organised into discrete modules that correspond to particular stages of a building's life. The product stage (A1–A3) captures emissions from raw material extraction, processing and manufacturing before products leave the factory gate; the construction stage (A4–A5) covers transport of those products to site and the energy and material use inherent in on-site assembly; the use stage (B1–B7) encompasses emissions during occupation, including maintenance, repair, replacement, refurbishment and the building's operational energy and water consumption; and the end-of-life stage (C1–C4) accounts for demolition or deconstruction, waste transport, processing and disposal. In addition to these core modules, there is an optional module D, which lies beyond the formal system boundary and may be declared separately to reflect potential benefits or burdens from reuse, recycling or material recovery that occur in subsequent life cycles.

On the one hand, defining regulatory compliance solely in terms of zero operational emissions, while treating life-cycle emissions as a matter of transparency rather than enforceable limits, may spill-over into other sectors, or into other stages of the building life cycle, including material production and construction. This occurs because the "buildings" sector typically encompasses activities associated with building operation, whereas the construction of those same buildings is classified under the "industry" sector, meaning emissions from construction may be displaced rather than reduced.

On the other hand, this approach has the benefit of allowing member states, particularly those still unfamiliar with policies, methodologies, databases, tools or benchmarks for life cycle assessments for buildings to implement the legal, regulatory, as well as know-how base on the carbon footprint of buildings across the EU. Thus, the current ZEB definition may be seen as a transitional stage to build capacities and the necessary regulation, in anticipation of further requirements for compensation or offsets of GHG emissions throughout the buildings' life cycle.

5.2. Spatial boundaries

The ZEB requirements focus on the building as the assessment object – the spatial boundaries. Meeting the high energy performance requirements and the obligation to use renewable energy from different sources translates into design choices, including optimisation of building geometry, orientation to maximise the solar gains for solar PV panels, as well as careful consideration of building category and associated energy demand profiles. However, the flexibility provided under the ZEB standard about the energy sources used to cover annual total primary energy demand, such as on-site or nearby RES generation, renewable energy communities, efficient district heating and cooling systems, and other low-carbon energy sources, implicitly points to the relevance of assessment within broader spatial boundaries, at neighbourhood or city level.

This consideration also gained traction in EPBD recast. Expanding the boundaries of assessment has been shown to deliver more substantial emission reductions (Sandberg, et al., 2021), to enable planning solutions in urban and high-density contexts where on-site RES generation may be limited, and to better integrate in the existing local energy systems, when the transition of the building sector is coupled with the transition of the energy sector.

6. Sufficiency in the building sector

Sufficiency policies are a rather underdeveloped dimension of the built environment regulation, compared to energy efficiency, circularity and RES. This is despite a growing body of academic and policy literature demonstrating their potential for delivering emission reductions for the sector.

In the built environment, sufficiency measures encompass policies that, for example, incentivise the use of existing, vacant or under-occupied building stock, prioritise renovation and adaptive reuse over demolition and new construction, and encourage a more intensive and flexible use of buildings. These measures can be embedded across multiple scales, from limiting excessive new floor area through building regulation and design of adaptable buildings that can be subdivided or repurposed, to urban planning strategies and policies that limit urban sprawl, support mixed uses, and prioritise inner-city development. Evidence from several European countries, including Belgium, France, Germany, Ireland and Poland, indicates that avoiding the creation of new floor area can yield substantial reductions in embodied carbon emissions (BPIE, Ramboll, 2024).

Sufficiency measures must be sensitive to and accommodate the specific contextual factors of each region. At the EU level, this entails careful consideration of the substantial disparities between Member States in built and residential floor area per capita, housing size, type, and quality. Residential floor area per capita is generally highest in Northern and Western Europe, whereas countries in Central and Eastern Europe tend to have considerably less space, often of lower quality. This calls for sufficiency strategies that are tailored to national contexts: in high-consumption contexts, policies should focus on limiting new construction, addressing under-occupation, and promoting the renovation and adaptive reuse of existing buildings; in lower-consumption contexts, the focus should be on maximising the value of new buildings and meet human needs, such as improving housing quality and adequacy, while avoiding a lock-in to carbon- and resource-intensive growth patterns.

Urban planning and urban policies can offer a powerful, albeit underutilised leverage point for advancing sufficiency-oriented action in the built environment (Sjökvist, et al., 2025). Planning instruments such as limits on permissible new builds, development strategies like Compact City, Land Recycling, designation of Urban Development Areas (UDAs) are mechanisms that operationalise sufficiency measures at the local level. These models steer the development towards existing urban areas and constrain unnecessary construction, and in doing so, help reduce demand for new buildings and associated material use, while also lowering whole life carbon emissions and supporting green growth.

Compact City is an urban planning and development model associated with high density and mixed-use development, and promotion of movement of pedestrians, cyclists, and public transport users. Compact City policies promote densification and prioritise development in existing built-up areas through regulatory tools that manage urban expansion, alongside fiscal measures that support infill development. In practice, the model encompasses a range of strategies, including the introduction of minimum density requirements for new developments, prioritisation of brownfield over greenfield sites, regeneration of existing residential areas, promotion of transit-oriented development, and the intensification of under-used urban assets.

Likewise, Land Recycling represents a more targeted and comparatively recent approach in urban planning, focuses explicitly on limiting urban sprawl by restoring, retrofitting, or redeveloping idle, degraded, or under-utilised land—such as contaminated, vacant and abandoned sites—for new development. These models and planning principles for sufficiency can be complemented with the designation UDAs, which is a planning instrument that municipalities may use to strategically concentrate development within clearly defined areas in cities, in order to steer growth to places where it is most efficient, sustainable and socially beneficial. UDAs take the form of urban development corridors, where land recycling, new construction and renovations, are closely coordinated with investments in public transport and other infrastructure. An example of this joint approach, in practice, can be found in the municipal planning framework of Copenhagen (Greater Copenhagen Region, 2024).

Although local authorities can, through urban planning, enforce many of these measures, there is still a lack of robust, context-specific evidence on their emissions reduction impacts. Moreover, planning practices often lack the necessary analytical tools needed to explicitly recognise and address carbon-intensive construction activities, and decisions about zoning, density, demolition or redevelopment are rarely framed in carbon terms (Kolkwitz, et al., 2023). Also, gaining better understanding of vacant or underused built spaces could serve as a good starting point for sufficiency planning measures at the local level.

7. Policy recommendations for the Romanian building sector

This study has pointed out that the paradigm of sustainability, in its current interpretations and renewed formulations, remains a powerful working concept for shaping and delivering policies for the built environment. Policy instruments for new construction, namely the ZEB standard and the provisions requiring life cycle emissions assessments, mark an important shift in how sustainability and limits are addressed within the building sector.

Expanding the regulatory attention beyond operational energy efficiency to include circularity, RES and whole-life carbon impacts, these instruments expand on what constitutes a "sustainable" building. However, when embedded in wider urban development and economic growth strategies, closely intertwined with social goals, housing provision, land values and investment dynamics, they open up a broader space for reflection on the normative decisions and actions, both technological and non-technological that the Member States must undertake to align the building sector with a sustainability agenda.

The implementation of ZEB and the embodied carbon calculations for ZEB buildings, while necessary, is insufficient to address the full complexity of what a sustainable and decarbonised building sector entails. Sustainability has a political facet, too, in which governments are required to make choices not only about how buildings should be more efficient, but also which sectors involved in buildings' life cycle emissions should be more strictly regulated, how costs should be shared, as well as when, where, and whether it is necessary to build in the first place.

Against this backdrop, the study identifies several directions for policy development. These include expanding spatial boundaries of assessment to set limits to the construction of ZEB buildings against national and local carbon budgets; developing cross-sectoral municipal planning frameworks to enable ZEB compliance, particularly in dense urban areas; addressing demand through sufficiency-oriented measures; and building public and stakeholder acceptance around such measures. These steps prove essential to improving the prospects of a sustainable building sector.

Understanding the material constraints for ZEB

Romania should implement a framework to assess construction of new buildings against the sector emission limits set out in NECP, using national carbon budgets to understand sectoral material constraints related to new buildings and defining a national "safe operating space" for life cycle emissions of the built environment.

In setting carbon limit values for buildings' life-cycle GWP, national policymakers should go beyond the minimum requirement to define these limits contingent on the building area alone and instead develop more nuanced CO2 emissions limits for buildings. Some functions are more important to human well-being than others, and for some building typologies it is easier to reduce the impact because of differences in technical requirements (Heide, et al., 2023). It would therefore make sense to have differentiated function-based approaches.

Advancing cross-sectoral integrated planning to enable ZEB implementation, especially in dense urban areas

Transitioning to ZEB requires coordinated actions between the building and the energy sectors, particularly at local level. This is only useful but necessary in dense urban areas, where ensuring ZEB compliance and the ban of on-site fossil fuels may be difficult to square, placing increased pressure on the centralised heating systems and electricity grids to decarbonise. In Romania, this strong dependence risks becoming a structural vulnerability. Long-standing infrastructure decline, outdated system designs and continued reliance on public subsidies have centralised heating &cooling systems currently ill-prepared to support ZEB-compliant new buildings (Energy Policy Group, 2025). Adopting national and local strategies with a clear vision for the refurbishment and decarbonisation of centralised heating and cooling systems can leverage them as a strategic, enabling infrastructure for ZEB buildings.

Complementing the new building standards ZEB and embodied emissions policies with sufficiency measures

Integrating sufficiency measures, alongside efficiency, circularity and RES in the national policies for the built environment, that particularly target the construction of new buildings, shows significant potential to reduce embodied emissions from buildings. This may include stricter planning regulations to restrict building permissions if there are vacant buildings in surroundings areas, evaluation of the potential reuse of buildings before any demolition or new construction occurs, limiting the development on greenfield sites. Urban planning is a central leverage point for addressing these sufficiency measures and strategies like Compact City, Land Recycling, or UDAs.

However, urban planning practice must be able to better account for carbon impact, develop planning tools and assessment methods to inform planning and permitting decisions at the local level. Furthermore, establishing national or municipal databases of vacant and underused buildings, linked to spatial planning and housing strategies, would serve as a knowledge base for decision-making for sufficiency-oriented measures and help municipalities identify opportunities to avoid unnecessary new construction.

Tackling the political risks for national efficiency, circularity, and sufficiency policies

Some measures, such as setting differentiated life-cycle emission thresholds for specific building types or introducing limits to new builds, challenge social and cultural norms around consumption, property ownership rights, and urban development. They incentivise the construction of certain types of buildings over others (e.g. social housing, hospitals, commercial or real estate), certain areas and regions are allowed to grow, and others are expected to stabilise. Thus, unlike efficiency, sufficiency policies often receive political resistance and contestation, despite their proven emission reduction potential for the building sector.

Implementing sufficiency measures in Romania is likely to prove challenging, particularly at the local level, where there are currently little financial incentives to limit new construction or to promote the use of existing building stock. New construction tends to generate higher fiscal returns, as increases in built floor area and property values directly expand municipal tax bases.

Moreover, the recent removal of preferential tax treatment linked to building age or density is, in effect, reinforcing local authorities' reliance on revenue streams associated with property development. Local authorities may thus be reluctant to adopt measures perceived as limiting construction because of their implications for municipal finances and local economic context. Likewise, for investors, developers and other stakeholders from the building design and planning, sufficiency policies may be difficult to accept. Consequently, any action in the direction of sufficiency will need to focus on unpacking competing financial interests, social and cultural norms and to investigate the communicative strategies to build public and stakeholders' acceptability, that would facilitate the introduction of such measures.

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