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From Brundtland to Net-Zero Buildings: Governing Sustainable Development in the Built Environment

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Abstract

Since the Brundtland Report (1987), its definition has anchored sustainable development. An EBSCOhost co-mention scan (1987–2025) finds 259,112 records linking "sustainable development" with the Brundtland Report—used only as a descriptive attention proxy, sensitive to coverage, indexing, keywords, and residual duplicates. We then analyze concept-to-implementation barriers in building governance and propose an update pathway: explicit boundaries, minimum disclosures, and assurance logic. Yet in the built environment—characterized by long-lived assets, carbon lock-in, and net-zero commitments—the definition is difficult to operationalize without explicit boundaries, measurable indicators, and auditable trade-offs. We identify two concept-level weaknesses: (1) the definition reflects late-twentieth-century socio-technical conditions and offers limited guidance for practice shaped by digitalized delivery and operations, accelerated climate policy, and whole-life carbon accounting; and (2) its openness around "needs," "harm," and trade-offs enables boundary ambiguity (e.g., operational versus embodied emissions), fragmented standards and certifications, and greenwashing risks. We propose a built-environment update pathway that (i) operationalizes "needs" and "harm" through a minimum life-cycle indicator set linking affordability and occupant well-being with operational energy performance and whole-life carbon outcomes; and (ii) strengthens concept-consistent implementation via harmonized boundary declarations and verification principles across existing net-zero and green building tools, supported by targeted AEC capacity building.

Keywords: energy efficiency; whole-life carbon; carbon footprint; sustainability governance; life-cycle assessment (LCA); building sector governance

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1. Introduction

The built environment has become one of the most decisive arenas for sustainable development and climate mitigation. Recent global assessments show that buildings and construction account for a substantial share of global final energy use and energy- and process-related CO_2 emissions, positioning the sector as a cornerstone for both energy

saving and deep decarbonization [1,2]. At the same time, the sector is characterized by capital-intensive, long-lived assets and strong lock-in dynamics: design, construction, and retrofit choices made today can commit operational demand patterns and emissions trajectories for decades, narrowing future mitigation options and raising the value of early, credible action [3,4]. The IPCC identifies large, near-term building-sector mitigation potential through demand-side efficiency, electrification (notably heat pumps), and cleaner energy supply, while stressing that policy-relevant accounting requires consistent sector boundaries to avoid shifting impacts across life-cycle stages [5]. Finally, as building mitigation performance is increasingly evaluated through whole-life perspectives, boundary choices become determinants of comparability and credibility; without coherent boundary and verification rules, the same "sustainable" claim can mask divergent real-world outcomes [6–8]. Figure 1 illustrates how decision points across the building life cycle—particularly early-stage material choices during planning and design—lock in embodied carbon upfront while operational carbon accumulates over the use phase, underscoring why boundary declarations and auditable indicators must be specified from the outset. In scope, we focus on building-sector governance—residential and commercial/institutional buildings across design, construction, operation, and retrofit—while infrastructure is considered only insofar as it shapes system boundaries.

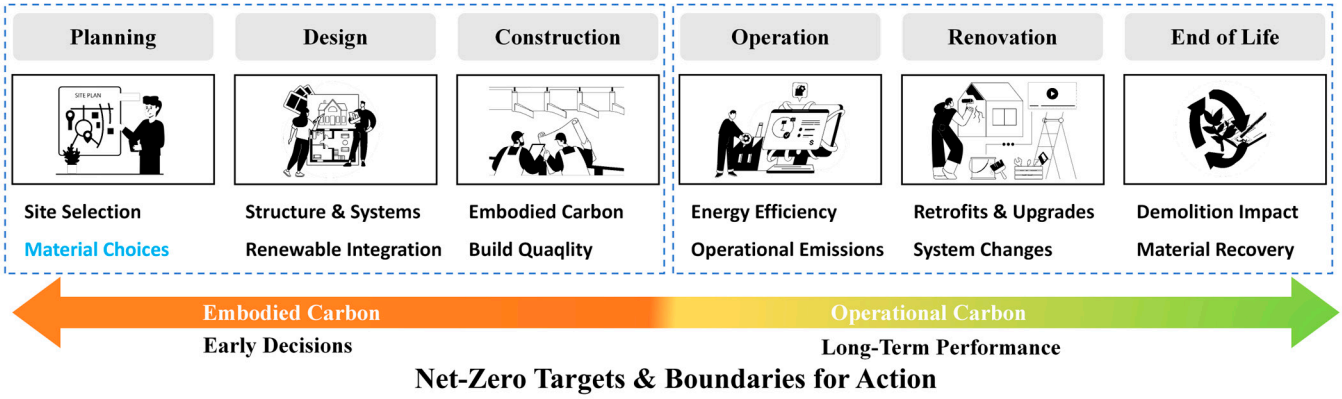


Figure 1. Carbon Lock-In Across the Building Life Cycle and Decision Points for Decarbonization.

While the concept of sustainable development has roots in ecology, its contemporary prominence is widely attributed to the 1987 Brundtland Report, "Our Common Future" [9,10]. The report defines sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" [10]. Over subsequent decades, this formulation has become a foundational reference across policy and scholarship, often treated simultaneously as a normative benchmark and an intentionally elastic concept that can be mapped onto divergent priorities and implementation pathways [11,12]. Since 1987, multiple related framings have also shaped built-environment debates—most notably the SDGs, green growth/green economy narratives, and the circular economy, alongside counter-proposals such as degrowth and agrowth. Because these framings diverge normatively but intersect in their operational demands, we do not attempt a parallel review of each; instead, we examine the boundary, disclosure, and assurance specifications that condition credibility across them in building practice. Rather than assuming a linear evolution from "sustainable development" to "net-zero," this paper treats net-zero targets as one outcome-oriented instrument among several and focuses on the operational requirements—explicit boundaries, minimum indicators, and assurance logic—that determine whether any framing can deliver measurable environmental outcomes in buildings. It has also provided an important reference point for later agenda-setting efforts that sought to reconcile poverty reduction, human well-being,

and planetary stability. Consistent with this enduring influence, our bibliometric scan of EBSCO-indexed publications (1987–2025) identifies 259,112 records featuring the keyword "sustainable development" that also reference the "Brundtland Report". This bibliometric count is used descriptively as an indicator of the sustained citation and academic attention given to the Brundtland Report. While this count provides a broad measure of the ongoing relevance of the concept in academic literature, it is sensitive to database coverage, indexing practices, keyword choices, and duplicates, and does not directly measure conceptual agreement or causal influence. However, the persistence of this concept in academic references highlights the need for clearer definitions and governance frameworks that can address the ambiguities and operational challenges associated with these concepts.

However, despite its historical importance, the Brundtland definition is increasingly difficult to operationalize in the built environment—particularly as professional practice and policy agendas shift from aspirational "sustainability" language toward quantified net-zero targets and whole-life carbon assessment [13–15]. Recent global assessments further indicate that progress toward the Sustainable Development Goals has stagnated or regressed across multiple dimensions [16]. Meanwhile, the latest synthesis of climate science underscores that current mitigation efforts remain insufficient to meet long-term climate and development objectives [1]. In the building sector, these pressures translate into governance and implementation questions that the Brundtland definition leaves under-specified, because "needs," "harm," system boundaries, and verification logics must be made explicit for long-lived, capital-intensive assets. For example, operationalizing "needs" in buildings implicates health and indoor environmental quality as well as affordability and energy poverty [17,18]. Defining "harm" requires boundary choices that can materially change conclusions—especially the operational-versus-embodied split and whole-life accounting conventions [6,19]. Finally, credible implementation requires verification against measured performance, yet evidence on performance gaps and certification-to-outcome slippage shows why "sustainable" claims can diverge from real energy and carbon outcomes [20,21].

In engineering and policy practice, these under-specified choices are not interpretive nuances—they can materially change the reported magnitude of "performance" and even the direction of conclusions. In sustainable construction assessments, different declarations of the functional unit and reference study period, and different system boundaries for what is counted in the building "system", can yield incompatible narratives of sustainability performance for the same project [22,23]. Likewise, whole-life results can vary substantially depending on which life-cycle stages are included (product and construction, replacements/maintenance, end-of-life) and on key methodological assumptions (inventory datasets/EPDs, allocation rules, and end-of-life modeling) [23]. Without minimum disclosure and verification expectations, such variability undermines comparability across projects and jurisdictions and weakens auditability for codes, procurement, and sustainable finance. Accordingly, this review specifies the minimum "rule-and-evidence" infrastructure for implementable AEC governance—harmonized boundary declarations, a minimum disclosure indicator set, and tiered assurance expectations tied to a verifiable evidence chain.

This operationalization gap is amplified by the sector's shift from an operational-energy lens toward whole-life perspectives—integrating life-cycle energy and life-cycle carbon across construction, use, and end-of-life stages [24,25]. As operational energy is reduced through efficiency retrofits and electrification, embodied emissions from materials, construction, replacements/maintenance, and end-of-life processes tend to become proportionally more significant—especially for high-performance buildings—making boundary choices central to credible decarbonization pathways [26–28]. The IPCC's AR6 mitigation assessment for buildings identifies substantial near-term potential via demand-side effi-

ciency, electrification (e.g., heat pumps), and cleaner energy supply, while emphasizing that policy-relevant accounting depends on consistent sector boundaries and definitions for life-cycle stages and responsibilities. Methodologically, building LCA and embodied-carbon estimates can vary materially with scope, datasets/EPDs, allocation rules, and model choice, creating comparability and governance challenges unless assumptions are disclosed and harmonized [29–34].

A second challenge is that the Brundtland definition's deliberate conceptual openness—especially around what counts as "needs," "harm," and acceptable trade-offs—permits wide latitude in interpretation, which becomes problematic when sustainability must be translated into building codes, procurement rules, investment criteria, and performance-based accountability [35,36]. In the building sector, this looseness materializes as boundary ambiguity and inconsistent "net-zero" narratives—for example, when operational energy/carbon is emphasized while embodied emissions from materials, construction, maintenance, and end-of-life are excluded, or when balancing rules (metrics, temporal scopes, renewable supply options, grid interaction, offsets) differ across definitions and jurisdictions [14,37,38]. A related governance consequence is fragmentation: multiple assessment tools, certification schemes, and reporting practices coexist with differing scopes, weightings, and verification expectations, which undermines cross-project comparability and creates incentives for strategic compliance rather than highest-impact decarbonization [39,40]. These dynamics also elevate greenwashing risks in real estate and construction, because sustainability claims can be framed around selectively chosen indicators while obscuring material impacts that fall outside the declared boundary [41–43]. The resulting proliferation of sector guidance on "net-zero carbon buildings" is therefore best read as an applied response to definitional under-specification—an attempt to standardize boundaries, metrics, and verification expectations where the Brundtland framing remains normatively powerful but operationally thin [38,44]. Finally, to avoid overly absolute terminology while preserving policy ambition, the International Energy Agency has promoted "zero-carbon-ready buildings," defined as highly energy-efficient and resilient buildings that use renewable energy directly or rely on an energy supply that can be fully decarbonized, with the concept explicitly covering both operational and embodied emissions—thereby reinforcing why boundary and verification rules are central to credible building-sector decarbonization [45].

In this paper, "governance" is used in an instrumental sense: the rule-and-evidence infrastructure that translates sustainability intent into comparable and auditable building outcomes. Current caveats in built-environment practice include fragmented standards and certification ecosystems, inconsistent boundary conventions, and uneven verification intensity—conditions that weaken comparability across projects and invite strategic compliance and greenwashing. Accordingly, governance is not treated as an end in itself, but as the enabling mechanism through which the holistic goals—verifiable energy savings, whole-life carbon reduction, and protection of core social needs—can be delivered consistently at scale.

Against this backdrop, this paper revisits the Brundtland concept through a built-environment lens to clarify the minimum specifications required for credible energy-saving and net-zero implementation in buildings—namely system boundaries, measurable indicators, and assurance logic. The remainder of the paper outlines the methods, develops two concept-level weaknesses that hinder operationalization in the buildings-and-construction sector, and then proposes two governance recommendations to improve comparability and credibility across existing net-zero and green building tools.

2. Materials and Methods

This study adopts a two-step approach. First, a bibliometric scan of EBSCOhost-indexed publications (1987–2025) was performed using a search string that combined "sustainable development" with "Brundtland Report" and "Our Common Future." The search string used was ("sustainable development") AND ("Brundtland Report" OR "Our Common Future"). The search was restricted to records indexed under all available collections within EBSCOhost. Inclusion criteria required that publications contain the keyword "sustainable development" and explicitly reference the Brundtland Report or Our Common Future in the title, abstract, or keywords. Exclusion criteria eliminated non-indexed publications, irrelevant records, or those lacking any explicit reference to the Brundtland Report. Duplicates were identified and removed using EBSCOhost's built-in tools, ensuring only unique records were included.

The bibliometric scan was used descriptively to track citation trends and gauge the continued reliance on the 1987 Brundtland definition across academic literature. The primary aim of this scan was to identify the volume and timing of references to the Brundtland Report in relation to the broader sustainability discourse, rather than to establish causality or conceptual endorsement.

Second, a structured narrative review and conceptual analysis was conducted to examine how the Brundtland definition has been operationalized in the building and construction domain. This analysis focused on the evolving specifications of sector boundaries, the introduction of life-cycle indicators (including both operational and embodied carbon measures), and the use of governance instruments to support implementation. The review identifies two key concept-level weaknesses: (1) the persistent lack of clarity in boundary setting and indicator specifications across tools and standards, and (2) the failure to integrate comprehensive verification rules.

These analyses provide the foundation for diagnosing the weaknesses in current governance frameworks and inform the development of recommendations for building-sector governance improvements aimed at enhancing comparability and auditability.

3. Key Weaknesses of the Sustainable Development Concept in the Built Environment

3.1. Weakness One: The Concept Does Not Reflect Changes in Socioeconomic Development

The Brundtland conceptualization of sustainable development needs updating [36]. Published in 1987, Our Common Future and its defining sentence are now nearly four decades old [46]. Yet the built environment—buildings, infrastructure, and the urban systems in which they operate—has entered a very different socioeconomic and socio-technical context [47]. This matters because the sector is dominated by long-lived, capital-intensive assets and strong path dependence [3,48]. In such settings, conceptual foundations are not neutral [3]. Definitions shape what counts as progress [12]. They also influence which indicators are selected, what trade-offs are permitted, and what is treated as legitimate in practice. If sustainable development is treated as a stable premise across time, the risk is not only academic stasis. It is practical misalignment in the rules and evidence used to govern delivery and performance. In buildings and construction, misalignment can produce ambiguous performance claims, inconsistent boundary setting, and governance gaps. These frictions can slow or distort energy saving and decarbonization efforts [20].

Because it is widely invoked as a normative and governance reference, the Brundtland definition functions less as a static rule and more as a framework that guides boundary setting and priority trade-offs. Frameworks of this kind are not epistemically stable: as evidence, technologies, policy objectives, and institutional capacities change, the same wording can be mobilized to justify divergent implementations. Without an explicit review-

and-update pathway, interpretive drift accumulates and undermines comparability and accountability—particularly in high lock-in sectors such as buildings [49,50].

As Godfrey-Smith notes, some theories operate primarily as context-dependent frameworks for coordination rather than as closed scientific explanations [51]. Sustainable development belongs to this coordinating category: it is valuable because it organizes decision-making under uncertainty, but that value depends on periodic clarification of what counts—system boundaries, indicators, and assurance expectations—as contexts evolve. In buildings, where investments are long-lived and performance claims are increasingly audited, leaving these elements implicit increases the risk of inconsistent reporting and strategic boundary selection [52].

3.1.1. Socioeconomic Change Matters More in Buildings Because of Long-Lived Lock-In

This subsection establishes the first structural weakness: the Brundtland definition leaves key implementation variables under-specified in buildings, making boundary-setting and indicator choice unavoidable rather than optional. Treating the Brundtland definition as a stable premise implicitly imports the late-1980s framing of "sustainable development" into today's building decisions, even though goals, indicators, and practice are historically contingent [12]. In that period, policy debates in many advanced economies were still shaped by the productivity slowdown and its macroeconomic implications [53]. Related analyses also emphasized measurement issues and structural change as part of the productivity narrative that influenced how energy and industrial performance were discussed [54]. In contrast, contemporary building-sector priorities are increasingly shaped by climate-risk assessment and disclosure expectations in real estate and construction markets [55]. This shift is reinforced by sector-specific work showing that climate-related financial disclosure is becoming a governance issue for property and construction firms, not only an environmental aspiration [56]. Socioeconomic change matters more in buildings because the stock is long-lived: once built, assets and institutions can create carbon lock-in that slows transitions even when alternatives are available [48]. Recent synthesis work further confirms that long-lived capital—including buildings and infrastructure—is a systematic source of lock-in that can hinder rapid decarbonization [57]. Operationally, building governance is now moving toward whole-life carbon accounting and stock-scale decision support, which makes boundary setting and data choices more consequential than Brundtland's general wording implies [13,58]. As operational energy demand is reduced, embodied emissions from materials, construction, and replacement cycles can represent a larger share of whole-life impacts, increasing the practical stakes of system boundaries and methodological choices [59]. Finally, if boundaries and verification expectations remain weakly specified, auditability declines and greenwashing incentives rise—an issue documented across sustainability claims and directly relevant to building-sector "low/zero-carbon" narratives [41].

3.1.2. Digitalization and New Governance Conditions Are Reshaping Sustainable Development Practice

This subsection argues that digital tools do not "solve" the Brundtland definition's normative under-specification; instead, digitalization acts as a governance stress test that exposes under-specified choices by forcing explicit declarations of boundaries, data provenance, indicators, and verification procedures—and it can only enable implementation once those choices are specified and auditable. Digital transformation has become a defining feature of the contemporary socioeconomic context, and the COVID-19 period accelerated its diffusion into everyday services and governance routines [60]. International policy actors increasingly argue that digital technologies can accelerate progress across many SDG targets, while simultaneously intensifying governance, equity, and accountability

concerns [61]. Recent scholarship therefore frames "digital governance" not as a technical add-on but as a sustainability-relevant institutional capacity—shaping transparency, participation, and implementation effectiveness [62]. At the same time, the digital economy has material and environmental footprints (energy demand, supply-chain impacts, and rebound effects) that complicate "digital-for-sustainability" narratives [63]. Empirical work also cautions that digitalization-driven development pathways can generate new resource pressures and externalities if governance does not explicitly manage these trade-offs [64].

These dynamics are especially concrete in the built environment, where digitalization is being embedded across the full project life cycle—from design and procurement to operation, retrofit, and end-of-life [65]. In buildings, these governance questions materialize through data-intensive delivery and operations that can enable continuous monitoring, simulation, and measurement and verification [66]. Beyond BIM, the literature increasingly frames digital twins as an interoperability layer for performance assurance, but also notes risks: data quality gaps, fragmented ownership, and uneven capacity across the supply chain can create new accountability failures if boundaries and verification rules are not explicit [67,68]. Recent work also highlights the potential and limits of AI-enabled analytics for fault detection, demand management, and retrofit optimization, reinforcing the need to specify what is measured, over what boundary, and under which assurance procedures [69,70]. Put differently, digitalization increases the visibility and stakes of boundary and verification choices: when concepts remain under-specified, digital tools tend to multiply incompatible outputs rather than converge practice. In short, digitalization raises the ceiling for operationalization, but it simultaneously increases the importance of transparent boundary declarations and auditable indicator definitions in building-sector sustainability claims [46].

3.1.3. From Chapter Review to Sector Misalignments: Why the 1987 Framing No Longer Maps Cleanly onto Buildings

This subsection shifts from conceptual critique to sector mechanics, showing why the 1987 framing no longer maps cleanly onto contemporary building delivery, operation, and governance. Rather than reproducing a chapter-by-chapter reassessment of Our Common Future, we highlight three misalignments between its late-1980s framing and the requirements of contemporary building decarbonization. Each misalignment has direct implications for system boundaries, indicator selection, and the credibility of building performance claims [36]. Figure 2 reproduces Lélé's synthesis of the Brundtland-era causal framing, highlighting feedbacks among poverty, affluence, and environmental degradation and the mediating roles of access to resources, technology, and culture values. When applied to buildings—where long-lived assets and net-zero claims require explicit boundaries, measurable indicators, and auditable trade-offs—this macro framing leaves "needs," "harm," and implementation choices under-specified. Figure 3 therefore translates the needs–harm–trade-offs chain into built-environment terms and summarizes three misalignments that motivate the boundary, disclosure, and assurance requirements discussed below.

Misalignment 1: Defining "needs" in building-service terms. In buildings, "needs" are experienced as access to safe, healthy, and affordable services (thermal comfort, indoor air quality, lighting, and basic energy services), not as energy consumption per se. Operationalization therefore requires indicators that link service outcomes and affordability to energy use and emissions, so that poverty-reduction objectives do not translate into long-lived harms through inefficient or carbon-intensive lock-in [17,71,72].

Misalignment 2: Accounting for harm over long-lived life cycles and lock-in. Building investments commit societies to material stocks, technologies, and operating patterns for decades, so harms must be evaluated across the full life cycle—from materials produc-

tion and construction to use-phase replacements and end-of-life processes. The growing emphasis on whole-life carbon makes boundary choices central to credible decarbonization pathways, and it elevates the importance of consistent reporting conventions for comparability [47,73–77].

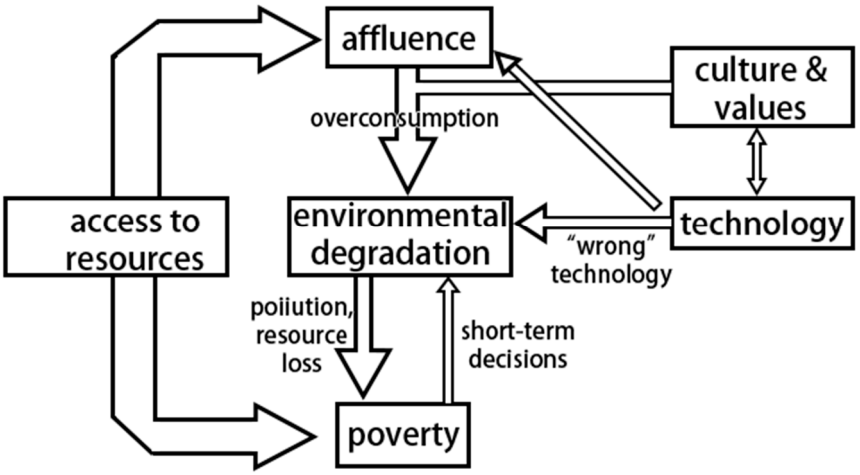


Figure 2. A more realistic representation of the poverty environmental degradation problem [36].

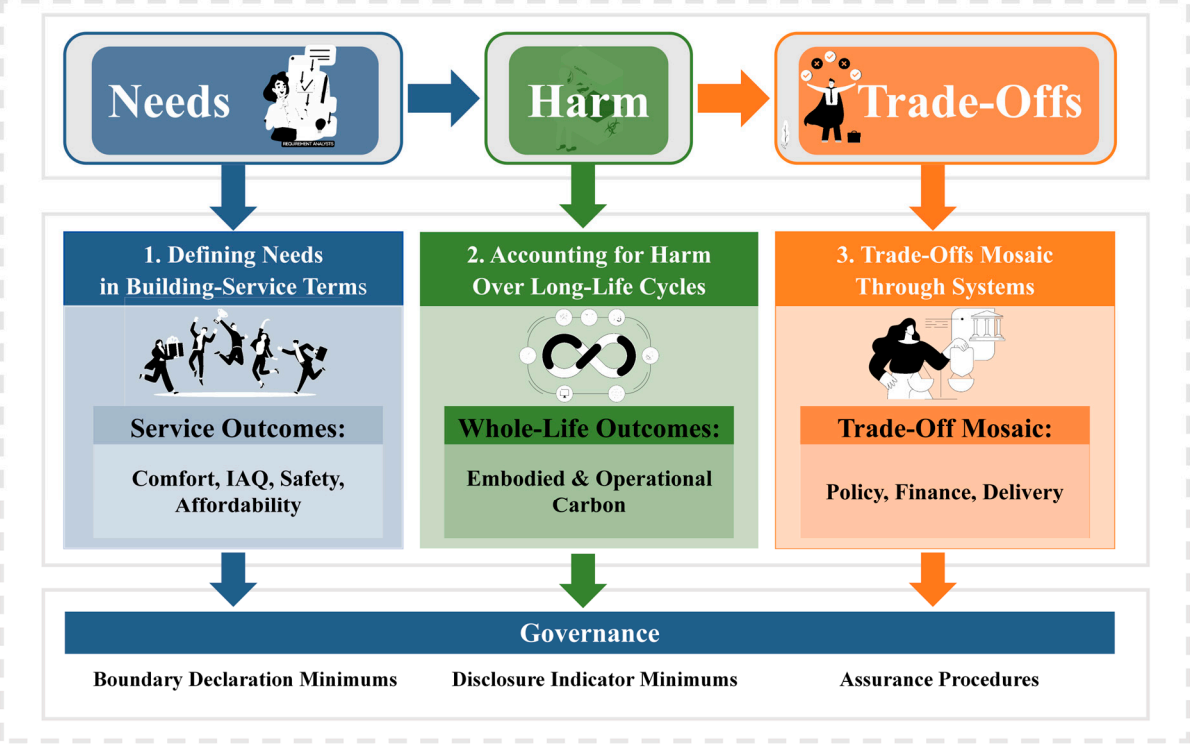


Figure 3. Translating "Needs" and "Harm" in the Built Environment: Three Misalignments.

Misalignment 3: Trade-offs are now mediated by policy, finance, and delivery systems. Our Common Future framed energy and industry choices as environmental choices, but today's building decarbonization is shaped by rapidly evolving climate policy, procurement requirements, and market instruments that reward claims as well as outcomes. Without explicit boundaries and assurance logic, trade-offs can be obscured or displaced (e.g., shifting emissions upstream into materials supply chains or downstream into offsets), undermining the credibility of net-zero and "sustainable building" narratives [5,13].

These misalignments are amplified in fast-urbanizing contexts where construction-led growth can expand housing supply but can also embed high-carbon materials and infras-

tructure at scale. This increases both the stakes of early design choices and the incentives for over-claiming in markets with uneven disclosure and verification capacity [30,78–81]. For building-sector governance, the implication is that the Brundtland concept must be supplemented by explicit boundary rules and disclosure minimums that can travel across programs and tools.

This need for specification is also reflected in how UN frameworks have evolved from broad principles toward more target-oriented agendas that demand measurable outcomes—an evolution that building-sector definitions and tools must be able to accommodate.

3.1.4. The UN's Evolving Frameworks Underline Why Brundtland's Concept Must Be Updated for Buildings

This subsection shows that the evolution of global sustainability frameworks changes the practical interpretation of "needs" and "harm," widening the gap between Brundtland language and building-sector decision rules. This need for specification is also reflected in the evolution of UN frameworks from broad principles toward goal-based monitoring architectures designed for implementation and reporting—from the MDGs to the SDGs and the 2030 Agenda [82]. A long-standing critique is that, while the Brundtland definition works as a unifying normative reference, it remains under-specified for operational decision-making when social "needs" must be reconciled with quantified ecological constraints [83,84]. In building-sector terms, that under-specification becomes visible when decarbonization pathways proceed without explicit safeguards for affordability, indoor health, and distributional impacts, or when housing expansion advances without stringent energy/carbon requirements—both of which can lock in future retrofit burdens and undermine long-run emissions trajectories [17,18,85]. The SDGs sharpen this implementation logic by emphasizing measurable targets across domains, and Sachs (2012) explicitly frames this as a shift toward quantification and policy focus [86]. Unlike these time-bound goal sets with formal follow-up and review, the Brundtland definition itself has remained essentially fixed, even as building governance has become increasingly metric-driven [5,46,83]. The implication for buildings is therefore straightforward: maintaining "sustainable development" as a governing concept requires clearer boundary declarations and decision rules that can support comparable disclosure and credible verification in practice.

3.1.5. Continued Reliance on the Literature Is Precisely Why Updating Matters

This subsection consolidates the misalignment diagnosis by stating why a built-environment update must be expressed as operational rules—explicit boundaries, minimum indicators, and verification logic—rather than as an abstract definition alone. A bibliometric scan of EBSCOhost-indexed publications (1987–2025) combining "Brundtland Report"/"Our Common Future" with "sustainable development" retrieved 259,112 records. Figure 4 reports the annual frequency of EBSCOhost-indexed records that co-mention "sustainable development" and the Brundtland Report/"Our Common Future" over 2011–2025. Co-mentions rise steadily after 2015 and accelerate in the early 2020s, peaking in 2024 before declining in 2025, while remaining well above pre-2020 levels. This trend is descriptive rather than causal: it indicates sustained and growing scholarly reliance on the Brundtland framing as a reference point, which strengthens the case for clarifying its operational meaning for building-sector boundary setting, disclosure, and verification.

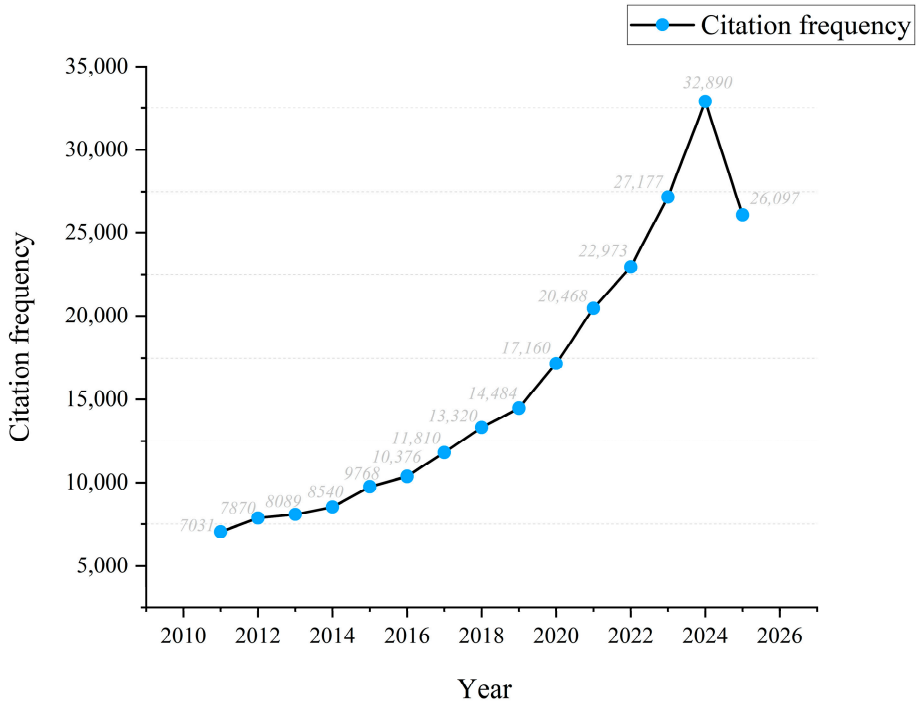


Figure 4. The number of "Brundtland Report" and "Our Common Future" or "sustainable development" citations from 2011 to 2025, retrieved from EBSCO in Nov 2025.

3.2. Weakness Two: Conceptual Vagueness and Boundary Ambiguity in the Built Environment

The second key weakness of the Brundtland concept lies in its consensus-building formulation logic: the definition was designed to be broadly acceptable across diverse stakeholders, and this inclusiveness intentionally left key terms under-specified [52]. The Brundtland Commission explicitly sought a definition that could "travel" across governmental, corporate, and civil-society contexts, which helps explain its exceptional longevity [46]. However, the same breadth has an operational cost: contemporary professionals must translate "sustainable development" into decisions, metrics, and accountability mechanisms, and in the built environment—where long-lived assets, large capital flows, and life-cycle impacts dominate—definitional precision becomes a precondition for credible energy saving and decarbonization. A long-standing critique is therefore not that the Brundtland definition is "wrong," but that it is too indeterminate for implementation—particularly because it does not operationalize "needs," specify what counts as "harm," or clarify the mechanisms by which an environmentally sustainable society is to be achieved [87–89].

For the built environment, this critique implies two closely related deficiencies: (i) the definition does not specify what "needs" mean in operational terms, and (ii) it does not clarify mechanisms, system boundaries, or verification logic [52]. In practice, repeated international adoption has not resolved this indeterminacy; instead, the concept's openness often expands as it is implemented under different mandates, incentives, and accountability regimes. In the building sector, this amplification is structurally reinforced by a multi-actor delivery chain—governments and NGOs, but also developers, asset owners, investors, rating-system operators, designers, contractors, and manufacturers—each of whom can claim alignment while implicitly selecting different boundaries, indicators, and time horizons, weakening comparability across projects and jurisdictions [89]. Owing to this under-specification, practitioners frequently rely on discretionary interpretation rather than shared decision rules, and this becomes more consequential under contemporary decarbonization and "just transition" imperatives. Recent just-transition research emphasizes that decarbonization must integrate poverty reduction and equity objectives to

preserve legitimacy and inclusiveness [90]. Consistent with this, UNDP stresses that a just energy transition requires governance arrangements that institutionalize fairness, inclusion, and accountability rather than relying on aspirational targets alone. These concerns map directly onto the built environment, where affordability, energy poverty, healthy indoor conditions, and climate resilience are "needs" that must be specified alongside carbon and energy targets rather than assumed to be co-produced by decarbonization [17]. When "needs" and "harm" are not operationalized in building terms, project teams can optimize for what is easiest to report—e.g., modeled operational energy or an aggregate rating score—while leaving embodied carbon, offset dependence, post-occupancy performance, and affordability/health outcomes outside scope; the result is boundary gaming, non-comparable metrics, and weak verification that undermine both decarbonization credibility and distributional legitimacy [90].

3.2.1. Direct Misuse: Invoking "Sustainable Development" to Justify Inconsistent Boundaries and Unverifiable Claims in Buildings

This subsection defines and illustrates direct misuse: project-level actors exploit under-specification to select favorable boundaries, metrics, and evidence thresholds, producing non-comparable "net-zero" or "sustainable" narratives. There are two broad forms of misuse of the Brundtland concept in practice: direct and indirect [36]. Direct misuse arises when the definition's looseness allows actors to operationalize key terms—especially "needs" and "harm"—in ways that privilege narrow interests, short time horizons, or convenient reporting choices [87]. We use a practical criterion to distinguish the two. Direct misuse is claim-level: the distortion is driven by project-specific accounting and reporting choices (e.g., functional unit, system boundary, reference period, datasets/EPDs, allocation rules, and verification thresholds) that materially change what is counted and evidenced. Indirect misuse is framing-level: the distortion is driven by a shift in how "development" is interpreted (e.g., toward growth-as-development), which changes what trade-offs and priorities are treated as legitimate in policy, finance, and public narratives, even when individual project claims appear internally consistent. In the built environment, this most often takes the form of boundary ambiguity and selective accounting: projects can be branded as "sustainable" while the chosen scope, metrics, and evidence base are tailored to produce favorable narratives, weakening accountability even when intentions appear aligned [91].

A clear building-sector example is the proliferation of "net-zero" and "low-carbon" claims without consistent definitions, transparent boundaries, or verification rules [14,37,38]. Because Brundtland does not specify what counts as "harm" across time and system boundaries, actors can frame sustainability around near-term objectives—lower bills, market positioning, or compliance optics—while downplaying longer-term and indirect impacts [46]. In practice, some claims privilege operational energy/carbon (annual consumption reductions, on-site renewables) while excluding embodied emissions from materials, construction, maintenance, and end-of-life processes [13,92].

This divergence is not merely semantic: it reflects different accounting boundaries and different interpretations of what is inside the "net-zero" footprint. As illustrated in Figure 5, ambiguity arises at two levels—(i) what is counted within the operational boundary, and (ii) which life-cycle stages are included in the embodied/whole-life scope, together with how exports and future consumption are treated. The figure also highlights recurring "claim-design" ambiguities, which is why explicit boundary declarations and verification rules are central to credibility. Others depend heavily on offsets without clear disclosure of residual emissions, the durability and additionality of the mitigation instrument, or the evidentiary basis for equivalence over time. Empirical evaluations of carbon crediting

further suggest that quality varies widely across projects, reinforcing why "net-zero" claims require auditable rules rather than rhetorical flexibility [93].

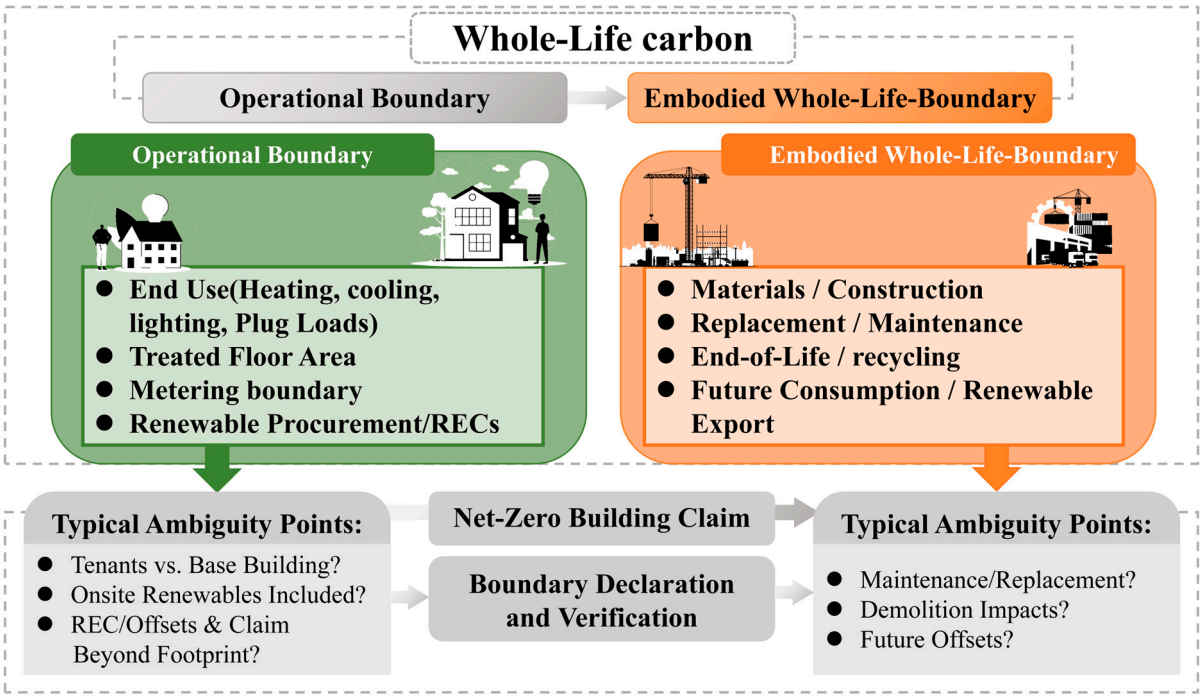


Figure 5. Boundary Ambiguity in Net-Zero Buildings: Operational vs. Embodied and Whole-Life Scopes.

A second building-sector example is the use of certification or rating outcomes as a proxy for sustainability without specifying which "needs" are being served and which "harms" are being constrained [94]. Because the Brundtland definition does not prescribe mechanisms, some actors treat "meeting needs" as equivalent to achieving a certification level or accumulating points across heterogeneous categories, even when key outcomes are not verified post-occupancy or when major impacts remain outside scope [20,95]. In practice, assessment tools vary substantially in emphasis—some prioritize operational energy, others foreground water, materials, indoor environmental quality, site, or management processes—so projects labeled "sustainable" may still perform unevenly on energy saving and carbon reduction when evaluated against consistent, comparable metrics [21,94]. This can shift incentives toward strategic compliance rather than high-impact interventions, and it can channel investment toward easily claimable features rather than measures that deliver durable decarbonization [96].

A third direct-misuse pathway appears in urban development and renewal projects justified as "sustainable development" because they satisfy visible near-term needs—economic growth, housing delivery, or amenity upgrades—while producing longer-term harms that are weakly captured in conventional narratives and appraisal practices. In the built environment, these harms often include displacement and affordability loss—an established concern in "ecological/green gentrification" debates—together with uneven access to the benefits of greening and upgrading [97]. They also include increased heat exposure and indoor/outdoor habitability risks when densification or redevelopment proceeds without climate-responsive urban and building design, which can concentrate vulnerability rather than reduce it [98]. Without an operational definition of "needs" (including affordability, health, accessibility, and resilience) and "harm" (including whole-life carbon and distributional impacts), projects can be framed as sustainable while eroding the intergenerational and justice-oriented intent that the Brundtland concept was meant to protect [97,99].

In short, direct misuse in the built environment stems from the same structural weakness highlighted by Castro: a definition broad enough to secure consensus but too indeterminate to discipline implementation. The result is that "sustainable development" can legitimize divergent—and sometimes contradictory—practices, including those that dilute accountability and slow genuine energy saving and decarbonization.

3.2.2. Indirect Misuse: Conflating Sustainable Development with "Sustainable Growth" in the Built Environment

This subsection defines indirect misuse as discourse-level reframing of sustainable development into "sustainable growth," which shifts the meaning of legitimate trade-offs and normalizes sufficiency-blind expansion. Unlike direct misuse, this pathway does not hinge on boundary definitions within a single project claim; it hinges on how the discourse of "sustainable development" is reinterpreted to normalize continued expansion under sustainability-labeled qualifiers. While Figure 5 highlights boundary ambiguity as a technical route to weak or incomparable net-zero claims, a parallel pathway operates at the level of language and framing. As Figure 6 shows, "sustainable development" can be decomposed into "sustainability" and "development". When the literal reading of sustainability is paired with development-as-growth, the concept readily collapses into "sustaining growth"—a contradictory or trivial interpretation that enables a rhetorical shift from "development within constraints" to "growth with qualifiers" [36]. In the built environment, this semantic drift has tangible consequences: urban expansion, rising floor area, and construction-led development can be narrated as "sustainable" via incremental efficiency gains even when absolute energy use, material throughput, and cumulative emissions continue to increase [100]. This is particularly problematic because buildings embody long-term resource commitments: once a high-carbon stock is built, adjustment is slow and costly, and the window for rapid decarbonization narrows.

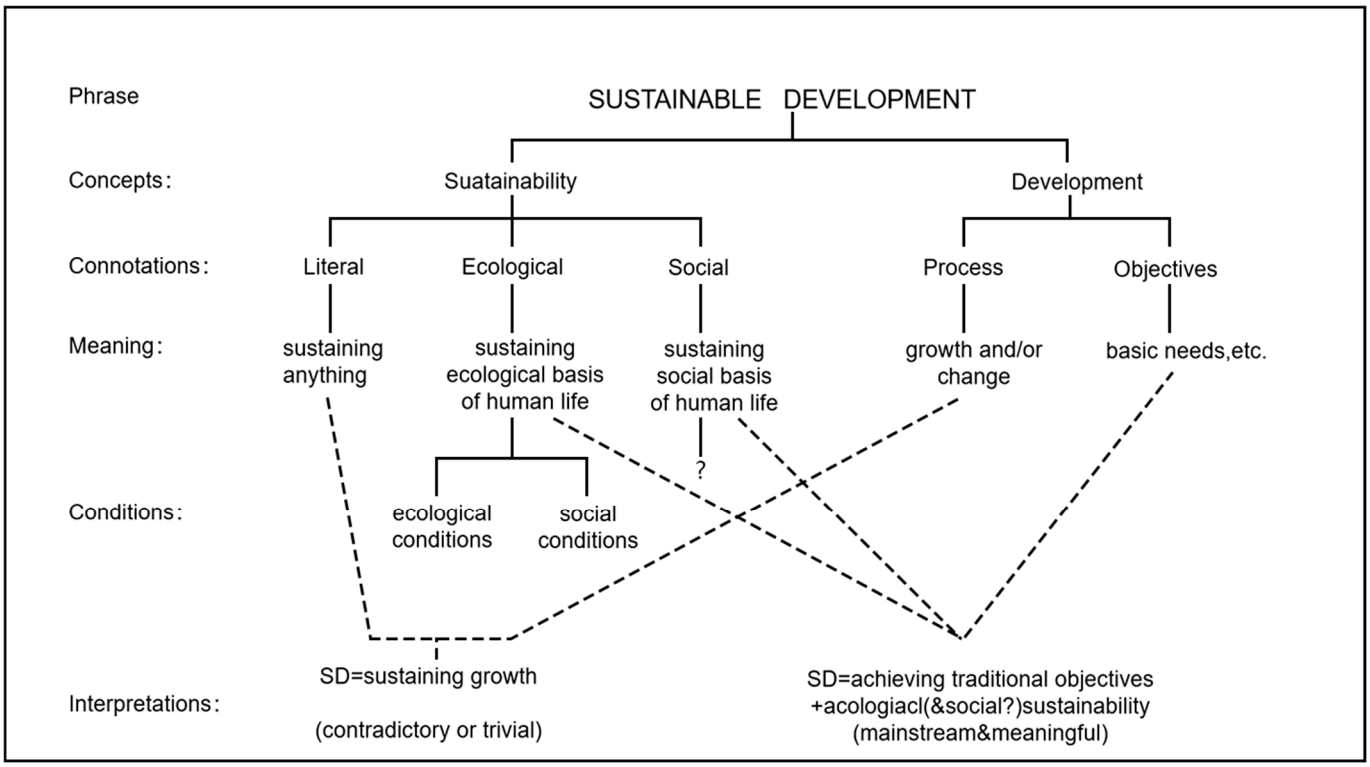


Figure 6. The semantics of sustainable development, source [36].

The broader argument that "sustainable growth" is neither sustainable nor feasible is echoed by The Limits to Growth [101]. While the built environment is not the only domain implicated, it is among the most materially intensive; if "sustainable development" drifts into a synonym for "sustained construction growth," the concept can inadvertently legitimize pathways that raise long-run environmental burdens even when near-term economic benefits are emphasized [102].

Taken together, direct and indirect misuses show why the Brundtland definition's looseness is not a neutral feature. In the built environment, vagueness enables boundary gaming, weak verification, fragmented tool use, and semantic drift toward growth-oriented narratives that can also shape policy priorities and investment signals. Without revisiting and operationalizing the concept, it will continue to justify practices inconsistent with credible building-sector energy saving and carbon reduction, undermining both climate objectives and the intergenerational justice logic central to Brundtland's original intent [36].

4. Possible Solutions to Improve the Sustainable Development Concept for the Built Environment

The weaknesses of the sustainable development concept described above have existed from the beginning and have intensified as socioeconomic conditions and implementation contexts have evolved. Although the Brundtland concept remains valuable as a normative anchor, its canonical definition is difficult to operationalize for contemporary built-environment decision-making, where energy saving and decarbonization depend on explicit boundaries, measurable indicators, and credible verification. The practical goal is therefore not to replace the Brundtland concept, but to refocus and reinvigorate it so that it can guide building-sector implementation more consistently.

To achieve this, two complementary mechanisms are proposed. First, a standing review-and-update mechanism for the built environment should periodically clarify the operational meaning of "needs," "harm," and acceptable trade-offs in building terms, including system boundaries (e.g., operational versus embodied carbon) and a minimum life-cycle indicator set that links well-being and affordability with operational energy performance and whole-life carbon outcomes. Second, an implementation-alignment and verification mechanism should reduce fragmentation across existing net-zero and green building standards, certifications, and disclosure tools by specifying baseline requirements for transparency and comparability (boundary declarations, metric definitions, and verification principles), supported by targeted capacity building for architecture–engineering–construction professionals. Together, these mechanisms aim to improve the credibility and comparability of building performance claims and accelerate energy efficiency improvements and carbon reduction across buildings and construction.

4.1. Recommendation One: Establish a Standing Review-and-Update Mechanism for Sustainable Development in the Built Environment

Due to the weaknesses of the Brundtland concept identified above—its declining fit with contemporary socio-technical conditions and its persistent conceptual vagueness—an explicit, periodic update mechanism is needed to keep the definition operational for the built environment. In buildings and construction, sustainable development is increasingly invoked to justify design choices, investment decisions, standards, and claims of "net-zero" or "low-carbon" performance. Yet these applications require clarity on system boundaries, minimum indicators, and acceptable trade-offs (e.g., operational versus embodied carbon; affordability and health versus cost and carbon constraints). A standing review-and-update mechanism would not replace the Brundtland definition's normative value; rather, it

would translate that value into versioned, evidence-informed guidance that can be applied consistently in building-sector decision-making.

A practical reference point is the way influential planning and design concepts have been maintained through structured community-based revision. The concept of New Urbanism, updated through the Congress for the New Urbanism (CNU), illustrates how a shared framework can remain adaptable over time while retaining continuity. New Urbanism aims to address urban sprawl, recreate communities, and improve quality of life while protecting the natural environment through the redesign of regions, neighborhoods, and buildings [103,104]. Trudeau [105] argues that New Urbanism provides a sustainability-oriented response to the environmental harms associated with suburban sprawl. Importantly, the concept has been revisited through organizational processes: since its establishment in 1993, CNU has maintained a charter, convened practitioners and researchers, and documented evolving priorities and principles over time. While sustainable development is broader in scope than New Urbanism, this example demonstrates the value of a transparent process that periodically clarifies a shared conceptual foundation and tracks its evolution.

Translating this logic to the Brundtland definition, a review-and-update mechanism should be designed around four principles. First, legitimacy and inclusiveness: because sustainable development is used across jurisdictions and sectors, updates must be developed through broad participation and credible representation, rather than closed expert deliberation alone. Second, transparency and version control: updates should be published as clearly dated versions with explicit change logs (what changed, why, and what evidence supports the change), allowing researchers and practitioners to cite and apply the concept consistently. Third, evidence-informed synthesis: each update cycle should review relevant empirical and methodological developments affecting the built environment (e.g., whole-life carbon accounting, retrofit policy and finance, indoor environmental quality, climate risk and resilience). Fourth, operational clarity: the mechanism should produce guidance that is actionable for building-sector implementation—especially around boundaries, indicators, and trade-offs—without turning the concept into a narrow checklist.

In practical terms, the mechanism's outputs should focus on clarification rather than certification. At minimum, each revision cycle should produce:

1. A refined interpretive statement of "needs", "harm", and acceptable trade-offs in built-environment terms;
2. A boundary guidance note that standardizes key scopes and accounting choices (operational versus embodied carbon, time horizons, and the treatment of offsets);
3. A minimum indicator set that links energy performance and whole-life carbon with occupant well-being (health, comfort), affordability, accessibility, and resilience;
4. A short "implementation implications" brief that links the conceptual update to the alignment and verification functions described in Recommendation Two.

To operationalize Item (3) in a minimally comparable and auditable way, Table 1 proposes a minimum disclosure indicator set that links operational energy and whole-life carbon to basic occupant outcomes and affordability, while making boundary choices explicit.

Table 1. Proposed minimum disclosure indicator set for operationalizing "needs" and "harm" in buildings.

Dimension	Minimum Disclosure	Boundary Notes	Minimum Evidence	Anchor Refs
Boundary declaration	Functional unit, floor area definition, assessment period, geography, building type; included/excluded scopes	Declare operational scope and whole-life scope; explicitly list exclusions and rationale	Completed boundary declaration template; data-source register; version/date of method used	[5,7,13–15]

Table 1. *Cont.*

Dimension	Minimum Disclosure	Boundary Notes	Minimum Evidence	Anchor Refs
Operational energy performance	Annual delivered energy by carrier and key end uses; intensity metric normalized by area	Specify metering boundary; treatment of on-site generation/export; weather normalization approach	Utility bills/submetering logs; metering plan; basic QA/QC	[5,20,106,107]
Operational GHG emissions	Annual operational GHG; grid emission factor source and year; time-matching approach if claimed	Must state emission factor source and temporal alignment; treatment of RECs/guarantees-of-origin and double counting	Calculations workbook; factor source documentation; traceability for certificates if used	[5,108]
Whole-life carbon/embodied + life-cycle	Whole-life carbon result; breakdown at minimum into embodied vs. operational; major contributors	Declare system boundary: product/construction, use-stage replacements/maintenance, end-of-life; treatment of refurbishment scenarios and end-of-life assumptions	LCA report summary with inputs list; EPD coverage statement; data quality level	[6–8,13,19,28,31,92]
Net-zero claim components	Claimed net-zero type; on-site vs. off-site renewables; residual emissions; offsets used	Explicitly state whether embodied/WLC is included; offsets only after reductions; disclose additionality/durability criteria used	Renewable procurement evidence; offset certificates; disclosure of residuals and reconciliation	[5,14,15]
Occupant well-being	Minimum set of IEQ/comfort proxies and basic safety/health considerations	Report whether metrics are design-stage, commissioning-stage, or operational monitoring; state assumptions and limitations	Commissioning records; monitoring snapshot or POE plan; referenced guideline basis	[18]
Affordability/energy burden	Affordability indicator and distributional note	State household/income basis or tenant type; disclose data source and whether it is modeled or measured	Administrative data source or documented assumptions; calculation note	[17]
Accessibility and resilience	If relevant, disclose accessibility baseline and resilience-related performance statement	Mark as context-dependent; specify hazard scenario and scope if claimed	Scenario description; cited standard/guideline if used	[5,16]

These disclosure minimums are intended to be taken up by Recommendation Two's alignment and assurance function, which can translate them into harmonized boundary declarations and tiered verification expectations across existing tools.

Institutionally, the mechanism does not need to imply a single global authority, but it does require a convening arrangement that can mitigate fragmentation in sustainability governance [109]. A credible pathway is to embed the mechanism within an internationally recognized platform, with technical participation from built-environment stakeholders and alignment with major sustainability agendas. Democratic participation and procedural legitimacy are critical to ensure that revisions gain broad acceptance [110], particularly given the diffusion of actors and responsibilities in contemporary environmental governance [111]. The key design objective is not institutional expansion per se, but the creation of a stable process capable of issuing periodic, citable clarifications that reduce interpretive drift in research and practice.

Finally, this mechanism should prioritize built-environment issues where Brundtland-era under-specification is most consequential. For example, the report's discussions of urbanization and the relationship between small and large cities remain relevant to contemporary urban development pressures [46], but they require updating in light of today's decarbonization imperatives, retrofit needs in existing building stocks, and equity concerns such as energy poverty and housing affordability. Likewise, the mechanism should explicitly address the built environment's contemporary transition challenges: whole-life carbon, verification expectations for net-zero claims, and the integration of decarbonization with health and resilience outcomes.

A review-and-update mechanism alone, however, is not sufficient. Even a clarified definition can be misapplied if standards, certifications, and disclosure tools continue to embed inconsistent boundaries and verification practices. For this reason, Recommendation Two complements the present proposal by focusing on implementation alignment, comparability, and capacity building across the tool landscape of buildings and construction.

4.2. Recommendation Two: Create an Implementation-Alignment, Verification, and Capacity-Building Organization for Built-Environment Sustainable Development

Even if the Brundtland definition is periodically clarified through the review-and-update mechanism proposed in Recommendation One, the concept can still be misapplied if implementation tools continue to embed inconsistent boundaries, metrics, and verification practices. This problem is especially acute in the built environment, where "sustainable development," "low-carbon," and "net-zero" claims are often made through a fragmented landscape of standards, certification schemes, and disclosure frameworks. Therefore, the second recommendation is to establish a permanent implementation-oriented arrangement—an institutional "alignment and assurance" function—whose primary role is to improve comparability, credibility, and professional capacity in building-sector practice, rather than to invent an entirely new sustainability agenda.

A useful reference point is the LEED (Leadership in Energy and Environmental Design) system administered through USGBC/GBCI, which illustrates how implementation credibility is strengthened when rating rules are explicit, scope is consistently declared, quality assurance is built into assessment routines, and professional training supports repeatable application at scale. The lesson for our purposes is not to position any single scheme as the arbiter of "sustainable development," but to extract these institutional design features—clarity, QA, and capacity building—as requirements for an interoperability-oriented assurance layer across diverse net-zero and green building tools.

However, the aim of this recommendation is not to replicate LEED as a single universal arbiter of "sustainable development." Instead, the proposed organization would perform three narrowly defined functions that directly respond to Weakness Two (conceptual vagueness and boundary ambiguity) in the built environment:

1. Tool alignment and interoperability. Building on the clarified concept produced under Recommendation One, the organization would publish baseline requirements that existing net-zero and green building tools can map to—especially around boundary declarations (operational vs. embodied carbon; time horizons), minimum metric definitions, and disclosure expectations. This is best framed as an interoperability layer rather than a replacement of existing standards. The objective is to reduce fragmentation and make claims comparable across jurisdictions and certification systems.
2. Verification principles and assurance pathways. The organization would articulate minimum verification expectations (what evidence is required, how performance is checked, and which claims require third-party review), thereby reducing greenwashing risk and raising confidence in building performance statements. A practical way to operationalize this is to define tiered assurance levels with explicit deliverables and trigger conditions. Tier 1 would require a standardized disclosure package (Table 1) with a completed boundary declaration template, traceable data sources, and a claim reconciliation sheet that reports residual emissions and any RECs/offsets used. Tier 2 would add independent verification through structured document review and consistency checks, ensuring that declared boundaries align with reported metrics, that calculations reconcile arithmetically, and that key inputs can be corroborated through spot checks against metering evidence and material/LCA assumptions. Tier 3 would be required for high-stakes or public-facing claims and would include audited

verification with performance checks against measured operation where feasible, plus validation of offset quality criteria. By explicitly tying each tier to the Table 1 evidence items, the same "net-zero/low-carbon" label becomes auditable rather than rhetorical. This function aligns with the broader governance insight that credible net-zero pathways depend on accountability structures and transparent reporting, not merely on aspirational targets.

3. Professional capacity building for AEC implementation. Because buildings are delivered through complex actor networks, concept-consistent implementation depends on trained professionals who can apply boundaries, metrics, and verification consistently. This capacity gap is amplified—not resolved—by digitalization: as BIM/digital twins and data-intensive M&V proliferate, weak boundary competence, low data literacy, and unclear assurance responsibilities become binding constraints on producing comparable and auditable sustainability claims. The organization would therefore accredit training content (rather than monopolizing training), develop role-based competencies (design, construction, commissioning, operations, auditing), and encourage harmonized professional standards that reduce interpretive drift in practice. To support diffusion at scale, these competency profiles and training materials can be embedded in university and continuing-professional education curricula and referenced by professional bodies and accreditation schemes, thereby mainstreaming boundary, metric, and assurance-related skills across AEC roles. Figure 7 summarizes this governance architecture as a closed loop: performance data, standards evolution, and policy signals feed the standing review-and-update function, which issues versioned guidance, changelog notes, and boundary clarifications; these are then operationalized by the assurance layer through boundary declaration templates, crosswalk mappings, verification tiers, and capacity building, yielding harmonized outputs that in turn generate performance data feedback for the next update cycle.

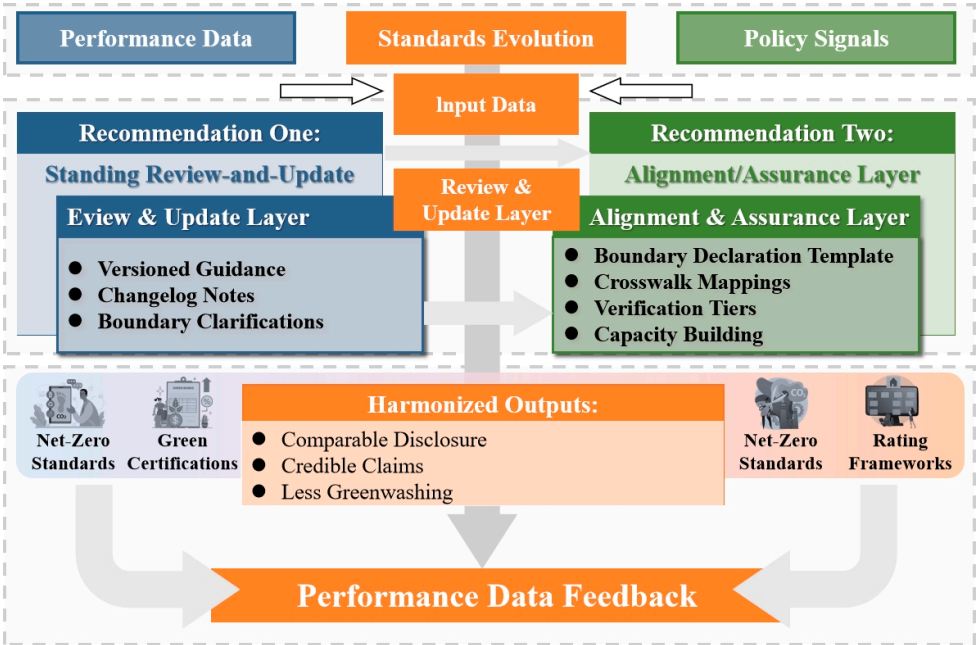


Figure 7. Two-Mechanism Governance Loop: Linking Specification, Disclosure, and Verification.

In addition, this implementation arrangement should explicitly interface with sustainable finance and investment governance where relevant. Decarbonization in buildings increasingly depends on aligning capital allocation with credible definitions of "low-carbon" and "net-zero" activities. The World Bank and related initiatives emphasize the

importance—and the complexity—of sustainable finance taxonomies for guiding investment classification and coordination. The proposed organization's role here would be limited and practical: providing a built-environment-relevant "activity and performance" schema that can be referenced by financiers and policymakers without requiring a single global taxonomy for all sectors.

Finally, this recommendation should be framed in institutional terms that remain compatible with a theory-driven paper. The organization could be established as a multi-stakeholder platform supported by internationally recognized conveners, but it need not rely on a single, centralized global authority. Its legitimacy would derive from transparent governance, public technical documentation, and demonstrated interoperability benefits for existing tools. Emerging digital technologies can further support this architecture by enabling more consistent measurement, reporting, and auditing—while also requiring adaptive governance to manage new risks and responsibilities.

Together with Recommendation One, this proposal completes a coherent pathway from concept to practice: the first mechanism periodically clarifies and versions the meaning of sustainable development for the built environment, while the second reduces fragmentation and improves credibility by aligning boundaries, strengthening verification, and building professional capacity—thereby accelerating energy efficiency improvements and carbon reduction across buildings and construction.

5. Conclusions

This paper revisits the Brundtland Report's definition of sustainable development through the lens of the built environment and identifies two weaknesses that increasingly constrain credible energy saving and decarbonization in buildings and construction. First, the definition has not been substantively updated since 1987 and therefore reflects late-twentieth-century socioeconomic and technological assumptions that provide limited operational guidance for contemporary building-sector practice shaped by accelerated climate policy, digitalized delivery and operations, and life-cycle carbon accounting. Second, the definition's intentional broadness—while historically important for consensus—leaves key terms such as "needs," "harm," and acceptable trade-offs under-specified. In the built environment, this under-specification can translate into boundary ambiguity (e.g., operational versus embodied carbon), fragmented standards and certification landscapes, non-comparable claims, and heightened greenwashing risks.

Rather than discarding the Brundtland concept, the paper argues for preserving its normative intent while making it operational for building-sector governance. Two complementary mechanisms are proposed. The first is a standing review-and-update mechanism that periodically clarifies the operational meaning of "needs," "harm," and trade-offs in building terms, issues versioned guidance with transparent change logs, and provides boundary notes and a minimum life-cycle indicator set that links whole-life carbon and operational energy performance with core social needs such as health, affordability, accessibility, and resilience. The second is an implementation-alignment and assurance mechanism that reduces fragmentation across existing net-zero and green building tools by establishing baseline requirements for transparency and comparability (boundary declarations, metric definitions, and verification principles), supported by targeted capacity building for architecture–engineering–construction professionals.

Together, these mechanisms provide a coherent pathway from concept to practice: they discipline interpretation without imposing a single universal tool, strengthen the credibility and comparability of building performance claims, and support policy coherence and investment alignment. By translating the Brundtland definition into actionable boundaries, indicators, and verification expectations for the built environment, the proposed framework

aims to accelerate energy efficiency improvements and carbon reduction across buildings and construction, while better integrating decarbonization with human well-being and equity considerations.

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References

1. Calvin, K.; Dasgupta, D.; Krinner, G.; Mukherji, A.; Thorne, P.W.; Trisos, C.; Romero, J.; Aldunce, P.; Barrett, K.; Blanco, G.; et al. *IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Core Writing Team, Lee, H., Romero, J., Eds.; IPCC: Geneva, Switzerland, 2023. [CrossRef]
2. United Nations Environment Programme; Global Alliance for Buildings and Construction. *Not Just Another Brick in the Wall: The Solutions Exist—Scaling Them Will Build on Progress and Cut Emissions Fast. Global Status Report for Buildings and Construction 2024/2025*; United Nations Environment Programme: Nairobi, Kenya, 2025. [CrossRef]
3. Seto, K.C.; Davis, S.J.; Mitchell, R.B.; Stokes, E.C.; Unruh, G.; Ürge-Vorsatz, D. Carbon lock-in: Types, causes, and policy implications. *Annu. Rev. Environ. Resour.* **2016**, *41*, 425–452. [CrossRef]
4. Tong, D.; Zhang, Q.; Zheng, Y.; Caldeira, K.; Shearer, C.; Hong, C.; Qin, Y.; Davis, S.J. Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. *Nature* **2019**, *572*, 373–377. [CrossRef]
5. Intergovernmental Panel On Climate Change (IPCC) (Ed.) *Buildings. Climate Change 2022—Mitigation of Climate Change*, 1st ed.; Cambridge University Press: Cambridge, UK, 2023; pp. 953–1048. [CrossRef]
6. Cabeza, L.F.; Rincón, L.; Vilariño, V.; Pérez, G.; Castell, A. Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renew. Sustain. Energy Rev.* **2014**, *29*, 394–416. [CrossRef]
7. Dixit, M.K.; Culp, C.H.; Fernández-Solís, J.L. System boundary for embodied energy in buildings: A conceptual model for definition. *Renew. Sustain. Energy Rev.* **2013**, *21*, 153–164. [CrossRef]
8. Röck, M.; Saade, M.R.M.; Balouktsi, M.; Rasmussen, F.N.; Birgisdottir, H.; Frischknecht, R.; Habert, G.; Lützkendorf, T.; Passer, A. Embodied GHG emissions of buildings—The hidden challenge for effective climate change mitigation. *Appl. Energy* **2020**, *258*, 114107. [CrossRef]
9. Brundtland, G.H. Our Common Future—Call for Action. *Environ. Conserv.* **1987**, *14*, 291–294. [CrossRef]
10. World Commission on Environment and Development. *Report of the World Commission on Environment and Development: Our Common Future*; United Nations General Assembly: New York, NY, USA, 1987.
11. Hopwood, B.; Mellor, M.; O'Brien, G. Sustainable development: Mapping different approaches. *Sustain. Dev.* **2005**, *13*, 38–52. [CrossRef]
12. Robert, K.W.; Parris, T.M.; Leiserowitz, A.A. What is sustainable development? Goals, indicators, values, and practice. *Environ. Sci. Policy Sustain. Dev.* **2005**, *47*, 8–21. [CrossRef]
13. RICS. *Whole Life Carbon Assessment (WLCA) for the Built Environment*; RICS: London, UK, 2024.
14. Sartori, I.; Napolitano, A.; Voss, K. Net zero energy buildings: A consistent definition framework. *Energy Build.* **2012**, *48*, 220–232. [CrossRef]
15. UKGBC. *Net Zero Carbon Buildings Framework*; UKGBC: London, UK, 2019.
16. United Nations Department of Economic and Social Affairs. *The Sustainable Development Goals Report 2023*, Special ed.; United Nations: New York, NY, USA, 2023. [CrossRef]
17. Bouzarovski, S.; Petrova, S. A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. *Energy Res. Social. Sci.* **2015**, *10*, 31–40. [CrossRef]

18. World Health Organization, United States; France, United States (Eds.) *WHO Housing and Health Guidelines*; World Health Organization: Geneva, Switzerland, 2018.
19. Ibn-Mohammed, T.; Greenough, R.; Taylor, S.; Ozawa-Meida, L.; Acquaye, A. Operational vs. embodied emissions in buildings—A review of current trends. *Energy Build.* **2013**, *66*, 232–245. [CrossRef]
20. De Wilde, P. The gap between predicted and measured energy performance of buildings: A framework for investigation. *Autom. Constr.* **2014**, *41*, 40–49. [CrossRef]
21. Newsham, G.R.; Mancini, S.; Birt, B.J. Do LEED-certified buildings save energy? Yes, but.... *Energy Build.* **2009**, *41*, 897–905. [CrossRef]
22. Kibert, C.J. *Sustainable Construction: Green Building Design and Delivery*; John Wiley & Sons: Hoboken, NJ, USA, 2016.
23. Yiu, W.Y. Life Cycle Assessment in the Construction Industry. Master's Thesis, The University of Hong Kong, Hong Kong, China, 2001. [CrossRef]
24. Ramesh, T.; Prakash, R.; Shukla, K.K. Life cycle energy analysis of buildings: An overview. *Energy Build.* **2010**, *42*, 1592–1600. [CrossRef]
25. Sartori, I.; Hestnes, A.G. Energy use in the life cycle of conventional and low-energy buildings: A review article. *Energy Build.* **2007**, *39*, 249–257. [CrossRef]
26. Dixit, M.K. Life cycle embodied energy analysis of residential buildings: A review of literature to investigate embodied energy parameters. *Renew. Sustain. Energy Rev.* **2017**, *79*, 390–413. [CrossRef]
27. Moncaster, A.M.; Rasmussen, F.N.; Malmqvist, T.; Houlihan Wiberg, A.; Birgisdottir, H. Widening understanding of low embodied impact buildings: Results and recommendations from 80 multi-national quantitative and qualitative case studies. *J. Clean. Prod.* **2019**, *235*, 378–393. [CrossRef]
28. Pomponi, F.; Moncaster, A. Embodied carbon mitigation and reduction in the built environment—What does the evidence say? *J. Environ. Manag.* **2016**, *181*, 687–700. [CrossRef]
29. Anand, C.K.; Amor, B. Recent developments, future challenges and new research directions in LCA of buildings: A critical review. *Renew. Sustain. Energy Rev.* **2017**, *67*, 408–416. [CrossRef]
30. Anderson, J.; Moncaster, A. Embodied carbon of concrete in buildings, part 1: Analysis of published EPD. *Build. Cities* **2020**, *1*, 198–217. [CrossRef]
31. De Wolf, C.; Pomponi, F.; Moncaster, A. Measuring embodied carbon dioxide equivalent of buildings: A review and critique of current industry practice. *Energy Build.* **2017**, *140*, 68–80. [CrossRef]
32. Pomponi, F.; Moncaster, A.; De Wolf, C. Furthering embodied carbon assessment in practice: Results of an industry-academia collaborative research project. *Energy Build.* **2018**, *167*, 177–186. [CrossRef]
33. Pomponi, F.; Lenzen, M. Hybrid life cycle assessment (LCA) will likely yield more accurate results than process-based LCA. *J. Clean. Prod.* **2018**, *176*, 210–215. [CrossRef]
34. Pomponi, F.; Moncaster, A. Scrutinising embodied carbon in buildings: The next performance gap made manifest. *Renew. Sustain. Energy Rev.* **2018**, *81*, 2431–2442. [CrossRef]
35. Berardi, U. Clarifying the new interpretations of the concept of sustainable building. *Sustain. Cities Soc.* **2013**, *8*, 72–78. [CrossRef]
36. Lélé, S.M. Sustainable development: A critical review. *World Dev.* **1991**, *19*, 607–621. [CrossRef]
37. Marszal, A.J.; Heiselberg, P.; Bourrelle, J.S.; Musall, E.; Voss, K.; Sartori, I.; Napolitano, A. Zero energy building—A review of definitions and calculation methodologies. *Energy Build.* **2011**, *43*, 971–979. [CrossRef]
38. Twinn, R.; Desai, K.; Box, P. *Net Zero Carbon Buildings: A Framework Definition*; UK Green Building Council: London, UK, 2019.
39. Berardi, U. Sustainability assessment in the construction sector: Rating systems and rated buildings. *Sustain. Dev.* **2012**, *20*, 411–424. [CrossRef]
40. Haapio, A.; Viitaniemi, P. A critical review of building environmental assessment tools. *Environ. Impact Assess. Rev.* **2008**, *28*, 469–482. [CrossRef]
41. Delmas, M.A.; Burbano, V.C. The drivers of greenwashing. *Calif. Manag. Rev.* **2011**, *54*, 64–87. [CrossRef]
42. Lyon, T.P.; Maxwell, J.W. Greenwash: Corporate environmental disclosure under threat of audit. *J. Econ. Manag. Strategy* **2011**, *20*, 3–41. [CrossRef]
43. Kim, E.-H.; Lyon, T.P. Greenwash vs. Brownwash: Exaggeration and undue modesty in corporate sustainability disclosure. *Organ. Sci.* **2015**, *26*, 705–723. [CrossRef]
44. World Green Building Council. *What Is a Net Zero Carbon Building?* World Green Building Council: London, UK, 2019.
45. IEA. *Final Energy Consumption of Buildings Relative to Other Sectors*; IEA: Paris, France, 2022. Available online: https://www.iea.org/data-and-statistics/charts/final-energy-consumption-of-buildings-relative-to-other-sectors-2022 (accessed on 19 January 2026).
46. Brundtland, G.H. *Our Common Future*; Reprinted; Oxford University Press: Oxford, UK, 1987.
47. Geels, F.W. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Res. Policy* **2002**, *31*, 1257–1274. [CrossRef]
48. Unruh, G.C. Understanding carbon lock-in. *Energy Policy* **2000**, *28*, 817–830. [CrossRef]

49. *ISO 14040:2006(en)*; Environmental Management—Life Cycle Assessment—Principles and Framework. ISO: Geneva, Switzerland, 2006.
50. *ISO 14044:2006(en)*; Environmental Management—Life Cycle Assessment—Requirements and Guidelines. ISO: Geneva, Switzerland, 2006.
51. National Standards Authority of Ireland. *Sustainability of Construction Works, Assessment of Environmental Performance of Buildings: Calculation Method*; NSAI: Dublin, Ireland, 2011.
52. Castro, C.J. Sustainable development: Mainstream and critical perspectives. *Organ. Environ.* **2004**, *17*, 195–225. [CrossRef]
53. Olson, M. The productivity slowdown, the oil shocks, and the real cycle. *J. Econ. Perspect.* **1988**, *2*, 43–69. [CrossRef]
54. Baily, M.N.; Gordon, R.J.; Nordhaus, W.D.; Romer, D. The productivity slowdown, measurement issues, and the explosion of computer power. *Brook. Pap. Econ. Act.* **1988**, *1988*, 347–431. [CrossRef]
55. OECD. *Future-Proofing Real Estate Investment: Place-Based Risks*; OECD Publishing: Paris, France, 2025. [CrossRef]
56. Siew, R.Y.J. Climate-related financial disclosure and the property and construction sector. *Proc. Inst. Civ. Eng. Eng. Sustain.* **2021**, *174*, 3–8. [CrossRef]
57. Fisch-Romito, V.; Guivarch, C.; Creutzig, F.; Minx, J.C.; Callaghan, M.W. Systematic map of the literature on carbon lock-in induced by long-lived capital. *Environ. Res. Lett.* **2021**, *16*, 053004. [CrossRef]
58. Mastrucci, A.; Marvuglia, A.; Leopold, U.; Benetto, E. Life cycle assessment of building stocks from urban to transnational scales: A review. *Renew. Sustain. Energy Rev.* **2017**, *74*, 316–332. [CrossRef]
59. Akbarnezhad, A.; Xiao, J. Estimation and minimization of embodied carbon of buildings: A review. *Buildings* **2017**, *7*, 5. [CrossRef]
60. Vial, G. Understanding digital transformation: A review and a research agenda. *J. Strateg. Inf. Syst.* **2019**, *28*, 118–144. [CrossRef]
61. Juez, F. *Digital Technologies Directly Benefit 70 Percent of SDG Targets, Say ITU, UNDP and Partners*; UNDP: New York, NY, USA, 2023.
62. Tariq, W.; Chen, Y.; Tariq, A.; Sumbal, M.S. Digital governance for sustainable development: A holistic review, framework, and roadmap. *Technol. Soc.* **2026**, *84*, 103135. [CrossRef]
63. Hilty, L.M. *ICT Innovations for Sustainability*; Springer International Publishing Imprint: Berlin/Heidelberg, Germany, 2015. [CrossRef]
64. Raihan, A. A review of the potential opportunities and challenges of the digital economy for sustainability. *Innov. Green Dev.* **2024**, *3*, 100174. [CrossRef]
65. Sacks, R.; Eastman, C.; Lee, G.; Teicholz, P. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 3rd ed.; John Wiley & Sons, Inc: Hoboken, NJ, USA, 2018.
66. Boje, C.; Guerriero, A.; Kubicki, S.; Rezgui, Y. Towards a semantic construction digital twin: Directions for future research. *Autom. Constr.* **2020**, *114*, 103179. [CrossRef]
67. Amasyali, K.; El-Gohary, N.M. A review of data-driven building energy consumption prediction studies. *Renew. Sustain. Energy Rev.* **2018**, *81*, 1192–1205. [CrossRef]
68. Wei, Y.; Zhang, X.; Shi, Y.; Xia, L.; Pan, S.; Wu, J.; Han, M.; Zhao, X. A review of data-driven approaches for prediction and classification of building energy consumption. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1027–1047. [CrossRef]
69. Vinuesa, R.; Azizpour, H.; Leite, I.; Balaam, M.; Dignum, V.; Domisch, S.; Felländer, A.; Langhans, S.D.; Tegmark, M.; Nerini, F.F. The role of artificial intelligence in achieving the sustainable development goals. *Nat. Commun.* **2020**, *11*, 233. [CrossRef]
70. Morley, J.; Floridi, L.; Kinsey, L.; Elhalal, A. From what to how: An initial review of publicly available AI ethics tools, methods and research to translate principles into practices. *Sci. Eng. Ethics* **2020**, *26*, 2141–2168. [CrossRef]
71. Mastrucci, A.; Byers, E.; Pachauri, S.; Rao, N.D. Improving the SDG energy poverty targets: Residential cooling needs in the global south. *Energy Build.* **2019**, *186*, 405–415. [CrossRef]
72. Satterthwaite, D.; Archer, D.; Colenbrander, S.; Dodman, D.; Hardoy, J.; Mitlin, D.; Patel, S. Building resilience to climate change in informal settlements. *One Earth* **2020**, *2*, 143–156. [CrossRef]
73. Naja, S.; Din Makhlouf, M.M.E.; Chehab, M.A.H. An ageing world of the 21st century: A literature review. *Int. J. Community Med. Public Health* **2017**, *4*, 4363. [CrossRef]
74. United Nations Department of Economic and Social Affairs. *World Population Ageing 2020 Highlights: Living Arrangements of Older Persons*; United Nations: New York, NY, USA, 2020.
75. Intergovernmental Panel On Climate Change (IPCC). *Climate Change 2022—Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1st ed.; Cambridge University Press: Cambridge, UK, 2023. [CrossRef]
76. Zhao, S.X.B.; Wong, K.K.K. The sustainability dilemma of China's township and village enterprises: An analysis from spatial and functional perspectives. *J. Rural. Stud.* **2002**, *18*, 257–273. [CrossRef]
77. Xu, H.; Liu, D.; Wu, H. Environmental regionalization for the management of township and village enterprises in China. *J. Environ. Manag.* **2001**, *63*, 203–210. [CrossRef]
78. Li, C.; Pradhan, P.; Chen, G.; Kropp, J.P.; Schellnhuber, H.J. Carbon footprint of the construction sector is projected to double by 2050 globally. *Commun. Earth Env.* **2025**, *6*, 831. [CrossRef] [PubMed]

79. Fankhauser, S.; Smith, S.M.; Allen, M.; Axelsson, K.; Hale, T.; Hepburn, C.; Kendall, J.M.; Khosla, R.; Lezaun, J.; Mitchell-Larson, E.; et al. The meaning of net zero and how to get it right. *Nat. Clim. Change* **2022**, *12*, 15–21. [CrossRef]
80. Hale, T.; Smith, S.M.; Black, R.; Cullen, K.; Fay, B.; Lang, J.; Mahmood, S. Assessing the rapidly-emerging landscape of net zero targets. *Clim. Policy* **2022**, *22*, 18–29. [CrossRef]
81. Meadowcroft, J.; Rosenbloom, D. Governing the net-zero transition: Strategy, policy, and politics. *Proc. Natl. Acad. Sci. USA* **2023**, *120*, e2207727120. [CrossRef]
82. Griggs, D.; Stafford-Smith, M.; Gaffney, O.; Rockström, J.; Öhman, M.C.; Shyamsundar, P.; Steffen, W.; Glaser, G.; Kanie, N.; Noble, I. Sustainable development goals for people and planet. *Nature* **2013**, *495*, 305–307. [CrossRef]
83. Holden, E.; Linnerud, K.; Banister, D. Sustainable development: Our common future revisited. *Global Environ. Change* **2014**, *26*, 130–139. [CrossRef]
84. Hedlund-de Witt, A. Rethinking sustainable development: Considering how different worldviews envision "development" and "quality of life". *Sustainability* **2014**, *6*, 8310–8328. [CrossRef]
85. OECD. *Home, Green Home: Policies to Decarbonise Housing*; OECD: Paris, France, 2023; Volume 1751. [CrossRef]
86. Sachs, J.D. From Millennium Development Goals to Sustainable Development Goals. *Lancet* **2012**, *379*, 2206–2211. [CrossRef] [PubMed]
87. Redclift, M. *Sustainable Development*, 1st ed.; Routledge: London, UK, 2002. [CrossRef]
88. Solow, R. An almost practical step toward sustainability. *Resour. Policy* **1993**, *19*, 162–172. [CrossRef]
89. Waas, T.; Hugé, J.; Verbruggen, A.; Wright, T. Sustainable development: A bird's eye view. *Sustainability* **2011**, *3*, 1637–1661. [CrossRef]
90. Malerba, D. *Just Transitions: A Review of How to Decarbonise Energy Systems While Addressing Poverty and Inequality Reduction*; German Institute of Development and Sustainability: Bonn, Germany, 2022. [CrossRef]
91. Lublóy, Á.; Keresztúri, J.L.; Berlinger, E. Quantifying firm-level greenwashing: A systematic literature review. *J. Environ. Manag.* **2025**, *373*, 123399. [CrossRef] [PubMed]
92. World Green Building Council. Bringing embodied carbon upfront. In *Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon Circular Cities and Regions Initiative*; World Green Building Council: London, UK, 2019.
93. Probst, B.S.; Toetzke, M.; Kontoleon, A.; Díaz Anadón, L.; Minx, J.C.; Haya, B.K.; Schneider, L.; Trotter, P.A.; West, T.A.P.; Gill-Wiehl, A.; et al. Systematic assessment of the achieved emission reductions of carbon crediting projects. *Nat. Commun.* **2024**, *15*, 9562. [CrossRef]
94. Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Zhang, T.; Ghaffarianhoseini, A.; Tookey, J. A critical comparison of green building rating systems. *Build. Environ.* **2017**, *123*, 243–260. [CrossRef]
95. Afroz, Z.; Burak Gunay, H.; O'Brien, W. A review of data collection and analysis requirements for certified green buildings. *Energy Build.* **2020**, *226*, 110367. [CrossRef]
96. Matisoff, D.C.; Noonan, D.S.; Mazzolini, A.M. Performance or marketing benefits? The case of LEED certification. *Environ. Sci. Technol.* **2014**, *48*, 2001–2007. [CrossRef]
97. Anguelovski, I.; Connolly, J.J.T.; Pearsall, H.; Shokry, G.; Checker, M.; Maantay, J.; Gould, K.; Lewis, T.; Maroko, A.; Roberts, J.T. Why green "climate gentrification" threatens poor and vulnerable populations. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 26139–26143. [CrossRef]
98. Zhu, W.; Yuan, C. Urban heat health risk assessment in Singapore to support resilient urban design—By integrating urban heat and the distribution of the elderly population. *Cities* **2023**, *132*, 104103. [CrossRef]
99. Sax, D.L.; Nesbitt, L.; Quinton, J. Improvement, not displacement: A framework for urban green gentrification research and practice. *Environ. Sci. Policy* **2022**, *137*, 373–383. [CrossRef]
100. Ness, D. Growth in floor area: The blind spot in cutting carbon. *Emerald Open Res.* **2023**, *1*. [CrossRef]
101. Meadows, D.; Randers, J. *The Limits to Growth*, 1st ed.; Routledge: London, UK, 2012. [CrossRef]
102. Zhong, X.; Hu, M.; Deetman, S.; Steubing, B.; Lin, H.X.; Hernandez, G.A.; Harpprecht, C.; Zhang, C.; Tukker, A.; Behrens, P. Global greenhouse gas emissions from residential and commercial building materials and mitigation strategies to 2060. *Nat. Commun.* **2021**, *12*, 6126. [CrossRef]
103. Fainstein, S.S. New Directions in Planning Theory. *Urban Aff. Rev.* **2000**, *35*, 451–478. [CrossRef]
104. Leccese, M.; McCormick, K.; Congress for the New Urbanism (Eds.) *Charter of the New Urbanism*; McGraw Hill: New York, NY, USA, 2000.
105. Trudeau, D. New urbanism as sustainable development? *Geogr. Compass* **2013**, *7*, 435–448. [CrossRef]
106. Creutzig, F.; Niamir, L.; Bai, X.; Callaghan, M.; Cullen, J.; Díaz-José, J.; Figueroa, M.; Grubler, A.; Lamb, W.F.; Leip, A.; et al. Demand-side solutions to climate change mitigation consistent with high levels of well-being. *Nat. Clim. Change* **2022**, *12*, 36–46. [CrossRef]
107. Urge-Vorsatz, D.; Petrichenko, K.; Staniec, M.; Eom, J. Energy use in buildings in a long-term perspective. *Curr. Opin. Environ. Sustain.* **2013**, *5*, 141–151. [CrossRef]

108. Van Heerden, R.; Edelenbosch, O.Y.; Daioglou, V.; Le Gallic, T.; Baptista, L.B.; Di Bella, A.; Colelli, F.P.; Emmerling, J.; Fragkos, P.; Hasse, R.; et al. Demand-side strategies enable rapid and deep cuts in buildings and transport emissions to 2050. *Nat. Energy* **2025**, *10*, 380–394. [CrossRef]
109. Van Driel, M.; Biermann, F.; Kim, R.E.; Vijge, M.J. International organisations as 'custodians' of the sustainable development goals? Fragmentation and coordination in sustainability governance. *Glob. Policy* **2022**, *13*, 669–682. [CrossRef]
110. Pickering, J.; Hickmann, T.; Bäckstrand, K.; Kalfagianni, A.; Bloomfield, M.; Mert, A.; Ransan-Cooper, H.; Lo, A.Y. Democratising sustainability transformations: Assessing the transformative potential of democratic practices in environmental governance. *Earth Syst. Gov.* **2022**, *11*, 100131. [CrossRef]
111. Sörlin, S.; Warde, P.; Akerman, I.; Höglund Hellgren, J.; Höhler, S.; Isberg, E.; Samosír, G.; Schrøder, T.H. The great dispersal: The fall and rise of global environmental governance. *Ambio* **2025**, *54*, 1267–1288. [CrossRef] [PubMed]

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