

Visualizing Sustainability in Architectural Design: A Taxonomy of Environmental Performance Representation Strategies

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This study examines how environmental performance indicators—such as embodied carbon, lifecycle metrics, and material strategies—are visually communicated in architectural design. It addresses the underexplored relationship between sustainability metrics and graphical representation, with implications for how designers, stakeholders, and the public engage with environmental reasoning in built environments. Drawing on a dual-stream methodology, the research analyzes two datasets: 37 European dissemination projects aligned with LEVEL(s) principles, and 5 Spanish professional projects certified under BREEAM and LEVEL(s), accessed through collaboration with a sustainability-focused architecture firm. Through inductive coding of visual outputs, including technical drawings, lifecycle diagrams, and narrative visuals, the study identifies ten representational strategies, organized into three overarching categories: Compliance-Driven, Direct Performance Visualization, and Narrative Visualization.

While dissemination projects employ visually rich storytelling, certified practice often lacks graphic integration of environmental data. In both contexts, sustainability indicators remain largely absent from early-stage design communication. The study proposes a taxonomy for operationalizing sustainability visually in architectural workflows and calls for more integrated protocols—particularly through BIM—to improve transparency, early decision-making, and civic understanding of environmental performance. These findings contribute to ongoing discussions on how design representation supports resilient and informed architectural practices.

Keywords: architectural representation; BIM; design communication; LEVEL(s); sustainability visualization.

In contemporary architectural practice, environmental sustainability has become a defining imperative (Dodd et al., 2020). Regulatory frameworks, global benchmarks, and client expectations increasingly center on metrics such as embodied carbon, circularity, and life-cycle impact. Assessment systems like LEED, BREEAM, and the European Commission's LEVEL(s) framework have structured these demands into quantifiable performance indicators (Sánchez Cordero et al., 2020; Ferrari et al., 2022). However, despite their technical rigor, these tools primarily rely on textual documentation, charts, and numerical reports - formats largely disconnected from the visual languages architects use to develop and communicate their ideas (Hollberg et al., 2021).

This disconnect is notable given the central role of visual representation in architectural

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Abstract

Introduction



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epistemology. As argued by Allen (1998) and Frascari et al. (2007), architectural drawings and diagrams are generative instruments in design thinking. However, environmental metrics are often handled externally, produced by consultants, documented in technical reports, and rarely embedded in the drawings or models that inform early-stage design (Grover et al., 2019; Meex et al., 2018). This creates a disjunction between performance evaluation and architectural expression.

This study addresses that gap by investigating how environmental performance is (or is not) visually represented in architectural deliverables. Certification systems such as BREEAM and LEED structure sustainability evaluation through predefined scoring systems (Doan et al., 2017) but rarely require visual integration in design media. Findings from a collaboration with a Madrid-based architecture firm confirmed that certification data is typically documented in Life Cycle Assessment (LCA) reports and compliance forms but do not appear in Building Information Modeling (BIM) models or architectural visuals. This reflects a broader issue: visual integration is not institutionally required, and thus often omitted (Nygaard Rasmussen et al., 2020).

In contrast, curated European projects disseminated through architectural platforms like ArchDaily and Divisare frequently employ rich visual storytelling—exploded axonometries, annotated diagrams, or lifecycle illustrations—to narrate sustainability strategies. However, these outputs often emerge post-factum, oriented more toward public dissemination and marketing than early-stage decision-making (Esen & Dinç Kalayci, 2021; Landgren et al., 2019). This divergence motivated a comparative investigation into the roles and representational timing of sustainability visuals in contemporary practice.

The research investigates how sustainability-related data—especially material selection, embodied carbon, and circularity—is communicated through architectural visuals. It poses the following questions:

1. Which visual strategies are currently used to express environmental performance?
2. How do these differ between certified internal documentation and curated public dissemination?
3. What opportunities exist to embed environmental performance more effectively within visual design logic?

To explore these questions, the study adopts a dual-stream empirical methodology, analyzing 42 projects: five certified Spanish architectural projects with complete technical documentation, and 37 European dissemination cases selected for their alignment with LEVEL(s) principles. Through qualitative visual analysis and inductive categorization, the study develops a taxonomy of sustainability representation strategies. These are grouped into three categories that reflect increasing levels of representational integration: Compliance-Driven, Direct Performance Visualization, and Narrative Visualization.

The study reveals a persistent representational gap in architectural practice. In certified projects, visuals tend to follow regulatory templates, limiting their capacity to convey sustainability as design intelligence. In dissemination contexts, rich visual storytelling is more common yet rarely informs early decision-making. To address this, the article introduces a taxonomy that classifies ten sustainability representation strategies—bridging compliance, communication, and spatial reasoning in architectural workflows.

The article is structured as follows: Section 2 outlines the empirical methodology; Section 3 reviews the theoretical background; Section 4 presents the taxonomy and findings; Section 5 discusses implications for practice and representation; and Section 6 concludes.

Methods

This research adopts a dual-stream empirical methodology, combining qualitative visual analysis with inductive typology development (Kluge, 2000). It investigates how environmental performance, particularly in relation to embodied carbon, lifecycle design logic, and material strategies,

is visually represented in architectural deliverables. The method bridges theoretical inquiry with practice-based evidence, drawing from a comparative sample of dissemination-oriented European projects and certified Spanish professional cases. Through iterative coding, thematic clustering, and cross-case analysis, the study formulates a ten-strategy taxonomy structured along a representational engagement continuum.

Research Design

The methodology used two purposefully selected datasets and proceeded through four analytical stages:

1. Case selection and sampling based on relevance to environmental performance representation;
2. Visual data collection and curation, focusing on project documentation;
3. Visual coding and thematic clustering, to identify patterns of representation;
4. Typology construction, resulting in a taxonomy of ten distinct visual strategies.

This design enabled a structured comparison between public-facing dissemination (Group A) and professional practice (Group B), identifying systemic patterns in how environmental reasoning is communicated graphically across architectural outputs.

Case Selection

Two empirical groups were constructed (Table 1), to reflect contrasting project cultures and representational aims:

a. Group A – Dissemination Projects:

Comprising 37 European architectural projects completed after 2015. These were selected based on their thematic alignment with the EU's LEVEL(s) framework, demonstrated through recurring references to embodied carbon, circularity, or lifecycle awareness, as well as the richness of publicly available visual documentation. Only projects that visually expressed environmental performance through communicative strategies such as annotated diagrams, lifecycle illustrations, or material breakdowns were included. Sources included dissemination platforms, architectural competitions, EU databases, and institutional publications.

b. Group B – Certified Professional Projects:

Consisting of 5 Spanish building projects certified under BREEAM or LEVEL(s) protocols. These cases were accessed through a collaboration with a sustainability-focused architectural office. While this allowed access to complete technical documentation, it also introduces a degree of methodological limitation: the visual material reflects the conventions and representational culture of a single firm. The documentation reflects standard professional workflows, consultant inputs, and compliance-based deliverables.

Dataset	Source Type	No. of Projects	Certification	Visuals Analyzed	Typical Visual Formats
Group A	Dissemination (EU projects)	37	LEVEL(s)-aligned	358	Technical drawings, BIM screenshots, circularity diagrams, photographs, curated schemes
Group B	Spanish professional practice	5	BREEAM, LEVEL(s)	87	Technical drawings, consultant reports, certification scorecards, photographs
Total		42		445	

Table 1

Project dataset overview

Projects are coded A01–A37 (Group A) and B01–B05 (Group B). See Appendices A and B for full list of projects and metadata.

Data Types and Visual Material

Visual data included both quantitative and qualitative outputs related to environmental performance. Up to 25 visuals were extracted per project, focusing on: LCA or embodied carbon calculations; Construction material choices and sourcing strategies; Passive design logic (orientation, daylight, ventilation); Visual communication of sustainability narratives. Visual types included: Floor plans, sections, and axonometries; Construction details and assembly diagrams; 3D models, BIM screenshots, and exploded views; Certification dashboards and environmental charts; Concept renderings, post-construction photography, and narrative panels.

Visuals were curated in a structured matrix workspace (Fig. 1) and labeled for metadata including origin, visual type, and its link to sustainability indicators. A total of 445 visuals were analyzed.

Fig. 1

Visual data matrix used during the empirical coding process. Each column corresponds to one of the 42 projects, with visuals categorized by type, phase, and representational strategy. The workspace enabled inductive clustering and cross-case comparison between Group A and Group B.



Data Analysis

The visual material was analyzed through a four-step process combining iterative coding with inductive synthesis:

1. **Initial Coding.** Each visual was reviewed and tagged for its source, type, and role in communicating environmental performance. Coding included format (e.g., plan, section, rendering), design phase, and relation to environmental metrics.
2. **Cross-Group Differentiation.** Differences between Group A and Group B were identified in terms of visual integration, purpose, and form. Patterns were inductively grouped based on representational intent and design embedment.
3. **Strategy Identification.** Ten distinct strategies of environmental performance representation were derived from the dataset. These ranged from complete visual absence to narrative post-construction dissemination.
4. **Taxonomy Construction.** The ten strategies were organized into three epistemic categories—compliance-driven, direct performance visualization, and narrative visualization—forming a representational continuum. This taxonomy reflects the varying degrees to which environmental reasoning is embedded in architectural visuals.

State-of-the-art

Visual communication of environmental performance has become an isolated theme in architectural practice. While sustainability certifications and LCA offer clear benchmarks for carbon and material impact, their integration into architectural representation remains limited (Pomponi & Moncaster, 2016; Hollberg et al., 2021). Traditional drawing sets, BIM models, and construction details often fall short of communicating a project's environmental reasoning. This separation between measurable sustainability and visual expression raises critical questions about how architecture both conceives and communicates its sustainability agenda (Frampton, 2020).

As climate targets tighten and design accountability increases, architects face growing pressure not only to deliver lower-impact buildings but also to make environmental performance legible to clients, consultants, and the public (Ibrahim et al., 2024). Yet current visual languages remain misaligned with this ambition. Architectural representation serves both as a technical tool and an epistemic medium—meaning it serves not just to illustrate, but to generate knowledge within the design process (Evans, 2000; Corner, 1999). This section outlines three overlapping challenges: the detachment of sustainability metrics from representational media, the limits of current certification workflows, and the paradoxes posed by emerging digital tools.

Environmental Data and Architectural Representation

Architectural representation has historically prioritized spatial and aesthetic clarity over quantitative analysis (Allen, 1998). As sustainability metrics have become more prominent, they are often introduced largely through parallel technical reports, certification templates, and performance dashboards (Miyamoto et al., 2022). Although these tools carry authority, they are visually detached from the project's architectural language. As a result, data on embodied carbon, lifecycle impact, or energy use exists in a silo—available to consultants but disconnected from drawings or diagrams that shape early-stage design.

This disjuncture creates two problems. First, it limits feedback between performance metrics and design reasoning. Second, it makes environmental logic opaque to non-specialists. In both cases, architectural culture maintains a gap between environmental accountability and representational intelligence (Messaris & Abraham, 2001). Bridging this gap requires not only enhanced tools but a rethinking of what architectural visuals are meant to express.

Metrics Without Media: The Limits of Certification Frameworks

Assessment protocols such as BREEAM, LEED, and LEVEL(s) translate sustainability into technical outputs—checklists, scores, and compliance forms (Ferrari et al., 2022; Sánchez Cordero et al., 2020). While effective for environmental accountability, they rarely integrate performance metrics into the visual and spatial core of design. Although the European LEVEL(s) framework promotes embedding sustainability within project documentation, this seldom translates into visual architectural outputs (Malmqvist et al., 2011).

Environmental evaluations are frequently externalized to consultants and occur late in the design process, bypassing the drawings and models where decisions are made (Hollberg et al., 2021; Pomponi & Moncaster, 2016). As a result, certification frameworks tend to function as audit mechanisms rather than design tools. Even when assessments occur in early stages, the visual communication challenges remain.

Among existing systems, LEVEL(s), with its emphasis on lifecycle documentation, offers stronger potential for visual integration. However, this remains largely unrealized, confirming the representational gap present in point-based GBRs.

Digital Tools and the Representation Paradox

BIM and LCA platforms offer increasing potential to embed environmental performance in architectural workflows (Meex et al., 2018; Forth et al., 2023). Yet their representational impact remains limited. In practice, BIM-LCA integration occurs through several distinct approaches. In sequential workflows, designers export BIM models to external platforms such as OneClick or Athena, often late in the design process. While these tools support compliance assessments, their outputs—graphs, tables, or dashboards—rarely feed back into spatial or visual reasoning (Pomponi & Moncaster, 2016). Plugin-based tools like Tally or OneClick's Revit add-on allow earlier-stage material assessments but still prioritize numerical outputs over visual articulation (Meex et al., 2018). More recently, researchers have proposed spatial visualization techniques—including

overlays, color mapping, and material-coded diagrams—to embed impact data directly into drawings or models (Hollberg et al., 2021). However, these strategies remain underutilized in professional workflows.

A paradox thus emerges: despite the increasing capacity of digital tools, architectural representation has not evolved to reflect environmental metrics in spatial or communicative form. Performance is quantified but rarely visualized within the drawings and diagrams that guide design. Meanwhile, dissemination-oriented visuals—produced for awards, exhibitions, or clients—often frame sustainability symbolically through green imagery or narrative overlays. These images communicate intent but seldom reflect integrated environmental reasoning (Cucuzzella, 2015; Yigitbas et al., 2023). This study addresses this gap by examining how architectural projects variously integrate or omit environmental reasoning in visual form. Through comparative visual analysis, it proposes a taxonomy of representation strategies—highlighting how environmental intelligence is expressed within the visual culture of architectural practice.

Results

This section presents the empirical outcomes of an analysis of 42 architectural projects, divided into two groups:

Group A: 37 dissemination-focused European projects aligned with the LEVEL(s) framework.

Group B: 5 certified Spanish professional projects.

A total of 445 visual materials were examined to understand how environmental performance, particularly in relation to LCA, embodied energy, material construction logic, and carbon-related design reasoning—is represented in architectural outputs. These include both quantitative outputs (e.g., dashboards, analytical overlays) and qualitative visuals (e.g., architectural renderings, construction photographs, or exploded diagrams) that express environmental intent.

Main Characteristics of Visuals Across Both Domains

Substantial differences were observed between the two project groups in how environmental performance was visually represented in architectural documentation.

Certified Projects (Group B)

Certified projects generally externalized environmental content into consultant-authored documents such as LCA reports and compliance dashboards. These sources presented numerical data on embodied carbon or energy use but were rarely integrated into architectural drawings or BIM models. Automated BIM–LCA integration was absent, as external resources were required to manage this linkage. Consequently, design deliverables lacked embedded visual strategies for communicating environmental performance. While well adapted to internal workflows, these processes resulted in a disconnect between environmental objectives and architectural representation.

Dissemination Projects (Group A)

Dissemination-oriented projects displayed a diverse and visually expressive approach. These included axonometric assemblies, lifecycle overlays, and conceptual renderings emphasizing low-embodied carbon construction or circular material strategies. However, such visuals were typically developed for external communication—through exhibitions, publications, or award submissions—rather than as tools for guiding design decisions. Most were produced post-construction and were not integrated into the project's technical or regulatory workflows. Still, these projects demonstrated broader visual vocabulary for conveying environmental intent, especially in public-facing formats.

Cross-Group Comparison

Only a narrow range of visual strategies—such as construction details and distribution

plans—appeared in both project groups. These were usually part of the standard documentation package and conveyed environmental performance only indirectly, by requiring interpretation of implied sustainable characteristics. No project in the dataset demonstrated consistent or comprehensive visual engagement across all identified strategies. This discontinuity reflects a systemic gap between environmental objectives and their graphic articulation in architectural practice.

Empirical Overview of Representational Strategies

The analysis identified ten distinct strategies through which environmental performance is represented in architectural visuals (Table 2). These strategies range from absent performance expression to highly narrative or data-integrated graphics. While the taxonomy is formally introduced in the following section, the descriptive inventory provided here lays the groundwork for understanding the visual logic each strategy entails. Fig. 2–4 offer representative visual examples drawn from the project dataset. Rather than simply illustrating the presence of environmental content, these visuals make visible how different projects communicate sustainability through format, style, and positioning within design workflows.

Strategy		Description
1	Visual Representational Absence	Environmental data was recorded exclusively in LCA reports or spreadsheets, with no appearance in architectural models or graphics. This strategy reflects a complete disconnection between environmental reasoning and visual communication. See Fig. 2 a-c.
2	Meta-Absence in Technical Drawings	Environmental performance was latent in technical drawings—visible only through construction logic (e.g., use of timber or insulation), without explicit annotation or graphical cues. This passive embedding relies on interpretive reading rather than communicational intent.
3	Certification Dashboards	Compliance visuals were produced via third-party tools or consultants to meet rating system criteria (e.g., LEVEL(s), BREEAM, or LEED). These dashboards appeared in reports without being integrated with design drawings or spatial representations. See Fig. 2 d-f.
4	Passive Design Visualization	Sections, plans, or climate diagrams were used to depict passive strategies like ventilation, solar control, or daylighting. These visuals were design-integrated and spatially defined, offering inferred environmental logic rather than numeric validation.
5	Material Mapping	Environmental attributes (e.g., embodied carbon, recyclability, materials origin) were annotated within axonometries or exploded diagrams. These representations linked material selection with sustainability goals in a visually accessible way.
6	Spatial/Formal Environmental Logic	Environmental strategies were conveyed through formal spatial arrangements—such as compact massing, orientation, or zoning. While typically unannotated, these configurations suggested environmental reasoning embedded in form.
7	Construction Logic Visualization	Exploded diagrams or BIM-derived views illustrated low-carbon construction systems, such as modular timber assemblies. These visuals made material systems explicit, often showing how the choice of construction systems contributes to performance, even without numerical backing. See Fig. 3.
8	Early Design Representation	Concept-phase sketches and renderings were used to signal ecological intent—often showing modularity, light-frame construction, or passive design strategies. Though symbolic, these visuals framed the project's sustainability narrative early on. See Fig. 4 a-c.

Table 2

Sustainability representational strategies identified in the dataset

Strategy		Description
9	Construction Process Narratives	Photos or sequential visuals documented construction as an environmentally responsible process. Strategies included manual building methods, prefabricated construction, and low-emission techniques, positioning the act of building as a sustainable practice.
10	Post-Construction Dissemination	Completed projects were portrayed through curated imagery (photos, posters, infographics) emphasizing their environmental success. These visuals targeted public audiences and contributed to the project's identity. See Fig. 4 d-f.

This overview not only catalogues existing visual types but reveals the structural roles they serve. Some strategies function to certify (1–3), others are explanative (4–7), and others narrate (8–10). Their positioning along the project timeline—from early design to post-completion—mirrors their epistemic weight. For instance, Strategy 8 (Early Design Representation) belongs entirely to the early stages but is rarely supported by quantifiable data. In contrast, Strategy 2 (Meta-Absence in Technical Drawings) appears during execution phases but lacks communicative context. This suggests that even within exemplary sustainable projects, visuals tend to cluster around isolated functions rather than forming coherent visual reasoning.

Fig. 2-4 illustrates how select projects implement these strategies. These figures reveal not only variation in technique, but also in audience, intention, and design phase—reinforcing the representational fragmentation identified in this study. They reflect a shift from quantitative to qualitative representation, underscoring the multi-faceted nature of architectural projects.

Fig. 2

- (a) SWOT matrix extracted from the LEVEL(s) compliance report.
- (b) Global Warming Potential (GWP) breakdown by building components from the LCA report.
- (c) Screenshot of material impact assessment using the One Click LCA platform.
- (d) Visualization of embodied carbon across building lifecycle stages.
- (e) Comparative impact assessment of building materials.
- (f) Breakdown of material reuse versus new materials in Upcycle Studios, across internal structures, concrete, and cost distributions.



Sources: (a–c) Obtained from Case Study CS3. Spanish professional practice dataset. (d) Adapted from IVL Swedish Environmental Research Institute (2018), Building LCA – Structural Frame, Report B2354, p. 26. (e–f) Adapted from NREP (2020), Upcycle Studios: LCA/LCC Report. Used under academic fair use for educational, non-commercial purposes.

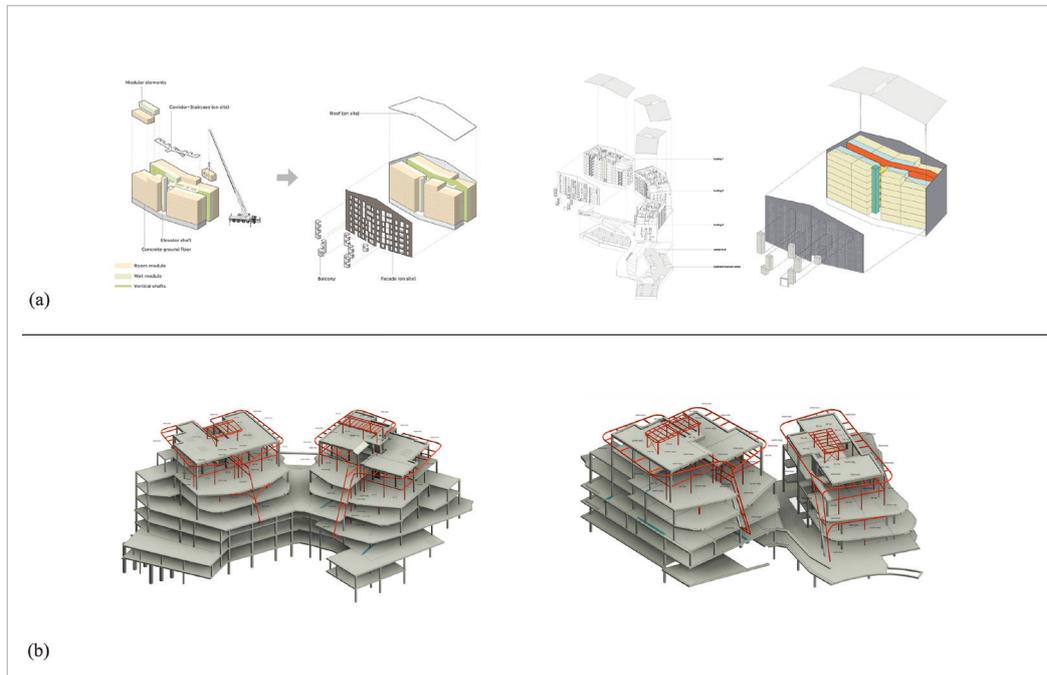


Fig. 3

Construction logic visualization.
 (a) Axonometric diagrams of the Puukuokka Housing Block illustrating modular construction logic and prefabricated timber structure.
 (b) BIM-derived axonometric view of the building's construction.

Sources: (a) Adapted from OPEAA, Puukuokka Housing Block, ArchDaily (<https://www.archdaily.com/614915/puukuokka-housing-block-oopeaa>). Used under academic fair use for educational, non-commercial purposes. (b) Case Study CS3. Spanish professional practice dataset.

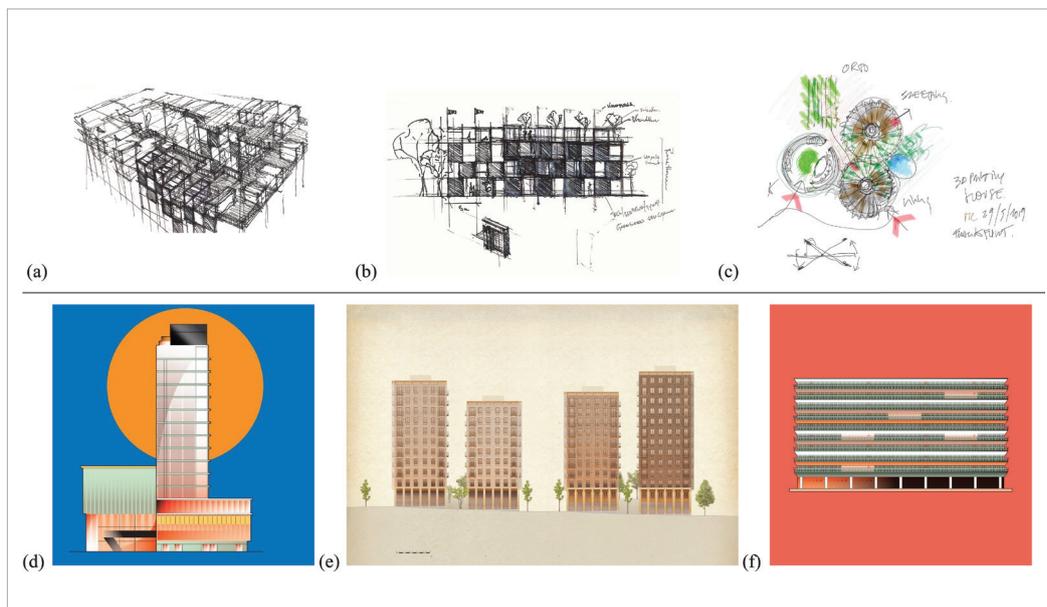


Fig. 4

Early design representation.
 (a) Conceptual axonometric diagram of the Resource Rows block.
 (b) Early design sketches illustrating facade modulation and rooftop vegetation for Resource Rows, Copenhagen.
 (c) Conceptual sketch of a circular earthen house layout developed for 3D printing.
 (d) Stylized elevation of the Sara Kulturhus Center in Skellefteå, Sweden, designed by White Arkitekter.
 (e) Elevation rendering of the Cederhusen housing complex in Stockholm, Sweden.
 (f) Stylized elevation of "530 Dwellings," Bordeaux, by Lacaton & Vassal, visualized by Jack Bedford as part of the Dezeen 25 series.

Sources: (a-b) Adapted from Detail Magazine, Brick Patchwork for the Climate's Sake – Resource Rows in Copenhagen. (c) Adapted from ArchDaily, Casas Circulares de Tierra Cruda: Estructura y Revestimiento en 200 Horas de Impresión 3D (<https://www.archdaily.cl/cl/955440/casas-circulares-de-tierra-cruda-estructura-y-revestimiento-en-200-horas-de-impresion-3d>). (d) Adapted from Dezeen (2025), Sara Kulturhus by White Arkitekter. (e) Adapted from Folkhem (2023), Cederhusen. (f) Adapted from Jack Bedford Portfolio (2020), based on Lacaton & Vassal's project published by Dezeen (2025). Used under academic fair use for educational, non-commercial purposes.

Taxonomy of Environmental Performance Representation Strategies

The study identified ten distinct representation strategies, structured into a taxonomy organized around three overarching categories: Compliance-Driven, Direct Performance Visualization, and Narrative Visualization. This structure reflects a continuum of integration between environmental reasoning and visual representation—ranging from visuals produced for certification and regulation, to those that embed performance logic directly into spatial or material thinking, and finally to visuals that communicate sustainability to broader publics.

The distribution of these strategies across Group A (dissemination projects) and Group B (certified practice) is presented in Table 2. While the taxonomy is qualitative, the comparative mapping illustrates where and how each strategy materializes in real projects. Projects may include multiple strategies and visualization types.

This taxonomy reveals not only the variety of representational strategies, but also systemic patterns in how environmental content is treated across architectural practice. Notably, direct performance visualizations, such as building sections and axonometries, connected the other two groups by addressing environmental impact both quantitatively and qualitatively. These visuals appear embedded within the project's spatial reasoning, indicating their potential as bridges between performance data and design logic.

In contrast, compliance-driven visuals dominate in certified projects (Group B), often isolated within technical reports or regulatory forms. These visuals serve accountability functions but remain peripheral to architectural communication. Meanwhile, narrative visualizations are prevalent in dissemination projects (Group A), where they serve storytelling and public engagement functions but are typically produced post-construction and detached from early decision-making.

This taxonomy reveals that visual representation of environmental performance reflects deeper project cultures, institutional priorities, and epistemic regimes. It is not simply a matter of format, but of operational reasoning. As architectural workflows evolve, the most productive trajectory may be a movement from fragmented, compliance-oriented visuals toward integrated visual intelligence—where environmental metrics and spatial logic are co-developed to support informed design decision-making.

Discussion

This section synthesizes the findings, relates them to existing literature, and outlines implications for architectural practice, digital workflows, and environmental communication. The results confirm a widespread disjunction between architectural representation and environmental impact metrics, revealing how visual strategies in practice often fail to support environmental reasoning across project phases.

From Compliance to Communicative Representation

GBRSs such as BREEAM and LEED have operationalized sustainability into quantifiable metrics. However, these are largely communicated through text-based documentation, disconnected from the spatial and visual tools architects rely on. While LCA tools support precision in assessment, their outputs often remain isolated from drawings or models central to design communication (Hollberg et al., 2021; Meex et al., 2018).

The LEVEL(s) framework introduces lifecycle thinking and encourages integration within design documentation (Dodd et al., 2020). However, as findings from Group B show, this potential is not yet realized in visual terms. Environmental content often remains in consultant-generated reports rather than embedded within architectural visuals. Institutional workflows and lack of policy mandates for visual integration continue to marginalize sustainability in representational practice.

This gap also holds implications for architectural education, where representation remains

Epistemic stage	Strategy	Visualization types	Group A	Group B
Compliance-driven	Certification-oriented	Reports	A02	B01, B02, B03, B04, B05
	Meta-Absence	Construction details	A04, A10, A11, A12, A14, A20, A22, A26, A29, A31	B02
	Dissemination-oriented	Report-derived charts	A01, A03, A21, A27, A28	—
Direct performance visualization	Passive Design Visualization	Building sections	A01, A31, A37	B03
		Axonometries	A01, A07, A13, A20, A27	—
	Material Mapping	Axonometries	A04, A16, A30	—
	Spatial Configuration and Volumetric Formulation	Plans	A02, A08, A10, A12, A17, A22, A23, A24, A25, A26, A28, A29, A31, A32, A33, A34, A35, A36, A37	B01, B03, B04, B05
		Axonometries	A04, A08, A09, A15, A20, A26, A27, A32, A33	B04
		Exploded axonometries	A08, A09, A11, A22, A23, A32	—
	Construction System Presentation	3D models-derived	A05, A06, A07, A10, A11, A13, A15, A16, A22, A32, A37	B03
		Sections	A07, A08, A10, A11, A12, A22, A23, A24, A25, A26, A29, A31, A34, A36, A37	B03
		Construction detail-derived schemes	A05, A09, A10, A14, A29, A32, A37	—
Narrative visualization	Early Design Communication	Sketches	A04, A05, A06, A10, A11, A15, A17, A20	B02
		Visualizations	A01, A06, A07, A11, A13, A17, A18, A20, A24, A32, A36	B02, B03
	Construction Process Narratives	Construction site photographs	A02, A09, A10, A11, A12, A14, A15, A17, A22, A25, A27, A28, A29, A30, A31	B05
	Post-construction Visual Narratives	Photographs	A01, A02, A03, A04, A05, A08, A09, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37	B02, B05
		Posters	A07, A22, A25	—
		Narrative post-production schemes	A03, A04, A05, A06, A09, A11, A15, A18, A21, A25	—

Table 3

Distribution of Sustainability Representation Strategies across Project Groups

centered on formal exploration, and environmental impact assessment remains a peripheral concern. Embedding environmental reasoning into visual training could better align future practice with evolving performance mandates.

BIM's Inherent Visual Capacity

BIM offers a platform for embedding environmental metrics into project workflows, yet its representational potential remains underdeveloped. In Group B, BIM was primarily used for coordination, with environmental metrics externalized through separate LCA platforms. This mirrors findings from Tavares et al. (2023), who note that while BIM supports environmental data management, it lacks influence on the visual articulation of design.

BIM's promise lies in its ability to host environmental metadata and generate design-informed visualizations, but this capacity is curtailed by software silos and limited designer agency over LCA outputs. Bridging this gap requires workflow changes and policy incentives that recognize environmental representation as integral to design, not an ancillary task managed by consultants. This underutilization underscores the broader need for workflow transformation. Design teams must be trained in the epistemic affordances of digital tools—how they can support integrative reasoning about performance, materiality, and form.

Dissemination Projects: Aesthetic Depth, Operational Disconnection

Group A illustrated a contrasting visual culture: public-facing dissemination projects often employ sophisticated sustainability imagery—exploded axonometries, lifecycle diagrams, and annotated renderings. However, these visuals are typically produced post-construction and serve rhetorical rather than design functions. They communicate environmental ambition but rarely inform spatial or material decision-making.

This phenomenon raises critical concerns. Although graphically rich, dissemination visuals often decouple sustainability from operational design processes and contribute to an image-centric discourse that prioritizes appearance over performance. This aligns with critiques in the literature regarding the symbolic aestheticization of sustainability (Cucuzzella, 2015). As a result, such practices deepen concerns about greenwashing, as they fail to establish a clear connection between quantitative metrics and qualitative design expression (Delmas & Burbano, 2011).

Yet the representational techniques used in these dissemination projects—despite their post-hoc nature—hold a generative value. Strategies such as lifecycle overlays, exploded diagrams, or annotated sequences possess the capacity to structure design thinking around environmental logics if repositioned earlier in the workflow. Rather than functioning solely as explanatory visuals for public audiences, these formats could serve as decision-making tools that guide spatial organization, assembly logic, and material selection. Reintegrating such strategies into the early design phase would require a shift in representational culture: from illustrating sustainability after the fact to operationalizing it as a central architectural concern.

Toward Integrated Visual Intelligence

The fragmentation of sustainability representation across architectural outputs reflects the absence of a unified visual protocol. The ten strategies identified in this study stem from distinct workflows and communicative purposes. However, rather than existing in isolation, their coexistence reveals an untapped potential for integration.

Current practice struggles to communicate environmental performance both rigorously and intuitively. Environmental data is frequently relegated to technical documentation, seldom entering the spatial or graphic discourse of design. Conversely, visually compelling renderings or diagrams may gesture toward ecological intent without offering verifiable data. This polarization weakens

the epistemic role of visuals and undermines their contribution to performance-driven design cultures.

To support a shift toward integrated visual cultures, institutions must revise documentation protocols, encourage BIM–LCA integration with design-oriented outputs, and support training in sustainability representation. Rather than remaining isolated in compliance reports, sustainability logic must become intrinsic to the visual modes through which architecture is conceived and communicated.

This answers RQ3, underscoring the need for a more integrated visual culture—where visuals mediate between quantitative assessment and spatial thinking. Sustainability visuals must be reimagined as active design tools—shaping, not just reflecting, decision-making. For example, passive design strategies were clearly articulated in sections, material sourcing in exploded views, and lifecycle performance in BIM-linked overlays. Recent studies propose BIM-based color coding (Hollberg et al., 2021) to visually embed lifecycle data into project development—offering a bridge between technical assessments and design representation.

Architecture curricula should adopt sustainability visuals not only as post-design documentation but as formative tools within studio culture. Exercises might include drawing-based LCA mappings, lifecycle phase overlays using BIM software, or iterative massing studies linked to carbon benchmarks. These would help embed ecological reasoning into spatial decision-making from the outset. Architects and consultants should likewise develop hybrid representational formats that serve both certification and conceptual exploration—such as BIM-integrated dashboards, plan-based impact visualizations, or carbon-coded material libraries. Without systemic changes in how environmental impact is taught, visualized, and operationalized, performance metrics will remain ancillary to architectural practice.

The taxonomy developed here can also guide design teams in applying appropriate visual strategies throughout a project's lifecycle. For instance, Passive Design Visualization or Material Mapping strategies may support early-stage orientation and form-finding, while Construction Logic or Certification Dashboards can structure technical coordination and reporting. Narrative Visualization formats may help communicate ecological goals to broader audiences. Rather than offering a prescriptive model, the taxonomy enables teams to identify representational gaps and select contextually relevant tools—whether analytical, technical, or communicative.

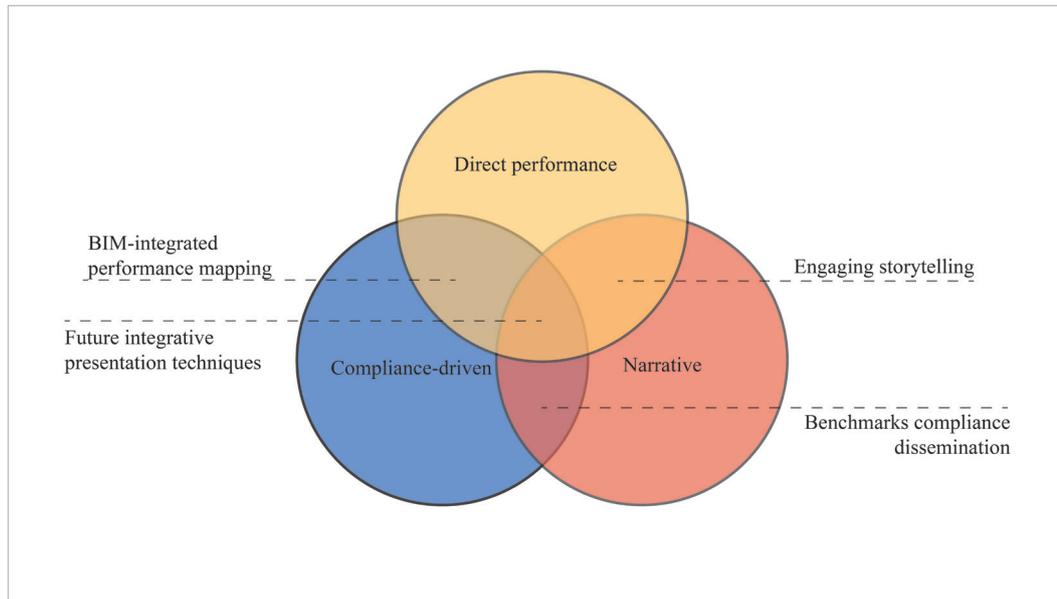
This conceptual shift is illustrated in Fig. 5, which synthesizes the taxonomy into a schematic representation. Each circle represents one of the core registers: Compliance-Driven, Direct Performance Visualization, and Narrative Visualization. Their overlaps signal emerging areas of integration—where visual tools such as BIM or dissemination visuals can articulate environmental logic across domains. These intersections, while currently underdeveloped, suggest concrete opportunities for future representational convergence.

Representational convergence does not imply homogenization but the ability to operate across multiple registers of architectural communication. The future of environmental visual intelligence lies in hybridized methods—where compliance tools become spatially expressive, narratives are grounded in metrics, and performance data shapes the visual language of design.

The integration of these visual strategies into early-stage design has implications beyond representation. When lifecycle diagrams shape massing decisions, or when BIM-linked overlays expose the carbon consequences of different assemblies, environmental reasoning becomes embedded in spatial logic. These formats offer designers a feedback mechanism that is both intuitive and performative. By translating performance data into graphic form, architects can test material systems, iterate construction sequences, and communicate ecological priorities more coherently. Ultimately, sustainability representation must evolve from an explanatory layer to an operational medium—bridging conceptual exploration with measurable outcomes.

Fig. 5

Schematic synthesis of sustainability visualization strategies across three domains and emerging integrative approaches. Source: Authors.



Researcher Positionality and Limitations

This study reflects a hybrid research stance: authors collaborated with professional practice (Group B) and analyzed publicly disseminated projects (Group A). This duality enabled cross-contextual insight but introduced epistemic asymmetries. Visuals from Group A were curated and often polished for publication, while Group B offered access to technical processes within an industry setting.

This study is not without limitations. The sample is not exhaustive. Group A focused on high-profile dissemination projects, which may overrepresent representational richness. Group B, sourced from a single office, reflects specific institutional workflows. Additionally, the study lacks user reception data—future research could include stakeholder interviews and cognitive studies on how sustainability visuals shape understanding and decision-making.

All participants involved in this research were informed of its objectives and provided written consent for the use of anonymized project materials.

Conclusions

This study examined how environmental sustainability is visually represented in contemporary architectural practice. By analyzing 42 projects across certified professional documentation and curated dissemination platforms, it identified a critical gap between the representational logic of sustainability assessment tools and architectural outputs. While visual representation remains a core instrument of architectural reasoning, sustainability metrics are often externalized into textual or numerical materials and are rarely integrated into drawings, schemes, or BIM-native visuals. The research developed a taxonomy of sustainability representation strategies—compliance-driven, direct performance visualization, and narrative-based—which exposes the fragmented nature of current practices. Certified projects tend to prioritize documentation for compliance, while dissemination-focused cases excel in storytelling, yet both approaches generally lack integration across the design process. In neither case do sustainability visuals consistently function as decision-making tools.

This study reframes sustainability communication not only as a matter of performance validation, but as a representational and epistemic challenge. For sustainable design to move beyond parallel verification processes, architects, educators, and policymakers must embrace visual representation as a central instrument of environmental reasoning—operational from concept to completion.

These insights have practical implications for both studio teaching and architectural workflows, as discussed above. Particularly, tools such as BIM and frameworks like LEVEL(s) offer promising avenues for embedding environmental intelligence directly into visual outputs. However, their representational potential remains underutilized. Greater alignment between certification protocols, representational practices, and design workflows could support more transparent, iterative, and communicative sustainability integration. Only through such cross-disciplinary realignment can sustainability become a visually operative agent in shaping architecture's future.

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We thank the collaborating architectural practice for providing access to technical documentation used in the case study analysis. All third-party visuals were selected for scholarly use and are reproduced under academic fair use for non-commercial purposes. Every effort has been made to ensure appropriate citation and non-commercial application in accordance with applicable intellectual property standards.

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