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Towards Climate-Just and Sustainable Schools: Developing the Level(s)+37 Passive Design Framework

Carmen Díaz-López [1,*], Antonio Serrano-Jimenez [2], Konstantin Verichev [3] and Ángela Barrios-Padura [1]

[1] Department of Building Construction I, School of Architecture, University of Seville, 41012 Seville, Spain; abarrios@us.es
[2] Department of Building Construction, School of Architecture, University of Granada, 18071 Granada, Spain; serranojimenez@ugr.es
[3] Institute of Civil Works, Austral University of Chile, Valdivia 5091000, Chile; konstantin.verichev@uach.cl
* Correspondence: cdiazl@us.es

Featured Application

The proposed Level(s)+37 Passive Design Framework can be directly applied to the renovation and design of educational buildings, helping architects, engineers, and policymakers to reduce embodied and operational carbon, enhance resilience against climate change, and ensure healthier indoor environments for students and teachers. Its application supports decision-making processes in line with EU directives on building performance and the New European Bauhaus principles.

Abstract

This study presents the Level(s)+37 Framework, a decision-support tool consisting of 37 indicators designed to evaluate and enhance passive design performance, social equity, and climate resilience in primary and secondary schools. Aligned with the six macro-objectives of the European Level(s) scheme, the indicators are organised into seven thematic clusters—thermal comfort, indoor air quality, solar control and daylighting, environmental ergonomics, ecological sustainability and circular economy, climate justice and social equity, and educational value with stakeholder participation—covering all life-cycle stages from design to retrofit. The framework was developed through a six-phase mixed-methods protocol, including a systematic review of 210 scientific and regulatory sources, 24 semi-structured interviews with school stakeholders, and a Delphi–AHP involving 170 experts. The resulting hierarchy of indicators (CI < 0.10; Kendall's W = 0.78) ensures methodological robustness and contextual relevance for the Spanish school building stock. By integrating environmental, technical, and pedagogical dimensions, the Level(s)+37 Framework serves as both an evaluation tool and a catalyst for sustainable transformation, promoting participatory governance and climate-responsive learning environments.

Keywords: passive design; climate justice; school retrofitting; level(s) framework; sustainability indicators; educational environments

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1. Introduction

Environmental comfort is fundamental to people's well-being and integral to development, especially in the educational context, where thermal, lighting, acoustic, and air quality conditions directly impact health, academic performance, and student learning quality [1]. Traditionally, architecture has used passive strategies adapted to local climatic characteristics to optimise these conditions; however, the current prevalence of active air-conditioning systems has led to a considerable increase in energy consumption, the loss of contextual architectural diversity and a growing environmental impact [2].

At the European level, buildings account for approximately 40% of total energy consumption and contribute 36% of greenhouse gas emissions, while 75% of the building stock has significant energy inefficiencies [3]. In the Spanish context, school buildings' energy and environmental problems are particularly critical [4]. More than 80% of schools were built before the Technical Building Code (CTE) came into force in 2006, so most were designed without current regulatory criteria for energy efficiency, thermal insulation or adequate ventilation [5]. This regulatory obsolescence means that approximately 90% of school buildings urgently need refurbishment to bring them up to contemporary standards of sustainability and indoor comfort [6]. It is a task that requires the collaboration of all stakeholders.

In addition to these structural deficiencies, schools are highly vulnerable to climate change, especially rising temperature extremes and heat waves. Recent reports highlight that more than 60% of schools regularly exceed 27 °C during the spring and summer months, a situation that significantly hampers the concentration, academic performance, and well-being of students and teachers [7,8]. This critical situation is intensified in spaces with high occupancy density, lack of external shading, poor thermal inertia and low cross-ventilation capacity. The thermal deterioration of classrooms not only compromises the quality of learning but can also have implications for children's health, especially in contexts of energy poverty or social vulnerability. It can lead to scenarios of climate injustice, such as students falling ill due to extreme temperatures or being unable to concentrate in class, requiring urgent attention in school infrastructure design and management [9,10].

The European and national regulatory framework supports transforming the built environment through energy efficiency, sustainability, and climate justice. In this context, school buildings' energy retrofit is strategically important, as it combines technical and social objectives: reducing energy demand, improving thermal comfort, promoting territorial equity, and fostering environmental education [11].

Directive (EU) 2018/844 introduces the "energy efficiency first" principle, prioritising passive design strategies—such as insulation, natural ventilation, and solar control—especially in public buildings [12]. Spain's Long-Term Strategy for Energy Rehabilitation (ERESEE 2020) translates this approach into a comprehensive vision incorporating social sustainability, circular economy principles, and climate resilience, focusing on vulnerable educational environments [13]. The Spanish Technical Building Code [14] and the National Energy and Climate Plan (PNIEC 2021–2030) [15] further support this framework by setting performance requirements and identifying schools as key infrastructures for sustainable renovation.

Additionally, the EU Taxonomy (Regulation 2020/852 [16]) and the "do no significant harm" (DNSH) principle require interventions that go beyond energy performance to include waste reduction, sustainable materials, and climate adaptation. In this light, school retrofits also become tools for active environmental education, engaging the school community and fostering ecological awareness from an early age [17].

The Level(s) framework, developed by the European Commission, provides a standard set of indicators to assess the sustainability of buildings across their life cycle. Its application in school environments enables monitoring energy performance, indoor environmental quality, circular use of resources, and user well-being—aligning technical goals with educational and social values [18–20].

Thus, sustainable school refurbishment emerges as a physical intervention and a multidimensional strategy integrating energy efficiency, climate justice, and civic education. It is a collective effort, and your role as educators, policymakers, and sustainability advocates is crucial for this just and inclusive ecological transition [21].

Within this holistic framework, it is proposed to conceptualise the school as a climate shelter: a safe and comfortable space that protects its community from adverse environmental conditions, such as heat waves, air pollution and increasingly frequent extreme weather events [22]. This vision expands the traditional role of the school building, elevating it to a strategic asset for community health, safety and learning, contributing to climate justice and social equity [23]. It also envisions the school as a protective environment and an urban and pedagogical landmark: a model of sustainable infrastructure that inspires and guides similar transformations in other municipal facilities and, simultaneously, an exemplary educational space that fosters environmental awareness inside and outside the classroom [23].

Several studies show that applying passive strategies in schools can reduce energy consumption by 30–60% while improving thermal comfort by more than 70% [4,24–26]. As educators, school administrators, and policymakers, your role is crucial in implementing these strategies. Research in different climates in Spain (Andalusia, Castilla-La Mancha, Valencia) shows that bioclimatic design can reduce indoor temperatures by up to 5 °C without mechanical air conditioning [27–29]. According to the International Energy Agency, comprehensive interventions—improvements in the thermal envelope, ventilation, lighting and use of renewables—can reduce heating demand by 55–75% and electricity demand by 30–40%. Notable examples include the Egebjerg school (Denmark) and the ZEB school (Norway), the latter with a positive energy balance thanks to Passivhaus standards. In Spain, the El Garrofer school (Viladecans), refurbished under the EnerPHit standard, has reduced its heating demand by 90% and achieved high thermal comfort and air quality levels. Cases in Europe and countries such as India, Ghana, and Mexico show that passive strategies adapted to the context can significantly reduce thermal discomfort, with indoor temperature decreasing between 2 °C and 6 °C.

Recent national and international studies show an increasing convergence between academic research, public policies and architectural practice, which underlines the need for a standard set of indicators adapted to the Spanish context. In this scenario, the present work proposes to adapt the European Level(s) framework to primary and secondary schools in Spain so that it becomes an effective tool to assess, design and rehabilitate school buildings as sustainable, resilient and inclusive climate shelters, in line with the Sustainable Development Goals, the European Green Pact and the New European Bauhaus.

The research aims to elaborate on a methodology that calibrates the Level(s) system to the unique characteristics of Spanish school buildings, such as their architectural design, climatic conditions, and regulatory framework. This adaptation will facilitate their transition towards healthier and lower environmental impact environments. To this end, indicators focused on environmental comfort, energy efficiency, circular economy and climate justice will be identified, systematised and applied, integrating passive design strategies and retrofitting guidelines in line with the climatic, social and regulatory conditions of the education sector in Spain.

It is also expected that the schools will improve their environmental performance and become pedagogical and urban references, reinforcing environmental education, territorial equity, and climate resilience in their communities. As active nodes of transformation, each school can extend its influence beyond its grounds, fostering a culture of sustainability and inspiring other public facilities and citizens in general.

Within this context, the originality of the present study lies in the development of the Level(s)+37 Passive Design Framework, an expanded and locally calibrated version of the European Level(s) scheme. This framework introduces 37 new indicators specifically designed for Spanish primary and secondary schools, addressing the unique climatic, architectural, and regulatory characteristics of the national educational building stock. Unlike existing tools such as Level(s), BREEAM-Education or DGNB, which primarily focus on environmental and energy performance, the proposed framework integrates passive design principles with climate justice, social equity, and educational value, offering a holistic approach that connects technical efficiency with social inclusion and pedagogical transformation. The main research gap this work addresses is the absence of a context-sensitive, comprehensive evaluation tool capable of assessing school buildings not only in terms of sustainability and comfort but also through their contribution to equity, resilience, and environmental awareness. By filling this gap, the Level(s)+37 framework contributes to the scientific and practical advancement of sustainable school refurbishment as a cornerstone of the ecological and social transition in Southern Europe.

State of the Art

Over the past two decades, transforming school buildings into low-energy, high-quality learning environments has moved from the margins of building science to the centre of international research and policy-making. A milestone in this trajectory is the meta-analysis published by the IEA/OECD in 2005, which synthesised twenty-five deep-renovation projects (eighteen of them schools) carried out in Europe and the United States [30]. By comparing monitored data before and after intervention, the study showed that comprehensive packages—continuous insulation, airtight triple glazing, demand-controlled ventilation, high-efficiency lighting and on-site renewables—can reduce space-heating demand by 55–75% and electricity use by 30–40%, cutting the specific heat load from 200 to 280 kWh m^{-2} yr^{-1} to 50–90 kWh m^{-2} yr^{-1}. These findings established an empirical baseline that has since informed national roadmaps and European funding lines [31].

Subsequent demonstration projects across Northern Europe have confirmed—and in some cases surpassed—the IEA/OECD figures. In Denmark, the retrofit of the Egebjerg School combined external mineral-wool insulation, triple-low-e glazing, solar chimneys and a hybrid ventilation system. Post-occupancy monitoring revealed a 52% reduction in heating demand and statistically significant improvements in perceived indoor air quality and daylight [32]. A more recent example is the Oslo ZEB School, Norway's first energy-positive public school. Designed to Passivhaus and BREEAM-Excellent standards, the building integrates 338 kWp of photovoltaics, laminated-timber structure and an AI-driven building-management system (BMS), achieving a measured surplus of +34 kWh m^{-2} yr^{-1} while maintaining the Passivhaus comfort envelope [33,34]. Across the Atlantic, U.S. districts have begun to replicate the Scandinavian model: Discovery Elementary in Arlington, Virginia, combines geothermal heat pumps, 1700 solar panels and a real-time "energy dashboard" used in STEM classes, saving an estimated USD 117,000 per year on utilities [35]. Similarly, the Watertown Net-Zero Schools programme in Massachusetts is on track to deliver an energy-use intensity (EUI) below 25 kBtu ft^{-2} yr^{-1}—about 70% lower than the ASHRAE 90.1-2016 baseline—through a mix of ground-source and zoned air-source heat pumps topped with rooftop PV [36]. These cases demonstrate that near-zero or positive energy balances are technically and economically attainable even in heating-dominated climates when passive design, efficient services and renewables are integrated from the outset.

Spain faces a distinct set of challenges. A large share of its public schools was erected before the first national thermal code (NBE-CT 79) and therefore relied on thin masonry walls, single glazing and decentralised heating units. The NGO report Escuelas Renovadas surveyed 5300 classrooms nationwide and found that 85% of pupils rely on portable fans to cope with the heat. In contrast, 80% of teachers report indoor temperatures well above 27 °C during spring and autumn [37]. The EnerPHit refurbishment of CEIP El Garrofer in Viladecans illustrates the scale of the potential gains: a continuous EPS façade wrap, triple-panel windows, mechanical ventilation with 88% heat recovery, and a 60 kW photovoltaic canopy slashed gas consumption for heating by 90% and doubled the share of teaching hours with CO_2 below 1000 ppm—from 43% to 76%—although electricity rose by 28% due to the MVHR fans [38]. National grant schemes such as PREE 5000 and EU Next-Generation funds currently subsidise up to 50% of the investment costs for similar retrofits, and preliminary assessments by the national energy agency (IDAE, 2023) suggest that a well-executed package can cut HVAC loads by 40–80% in most climate zones on the Iberian Peninsula [38]. This potential for significant energy savings should make the audience feel optimistic and motivated to explore sustainable building practices.

Where cooling rather than heating dominates, passive design has proven more cost-effective than mechanical air-conditioning. The CEELA Adaptive Comfort Guide—developed for Latin-American schools—outlines fifteen principles ranging from high-albedo ventilated roofs to movable exterior shading, cross-ventilation and landscape devices [39]. Pilot applications in Mexico, Peru and Brazil logged peak-temperature reductions of 2–10 °C and halved fan use during the hot season [40]. In West Africa, field measurements in Ghana revealed that installing an insulated false ceiling under corrugated metal roofs reduced overheating hours by nearly 50% [41,42]. Surendran et al. [43] simulated two envelope-retrofit packages for a typical Chennai school in South Asia. They found that adding 50 mm of polyurethane insulation plus spectrally selective glazing would lower indoor operative temperature by 3 °C and trim annual energy consumption by 13%—all without altering the existing HVAC plant. This emphasis on passive design in warm and humid climates should make the audience feel more informed and knowledgeable about sustainable building practices.

Recent scholarship supplements built-case evidence with data-driven decision tools that help school managers target the most cost-effective retrofit actions. Serrano-Jiménez et al. [44] developed a GIS-based multi-criteria model that fuses Landsat surface-temperature maps, airborne LiDAR canopy data and ground surveys to locate heat-stress "hot spots" and shade deficits in Spanish schoolyards, ranking remedial measures via an *Environmental Ergonomics Index*. Díaz-López et al. [45] produced a critical review of twenty passive-cooling tactics for Mediterranean schools, documenting operative-temperature reductions of up to 4 °C and 25% primary-energy savings when dynamic shading, vegetated roofs and night-flush ventilation are combined. Her earlier bibliometric mapping of 537 peer-reviewed articles catalogued twenty-four passive strategies deployed across forty-two countries but also flagged a lack of standardised performance metrics.

The evidence confirms that deep retrofits in heating-dominated climates typically deliver 55–90% heating-energy savings, while climate-responsive passive packages in warm regions yield 2–10 °C comfort gains without mechanical cooling [46]. Secondary benefits include improved IAQ, reduced absenteeism, and higher cognitive performance, strengthening the socio-economic case for intervention. However, the proliferation of bespoke assessment methods underscores the urgency of adopting a unified indicator framework. Adapting the European Level(s) scheme to the Spanish school stock would provide the standard metrics needed to compare, prioritise and monitor projects, thereby aligning public funding mechanisms with high-performance certification labels (Passivhaus, BREEAM, ZEB) and with the EU's climate-resilience agenda.

Building on this approach, the present study highlights the originality of the Level(s)+37 Passive Design Framework and defines the specific knowledge gap it addresses. Despite increasing convergence between research, policy, and architectural practice, there is still no integrated and context-sensitive framework capable of linking passive design strategies with climate justice, social equity, and educational value in school environments. Existing systems such as Level(s), BREEAM-Education, and DGNB primarily focus on environmental and energy performance, overlooking the social and pedagogical dimensions of sustainability. The Level(s)+37 Framework extends the European Level(s) system through 37 new context-specific indicators tailored to Spanish primary and secondary schools, responding to their distinct climatic, architectural, and regulatory conditions. By integrating passive design principles with educational and social values within a single evaluative structure, this framework provides a localised, holistic tool that bridges research and practice, connecting environmental performance with social inclusion, resilience, and educational transformation in school environments.

2. Theoretical Framework

This interdisciplinary study rests on three interrelated conceptual pillars—bioclimatic architecture, educational sustainability, and environmental assessment systems. It treats environmental education, circular economy, and climate justice as cross-cutting elements reinforcing the study's integrated outlook.

2.1. Bioclimatic Architecture and Passive Strategies

Bioclimatic architecture advocates designing and constructing buildings that respond harmoniously to local climatic conditions, optimising indoor comfort through natural means and minimising energy demand [44,45]. Core passive strategies include cross-ventilation for air renewal, architectural solar-control devices that prevent overheating, exploitation of thermal mass for temperature regulation, and daylighting to enhance visual comfort and reduce electrical consumption. A robust body of scientific literature confirms the effectiveness of these techniques in boosting energy efficiency and comfort without jeopardising habitability [4].

2.2. Educational Sustainability and Environmental Education

Sustainability in the educational realm extends beyond the mere functionality of school buildings, recognising the physical environment as an active pedagogical agent. Scholars are school spaces that constitute ethical and environmental learning arenas where values of responsibility and ecological stewardship are nurtured. Place-based education reinforces this stance by fostering direct interaction between the school community and its surroundings [47].

Environmental education thus becomes an indispensable transversal component, integrating sustainable spatial management into curricula and encouraging the active participation of students, teachers, and families in refurbishment and maintenance processes. Such integration cultivates ecological citizenship and aligns with the principles of the New European Bauhaus [48], which promotes sustainable, inclusive, and aesthetically enriching spaces.

2.3. Circular Economy and Climate Justice

In construction, the circular economy paradigm advances a regenerative model that maximises material reuse and recycling, curbs waste generation, and prolongs infrastructure lifespans. With its potential to significantly reduce environmental impact and maximise social and economic returns, this approach is especially pertinent to retrofitting educational facilities, instilling a sense of optimism in the audience about its impact [49].

Concurrently, climate justice demands that climate mitigation and adaptation policies incorporate equity criteria, ensuring that vulnerable communities—including those in under-resourced educational settings—benefit from substantial environmental quality and comfort improvements. Embedding this social perspective in the design and evaluation of school buildings is paramount for fostering healthy, resilient environments and narrowing inequality gaps.

2.4. The Level(s) Framework and Its Application to Schools

Level(s), a voluntary European Commission toolkit, provides a holistic reference for assessing building sustainability through six macro-objectives: resource, energy and water efficiency; indoor environmental quality; health and comfort; adaptation and resilience; and social and economic value. Although developed for buildings, its dedicated application to educational facilities remains emergent. However, its practicality and adaptability make it a confident choice for assessing school sustainability [18].

This research adapts Level(s) to establish a set of context-specific indicators for passive-strategy implementation in schools—indicators that remain scalable and relevant across all building-life-cycle stages. The adaptation is informed by practical experience gleaned from energy-retrofit programmes in Germany, Italy, and Spain, illustrating the efficacy of integrated approaches that couple technical and environmental criteria with pedagogical considerations to enhance energy performance, comfort, and educational function.

This study positions schools as pivotal in transitioning toward a more sustainable, equitable, and resilient society. It does so by weaving together physical refurbishment and pedagogical transformation and offering practical solutions for implementing sustainable practices in school design.

3. Materials and Methods

Phase 1. Conceptual Scope and Desk Review

The study commenced with a meticulous screening of 210 scientific papers, EU directives, and best-practice guides. This comprehensive scoping exercise meticulously mapped the six macro-objectives of Level(s) against the specific demands of school buildings, identified knowledge gaps, and generated an initial inventory of passive-design variables pertinent to primary and secondary education.

Phase 2. Context Analysis (Stakeholder Mapping and SWOT Matrix)

Twenty-four semi-structured interviews were conducted with head teachers, maintenance managers, and education authority officials. The resulting data fed a SWOT matrix that identified internal strengths and weaknesses and external opportunities and threats influencing the uptake of passive strategies. This contextual diagnosis established the critical factors to be tackled in later stages.

These three pillars are not conceived as isolated domains but as mutually reinforcing dimensions that interact throughout the framework's design and application. The environmental pillar focuses on passive design strategies, thermal comfort, indoor air quality, and circular resource use. The social pillar embeds climate justice, accessibility, and resilience, ensuring that energy and environmental improvements contribute to equity and inclusion. The educational pillar links these objectives to pedagogical and cultural practices, transforming the school into a living laboratory for sustainability and participatory governance. The interaction among these pillars generates a cross-cutting structure where environmental strategies support social inclusion and educational engagement, leading to long-term behavioural change. This triadic model ensures that each indicator simultaneously contributes to environmental performance, social justice, and educational value, reinforcing the holistic vision of the Level(s)+37 Framework.

Phase 3. Delphi Survey for Expert Consensus

Building on the SWOT findings, a two-round Delphi survey was conducted with the active participation of 170 specialists from technical, pedagogical, research, and administrative fields. Using Likert scales and open questions, this process fostered consensus (IQR $\leq$ 1) on benefits, barriers, and a comprehensive list of 40 potential indicators.

Semi-structured interviews. The interviews followed a semi-structured protocol designed to identify perceived barriers and opportunities for integrating passive design strategies in schools. The guiding questions focused on five dimensions: (1) environmental comfort and indoor air quality; (2) maintenance and energy management practices; (3) user behaviour and pedagogical dynamics; (4) institutional barriers and funding mechanisms; and (5) perceptions of climate resilience and equity. Each session lasted between 40 and 60 min and was recorded and transcribed for qualitative coding.

Delphi Survey. The selection of the 170 experts was based on four inclusion criteria: (1) professional experience ($\geq$10 years) in education, building design, or sustainability policy; (2) regional representation across Spain's five climatic zones (Mediterranean, continental, oceanic, semi-arid, and mountain); (3) disciplinary diversity (technical, pedagogical, research, and administrative); and (4) gender balance. The final panel included 35% technical professionals (architecture, engineering, energy retrofit), 28% educational specialists (teachers, principals), 25% academic researchers in sustainability and building performance, and 12% public administrators. Gender representation was 54% women and 46% men. This distribution ensured the integration of environmental, technical, social, and pedagogical perspectives, while mitigating geographic or disciplinary bias.

Phase 4. Prioritisation Via Analytic Hierarchy Process (AHP)

The candidate indicators and SWOT factors underwent pairwise comparisons using the Analytic Hierarchy Process (AHP), translating qualitative judgements into quantitative weights. Model reliability was confirmed (Consistency Index < 0.10; Kendall's W = 0.78), yielding a ranked hierarchy to guide the implementation strategy.

To ensure representativeness and methodological robustness, the Delphi–AHP engaged 170 experts from four complementary domains: technical professionals in architecture, engineering, and energy retrofit (35%); educational and pedagogical specialists, including school principals and teachers (28%); academic researchers in sustainability and building performance (25%); and policy representatives from public administrations (12%). Gender balance (54% women, 46% men) and regional diversity across Spain's five main climatic zones were guaranteed.

The AHP weighting process itself was performed by a subset of 48 experts drawn from this larger panel, selected to ensure both disciplinary diversity and technical expertise. The composition of this group reflected the same four domains, including 37% technical professionals, 27% educational specialists, 24% academic researchers, and 12% policy representatives. Participants were distributed across the five climatic regions to maintain geographical representativeness. Gender balance within this subset was 52% women and 48% men.

This cross-sectoral approach ensured that environmental, technical, social, and pedagogical perspectives were equally reflected in the pairwise comparisons. Statistical validation using Kendall's W coefficient (W = 0.71) confirmed a high level of inter-group consensus, while the resulting Consistency Ratio (CR = 0.08) verified methodological reliability. The subsequent Analytic Hierarchy Process refined the weighting of the 37 indicators through comparative analysis, resulting in a balanced, transparent, and replicable structure for the Level(s)+37 Framework.

Phase 5. Strategic Formulation with the TOWS-CAME Framework

AHP weights were embedded in a TOWS matrix and converted into CAME action lines: Correct shortcomings (e.g., lack of specific metrics), Address threats (climatic or regulatory risks), Maintain strengths (the building's pedagogical value) and Exploit opportunities (EU funding and New European Bauhaus programmes). Together, these guidelines form a roadmap for mainstreaming passive design in schools.

Phase 6. Detailed Design of the Indicator System

Expert consensus distilled a catalogue of 37 indicators, organised into seven thematic clusters: thermal comfort, indoor air quality, solar control and daylighting, environmental ergonomics, ecological sustainability and circular economy, climate justice and social equity, and educational value and participation. For each metric, the calculation formula, unit, life-cycle phase, related Level(s) macro-objective, SWOT/TOWS linkage, and associated passive strategy were precisely defined.

The selection and weighting of the 37 indicators were directly informed by the characteristics of the Spanish school building stock. More than 80% of schools were constructed before the 2006 Technical Building Code (CTE), which means they lack sufficient thermal insulation, solar protection, and ventilation systems. Therefore, indicators related to passive envelope performance, thermal inertia, and natural ventilation were prioritised. The climatic diversity of Spain—encompassing Mediterranean, continental, and oceanic zones—also required specific weighting criteria for context sensitivity. Additionally, regulatory obsolescence and social vulnerability led to reinforcing indicators on indoor air quality, user comfort, and adaptive reuse. Consequently, the seven thematic clusters were designed to balance environmental performance with social and educational value, ensuring coherence with the European Level(s) framework while reflecting Spain's specific climatic and regulatory realities.

To ensure consistency and reproducibility in the evaluation of qualitative indicators, two context-sensitive metrics—"Community climate resilience" and "Building as a teaching aid"—were further developed using a hybrid qualitative–quantitative methodology.

The "Community climate resilience" indicator assesses the capacity of the school and its surroundings to adapt to climatic extremes while strengthening social cohesion. It combines three sub-criteria:

Adaptive infrastructure: the presence of passive design elements contributing to resilience, such as shading devices, permeable surfaces, rainwater retention, and thermal inertia.

Institutional participation: the degree of involvement of the school community in local or regional climate adaptation plans, measured through documentary evidence and interviews with management staff.

Community engagement: participation in educational or civic initiatives addressing climate adaptation (e.g., heatwave protocols, biodiversity gardens, or community awareness campaigns).

Each sub-criterion is rated on a 0–3 ordinal scale, where 0 = absent, 1 = emerging, 2 = partially implemented, and 3 = consolidated, using verifiable sources such as municipal plans, school documentation, and stakeholder surveys.

The "Building as a teaching aid" indicator captures the pedagogical dimension of sustainability, evaluating how architectural and technical features of the school environment are integrated into teaching and learning activities. Three sub-criteria are defined:

Curricular integration: evidence of the use of building systems (e.g., photovoltaic panels, green roofs, ventilation) in science, technology, or environmental education modules.

Pedagogical innovation: the existence of structured projects or lesson plans where students interact with building data (energy metres, CO_2 sensors, daylight levels) to develop STEM or sustainability competencies.

Visibility and accessibility: the extent to which sustainable systems are made visible and interpretable to students and visitors through signage, dashboards, or guided tours.

Each sub-criterion follows the same 0–3 scale and is evaluated through curriculum audits, teacher questionnaires, and classroom observations.

These detailed evaluation protocols provide the level of standardisation and transparency required to avoid inconsistent results when applying the Level(s)+37 Framework. By integrating social, educational, and environmental dimensions within measurable criteria, these "soft metrics" reinforce the holistic, participatory nature of the assessment model and its applicability to diverse educational contexts.

Figure 1 presents a graphical summary of the six-phase methodology used to design, validate, and implement the Level(s)+37 Passive Design Framework. The process integrates quantitative and qualitative methods, combining Delphi surveys, AHP weighting, and pilot validation to ensure scientific rigour, stakeholder participation, and contextual adaptation.

Figure 1. Materials and methods.

4. Results

The findings are presented in five sections, mirroring the methodological path to create the indicator language grounded in passive-design strategies and the Level(s) framework.

4.1. Qualitative Survey Analysis

One hundred seventy specialists from the technical, educational, research, and administrative arenas completed the online questionnaire. The findings reveal a promising future for school building design, with respondents unanimously agreeing on the value of passive strategies. Specifically, 92% cited improved thermal comfort as a primary benefit, 85% highlighted lower energy consumption, and 78% emphasised the pedagogical value of passive design for environmental education.

Relevant barriers were also identified, underscoring the urgency of the situation: 67% indicated a lack of specialised technical training, 61% noted the absence of clear metrics to assess passive performance, and 53% mentioned regulatory or institutional constraints. The most frequent recommendations were developing dedicated evaluation tools and reinforcing technical–pedagogical training programmes, which are crucial for overcoming these barriers.

4.2. SWOT Matrix

Drawing on the documentary review and survey results, a SWOT matrix was compiled to isolate the key factors that condition the adoption of passive strategies in schools (Table 1).

Table 1. SWOT analysis of the key factors that condition the uptake of passive-design strategies in school buildings.

SWOT Dimension	Key Factors Influencing the Adoption of Passive-Design Strategies in Schools
Strengths	The Level(s) framework provides a recognised European reference that integrates technical, environmental and social criteria. Growing environmental awareness and explicit alignment with the SDGs and the European Climate Pact among school communities and facility managers. The school building can serve as a living laboratory for environmental education and climate awareness. EU funding streams—e.g., Next Generation EU and the New European Bauhaus—support sustainable renovation and circular-economy pilots. Readily available natural resources (daylight, prevailing winds, vegetation) and vernacular know-how can be harnessed as passive climate refuges.

Table 1. *Cont.*

SWOT Dimension	Key Factors Influencing the Adoption of Passive-Design Strategies in Schools
Weaknesses	Lack of specific indicators to monitor passive and circular performance in school buildings, limiting the impact of traceability. Insufficient professional training in circular economy, environmental ergonomics and bioclimatic design among teachers and technical staff. Ageing infrastructure that is difficult to retrofit to modern comfort and indoor-environment standards. Local regulations remain fragmented and are only partially aligned with Level(s) and New European Bauhaus principles. Cultural and technological dependence on energy-intensive active systems undermines resilience.
Opportunities	Direct correspondence with multiple SDGs (4, 7, 11, 12, 13) and EU climate policies creates a favourable policy window for sustainable school retrofits. European and national programmes offer financial and technical support for Level(s)-based pilot projects in passive design and circular economy. Place-based environmental education can turn the building into an active pedagogical resource, fostering student engagement and eco-citizenship. Digital monitoring technologies enhance participatory governance and real-time environmental management. Interdisciplinary alliances promoted by the New European Bauhaus encourage collaboration between technical, educational and social sectors.
Threats	Delayed climate adaptation and educational innovation if integrated, multi-disciplinary approaches are not adopted. Frequent shifts in educational or administrative policy jeopardise long-term funding and project continuity. Limited technical expertise in environmental ergonomics and climate-refuge design constrains intervention quality. Exposure to extreme weather events without clear maintenance and resilience protocols increases operational risk. Cultural and economic barriers—particularly in resource-constrained contexts—hinder the mainstreaming of circular and genuinely sustainable models.

4.3. AHP Prioritisation

To quantify the relative importance of the SWOT factors, the study applied the *Analytic Hierarchy Process* (AHP) After pair-wise comparisons completed by the expert panel, the priority vector was normalised and its consistency ratio (CR = 0.06) verified as acceptable (<0.10). The resulting weights are shown in Table 2.

Table 2. AHP priority weights for the leading SWOT factors.

AHP Category	Highest-Ranked Factor	Relative Weight (%)
Strengths	Educational value of the school building as a "living laboratory"	31
Weaknesses	Absence of specific metrics to monitor passive and circular performance	34
Opportunities	Availability of dedicated European funding streams (e.g., Next Generation EU, New European Bauhaus)	37
Threats	Technical-maintenance deficit that jeopardises long-term performance	33

The weights reveal two critical leverage points for scaling passive-design strategies, such as natural ventilation and daylighting:

Metric gap (34%)—As revealed by the weights, the absence of a transparent indicator set is a critical issue. It is challenging to demonstrate performance, secure investment, or embed passive methods in regulatory frameworks. This gap must be addressed as the first and most crucial corrective action, emphasising the gravity of the situation and the need for immediate action. European funding (37%)—The availability of external finance, particularly from European sources, presents a significant opportunity and immediate implementation catalyst. Aligning project proposals with Level(s) and New European Bauhaus criteria maximises eligibility for these resources, offering a hopeful and optimistic outlook for the future of passive-design strategies.

Conversely, the high score assigned to *maintenance deficit* (33%) reiterates the importance of preventive upkeep in maintaining the performance of well-designed passive solutions. This underscores the need for institutionalisation of maintenance practices. Finally, the substantial weight for the *building's educational value* (31%) underscores that passive retrofits are not just technical upgrades but also a powerful pedagogical asset for climate literacy and community engagement, inspiring and motivating us to consider the broader impact of our work.

4.4. TOWS-Based Strategic Planning

The TOWS cross-matrix distilled the internal–external diagnosis into four high-leverage strategic lines that guide the deployment of passive-design measures and Level(s) indicators in schools (Table 3).

Table 3. Strategic lines derived from the TOWS analysis.

CAME Strategy	Rationale	Proposed Actions
Correct Weaknesses (C)	Mitigate the lack of dedicated metrics and training gaps by embracing a holistic perspective—one that integrates circular economy, environmental ergonomics, and environmental education.	Develop and standardise a Level(s)-based indicator set tailored to schools, encompassing thermal comfort, circularity, pedagogical value, and climate-shelter criteria. Launch multidisciplinary training programmes for teachers, building managers, and technical staff on passive design, environmental ergonomics, and climate justice. Update local regulations to embed circular-economy principles, resilience requirements, and international benchmarks (SDGs, European Climate Pact).
Address Threats (A)	Minimise external risks to ensure the long-term viability, resilience, and social acceptance of passive-design approaches.	Establish standard protocols for predictive maintenance, climate-risk management, and adaptive operations. Run awareness campaigns to reduce dependence on energy-intensive active systems and to normalise passive-design culture. Promote stable policy frameworks and robust institutional governance that secure sustained financing and long-term monitoring.
Maintain Strengths (M)	Consolidate and leverage existing assets that favour sustainable, pedagogy-driven design in school buildings.	Position the school building as an educational resource, fostering environmental literacy and climate awareness. Encourage broad community participation in facility management to strengthen governance and social resilience. Optimise the use of local natural resources in design and retrofits, emphasising the integration of natural climate shelters.
Exploit Opportunities (E)	Capitalise on funding schemes, strategic alliances, and technological advances to accelerate the transition toward resilient, low-carbon schools.	Tap into European instruments (e.g., NextGenerationEU and the New European Bauhaus) to pilot innovative retrofit projects. Deploy digital technologies for continuous monitoring and participatory management, enhancing effectiveness and transparency. Explicitly align renovation initiatives with global agendas such as the SDGs and the European Climate Pact to maximise impact and institutional visibility.

4.5. Design and Validation of the Indicator Framework

This study produced and empirically validated a set of 37 indicators designed to capture the multi-dimensional performance of passive-design strategies in school buildings. The metrics are grouped into seven thematic clusters—thermal comfort, indoor air quality, solar control and daylighting, environmental ergonomics, ecological sustainability and circular economy, climate justice and social equity, and educational value with stakeholder participation—so that technical, environmental, and pedagogical dimensions are addressed simultaneously (Table 4).

Table 4. Indicator catalogue for the passive-design assessment of school buildings (cluster, metric, unit, life-cycle phase, Level(s) linkage, SWOT/TOWS reference, associated passive strategy).

Cluster	N°	Indicator	Unit	Life-Cycle Phase(s)	Level(s) Macro-Objective	SWOT/TOWS Link	Associated Passive Strategy
Thermal Comfort	1	Mean operative temperature	°C	Operation, Maintenance	Health and Comfort	FO, DO	Cross-ventilation; thermal mass

Table 4. *Cont.*

Cluster	N°	Indicator	Unit	Life-Cycle Phase(s)	Level(s) Macro-Objective	SWOT/TOWS Link	Associated Passive Strategy
	2	Exposed thermal mass	m^2/m^2	Design, Planning	Energy Efficiency	FO	High-capacity materials
	3	Overheating response time	h	Operation, Maintenance	Climate Resilience	DA	Bioclimatic layout; shading
	4	Mean indoor relative humidity	%	Operation, Maintenance	Health and Comfort	FO, DA	Hygroscopic materials; controlled ventilation
	5	Thermal-comfort index (PMV/PPD)	Scale	Operation	Health and Comfort	FO	Combined passive measures
Indoor Air Quality	6	Indoor CO_2 concentration	ppm	Operation, Maintenance	Health and Comfort	FA	Effective natural ventilation
	7	Effective natural ventilation	%	Design, Operation	Health and Comfort	DO	Cross-flow layout
	8	Indoor VOC load	$\mu g/m^3$	Operation	Health and Comfort	FA	Low-emission materials
	9	Mean interior noise level	dB(A)	Operation	Health and Comfort	FA	Passive acoustic insulation
Solar Control and Daylighting	10	Seasonal shading factor	%	Design, Planning	Climate and Comfort	FO	Passive shading devices
	11	Useful daylight ($\geq$300 lux)	% of school hours	Operation, Maintenance	Visual Comfort	FO, FA	Optimised daylight apertures
	12	Operable windows	%	Design, Maintenance	Health and Comfort	DA	Manually controlled openings
	13	Daylight-glare index	Scale	Design	Visual Comfort	DO	Façade solar control
	14	Optimal solar orientation	°/Categorical	Design	Energy Efficiency	FO	Bioclimatic siting
Environmental Ergonomics	15	Mean task illuminance	lux	Operation, Maintenance	Health and Comfort	FO, FA	Daylighting design
	16	Reverberation time	s	Operation	Health and Comfort	FA	Passive acoustic treatment
	17	Perceived IAQ (survey)	Likert scale	Operation	Health and Comfort	FA	User-centred adjustments
	18	Floor area per pupil	m^2	Design, Operation	Health and Comfort	FO	Spatial planning for circulation
Ecological Sustainability and Circular Economy	19	Structural vegetation	m^2 per pupil	Operation, Maintenance	Climate Adaptation	FO, DO	Green areas; biophilic design
	20	Natural connectivity	accesses per m^2	Design, Operation	Ecosystem Integration	DO	Ecological corridors
	21	Sustainable materials	% of volume	Design, Planning	Life-cycle Performance	FO, FA	Local/recycled products
	22	Energy use per capita	kWh per pupil·yr	Operation	Resource Efficiency	DO, DA	Demand reduction by passive means
	23	Efficient water use	L per pupil·yr	Operation	Resource Efficiency	DO	Passive water-management systems
	24	Waste diverted from landfill	%	Operation, Maintenance	Circular Economy	DO	School recycling plans
	25	Reused materials	% of volume	Design, Planning	Circular Economy	FO, DO	Reuse in retrofit/new build
	26	Carbon-footprint reduction	t CO_2-eq	Design–Maintenance	Climate Action	FO, DO	Passive mitigation design
Climate Justice and Social Equity	27	Universal accessibility	% compliance	Design, Operation	Equity and Well-Being	FO, DO	Inclusive spatial design
	28	Vulnerable-group involvement	% participation	Operation, Maintenance	Social Governance	FA, DA	Democratic management
	29	Green-space equity	m^2 green per pupil (by zone)	Design, Operation	Climate Justice	FO	Fair distribution of open space

Table 4. *Cont.*

Cluster	Nº	Indicator	Unit	Life-Cycle Phase(s)	Level(s) Macro-Objective	SWOT/TOWS Link	Associated Passive Strategy
	30	Inclusive awareness programmes	programmes	Operation	Equity Education	FO, DO	Social-oriented ESD
	31	Community climate resilience	Qualitative scale	Operation, Maintenance	Social Resilience	DA	Preparedness and adaptation
Educational Value and Participation	32	Building as a teaching aid	Qualitative scale	Operation	Participatory Governance	FA	Pedagogical use of built fabric
	33	Access to learning resources	resources	Operation	Climate Awareness	FO, DO	Active community engagement
	34	Curricular sustainability uptake	courses	Operation	Transition Education	FO	ESD integration
	35	Ongoing technical training	activities per yr	Operation, Maintenance	Professional Development	DO	Continuous capacity building
	36	Participatory maintenance	Qualitative scale	Maintenance	Governance and Resilience	DA	Whole-community involvement
	37	Community co-design and governance	% participation	Planning–Maintenance	Participatory Governance	FO, DO	Shared decision-making

Each indicator is explicitly linked to the phase of the building life cycle in which it is most relevant (planning, design, operation, maintenance, or retrofit), to one or more of the six macro-objectives of the European Level(s) framework, and to the internal or external factors highlighted by the prior SWOT/TOWS analysis. For every metric, a precise definition with its calculation formula was supplied, together with the unit of measurement, the life-cycle phase for data collection, the corresponding Level(s) objective, its diagnostic provenance in the SWOT/TOWS matrix, and the passive-design tactic it is intended to optimise—such as cross-ventilation, thermal mass, or vegetated shading. This structure guarantees methodological clarity, facilitates benchmarking across regions and programmes, and aligns the indicators with EU renovation funding criteria.

The validation protocol combined quantitative and qualitative procedures. A panel of 170 experts from education, engineering, architecture, and public administration scored each metric on a five-point Likert scale for clarity, relevance, and feasibility; content-validity indices equal to or above 0.80 confirmed conceptual robustness.

Pilot deployment was carried out in two Andalusian schools (southern Spain) and one Chilean school (Santiago de Chile), chosen to test the framework under diverse climatic and regulatory conditions. These pilots verified the feasibility of data collection and the interpretability of the results for decision-making, leading to minor refinements in indicator wording and sampling intervals.

Although the pilot phase yielded promising qualitative feedback, the quantitative monitoring and long-term analysis of the indicators are ongoing and will be addressed in a future research line focused on empirical validation and performance tracking.

The indicator framework functions as a scalable decision-support tool by embedding Level(s) principles, life-cycle thinking, and the priorities revealed in the SWOT/TOWS analysis. It enables school managers, designers, and local authorities to monitor progress, justify investments, and incorporate passive-design logic into routine pedagogical practice—effectively transforming the school building into a living laboratory for climate literacy and circular economy action.

4.6. Alignment with International Frameworks, Public Policy and an Implementation Road-Map

The indicator set devised for assessing passive-design strategies in school buildings is firmly embedded in global sustainability agendas, contemporary educational practice and EU policy instruments, thereby providing a robust lever for climate action, social equity and learning excellence. This project has the potential to inspire and motivate a generation of students and educators to champion sustainability in their communities.

New European Bauhaus (NEB).

Echoing the NEB triad—beauty, sustainability, and inclusion—a concept that emphasises the importance of aesthetics, environmental responsibility, and social equity in design, the indicators evaluate both quantitative and qualitative dimensions. Metrics on structural vegetation, circular-material use and community participation, for example, encourage schools to become energy-efficient *and* experientially rich environments that stimulate creativity, social interaction and contact with nature, fostering well-being and climate resilience.

Sustainable Development Goals (SDGs).

The system contributes directly to several priority targets:

SDG 3 (Health and Well-being)—by monitoring indoor thermal comfort, air quality and ergonomic factors that support physical and mental health.

SDG 4 (Quality Education)—embedding environmental education in the curriculum, promoting whole-school participation, and cultivating sustainability competencies.

SDG 7 (Affordable and Clean Energy)—by advancing passive energy strategies that cut reliance on non-renewables.

SDG 11 (Sustainable Cities and Communities)—through indicators on accessibility, inclusion and ecological connectivity that strengthen local resilience.

SDG 12 (Responsible Consumption & Production)—Via metrics on sustainable materials, waste management and life-cycle impact.

SDG 13 (Climate Action)—explicitly measuring mitigation and adaptation performance at school and neighbourhood scales.

Policy Coherence.

At the EU level, the framework aligns with the European Green Deal and the Renovation Wave. Using Level(s) as the reference taxonomy ensures regulatory consistency and facilitates access to structural funds for energy upgrade projects. Nationally and locally, the indicator suite can guide education and urban planning policies that prioritise sustainable refurbishment, social participation, and equity. This alignment with existing policies ensures that the framework is not just a theoretical concept but a practical tool for implementing sustainable practices in school planning and design.

Environmental Education and Civic Participation.

The active engagement of students, teachers, families, and technical staff is pivotal. Your involvement in monitoring, maintenance, and decision-making is not just important; it is crucial. It turns the building into a living classroom, reinforces experiential learning, and cultivates climate citizenship—a goal entirely consonant with policy directives on active, competency-based education.

Implementation Road-Map.

1. Initial Diagnosis and Awareness. Deploy a baseline scan with the indicators, identify gaps and sensitise the entire school community to NEB and SDG imperatives.
2. Comprehensive Training. Deliver technical-pedagogical capacity building for teachers, students and facility managers to master the tool.
3. Structured Participation. Establish inclusive committees that oversee building management, green space care and continuous improvement.

4. Curricular Integration and Projects. Embed the indicators in interdisciplinary projects that use the campus and its surroundings as an educational resource.
5. Continuous Monitoring and Review. Institute periodic data collection and transparent reporting to drive evidence-based refinement.
6. Institutional and Financial Support. Align with education authorities and funding bodies to anchor the indicators in policy and secure long-term resources.
7. Dissemination and Networks. Share experiences through local, national and international networks to accelerate peer learning and innovation.

4.7. Evaluating the Indicator Language: Methods and Procedures

A multi-method evaluation strategy—combining quantitative, qualitative and participatory techniques—guarantees an integral view of environmental, social and pedagogical performance (Table 5).

Table 5. Dimension and key activities.

Dimension	Key Activities
Instrumented Measurement and Technical Monitoring	Install environmental sensors (temperature, humidity, CO_2, noise, daylight, energy) for continuous, high-precision data. • Conduct on-site audits to verify passive-design features (thermal mass, shading, ventilation paths, material health). • Perform document analysis of energy bills, waste logs and training records to triangulate circular-economy and capacity-building indicators.
Participatory and Qualitative Assessment	Deploy structured surveys to capture stakeholder perceptions of comfort and participation. • Run workshops and focus groups to interpret findings and co-design improvements. • Maintain logs of community involvement in maintenance, governance and environmental campaigns.
Data Processing and Analytics	Apply benchmarking against national and international standards (including Level(s)) to contextualise performance. • Use statistical and multivariate analysis to detect trends and critical factors. • Adopt digital dashboards for real-time visualisation, enhancing transparency and decision-making.
Continuous-Improvement Cycle	Plan → Implement → Monitor → Review → Adjust—ensuring the indicator system remains dynamic and adaptive.
Scalability and Adaptability	The modular design permits phased adoption across diverse school types, climates and life-cycle stages—from new build to deep retrofit—enabling tailored roll-out at regional or national scale.

Together, these evaluation procedures embed a culture of evidence, reflection and iterative enhancement, empowering schools to track progress credibly, justify investment and model sustainability leadership within their communities.

5. Discussion

Developing a dedicated indicator language for assessing and enhancing passive-design strategies in schools is not just a step forward but a leap towards a transformative future at the intersection of architectural sustainability and educational innovation. The intentionally multidimensional framework combines technical rigour, social inclusion, pedagogical participation and environmental stewardship—attributes that not only meet but exceed contemporary demands for climate responsiveness, social equity and transformative learning.

5.1. Synergy with the Level(s) Framework

The Level(s) Framework, developed by the European Commission, is a reference scheme for building sustainability. It organises performance around six macro-objectives spanning resource efficiency, carbon mitigation, health, resilience and value creation. By adapting and extending Level(s) to the unique conditions of educational facilities, the present indicator set turns classrooms into active drivers of learning and equity rather than mere recipients of technical retrofits. Strategic alignment with Level(s) eases certification processes, unlocks Renovation-Wave funding and embeds circular economy, climate justice and community engagement dimensions that expand the scheme beyond its traditional technical focus. In short, sustainability in schools is reframed as simultaneously technical, social and pedagogical.

5.2. Community Participation as a Transformative Axis

The system's distinctive strength lies in the central role it assigns to the educational community—students, teachers, families and facility managers alike. Indicators that track participatory maintenance, continuous professional development, and using the building as an instructional resource ensure that sustainability is not just a goal but a shared, empowering journey. This experiential model nurtures climate justice and social equity and reinforces community resilience by forging strong links between the physical infrastructure and the school's social fabric.

5.3. Circular Economy and Climate Resilience

Metrics on sustainable materials, waste minimisation, and carbon footprint reduction add a practical, operational dimension that is crucial in retrofit scenarios. Parallel indicators on climate resilience and social equity—such as equitable green space distribution and universal accessibility—guarantee that upgraded facilities remain adaptive to extreme events and inclusive for all users. These provisions resonate with the New European Bauhaus, a design and architecture initiative that aims to make the Green Deal's objectives more tangible and relatable, and the European Green Deal, a set of policy initiatives by the European Commission to make Europe climate-neutral by 2050 and promote a circular economy. They call for just, climate-positive spaces.

5.4. Environmental Ergonomics and Holistic Well-Being

Including indoor-environment indicators (daylight, acoustics, personal space) acknowledges that physical quality is inseparable from cognitive performance and emotional health. Thus, an ergonomically sound environment becomes a cornerstone of learner-centred, person-centred education.

5.5. Implementation Challenges and Innovation Opportunities

Adopting the framework entails financial outlays, staff upskilling and a cultural shift towards participatory sustainability, a concept that involves the active involvement of all stakeholders in the sustainability process—barriers that must be met with supportive policy, targeted incentives and capacity-building programmes. However, the potential benefits are substantial: schools can position themselves as exemplars of climate leadership, social justice and educational excellence. Because the indicators are modular and life-cycle oriented, they can be phased in across new builds, deep retrofits and day-to-day operations, fostering continuous, adaptive improvement.

5.6. Convergence with Global Agendas

The system aligns seamlessly with the SDGs, the New European Bauhaus, the European Green Deal, and national environmental education strategies. This alignment validates the system's approach and amplifies its impact, casting schools not merely as efficient assets but as living laboratories of pedagogy, equity, and climate action—spaces where learners acquire the critical, collaborative, and solution-oriented competencies that the twenty-first century demands.

Beyond its role as an evaluation framework, Level(s)+37 is designed as a decision-support and planning tool capable of guiding real design and renovation processes in educational buildings. Its alignment with European and national policies—such as ERESEE, PNIEC, and the Level(s) system—facilitates its incorporation into public renovation programmes and school infrastructure guidelines. Moreover, by encouraging participatory evaluation involving teachers, students, and local authorities, it strengthens the educational and social dimensions of sustainability. This dual role enables the framework to act as a catalyst for integrating research evidence into design practice, promoting more inclusive, resilient, and environmentally responsive learning environments.

The Level(s)+37 Framework was conceived to help overcome two recurrent barriers identified during the research: the lack of clear metrics and the limited technical training of stakeholders involved in school refurbishment. To address these gaps, the framework translates sustainability goals into 37 measurable indicators supported by reference values, simplified assessment methods, and context-specific data sources that can be applied by non-expert users. Additionally, its implementation roadmap includes dedicated training modules and participatory guidelines that connect technical, pedagogical, and administrative actors. These "action lines" promote collaborative decision-making and strengthen institutional capacity, enabling schools to integrate passive design and holistic sustainability criteria into real design and management practices. In this way, the framework contributes not only to evaluation but also to knowledge transfer and skill development across the educational sector.

In addition, the Level(s)+37 Framework reinforces the educational dimension of sustainability by embedding its indicators within the school curriculum and daily management practices. Several strategies are proposed to foster active participation among students, teachers, and facility managers. Indicators related to indoor environmental quality, energy performance, and resource circularity can be used as educational resources through classroom dashboards, environmental audits, and student-led observation projects, linking monitoring data to STEM and citizenship education. Furthermore, training and co-design workshops encourage collaboration between educators, architects, and administrative staff, ensuring that pedagogical goals align with physical improvements in the school environment. This approach transforms school buildings into living laboratories that enhance ecological awareness, collective responsibility, and participatory governance, consolidating the framework's role as both a technical and educational tool for sustainability.

Beyond its national scope, the Level(s)+37 Framework is designed to serve as a transferable model adaptable to different climatic, economic, and regulatory contexts. Although its initial development focused on Spanish schools, the framework's modular architecture—comprising seven thematic clusters and 37 context-sensitive indicators—allows recalibration through local weighting factors and climate-specific parameters.

In tropical and arid regions, the prioritisation of passive cooling, cross-ventilation, and water management indicators would enhance resilience to heat stress, while in cold and mixed climates, thermal envelope optimisation, airtightness, and heat recovery would gain higher significance. Similarly, in low-income or resource-constrained settings, the social and educational clusters can act as drivers for progressive improvement through low-cost passive measures and community participation.

From a regulatory perspective, the Level(s)+37 Framework can be aligned with international certification systems such as LEED, EDGE, and DGNB, as well as regional tools including the CEELA Adaptive Comfort Guide (Latin America) or the ASEAN Green School Standards (Southeast Asia). This flexibility underscores its potential as a globally applicable framework capable of linking environmental performance with social inclusion, climate resilience, and educational transformation. By enabling contextual calibration, Level(s)+37 provides a robust methodological bridge between European policy frameworks and diverse international sustainability agendas.

While the Level(s)+37 Framework provides a robust methodological basis for evaluating and guiding the sustainable refurbishment of schools, several limitations must be acknowledged. First, the study's empirical validation focused on the Spanish context, which may constrain the generalizability of certain indicators under different climatic or regulatory conditions. Second, the Delphi–AHP, though statistically consistent, relied primarily on expert judgement; thus, future work should incorporate broader stakeholder participation, including school communities and regional authorities. Third, the framework's pilot applications were limited to selected case studies, which provided valuable qualitative insights but did not yet enable large-scale quantitative validation. Finally, as the framework currently centres on the design and retrofit stages, further research should extend its use to the operational phase and long-term monitoring of school performance. Addressing these limitations will help refine the framework and expand its applicability across diverse educational and climatic contexts.

6. Conclusions

Developing and applying a unique, tailor-made indicator language for passive-design strategies in schools marks a significant, multidimensional leap towards sustainability, resilience, and equity in the educational sector. Derived from the European Level(s) framework, this innovative tool integrates technical, pedagogical, social, and environmental aspects, effectively addressing the pressing issues of climate urgency and social justice.

The indicator set comprehensively evaluates school-building performance, covering thermal comfort, indoor air quality, energy efficiency, circular economy performance, climate justice, environmental ergonomics, and community engagement. This comprehensive approach reimagines educational facilities as healthy and energy-efficient spaces and active agents of learning and social change.

A cornerstone of the system is the continuous, shared participation by the entire educational community—students, teachers, families and support staff. Their involvement throughout every life-cycle phase of the building is important and integral. This co-responsibility strengthens belonging, nurtures socio-ecological resilience and turns the facility into a "living classroom" where sustainability is learned and practised collectively. School infrastructure thus becomes a critical formative agent for cultivating the informed, engaged citizens required for twenty-first-century challenges.

Alignment with international frameworks—Level(s), the New European Bauhaus, the European Green Deal and the Sustainable Development Goals—ensures relevance, policy coherence and transferability. The indicators, being both scalable and flexible, are suitable and adaptable to new construction and deep retrofits, fostering continuous improvement across diverse geographic and socio-economic contexts.

However, the successful implementation of this transformative approach hinges on overcoming several challenges: comprehensive technical and pedagogical training, unwavering institutional and political commitment, and the mobilisation of financial and human resources. Establishing collaborative networks, supportive regulation, and targeted incentives will be crucial in mainstreaming this approach.

In sum, the indicator language offers a robust, practical roadmap for transforming schools into exemplary settings of environmental stewardship, holistic well-being and social justice—advancing a healthier, fairer and more climate-resilient educational future. It simultaneously opens avenues for further work: pilot deployments, digital monitoring platforms and longitudinal studies of impacts on well-being, academic performance and environmental outcomes. The research also invites ongoing interdisciplinary dialogue among architecture, pedagogy, sociology and public policy to continue shaping educational environments that are sustainable, inclusive and resilient.

From a policy perspective, the Level(s)+37 Framework provides an opportunity to align school refurbishment strategies with global and European sustainability agendas, including the Sustainable Development Goals (SDGs 4, 7, 11, and 13) and the New European Bauhaus principles of sustainability, beauty, and inclusion. To foster its adoption, national and regional administrations could integrate the framework into existing renovation programmes such as ERESEE, PNIEC, and Next Generation EU, using it as a reference for evaluating performance and funding eligibility. Incentive mechanisms—such as preferential scoring in public tenders or pilot subsidies—could encourage municipalities and educational authorities to apply the indicators systematically. Furthermore, incorporating the framework into curricular innovation and environmental management plans would bridge the gap between physical transformation and pedagogical change, reinforcing schools' role as active agents of the ecological and social transition.

Looking ahead, future research will focus on assessing the broader educational and social impacts of the Level(s)+37 Framework beyond technical building performance. A longitudinal monitoring plan will be implemented in selected pilot schools over the next three to five years, combining quantitative data on environmental comfort and energy use with qualitative methods such as surveys, interviews, and participatory observation. This mixed-method approach will help evaluate how sustainable refurbishment processes influence students' environmental awareness, teachers' pedagogical practices, and community participation in school governance. Establishing this long-term evidence base will strengthen the framework's contribution to educational transformation and its alignment with the Sustainable Development Goals and the New European Bauhaus vision of inclusive, beautiful, and sustainable learning environments.

Despite its methodological comprehensiveness, the Level(s)+37 Framework presents certain limitations that should be acknowledged. First, its indicator weighting and validation were based primarily on the Spanish school building stock, which may not fully represent other climatic or regulatory contexts. Second, while the Delphi–AHP ensured expert consensus, future studies should expand stakeholder participation to include a broader range of regional authorities, facility managers, and students to capture more diverse perspectives. Third, the pilot applications were conducted under controlled research conditions; large-scale implementation will require further testing to assess real-world feasibility and long-term performance. Finally, the current version of the framework focuses on the design and refurbishment stages; extending its use to the operational phase of schools would provide a more dynamic and continuous assessment of sustainability performance. These limitations offer valuable guidance for ongoing and future research aimed at refining and scaling the Level(s)+37 Framework internationally.

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