

An Integrated Assessment of Environmental Performance in Sustainable Public Buildings in the Mediterranean Context: A Case Study from Morocco

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Achieving high environmental performance in public buildings extends beyond the mere integration of advanced energy-efficient technologies; it requires the adoption of a coherent and structured governance framework capable of guiding design, implementation, and operational decisions throughout the building lifecycle. From this perspective, the present study develops an integrated assessment framework for evaluating the environmental performance of sustainable public buildings in the Mediterranean context. The proposed approach is applied to a representative case study located in northwestern Morocco (34.26° N), within RTCM Climate Zone z2 (Tangier reference zone), which is characterized by a humid Atlantic-Mediterranean climate. The investigation focuses on the new headquarters of the Kenitra–Sidi Kacem–Sidi Slimane Agency (AUKSS), a four-story public administrative building with a total floor area of 4,394 m², providing a comprehensive, multidimensional evaluation of its environmental performance. Unlike comparable studies that focus on output-based per-

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formance indicators, such as primary energy consumption, thermal comfort exceedance, and photovoltaic energy production, this research adopts an input-oriented perspective. It emphasizes the certification methodology, decision-making logic, prioritization strategies, and governance mechanisms that shape environmental performance outcomes. Using the Environmental Performance Profile for Buildings (PPEB) developed by Bureau Veritas as the primary analytical framework, the study systematically compares two certification scenarios: Excellent (10 stars) and Exceptional (13 stars). This approach highlights how different levels of certification ambition influence environmental priorities and decision-making. The analysis is conducted across fourteen environmental criteria organized into four domains: Environmental Construction (C1–C3), Environmental Management (C4–C7), Comfort (C8–C11), and Health (C12–C14). For each criterion, the study identifies the associated technical, architectural, and regulatory requirements necessary to progress from one certification level to the next. It further evaluates design-related risks and maps critical decision points across key project phases, including pre-design, preliminary design, and final design. The findings indicate that four criteria – energy performance (C4), hygrothermal comfort (C8), natural lighting (C10), and water management (C5) – play a decisive role in achieving higher certification levels. These criteria are governed by early-stage design decisions that become effectively irreversible after the preliminary design phase, underscoring the need for strategic prioritization during the initial stages of project development. This research contributes a structured responsibility matrix that allocates roles across six technical domains, together with a critical-path-based prioritization schedule. The proposed framework offers a process-based methodology that can inform future studies of environmental performance in public buildings, particularly in developing countries and Mediterranean regulatory contexts, although further validation across multiple case studies and climate zones is recommended.

Key Words: Building Environmental Performance Profile (PPEB), target rioritization, Dynamic Thermal Simulation (DTS), RTCM, Moroccan public buildings, eco-construction, eco-management, sustainable building governance



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INTRODUCTION

The global imperative to decarbonize the built environment has accelerated the adoption of multicriteria environmental certification frameworks in both developed and emerging economies (Too et al. 2025). In Morocco, where the building sector accounts for approximately 33% of final energy consumption and where the National Strategy for Sustainable Development (SNDD) mandates progressive alignment with international climate commitments (Majaty et al. 2023), the Haute Qualité Environnementale (HQE™) framework has emerged as the reference standard for tertiary buildings seeking to exceed the minimum requirements established by the Moroccan Thermal Construction Regulation (RTCM; Morocco 2014) (Asri et al. 2023; Dahmani et al. 2025).

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Despite growing institutional interest in HQE™ certification, peer-reviewed analyses of how the certification process is operationalized in Moroccan public procurement remain scarce. Most published studies either focus on output-based performance measures – such as simulation-derived energy savings, comfort indicators, or renewable energy yields – or remain limited to descriptive overviews of certification targets without examining the governance mechanisms that determine whether certification can be achieved in practice (Mata et al. 2013).

The new headquarters of the Agency of Kenitra–Sidi Kacem–Sidi Slimane (AUKSS), one of the first public administrative buildings in Morocco to be designed according to explicit HQETM principles, serves as the case study for this process-based analysis of the HQETM International certification framework (El Jaafari et al. 2024). The Building Environmental Performance Profile (PPEB), developed by Bureau Veritas in its capacity as the certified HQE Assistant to the Contracting Authority (AMO), was applied to all 14 certification targets under two certification scenarios: Excellent (10 stars) and Exceptional (13 stars).

The complete design and simulation documentation has been made available for academic analysis, making the AUKSS project an exceptionally well-documented case study. The simulation results for dynamic energy balance, U-value compliance, summer thermal

comfort exceedance, and photovoltaic system economics are presented in detail in a companion study of the same building (Moreno et al. 2025).

- [4] The purpose of the present study is to analyze the decision-making architecture that produces these performance outcomes rather than to replicate the simulation results. For transparency, table A1 (supplementary data, available from the corresponding author) reproduces the key simulation outputs from the companion study that are referenced in this analysis, including the BECTh of 28.4 kWh/m²/year achieved under the VRF+PV scenario (C4), the annual free-cooling duration (156 h/year; C8), and the annual water savings achieved through the rainwater harvesting system (52% reduction relative to the baseline; C5). All other performance claims in this paper that relate to design-stage targets, rather than simulation-validated outcomes, are explicitly identified as such.

The study is structured around three interrelated objectives. The first is to describe the HQETM framework as a management system, situate it within the Moroccan regulatory context, and distinguish its underlying approach from that of the mandatory RTCM (Laassili and Ejbari 2025). The second is to identify, for each certification target, the design variables, responsible stakeholders, and project-phase decision gates required to progress from Excellent to Exceptional certification. The third is to develop, based on this analysis, a transferable prioritization methodology that can be applied to similar public procurement projects in Morocco and throughout the Mediterranean region, thereby providing a practical process framework for a field that has received considerably more attention from performance studies than from governance analyses.

The central premise of this paper is that the difference between an Excellent and an Exceptional HQE™ rating is primarily procedural rather than technological (Mustapha and Sossi 2025). It depends on who makes key decisions, when those decisions are made, and how effectively the technical disciplines are integrated throughout the design process. The fourth section tests this premise through a comprehensive analysis of the decision lock-in structure associated with each of the 14 certification targets.



LITERATURE REVIEW

The HQE™ Framework as an Environmental Management System

The HQE™ framework, which originated in France in the 1990s and was subsequently internationalized under Certivéa management (see table 1 and figure 1), is fundamentally distinct from energy-focused certification systems such as Passivhaus or the energy credits within BREEAM. It functions as a two-pillar Environmental Management System (EMS) (Bidou 2006): the Operation Management System (OMS), which governs project organization, stakeholder engagement, and quality assurance throughout the building life cycle; and the Environmental Quality of the Building (EQB), which structures fourteen performance targets across four thematic domains (Motalebi et al. 2025). The OMS component is particularly significant in the Moroccan context, where the technical capacity [5]

TABLE 1 Summary of the Four HQE™ Themes, Fourteen Targets, and Their Principal KPIs

(1)	(2)	(3)	(4)
Eco-construction	C 1	Relationship of the building to its immediate environment	Site analysis, biodiversity, albedo, soft mobility
	C 2	Selection of construction products, systems and processes	LCA, VOC content, local and bio-based materials, circular design
	C 3	Low- impact construction sites	Waste recovery rate, noise and dust monitoring, community communication
Eco-management	C 4	Energy management	BE CTh (kWh/m ² /year), CO ₂ intensity, renewable energy share
	C 5	Water management	Annual water consumption (m ³ /year), rainwater harvesting
	C 6	Operational waste management	Accessibility of waste sorting, compactor provision, collection logistics
	C 7	Maintenance and durability of environmental performance	Life-cycle cost, ease of access, building management system (BMS) integration

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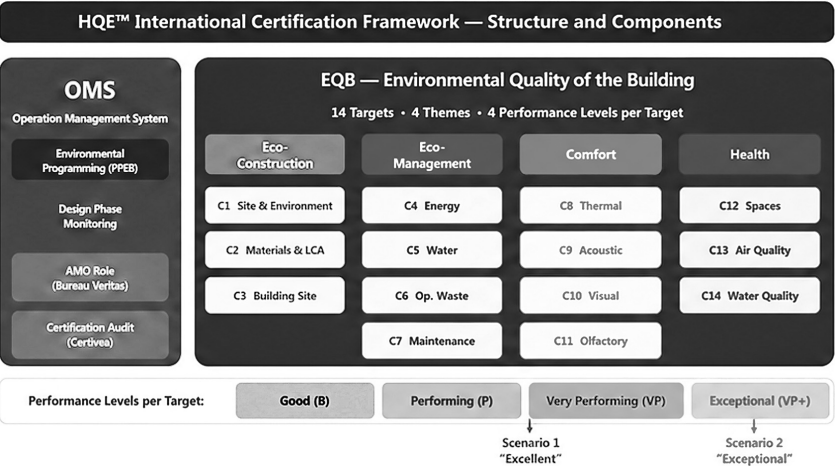
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TABLE 1 Continued from the previous page

(1)	(2)	(3)	(4)
Comfort	c 8	Hygrothermal comfort	Operative temperature, ASHRAE 55 compliance, free-cooling hours
	c 9	Acoustic comfort	Sound insulation (Rw, dB), reverberation time (RT60), noise rating (NR) curves
	c 10	Visual comfort	Daylight Factor (%), UGR, circadian lighting
	c 11	Olfactory comfort	Indoor air quality (IAQ), VOC concentration, ventilation rate (ACH), filter class
Health	c 12	Sanitary quality of spaces	Ergonomics, biophilic elements, active-design staircases
	c 13	Sanitary quality of indoor air	PM2.5 and CO2 monitoring, F7/F9 filtration, low-emission finishes
	c 14	Sanitary quality of water	Legionella risk management plan, anti-scald devices, dead-leg minimization

NOTES Column headings are as follows: (1) theme, (2) RTCM (mandatory regulation), (3) HQE™ certification (voluntary), (4) characteristic.

TABLE 2 The Four Themes and Fourteen Targets of the HQE™ Framework and Their Principal Key Performance Indicators (KPIs)



NOTES Adapted from Assadiki et al. (2022).

of public contracting authorities varies widely. The AMO (Assistant Maître d’Ouvrage) role, typically performed by a specialist consultant such as Bureau Veritas, serves both as a performance advisor and as an institutional anchor, ensuring methodological continuity



[7]

FIGURE 1 Structure of the HQE™ International Certification System, Comprising the OMS and EQB Pillars, Four Thematic Domains, Fourteen Performance Targets, Four Performance Levels for Each Target, and Four Composite Star Ratings

NOTES The two certification scenarios examined in this study are highlighted.

throughout all phases of the project. As shown in table 1, within the EQB, the EQB organizes its fourteen targets into four thematic categories: Eco-Construction (C1–C3), Eco-Management (C4–C7), Comfort (C8–C11), and Health (C12–C14). Each target is assessed at one of four performance levels: Good (B), Performing (P), Very Performing (VP), and Exceptional (VP+) (Aouifi et al. 2026). A building’s overall certification star rating is determined by the combination of performance levels achieved across all fourteen targets. The Excellent (10-star) and Exceptional (13-star) designations represent the two highest composite ratings. They are distinguished not merely by the number of targets rated VP but by the specific combination of targets elevated from P to VP and the resulting synergies across the four performance domains (Boisnier 2015).

HQE™ Adoption in Morocco: Context and Research Gap

Morocco’s adoption of the HQETM framework has been driven by the country’s institutional proximity to French construction practices, the framework’s comprehensive multi-criteria approach

[8] (which aligns with Morocco's priorities for indoor environmental quality and water conservation in addition to energy efficiency), and the availability of certified AMO firms, such as TERAQ and Bureau Veritas Morocco, capable of implementing the certification process (Er-retby et al. 2026). The contracting authority's selection of HQE™ International over competing certification systems (LEED and BREEAM) was explicitly documented in the AUKSS procurement brief on three grounds: (i) regulatory alignment, as HQE™'s energy performance pathway is calibrated to RTCM requirements, whereas LEED and BREEAM are benchmarked against North American and UK building codes; (ii) the availability of certified AMO expertise in Morocco, where Bureau Veritas and TERAQ are the only firms accredited as HQE™ International auditors; and (iii) the multi-criteria structure of HQE™, which explicitly incorporates water management and indoor environmental health – both institutional priorities for an Urban Agency operating in a water-stressed Mediterranean environment. These dimensions receive comparatively less emphasis within LEED's credit structure for North African climatic conditions. Despite these advantages, HQE™ remains relatively uncommon in Morocco. Its application is largely confined to flagship institutional projects rather than being adopted systematically across the public procurement portfolio (Batra 2023). This disparity between institutional ambition and practical implementation creates a significant knowledge gap. The peer-reviewed literature contains very few case studies that move beyond reporting the certification level achieved to examine how the certification process was organized, which decisions proved critical, and which governance structures facilitated or constrained project performance.

Existing studies of sustainable building certification in Morocco primarily focus on regulatory compliance or evaluate adherence to RTCM requirements across building stocks (Asri et al. 2023) or within specific technical domains, such as thermal envelope optimization (Ahtesham 2024) or photovoltaic system feasibility. By examining the HQE™ PPEB as a research case and deriving a transferable decision-making framework, the present study helps address this process-governance gap.



Target Prioritization and Lock-in in Multi-Criteria Certification

A recurring finding in the international sustainable building literature is that the attainability of high environmental certification ratings is strongly influenced by the sequence and timing of design decisions – a phenomenon variously described as ‘design lock-in,’ [9] ‘certification path dependency,’ or ‘initial condition sensitivity’ in building simulation studies (Vadnjal and Nouairi 2025). The practical implication is that targets determined early in the design process (building orientation, structural system, glazing ratio, HVAC system selection) have a disproportionate influence on overall certification outcomes compared with targets that can be addressed later through interior fit-out or equipment specifications. Although this asymmetry has been well-documented for energy performance in temperate European climates (Lyu et al. 2021), it has received comparatively little attention in Mediterranean and North African context, where cooling rather than heating is the dominant energy challenge and where passive design strategies interact differently with building envelope and HVAC system decisions.

The concept of an AMO-driven target prioritization process, in which a specialist consultant maps the lock-in characteristics of all certification targets before design development begins, has been promoted by Certivéa but is rarely described in sufficient methodological detail within the academic literature to enable replication. The methodology developed in this paper addresses that gap by assigning each certification target a design-stage weight, an estimated cost premium, a lock-in risk rating, and a corresponding project-phase decision gate.

REGULATORY CONTEXT: RTCM, HQE™,
AND THE ROLE OF URBAN AGENCIES

The RTCM: Mandatory Minimum Performance Requirements

Dahir Decree No. 2-13-874 (Morocco 2014) establishes the Moroccan Thermal Construction Regulation (RTCM), which defines mandatory thermal performance requirements for newly constructed buildings across six climatic zones. For Climate Zone Z2 (the Tangier reference zone, applicable to the Kenitra–Gharb plain), tertiary admin-

- [10] istrative buildings must satisfy the following requirements: an exterior wall U-value $\leq 1.20 \text{ W/m}^2\cdot\text{K}$; an exposed roof U-value of $\leq 0.55 \text{ W/m}^2\cdot\text{K}$ (for WWR 36–45%); a glazing U-value of $\leq 3.30 \text{ W/m}^2\cdot\text{K}$; and a maximum annual BECTH (Building Energy Consumption for Thermal Comfort) of $49 \text{ kWh/m}^2/\text{year}$ for the ‘Other’ tertiary building category. Compliance may be demonstrated through either a prescriptive building-envelope approach or a performance-based dynamic simulation approach (Jørgensen and Ma 2025). The RTCM establishes a necessary – but by itself insufficient – baseline for the level of environmental performance sought by the AUKSS project. Its scope is limited to thermal energy performance and does not address water consumption, indoor air quality, construction-site impacts, material life-cycle, acoustic comfort, daylighting, or occupant health. The HQE™ framework complements the RTCM by addressing all of these dimensions and providing a structured pathway from regulatory compliance to comprehensive environmental excellence (Kaczmarczyk et al. 2025).

Urban Agencies as Institutional Drivers of Sustainable Procurement

Established under Dahir Law No. 1-93-51, Morocco’s Urban Agencies (Agences Urbaines) play a central role in the country’s sustainable building agenda. Since their establishment, both their mandate and territorial reach have expanded (Morocco 1993). As the authorities responsible for issuing construction permits, approving development plans, and regulating urban land use, they both enforce environmental standards for private developers and are uniquely positioned to apply those same standards to their own building projects. The contracting authority explicitly characterizes the AUKSS project as a ‘lead-by-example’ initiative, meaning that the building is intended to demonstrate the standards the agency requires of others. This institutional rationale further justifies the decision to pursue an Exceptional certification rather than merely an Excellent certification (Soares et al. 2021). The Exceptional target therefore represents both a technical objective and an institutional commitment. An Urban Agency that settles for minimum regula-



TABLE 3 Comparison of the RTCM (Mandatory Thermal Regulation) and the HQTTM Certification Framework (Voluntary Multi-Criteria Environmental Certification Standard)

(1)	(2)	(3)
Nature	Mandatory (Morocco 2014)	Voluntary certification (Certivéa/Bureau Veritas)
Scope	Thermal energy performance and building envelope only	Multi-criteria framework encompassing 14 targets covering energy, water, materials, comfort, and health
Compliance method	Static calculation or prescriptive envelope thresholds	Performance-based certification supported by Dynamic Thermal Simulation (DTS)
Objective	Meet minimum regulatory requirements ($BE_{CTH} \leq 49 \text{ kWh/m}^2/\text{year}$ in Climate Zone Z2)	Achieve progressively higher levels of environmental performance: Good Performing Very Performing, and Exceptional
Performance levels	Binary: compliant or non-compliant	4 performance levels for each target; overall building certification ranges from Good (7) to Exceptional (13)
CO ₂ accounting	Not explicitly required	Mandatory for sub-target C4 (Energy Management), with annual CO ₂ emissions reported ($\text{kg eq CO}_2/\text{m}^2/\text{year}$)
Post-occupancy evaluation	Not required	Recommended and may support HQT Exploitation certification following project completion

NOTES Column headings are as follows: (1) characteristic, (2) RTCM (mandatory regulation) HQTTM certification (voluntary).

tory compliance would weaken its own normative authority. Understanding this governance rationale is essential for interpreting the target-prioritization decisions documented in the PPEB and analyzed in the fourth section.

METHODOLOGY
Case Study Selection and Data Sources

The AUKSS building was selected as the case study because it is among the most comprehensively documented HQTTM-certified pub-

[12]

lic buildings in Morocco, with the complete PPEB dossier, architectural drawings, dynamic thermal simulation reports (Design Builder v5.5.2.007/Energy Plus v8.1, prepared by Bureau Veritas in December 2019), and target prioritization documentation available for scholarly analysis. The building is a four-story administrative headquarters with a conditioned floor area of 4,394 m², located at 34.26° N, 6.58° W (Kenitra urban area, Gharb plain), at an elevation of 31 m above sea level in north-western Morocco. The site is characterized by a humid Atlantic-Mediterranean climate, with a mean annual temperature of 17.5° C and a mean relative humidity of 81.3%. It is classified as RTCM Climate Zone Z2 (Tanger reference zone) and ASHRAE Climate Zone 3A (Tyler et al. 2021). Primary data sources include the Bureau Veritas PPEB dossier (STD-AUKSS-VO, prepared in December 2019), which specifies target performance levels, evaluation criteria, and scenario comparison data for all 14 HQE™ targets; the architectural program brief; and the thermal simulation report prepared for RGCPÉB compliance. Secondary sources include the Corteva's HQE™ Tertiary Building Referential, the RTCM technical annexes, and published studies on HQE™ implementation and sustainable building governance in Mediterranean climates (Ben Bacha, C., and F. Bourbia 2025).

Analytical Framework: Process-Based Target Analysis

For each of the fourteen HQE™ performance targets, the analysis follows five steps: (i) identify the performance level assigned in Scenario 1 (Excellent) and Scenario 2 (Exceptional) in the PPEB; (ii) specify the technical, architectural, or organizational measures that distinguish the two scenarios; (iii) assess the target's lock-in risk – that is, the extent to which key decisions become irreversible after a particular project stage; (iv) identify the primary decision gate – the project phase (preliminary design, Conceptual Preliminary Design, Final Preliminary Design, and Tender Dossier) at which the critical commitment must be made; and (v) identify the responsible technical work package (lot). Rather than serving as a static record of compliance, this analytical framework reorganizes the PPEB documentation into a practical decision-support tool. The target-



prioritization analysis employs a qualitative weighting framework based on two dimensions: (a) design-stage weight, representing each target’s combined influence on the overall certification rating and its sensitivity to early design decisions; and (b) cost uplift, representing the incremental cost of upgrading from the Excellent to the Exceptional provision. Both dimensions were evaluated using the P P E B documentation together with standard A M O practice benchmarks (Zegarra 2021). Design-stage weight scores were assigned by the research team through a structured interpretation of the P P E B target definitions and the Certivéa H Q E™ Tertiary Building Referential, cross-referenced with the documented target-prioritization rationale prepared by the Bureau Veritas A M O team. Cost-uplift ratings (Low/Medium) represent qualitative benchmarks derived from standard Moroccan public procurement cost data and were not independently quantified. This limitation is acknowledged, and a sensitivity discussion is provided in the Discussion section. Future research should incorporate inter-rater reliability testing to validate these assignments across multiple A M O firms and project settings. [13]

Target Prioritization and Critical Path Analysis

The complete Building Environmental Performance Profile (P P E B) comparison matrix for all fourteen H Q E™ targets is presented in table 4, together with the performance levels assigned to each scenario and the key provisions required to achieve the Exceptional certification level.

RESULTS: SCENARIO ANALYSIS ACROSS
THE 14 H Q E™ TARGETS

*Analysis of the Eco-Construction Targets (C1–C3):
Site, Materials, and Construction Practices*

The three Eco-Construction targets address the building’s relationship with its surrounding environment, the selection of construction products and processes, and the management of construction-site impacts. In the Excellent scenario, Targets C1–C3 are rated ‘Performing,’ while in the Exceptional scenario they are upgraded to ‘Very Performing.’ Although these targets involve relatively modest

TABLE 4 Comparison of the PPEB Target Matrix for the Excellent and Exceptional Certification Scenarios Across All Fourteen HQE™ Targets, Including the key Measures Required to Achieve the Higher Certification Level

[14]

(1)	(2)	(3)	(4)	(5)
C 1	Site and environment integration	Performing (P)	Very Performing (VP)	Albedo ≥ 0.45 ; solar-powered EV charging stations; 100% permeable paving in landscaped areas
C 2	Construction products and LCA	Performing (P)	Very Performing (VP)	$\geq 50\%$ of materials with Environmental Product Declarations (EPDs); bio-based insulation; design-for-disassembly connections
C 3	Low- impact construction site	Performing (P)	Very Performing (VP)	$\geq 70\%$ construction waste recovery; real-time water and electricity metering on site; community communication plan
C 4	Energy management	Performing (P)	Very Performing (VP)	VRF/DRV system (heating COP ≥ 3.5 ; cooling COP ≥ 4.0); 20 kWp PV; Class A BMS; target BECTH ≤ 30 kWh/m ² /year
C 5	Water management	Performing (P)	Very Performing (VP)	Dual-flush toilets (≤ 3 l/flush); sensor-operated faucets; rooftop rainwater harvesting for irrigation; $\geq 50\%$ potable water saving
C 6	Operational waste management	Good (B)	Performing (P)	Covered waste-sorting area ≥ 8 m ² ; dedicated compactor area; waste-tracking register
C 7	Maintenance and durability	Performing (P)	Very Performing (VP)	Digital O&M manual (BIM-linked); all equipment accessible within 0.6 m; 10-year maintenance plan

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cost increases and exhibit low-to- moderate lock-in risk, they have a level of reputational and contextual significance that exceeds their direct contribution to the overall certification score. For C 1 (Site Integration), the transition from Excellent to Exceptional requires an optimized surface albedo (target surface reflectance ≥ 0.45 for all hardscape surfaces), solar-powered EV charging stations aligned with Morocco’s national EV strategy, and 100% permeable paving in



TABLE 4 Continued from the previous page

(1)	(2)	(3)	(4)	(5)
C 8	Hygrothermal comfort	Performing (P)	Very Performing (VP)	Operative temperature of 20–26° C year-round; automated night free-cooling ≥ 150 h/year; IoT sensor network
C 9	Acoustic comfort	Performing (P)	Very Performing (VP)	Partition sound insulation $R_w \geq 40$ dB; $RT_{60} \leq 0.6$ s (offices); $NR \leq 35$ (open-plan offices); floating floor in the IT room
C 10	Visual comfort	Performing (P)	Very Performing (VP)	Daylight factor $\geq 2.5\%$ across $\geq 80\%$ of work surfaces; $UGR \leq 19$; automated Venetian blinds; maintained illuminance of 300 lux
C 11	Indoor air quality (olfactory comfort)	Performing (P)	Very Performing (VP)	$CO_2 \leq 800$ ppm; $VOC \leq 300 \mu g/m^3$; F 7 pre-filter and F 9 final filter; A+ low-emission paint specification throughout
C 12	Sanitary quality of spaces	Performing (P)	Very Performing (VP)	Biophilic wall panels; 1 plant per 15 m ² ; active-design staircase (natural light and wayfinding); ergonomic workstations
C 13	Sanitary quality of indoor air	Good (B)	Performing (P)	Real-time PM _{2.5} display in the lobby; supplemental HEPA filtration in meeting rooms; campus-wide no-smoking policy
C 14	Sanitary quality of water	Performing (P)	Very Performing (VP)	Thermostatic mixing valves; Legionella risk management plan; elimination of dead legs throughout the distribution system

NOTES Column headings are as follows: (1) target, (2) description, (3) scenario 1 ‘Excellent’ (10 stars), (4) scenario 2 ‘Exceptional’ (13 stars), (5) key transition provision. Adapted from the Bureau Veritas PPEB.

[15]

landscaped areas to improve stormwater management and mitigate the urban heat-island effect. These measures directly address the climatic conditions of the Gharb Plain, where dark paved surfaces measurably contribute to elevated summertime temperatures. The principal decision gate for these measures is the landscape design brief,

TABLE 5 Responsibility Matrix Assigning the 14 HQE™ Targets to the Relevant Technical Disciplines and Responsible Parties

[16]

(1)	(2)	(3)
Architecture	Architect (Maître d'Oeuvre)	C 1 (site integration, albedo, soft mobility); C 2 (material specifications, LCA coordina- tion); C 8 (thermal inertia, passive solar de- sign); C 10 (façade geometry, daylight factor); C 12 (biophilic design, active staircase)
HVAC and Flu- ids	Fluid Engineer- ing Consultant	C 4 (VRE/DRV sizing, PV inverter coordi- nation, BMS logic); C 5 (plumbing, rainwa- ter harvesting, sensor-operated fixtures); C 8 (free-cooling control, humidity set-points); C 11 (filtration specification, ACH verifica- tion); C 13 (mechanical exhaust); C 14 (ther- mostatic valves, dead-leg elimination)
Electrical and BMS	Electrical Engi- neering Consul- tant	C 4 (metering, load-balancing, BMS – Class A configuration); C 7 (predictive maintenance alerts); C 10 (lighting controls, dimming, cir- cadian lighting); C 13 (PM 2.5 and CO ₂ moni- toring)
Acoustics	Acoustical Con- sultant	C 9 (partition Rw specification, floating floor design, RT60 calculation, acoustic review)
Environmental Performance/ LCA	HQE™ AMO (Bureau Veri- tas)	All 14 targets: PPEB development, design audits, certification documentation, DTS model review, scenario comparison, and final Certivéa submission
Construction	General Con- tractor (lots co- ordination)	C 3 (construction waste management, re- source metering, community liaison); C 6 (waste-sorting facilities); C 7 (O&M documen- tation, BIM handover)

NOTES Column headings are as follows: (1) technical discipline, (2) responsible party, (3) associated targets and primary responsibilities.

which must be finalized before the Avant-Projet Définitif (APD). Beyond this stage, modifications to paving layouts or drainage geometry would require costly redesign of the civil works. For C 2 (Construction products), the Exceptional scenario requires that at least 50% of construction materials (by value) carry verified Environmental Product Declarations (EPDs) compliant with EN 15804; that bio-based insulation materials be used for non-structural building el-

TABLE 6 Critical-Path Prioritization of the 14 HQE™ Targets According to Design-Stage Importance, Cost Uplift, Lock-in Risk, and the Primary AMO Decision Gate

(1)	(2)	(3)	(4)	(5)	(6)
C 4	National energy policy; HQE prerequisite	5	Medium	High. HVAC system selection determines the project's energy pathway at the concept stage	Confirm the VRF system and PV capacity before Avant-Projet Sommaire (APS)
C 8	Thermal comfort and interaction with C 4	5	Low	High. orientation and thermal-mass decisions become irreversible early in design	Confirm orientation, glazing ratio, and thermal-mass strategy during preliminary design
C 10	Daylighting geometry; interaction with C 8	4	Low	High. Atrium geometry and WWR are fixed during design development	Finalize atrium dimensions and facade WWR before Avant-Projet Définitif (APD)
C 5	Water scarcity, operational savings; BMS integration	4	Medium	Medium. Plumbing layout remains adjustable until APD	Select dual-flush fixtures, sensor-operated faucets, and rainwater storage during APD
C 2	Procurement lead time for certified materials	3	Medium	Medium. Material procurement schedule is fixed at the tender stage	Include EPD requirement in the Bill of Quantities and pre-qualify suppliers
C 9	Partition and floor-system design	3	Medium	Medium. Acoustic floor assemblies are established during structural design stage	Confirm floating-floor requirements for the IT room during structural APD
C 1	Site planning and landscape design	3	Low	Low. Landscape design remains flexible through DCE	Include albedo and soft-mobility requirements in the landscape brief

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[17]

ements (such as compressed hemp batt or cork, the latter already incorporated in the AUKSS roof assembly because of its favorable

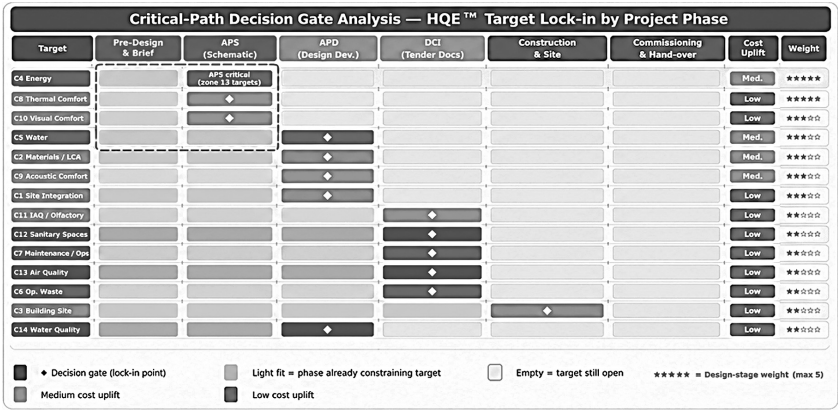
TABLE 6 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)	(6)
C13	Indoor air quality monitoring	2	Low	Low. Equipment can be specified during detailed design	Specify PM _{2.5} and CO ₂ monitoring equipment and BMS integration during DCE
C3	Construction-site management	2	Low	Low. Requirements are contractual	Include the Green Construction Site Charter and waste-recovery targets in the construction contract
C6	Waste-sorting facilities	2	Low	Low. Layout remains adjustable through APD	Reserve $\geq 8 \text{ m}^2$ for the waste-sorting room adjacent to the service entrance in floor plan
C7	O&M documentation and BIM deliverables	2	Low	Low. Contractual deliverable	Include digital O&M manuals and BIM handover requirements in the CCP
C11	Air filtration and maintenance access	2	Low	Low. Duct routing remains adjustable during MEP coordination stage	Confirm filtration (F7 + F9) and 0.6 m maintenance clearance in the HVAC design brief
C12	Biophilic and ergonomic design	2	Low	Low. Interior finishes are specified during the tender phase	Include biophilic design features and the active-staircase concept during APD
C14	Water system safety	1	Low	Low. Primarily a regulatory compliance issue	Include thermostatic mixing valves and a Legionella risk management plan in the plumbing specifications

NOTES Column headings are as follows: (1) target, (3) prioritization driver, (3) design-stage weight, (4) cost uplift, (5) lock-in risk, (6) primary AMO decision gate.

hygrothermal properties); and that structural connections be designed for disassembly to facilitate future material recovery without destructive demolition. Because these requirements directly affect the bill of quantities and contractor prequalification criteria, they introduce supply-chain constraints that must be addressed before issuance of the Dossier de Consultation des Entreprises (DCE). It





[19]

FIGURE 2 Critical-Path Decision-Gate Analysis

NOTES The filled diamonds indicate the project phase at which the key decisions for each HQE™ target become effectively irreversible. Targets are ranked according to their design-stage weight. The dashed box highlights the three highest-priority targets (C4, C8, and C10), all of which must be finalized by the APS (schematic design) stage.

should be noted that EN 15804-compliant EPD-certified products remain relatively scarce in the Moroccan market. The AUKSS specification addresses this limitation by permitting imported bio-based materials (e.g., cork and hemp) and accepting EPDS verified under equivalent European standards. Procurement teams should anticipate potential lead-time extensions of approximately 6–8 weeks when sourcing EPD-certified products and should explicitly identify this risk during contractor prequalification. For C3 (Low-impact construction site), the Exceptional scenario requires a resident communication plan that includes at least monthly written updates for neighboring occupants, real-time monitoring of on-site electricity and water consumption with monthly reporting to the contracting authority, and a minimum construction waste recovery rate of at least 70% by weight, segregated by material stream. These measures are implemented through the Green Construction Site Charter and the Cahier des Clauses Administratives Particulées (CCAP) as contractual obligations of the general contractor. Because they can be incorporated into the procurement documents without affecting earlier design decisions, their lock-in risk is considered low.

Eco-Management Targets (C4–C7): Energy, Water, Waste, and Maintenance

[20]

The four Eco-Management targets constitute the most influential category in the HQE™ certification system because they carry the greatest weight in the star-rating methodology and depend on design decisions made during the earliest project phases. The most critical of these is Target C4 (Energy management), whose performance level determines eligibility for the highest certification tier. After the Avant-Projet Sommaire (APS) stage, its principal technical decisions – the selection of the HVAC system type, the integration of on-site renewable energy, and the BMS specification, become effectively irreversible. To achieve the Exceptional level, C4 requires a 20 kWp rooftop photovoltaic system capable of supplying approximately 30% of the building's annual electricity demand; a Variable Refrigerant Flow (VRF/DRV) system serving the north-facing occupied spaces with a heating COP of at least 3.5 and a cooling COP of at least 4.0; a Building Management System (BMS) rated Class A under the French RE2020/RTCM classification; and a target BECTH of less than 30 kWh/m²/year, substantially below the RTCM Zone Z2 requirement of 49 kWh/m²/year. By comparison, the Excellent scenario specifies standard-efficiency equipment (COP > 3.0), without on-site photovoltaic generation or a Class A BMS. Target C5 (Water management) progresses from basic low-flow plumbing fixtures in the Excellent scenario to a comprehensive water-efficiency strategy in the Exceptional scenario. This strategy includes dual-flush WCs with a maximum flush volume of 3 liters, pressure-compensating sensor-operated faucets with a maximum flow rate of 1.5 liters per minute, a rooftop rainwater harvesting cistern with a minimum storage capacity of 10 m³ for landscape irrigation, and a monitored annual water consumption target at least 50% below the conventional baseline. This target is particularly significant given the increasing water stress affecting the Gharb region despite its relatively high atmospheric humidity. Although rainwater harvesting is technically feasible due to approximately 600–700 mm of annual precipitation, the practice remains uncommon in Moroccan public buildings because it is not mandated by regulation.



The management dimension of Eco-Management is represented by Targets C6 (Operational Waste Management) and C7 (Maintenance and Durability). For C6, the Exceptional scenario requires a covered waste-sorting area of at least 8 m² adjacent to the service entrance, a dedicated compactor area, and a digital waste-tracking register integrated with the BMS. For C7, the transition from Excellent to Exceptional introduces a BIM-linked digital Operations and Maintenance (O&M) manual. This requirement creates a specific BIM deliverable that must be included in the contractor's obligations and specified in the CCAP before the procurement process begins. Although BIM-linked O&M documentation is increasingly common in French public procurement, it remains relatively uncommon in Moroccan practice, making it a potentially transferable best practice for future HQE projects in the country. To minimize long-term performance degradation in complex automated building systems, particularly the BMS-controlled night free-cooling strategy, the Exceptional scenario also incorporates a structured operator-training program. This program requires at least 16 hours of commissioning-stage training for facility management personnel, annual BMS audits by the AMO during the first three years of operation, and the delivery of a digital twin linked to the BIM model, enabling operators to simulate changes in control set-point before implementation. These training requirements are established as contractual obligations within the CCAP rather than a post-occupancy recommendations.

[21]

Comfort Targets (C8–C11): Thermal, Acoustic, Visual, and Olfactory

The four Comfort targets directly influence occupant well-being, productivity, and the long-term operational performance of the building as a functional workspace. Their prioritization logic differs from that of Eco-Management targets. Whereas C4 and C5 depend primarily on equipment selection, the Comfort targets are governed largely by geometric and passive design decisions that must be resolved during the concept and preliminary design stages. Target C8 (Hygrothermal Comfort) is closely coupled with target C4 (Energy Management), because the same HVAC system responsible for min-

[22]

imizing energy consumption must also maintain indoor conditions within the ASHRAE 55-2017 thermal comfort envelope (operative temperature of 23–26° C and indoor air velocity ≤ 0.17 m/s) throughout the year. Beyond these baseline requirements, the Exceptional scenario introduces two additional provisions: a distributed IoT sensor network providing real-time temperature and relative humidity data at the zone level for adaptive BMS control, and automated night free cooling for at least 150 hours annually during the Kenitra shoulder seasons. This strategy exploits the Atlantic-Mediterranean diurnal temperature variation, which may reach 12–15° C during the spring and fall, thereby reducing cooling energy demand. The lock-in risk associated with C8 is classified as High because the building's thermal mass (the principal passive contributor to hygrothermal stability) is determined by the structural system and floor-slab specification, both of which are fixed during the structural APD stage. The dynamic thermal simulations (DTS) conducted for the AUKSS project used the current RTCM-referenced Kenitra Typical Meteorological Year (2019) weather file. Future climate conditions were not evaluated using projected IPCC 2050 or 2080 weather scenarios, representing a limitation of the analysis: projected increases of approximately 1.5–2.5° C in peak summer temperatures across the Gharb region under RCP4.5 and RCP8.5 scenarios could reduce the effectiveness of passive night free cooling by as much as 30% of its current contribution of approximately 150 per year. The authors recommend that future public building projects in RTCM Climate Zone Z2 should therefore incorporate morphing techniques and future-climate weather files (e.g., CCWorldWeatherGen or Climate.OneBuilding) into DTS to verify the long-term robustness of passive cooling strategies. Target C10 (Visual Comfort) also exhibits a high in lock-in risk because its principal determinants, the geometry and height of the central atrium, the floor-plate width-to-height ratio, and the glazing-to-building-envelope-volume ratio (WWR), are established during concept design stage. The Exceptional scenario requires a Daylight Factor (DF) of at least 2.5% across 80% of occupied work surfaces, uniform glare control ($UGR \leq 19$), and automated Venetian blinds that track the sun's position to minimize di-



rect glare while preserving diffuse daylight. Achieving the target DF of at least 2.5% on all four floor levels, including the partially shaded ground floor, requires radiance simulations to validate atrium geometry before concept design is finalized. The AUKSS dynamic thermal simulations also identified an important design trade-off between visual comfort (C10) and thermal performance (C8). Increasing the glazed area of the central atrium initially increased peak cooling demand by approximately 8–12% before solar-control measures were optimized. This conflict was resolved through automated Venetian blinds and high-performance solar-control glazing (g-value ≤ 0.35 on east- and west-facing façades), highlighting the importance of jointly optimizing C8 and C10 during concept design rather than addressing the two targets sequentially. Target C9 (Acoustic Comfort) occupies an intermediate position between passive architectural design and specialist engineering. The Exceptional scenario requires partition sound insulation of at least $R_w 40$ dB for all enclosed office spaces and meeting rooms, a reverberation time (RT60) of no more than 0.6 seconds in occupied office areas, a background noise criterion of $NR \leq 35$ for open-plan workstations, and a floating floor assembly in the IT room to reduce structure-borne vibration from server equipment and HVAC systems. The floating floor represents the principal lock-in-risk because the acoustical consultant must be engaged before completion of the structural APD to ensure that the additional structural loads are incorporated into the building design. Target C11 (Indoor Air Quality/Olfactory Comfort) is primarily a procurement and technical specification target. Although it has relatively low lock-in risk, it has substantial implications for occupant health. The Exceptional scenario requires a two-stage filtration system consisting of F7 pre-filters and F9 final filters for all outdoor air handling units, indoor CO₂ concentrations not exceeding 800 ppm in all occupied spaces (requiring demand-controlled ventilation or per-room CO₂ sensors), total VOC concentrations below 300 $\mu\text{g}/\text{m}^3$, and A+ rated low-emission interior finishes (including paints, adhesives, and floor coverings). The bill of quantities must therefore incorporate the A+ material specification before issuance of the Dossier de Consultation des Entreprises (DCE).

[23]

Health Targets (C12–C14): Sanitary Quality of Spaces, Air, and Water

[24]

Beyond the comfort-related criteria addressed by Targets C8–C11, the three Health targets focus on occupant safety, well-being, and the hygienic quality of the indoor environment. Collectively, they encompass water safety management, indoor environmental health-monitoring infrastructure, and biophilic design, making this the most comprehensive thematic category within the HQETM framework. Target C12 (Sanitary Quality of Spaces) exhibits the greatest difference in design ambition between the Excellent and Exceptional scenarios. The Excellent scenario satisfies ergonomic workstation requirements and specifies non-toxic, easy-to-clean interior finishes. The Exceptional scenario introduces biophilic design principles, a scientifically supported approach to integrating natural elements into the built environment to reduce physiological stress, lower cortisol levels, and enhance cognitive performance. The required measures include living wall panels, a minimum of one potted plant per 15 m² of occupied floor area, and a central vertical garden feature at the ground level of the atrium. Complementing the biophilic strategy, the Exceptional scenario also requires an ‘active design’ staircase. This primary circulation stair must be naturally illuminated, prominently positioned within the building’s spatial hierarchy, and equipped with wayfinding graphics and informational displays that encourage stair use instead of elevators – a design intervention that has been shown to increase occupants’ physical activity. Target C13 (Sanitary Quality of Air) builds upon the indoor air quality provisions established under C11 by introducing an additional monitoring and communication layer. The Exceptional scenario requires a real-time PM_{2.5} and CO₂ display at the building entrance to provide occupants and visitors with continuous air quality information; supplemental HEPA filtration units in all meeting rooms (where intermittent high occupancy places greater demands on the primary ventilation system); and enforcement of a comprehensive no-smoking policy throughout the entire site, including adjacent parking and landscaped areas. Because these measures are primarily operational rather than design-related, their lock-in risk



is relatively low. To verify the anticipated health and productivity benefits of the biophilic and active design interventions introduced under C12, post-occupancy evaluation will be conducted using validated assessment tools, including the Work Environment Survey (WES) and WELL Performance Testing protocols for biophilic element density and occupant well-being. These assessments will be complemented by objective indicators, including objective absenteeism rates and anonymized movement- sensor data monitoring staircase usage. The evaluation protocols will be incorporated into the Operations and Maintenance plan (O&M) plan developed under Target C7 to ensure continuity between design intent and operational performance. Target C14 (Sanitary Quality of Water) addresses Legionella prevention and protection against scalding. The Exceptional scenario requires thermostatic mixing valves at all user-accessible hot-water outlets, a systematic survey to eliminate dead legs throughout the water distribution system during commissioning, and a formal Legionella risk management plan consistent with World Health Organization (WHO) guidance and French DTU 60.1 standards referenced by the RTCM. These requirements represent detailed engineering provisions that can be incorporated into the plumbing specification during the APD stage.

[25]

DISCUSSION

The Process Gap: Why Certification Outcomes Are Determined Before Construction Begins

The critical-path analysis presented in table 6 demonstrates that at least four of the fourteen HQE™ targets (C4, C8, C10, and C5) are effectively determined by decisions made before or during the Avant-Projet Sommaire (APS) phase. In standard Moroccan public procurement, this corresponds to the schematic design stage, typically occurring within the first 10–15% of the overall project timeline. This finding has important implications for HQE AMO practice. Once the HVAC system type (C4), building orientation and structural thermal mass (C8), atrium geometry and glazing-to-building-envelope-volume ratio (TGBV) (C10), and below-grade civil works associated with the rainwater harvesting system (C5) have been established,

TABLE 7 Complete Transition Matrix from the Excellent to the Exceptional Certification Scenario for All 14 HQE™ Targets, Including Thematic Domain and Primary Design Decision Gate

	(1)	(2)	(3)	(4)	(5)
[26]	c 1	Site	Rainwater management; basic landscaping; bicycle parking	Surface albedo ≥ 0.45 ; solar-powered EV charging stations; 100% permeable paving in landscaped areas; biodiversity index documented	Site planning and landscape design brief
	c 2	Materials	Locally certified materials; limited use of EPDS; standard construction waste plan	$\geq 50\%$ of materials covered by Environmental Product Declarations (EPDS); bio-based insulation; design for structural disassembly	Bill of Quantities; supplier pre-qualification
	c 3	Construction-site impacts	Green Construction Site Charter; basic waste segregation	$\geq 70\%$ construction waste recovery; real-time electricity and water metering; monthly community communication reports	Contract documents (CCAP)
	c 4	Energy	Equipment with COP ≥ 3.0 ; standard BMS; no PV system	VRF/DRV system (heating COP ≥ 3.5 ; cooling COP ≥ 4.0); 20 kWp PV system; Class A BMS; BECTh ≤ 30 kWh/m ² /year	APS – HVAC and electrical design brief
	c 5	Water	Low-flow fixtures; no rainwater harvesting	Dual-flush WCS (≤ 3 l/flush); sensor-operated faucets; 10 m ³ rainwater storage tank; $\geq 50\%$ potable water savings	APD – plumbing and civil works
	c 6	Operational waste	Waste-sorting room provided; no formal tracking	Covered waste-sorting area ≥ 8 m ² ; dedicated compactor area; digital waste-tracking register	APD – floor plan allocation

Continued on the next page

the range of achievable certification outcomes becomes largely fixed. The remaining ten targets, although still important, can generally be addressed through specification and procurement decisions during



TABLE 7 Continued from the previous page

(1)	(2)	(3)	(4)	(5)
C 7	Maintenance	Paper O&M manuals; standard maintenance access	BIM-linked digital O&M manual; all equipment accessible within 0.6 m; 10-year maintenance contract	DCE – BIM deliverable requirements
C 8	Thermal comfort	ASHRAE 55 compliance; manual shading	Automated night free-cooling ≥ 150 h/year; IoT sensor network; BMS temperature control within $\pm 0.5^{\circ}\text{C}$	Preliminary design – orientation and thermal-mass strategy
C 9	Acoustic comfort	Moroccan code compliance; standard partitions ($R_w \geq 35$ dB)	Partitions with $R_w \geq 40$ dB; $RT_{60} \leq 0.6$ s (offices); floating floor (IT room); $NR \leq 35$	Structural APD – floating-floor design
C 10	Visual comfort	Daylight factor (DF) $\geq 1.5\%$ in offices; manual Venetian blinds	$DF \geq 2.5\%$ across $\geq 80\%$ of work surfaces; $UGR \leq 19$; automated blind control; maintained illuminance of 300 lux	Concept design – atrium and WWR
C 11	Indoor air quality	Standard ventilation; F5 filtration; general A+ finish specification	$CO_2 \leq 800$ ppm; $VOC \leq 300 \mu\text{g}/\text{m}^3$; F7+F9 two-stage filtration; room-level CO_2 sensors	APD – HVAC filtration and ductwork
C 12	Sanitary quality of spaces	Ergonomic workstations; non-toxic materials	Biophilic wall panels; 1 plant per 15 m^2 ; active-design staircase (natural daylight); wellness breakout areas	APD interior design brief
C 13	Sanitary quality of air	General A+ interior finishes; no real-time monitoring	Real-time PM _{2.5} and CO_2 display in the lobby; HEPA filtration in meeting rooms; site-wide no-smoking policy	DCE – BMS and monitoring system specification
C 14	Sanitary quality of water	Standard plumbing code compliance	Legionella risk management plan; thermostatic mixing valves; dead-leg elimination survey	APD – detailed plumbing design

[27]

the APD and DCE stages without requiring major revisions to the building design.

[28]

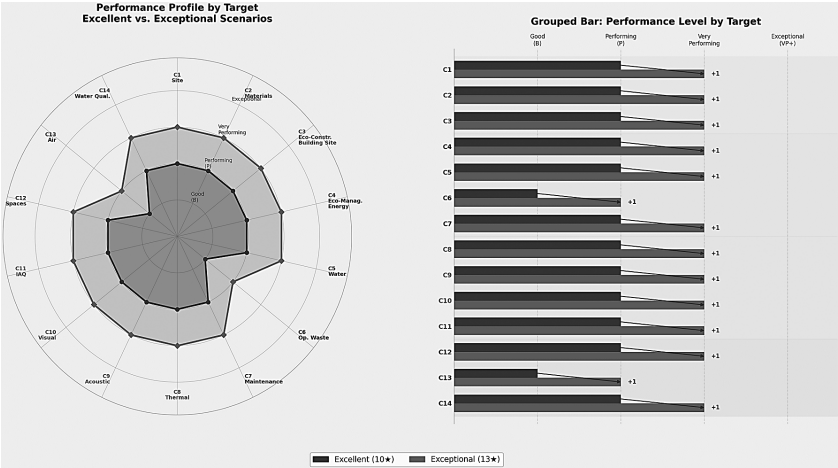


FIGURE 3 Performance Profiles of the Excellent (10-star) and Exceptional (13-star) HQE™ Certification Scenarios Analyzed in This Study

NOTES Left: radar chart illustrating the performance profile of each certification scenario. Right: grouped horizontal bar chart; red arrows indicate targets upgraded from Performing to Very Performing. Colors correspond to the four HQE™ thematic domains.

This structural asymmetry between early design decisions and later specification-based decisions has direct implications for the role of the AMO. The greatest opportunity for influencing HQE certification occurs during the preliminary design and APS phases, rather than during the preparation of construction documents, where most technical specifications are finalized. An AMO appointed only at the APD stage or later – a common practice in Moroccan public procurement, where environmental consultants are frequently engaged after the initial design has been completed – has little opportunity to influence the four highest-weighted targets. Consequently, achieving an Exceptional certification becomes unlikely regardless of the quality of the subsequent technical specifications. Three principal administrative and legal barriers contribute to delayed AMO appointment in standard Moroccan public procurement: (i) the standard *Cahiers des Clauses Techniques Particulières* (CCTP) and *Cahiers des Clauses Administratives Particulières* (CCAP) do not define a dedicated HQE™ AMO mission, requiring contracting

authorities to develop project-specific procurement documents; (ii) Decree No. 2-22-431 (Morocco 2023) requires competitive procurement for intellectual services exceeding MAD 500,000, potentially delaying AMO appointment by 3–6 months beyond the start of preliminary design; and (iii) awareness remains limited among urban planning committees regarding the decisive influence of the preliminary design stage on HQE™ certification outcomes. Addressing these barriers will require the explicit incorporation of early AMO appointment into national public building procurement guidance. The AUKSS case study provides practical evidence supporting this reform. More broadly, the findings extend existing Certivéa guidance on early AMO involvement by demonstrating, through a documented case study, how early engagement influences certification outcomes and by providing an empirical basis for advocating earlier AMO appointment in future public procurement frameworks. [29]

*The Cost Argument: Modest Modest Cost Premiums
for Significant Performance Gains*

A persistent barrier to ambitious environmental certification in public procurement within developing countries is the perception that achieving high certification levels requires prohibitively expensive investments. The AUKSS case study challenges this assumption. As shown in table 6, nine of the fourteen provisions required to transition from the Excellent to the Exceptional certification scenario are classified as having low cost uplift, indicating that their incremental cost relative to the Excellent baseline falls within the typical contingency allowance of a well-managed public construction project. The four provisions classified as medium-cost-uplift (C4, C5, C2, and C9) all correspond to measures with demonstrable life-cycle economic benefits. The VRF system and rooftop PV installation have an estimated simple payback period of approximately 7.01 years. The rainwater harvesting system reduces municipal water costs, with estimated payback periods generally below ten years under prevailing Moroccan water tariffs. As the Moroccan construction supply chain continues to mature, EPD-certified and bio-based materials are becoming increasingly cost-competitive with conven-

[30] tional alternatives. Similarly, the enhanced acoustic performance reduces productivity losses associated with open-plan office noise, a benefit that has been consistently documented in post-occupancy research. The only measure that represents a primarily capital expenditure without a direct economic return is the floating floor required for the IT room, which is justified primarily by equipment protection requirements rather than merely occupant comfort. To provide an indication of the overall financial implications, the combined capital cost premium associated with the four medium-cost-uplift measures (C4: VRF system and 20 kWp PV installation; C5: rainwater harvesting cistern; C2: EPD-certified materials; and C9: floating-floor assembly) is estimated at approximately 8–12% of the total construction cost, or roughly €150–220/m² based on 2019 Moroccan public construction prices. These figures represent order-of-magnitude estimates derived from the PPEB documentation and standard Moroccan public procurement cost benchmarks. A comprehensive life-cycle cost (LCC) analysis over a 30–50-year service life, incorporating capital costs, maintenance, energy savings, and water savings, remains an important priority for future research and would provide a more robust economic evaluation of the Exceptional certification scenario within the Moroccan public procurement context.

A key finding is that none of the fourteen transition measures can be classified as a high cost-uplift intervention. This observation supports the central hypothesis of the present study: within the Moroccan public procurement context, the principal barrier to achieving Exceptional HQE™ certification is not financial but procedural. Success depends primarily on early decision-making, integrated design coordination, and timely engagement of the AMO rather than on prohibitive capital investment.

The Moroccan Context: Institutional Replicability

The institutional role of the AUKSS as an Urban Agency – an organization that both enforces building regulations and occupies a building subject to those regulations – gives the project exceptional potential for replication across Morocco's public building portfolio.



lio. Morocco has 22 Urban Agencies, each responsible for a defined geographic jurisdiction and each managing a comparable portfolio of institutional facilities, including headquarters, district offices, and documentation centers. These buildings closely resemble the AUKSS case: multi-story administrative buildings with floor areas typically ranging from 2,000 to 6,000 m², located in Mediterranean or semi-arid climatic zones and procured through standard public procurement procedures. The PPEB methodology and target prioritization framework developed for the AUKSS project can therefore be transferred directly to this building portfolio without modification of its analytical structure, requiring only the substitution of site-specific climatic data and the applicable RTCM climate-zone thresholds. [31]

More broadly, the proposed process framework is applicable to public tertiary buildings throughout the Mediterranean region seeking Exceptional HQE™ certification in regulatory contexts characterized by: (a) a mandatory thermal-energy regulation comparable to the RTCM; (b) an AMO function performed by a certified third-party consultant; and (c) a procurement process following the standard French-influenced phased design sequence of preliminary design, APS, APD, DCE, construction, and commissioning. These characteristics suggest broader applicability of the framework. However, its transferability to other jurisdictions, including Tunisia, Algeria, and the French overseas territories, should be validated through multiple case studies before broader generalizations are made.

Comparison with the Literature and Study Limitations

The finding that early design decisions exert the greatest influence on multi-criteria certification outcomes is consistent with both the design lock-in literature and the literature on integrated design processes (IDPS) for sustainable buildings. However, the identification of Targets C4, C8, and C10 as the three highest-priority early lock-in targets within a Mediterranean climate represents a novel contribution. Studies conducted in temperate European climates typically identify C4 (Energy Management) and C8 (Thermal Comfort) as the dominant early design drivers but place less emphasis on C10

(Visual Comfort), largely because atrium-based daylighting strategies are less common in European administrative buildings than in Moroccan and other North African contexts, where daylighting and natural ventilation are integral components of the bioclimatic design tradition.

The principal limitation of this study is its single-case-study design. The PPEB data were derived from one building, evaluated by one AMO firm, within a single climatic zone. Consequently, the generalizability of the target-prioritization framework, design-stage weighting, and lock-in risk ratings requires validation comparative analyses involving multiple projects. In particular, the lock-in risk ratings and target weights presented in table 6 reflect the specific conditions of an RTCM Zone Z2 climate and a multi-story administrative building typology. Their applicability to other Moroccan climate zones (e.g., Zones Z3–Z6, encompassing arid and semi-arid regions) or to other public building types, such as schools or health facilities, should be verified, as the relative importance of Targets C8 and C10 is likely to vary with climatic conditions and passive design strategies. A further limitation is that the PPEB is a pre-construction, design-stage document. Consequently, the present study evaluates anticipated rather than measured building performance. Post-occupancy evaluation will therefore be essential to determine whether the Exceptional certification provisions were implemented as intended and whether they achieved the projected improvements in environmental performance and occupant well-being. Future assessment of the AUKSS building should include calibrated monitoring of energy consumption, water use, indoor environmental quality, and occupant comfort to provide the validation data that are currently lacking in the Moroccan HQE™ literature.

CONCLUSION

This study demonstrates that achieving high environmental performance in public buildings cannot be accomplished solely through the integration of energy-efficient technologies; it also requires a structured governance framework capable of guiding design, construction, and operational decisions throughout the building lifecycle.



To address this need, the study proposes an integrated assessment framework for evaluating the environmental performance of sustainable public buildings in Mediterranean climates. The framework was applied to a representative case study in northwestern Morocco (34.26° N), within RTCM Climate Zone Z2 (Tangier reference zone), which is characterized by a humid Atlantic-Mediterranean climate. [33]

The analysis focused on the headquarters of the Kenitra–Sidi Kacem–Sidi Slimane Urban Agency (AUKSS), a four-story public administrative building with a conditioned floor area of 4,394 m², enabling a comprehensive and multi-dimensional assessment of its environmental performance. The study also presents the first process-based analysis of HQE™ International certification for a Moroccan public administrative building. By reorganizing the Building Environmental Performance Profile (PPEB) into a decision-support framework linking each of the fourteen HQE™ targets to design-stage priorities, cost implications, lock-in risks, responsible stakeholders, and key decision gates, the research advances sustainability assessment methodologies for public buildings in Mediterranean emerging economies. More broadly, it bridges the gap between regulatory compliance and performance-driven design by providing both a methodological framework for future research and a practical decision-support tool for improving the environmental performance of public buildings.

The study makes three principal contributions. First, it provides an empirical contribution through a comprehensive comparison of the Excellent and Exceptional HQE™ certification scenarios across all fourteen targets (table 4), identifying the technical and organizational measures required to achieve the higher certification level. To the authors' knowledge, this is the first comprehensive scenario comparison reported for an HQE™-certified public building in Morocco. Second, it makes an analytical contribution by identifying a four-target critical path comprising C4 (Energy Management), C8 (Hygrothermal Comfort), C10 (Visual Comfort), and C5 (Water Management) whose defining design decisions become effectively irreversible after the Avant-Projet Sommaire (APS) stage. This find-

[34] ing underscores the importance of early-stage interdisciplinary coordination and redefines the AMO's principal role as one of strategic design coordination during the preliminary design phase rather than technical supervision during later project stages. Third, the study contributes a transferable prioritization framework (table 6) that supports target sequencing, budget planning, and decision scheduling for comparable public building projects in Mediterranean climates. The findings demonstrate that progressing from Excellent to Exceptional HQE™ certification requires relatively modest additional investment or technological innovation. Instead, success depends primarily on earlier decision-making, stronger interdisciplinary collaboration, and clearer allocation of responsibilities. These results support the central conclusion that the gap between the two certification levels is driven principally by project governance rather than by technological capability or financial constraints. The implications extend beyond the Moroccan context. For multi-criteria environmental certification systems, governance – including the timing of consultant appointments, stakeholder coordination, and performance management – may have a greater influence on certification outcomes than project budget alone.

Future research should validate the proposed framework through multiple case studies across different RTCM climate zones, incorporate post-occupancy performance evaluation, and develop comprehensive costbenefit and life-cycle cost models integrating long-term energy, water, maintenance, and occupant performance indicators.

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