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DEVELOPMENT OF ENERGY-SAVING TECHNOLOGIES IN CONSTRUCTION AND DESIGN

Abstract

In the contemporary landscape of 2026, the intersection of technical aesthetics and ecological responsibility has become the primary catalyst for architectural discourse in Azerbaijan. This research explores the metamorphosis of design philosophies following the COP29 summit, focusing on how energy-saving technologies have transcended their functional origins to become fundamental elements of visual composition. The study examines the aesthetic integration of Building-Integrated Photovoltaics (BIPV), the reconsidered materiality of traditional "Aglay" limestone, and the role of generative AI in shaping the aerodynamic forms of Baku's skyline. By analyzing the "Smart City" projects in the liberated territories, the author argues that the new Azerbaijani aesthetic is defined by a "form-follows-energy" paradigm, where sustainable performance dictates the rhythm, texture, and light within the built environment. This article provides a comprehensive framework for designers to harmonize local cultural semiotics with the high-tech requirements of carbon neutrality, ultimately proposing a new standard for technical aesthetics in the Caspian region.

Keywords: technical aesthetics, sustainable design vernacular, bipv integration, form-follows-energy paradigm, biophilic urbanism.

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Introduction

The evolution of technical aesthetics within the architectural landscape of Azerbaijan as of 2026 represents a profound and irreversible shift from the superficial, often performative application of "green" elements toward a deep-seated, ontological integration of energy-saving logic into the very DNA of architectural design. This transformation signifies an era where sustainability is no longer treated as a peripheral technical consideration or a mere regulatory checkbox, but rather as the primary catalyst for architectural discourse and visual innovation. Historically, the architectural identity of Baku has been defined by a persistent and productive tension between the tactile, earthy warmth of traditional stonework—most notably the pervasive use of "Aglay" limestone—and the stark, impersonal transparency of modernist glass and steel. For decades, this dichotomy dictated the aesthetic direction of the city, but the current era demands a radical synthesis where thermodynamic efficiency is elevated as the primary driver of beauty and spatial experience. Following the strategic directives and ambitious benchmarks established by the "Azerbaijan 2030" national priorities, the design community has decisively embraced a philosophy where the ecological footprint of a structure is treated as a fundamental aesthetic choice, equivalent in importance to its physical silhouette or symbolic stature. This new philosophy posits that the beauty of a building is intrinsically tied to its environmental performance, creating a paradigm where "form-follows-energy" and every visual decision is backed by a data-driven energy outcome.

The emergence of this new architectural standard is further supported by the current

regulatory environment in Azerbaijan, particularly through the initiatives of the State Energy Efficiency Fund. This institutional support has empowered a new generation of designers and researchers to move beyond the traditional view of energy as a technical constraint, instead treating it as a plastic and expressive medium. Within this framework, energy is conceptualized as something that can be shaped, reflected, and choreographed to create architectural spaces that are both environmentally responsible and visually arresting, effectively bridging the gap between functional utility and high-tech artistic expression [1]. As we analyze the state of the industry in 2026, it is increasingly clear that the "Green Transition" is far more than a technical challenge or a matter of engineering compliance; it represents a full-scale revolution in the sensory and symbolic language of Azerbaijani architecture [2]. This revolution necessitates the development of a sophisticated new methodology for the designer, who must now act as a cultural mediator balancing the stone-carved heritage of the past with the rigorous technological and carbon-neutral imperatives of a post-oil future. The integration of high-tech requirements for carbon neutrality into local cultural semiotics is now a core requirement for any project aspiring to regional and international significance, setting a new precedent for technical aesthetics in the Caspian region and the broader Turkic world.

This introduction further posits that the contemporary aesthetic of Baku is being reshaped by the intersection of technical aesthetics and ecological responsibility, where the "skin" of the building has become the most critical site for artistic intervention. The transition toward Building-Integrated Photovoltaics (BIPV) and the aesthetic rehabilitation of traditional materials like "Aglay" limestone have fundamentally altered the color palette, texture, and rhythm of the built environment. These advancements allow for the emergence of a "digital vernacular" that reflects the technological aspirations of modern Azerbaijan while serving the pragmatic need for thermal regulation and carbon neutrality. By analyzing the "Smart City" projects in the liberated territories and the role of generative AI in shaping aerodynamic forms, this research argues that the new Azerbaijani aesthetic is defined by a rhythmic, light-reactive, and biophilic geometry that harmonizes with the natural coastal topography. Ultimately, the study provides a comprehensive framework for designers to achieve a synthesis where efficiency is the primary driver of beauty, ensuring that the architectural legacy of 2026 is one of both technological superiority and cultural continuity.

The profound shift in Azerbaijani architectural philosophy as of 2026 is significantly anchored in the historical and strategic metamorphosis that followed the COP29 summit, a pivotal event that catalyzed the transition of energy-saving technologies from their purely functional origins to their current status as fundamental elements of visual and spatial composition. This transition has necessitated a reconsideration of design at every scale, where the aesthetic integration of Building-Integrated Photovoltaics (BIPV), the technological rehabilitation of traditional "Aglay" limestone, and the sophisticated application of generative AI have converged to redefine the skyline of Baku. By scrutinizing the development of "Smart City" and "Smart Village" initiatives in the liberated territories, it becomes evident that a new Azerbaijani aesthetic has emerged—one strictly governed by a "form-follows-energy" paradigm. In this contemporary framework, sustainable performance is no longer a secondary performance metric but the primary force that dictates the rhythm, texture, and light within the built environment. This study therefore seeks to provide a comprehensive and rigorous framework for modern designers, enabling them to harmonize local cultural semiotics with the increasingly stringent high-tech requirements of carbon neutrality, thereby establishing an innovative standard for technical aesthetics across the Caspian region.

Central to this introductory discourse is the recognition that the current regulatory landscape, bolstered by the strategic initiatives of the State Energy Efficiency Fund, has fundamentally empowered architects to treat

energy as a plastic and expressive medium—an element that can be shaped, reflected, and choreographed to produce structures that are simultaneously environmentally responsible and visually arresting [1]. This ideological shift is not merely a response to technical challenges but represents a full-scale revolution in the sensory and symbolic language of Azerbaijani architecture [2]. As the industry matures in 2026, it is clear that the "Green Transition" serves as a catalyst for a new design methodology, one that requires the contemporary architect to meticulously balance the deep-seated heritage of the past with the technological imperatives of a post-oil future. The traditional "digital vernacular" and the burgeoning "aero-aesthetic"—driven by the necessity of aerodynamic efficiency in response to the "Khazri" and "Gilavar" winds—stand as testaments to this evolution, where the pursuit of carbon neutrality has unlocked unprecedented creative opportunities. Ultimately, the integration of these high-tech systems into the architectural fabric of Azerbaijan serves as a definitive model for the broader Turkic world, proving that "Net Zero" design is both a cultural necessity and a technological triumph.

Research

The investigation into technical aesthetics within Azerbaijan's architectural discourse of 2026 reveals a fundamental shift in the conceptualization of the building envelope, which has definitively transitioned from a static enclosure to a multi-functional intelligent interface, serving as the primary site for both artistic and technological intervention. The contemporary design paradigm necessitates a deep-seated integration of energy-saving logic into the very DNA of architectural composition, marking a transition from the superficial application of "green" elements to a synthesis where operational performance becomes the primary driver of aesthetic appeal. At the heart of this transformation lies the widespread adoption of Building-Integrated Photovoltaic (BIPV) systems, which have radically altered the color palette and textural characteristics of modern facades in Baku, imbuing them with a dynamic, light-reactive quality that resonates with the surrounding environment. Unlike the cumbersome and visually discordant solar panels of the previous decade, innovative perovskite-based thin-film solutions allow modern designers to treat the building skin as a programmable canvas, capable of modulating its transparency and hue in response to the intensity of the Caspian sun and the immediate energy requirements of the structure [3].

The visual rhythm of such facade systems forms a fundamentally new "digital vernacular" that not only reflects Azerbaijan's technological aspirations in a post-oil era but also serves the pragmatic objectives of thermal regulation within the urban environment. In this context, technical aesthetics function as a tool for harmonizing local cultural semiotic codes with the rigorous requirements of carbon neutrality, a fact corroborated by research conducted under the "Azerbaijan 2030" national priorities framework [1]. Of particular importance is the aesthetic rehabilitation of traditional construction materials, specifically "Aglay" limestone, whose role in Baku’s architectural identity has been reconsidered through the lens of advanced engineering. By implementing modern ventilated systems, designers have gained the ability to structurally decouple the external stone surface from the building's thermal core, achieving a visual effect of "weightlessness" and enabling complex parametric geometries that were previously impossible within traditional masonry constraints. This combination of historical materiality with innovative anchoring and ventilation methods allows for the preservation of the Walled City’s heritage while effectively addressing contemporary challenges [4].

Further depth in the research indicates that by 2026, the architectural form of Baku’s high-rise developments is largely dictated by Artificial Intelligence algorithms acting as an active co-designer in the pursuit of aerodynamic efficiency. The aesthetic form of the modern skyscraper is now driven by the necessity of interacting with prevailing wind currents—the "Khazri" and "Gilavar"—where AI-powered generative design creates fluid,

organic volumes that minimize wind resistance and maximize natural ventilation potential [5]. This "aero-aesthetic" approach represents a definitive departure from the rigid orthogonal grids characteristic of late 20th-century modernism in favor of a more biophilic and responsive geometry that mirrors the natural coastal topography and rhythms of the Caspian [6]. Consequently, the region's new visual identity is forged at the intersection of algorithmic precision and natural forms, producing an architectural language that is simultaneously high-tech and deeply rooted in the specificities of the local landscape.

The research also encompasses the internal aesthetics of energy-efficient spaces, where the integration of Phase Change Materials (PCM) into interior partitions has significantly influenced the spatial organization of the domestic environment. Designers increasingly utilize the thermal properties of light-sensitive materials to create "living atmospheres," where the aesthetic experience of inhabiting a space is defined by the invisible movement of heat and airflows that shift throughout the day. In the context of implementing "Smart City" and "Smart Village" projects in the liberated territories, this synthesis reaches its apex, as the design of public and residential spaces is directly dictated by proximity to renewable energy nodes. This leads to the formation of a decentralized urban aesthetic that prioritizes human scale and ecological harmony, consciously moving away from traditional monumentalism toward sustainable performance. Statistical data and empirical observations from 2025–2026 confirm that the perception of design quality in Azerbaijan has shifted toward metrics-based criteria, where buildings that overtly display their energy-saving technologies—through visible solar integration or vertical biophilic forests—command significantly higher psychological value and market demand within the luxury real estate sector [2].

The second phase of this investigation focuses on the material and algorithmic reconstruction of the Azerbaijani built environment, specifically through the aesthetic rehabilitation of traditional "Aglay" limestone within a high-tech framework. In the contemporary context, "Aglay" is no longer utilized as a heavy, monolithic masonry element, but has been reimagined as a sophisticated, ventilated layer that decouples the aesthetic exterior from the structural and thermal core. By utilizing advanced ventilated systems, designers have unlocked a sense of "weightlessness" in this traditional material, allowing for the execution of complex, non-linear geometries that were previously impossible under the structural constraints of old-world masonry. This shift represents a broader metamorphosis of design philosophies following the COP29 summit, where materiality is reconsidered through its performance and carbon footprint. Parallel to this material evolution is the integration of generative Artificial Intelligence as a primary co-designer in the pursuit of aerodynamic efficiency. In 2026, the silhouette of Baku's skyline is increasingly shaped by the "Khazri" and "Gilavar" winds, where AI-driven generative design creates fluid, organic forms that minimize wind resistance while maximizing natural ventilation pathways. This "aero-aesthetic" serves as a definitive departure from the rigid grids of the late twentieth century, favoring a biophilic geometry that mirrors the natural coastal topography of the Caspian region.

Furthermore, the research delves into the internal technical aesthetics of energy-saving design, where the application of Phase Change Materials (PCM) into interior partitions has fundamentally altered the spatial organization of domestic and professional environments. Architects are now leveraging the thermal properties of these light-sensitive materials to create "living atmospheres" that shift dynamically throughout the day, where the aesthetic experience of a room is defined by the invisible movement of heat and air rather than static decoration. This approach is most visible in the "Smart City" and "Smart Village" projects located within the liberated territories, where the design of communal spaces is dictated by their proximity to green energy nodes. Such a decentralized urban aesthetic prioritizes human scale and ecological harmony over traditional monumentalism.

Empirical findings suggest that the Azerbaijani market's perception of "quality" has shifted toward a metrics-based aesthetic. Data from 2025 and 2026 indicates that buildings which overtly display their energy-saving technologies—such as visible Building-Integrated Photovoltaics (BIPV) and vertical forests—command a significantly higher psychological and market value. This "texture of efficiency," characterized by the use of recycled aluminum, low-carbon composites, and visible thermal breaks, has emerged as the new status symbol in Baku's premium real estate sector. Central to this is the use of multi-functional smart glazing, which enhances occupant comfort by modulating light and heat, thereby creating an unobstructed connection to the urban landscape without the need for heavy, energy-dampening drapes.

Conclusions

The synthesis of this research reinforces the definitive conclusion that by 2026, energy-saving technology has transcended its functional origins to become the primary medium of architectural expression in Azerbaijan. The study confirms that it is no longer possible to separate the "design" of a building from its "performance," as the visual success of any modern project is now inextricably linked to its thermodynamic integrity. This represents a profound shift in the "Azerbaijan 2030" national priorities, where the ecological footprint of a structure is treated as an aesthetic choice equivalent to its silhouette. The Azerbaijani design school is successfully navigating this transition into a post-oil aesthetic by leveraging the region's specific climatic challenges—most notably the intense sun and high-velocity winds—as creative opportunities rather than limitations. The research concludes that the most effective contemporary designs are those that treat technology as a "silent partner," where the complexities of AI-driven management and BIPV generation are integrated behind a veil of sophisticated technical aesthetics that prioritize human comfort and cultural continuity.

This evolution indicates that the "Green Transition" is not merely a technical challenge but a revolution in the sensory and symbolic language of Azerbaijani architecture. The current era demands a synthesis where efficiency is the primary driver of beauty, bridging the gap between the warmth of traditional stonework and the high-tech requirements of carbon neutrality. The findings argue that a new "form-follows-energy" paradigm now defines the built environment, dictated by sustainable performance across rhythm, texture, and light. By treating energy as a plastic medium that can be shaped and choreographed, designers are creating spaces that are both environmentally responsible and visually arresting. This methodology allows the modern designer to balance the rich heritage of the past with the technological imperatives of the future, ultimately proposing a new global standard for technical aesthetics in arid coastal regions.

Beyond the theoretical implications, the practical success of reconstruction projects in Karabakh serves as a definitive model for how "Net Zero" design can be both culturally meaningful and technologically superior. To institutionalize these findings, it is recommended that the Azerbaijan University of Architecture and Construction (AzUAC) establish a dedicated department for "Ecological Technical Aesthetics" to train a new generation of designers who are as proficient in energy modeling as they are in formal composition. Furthermore, there is a critical recommendation for the Baku City Architecture Department to incentivize the use of "Active Facades" by offering height bonuses for buildings that integrate solar generation into their primary aesthetic design. The professional design community must also advocate for the creation of a national database of "Low-Carbon Materials with High Aesthetic Value" to encourage the use of local sustainable resources in high-end projects.

At the operational level, the study strongly recommends that designers adopt 6D BIM (Building Information Modeling) as a standard tool for "Aesthetic Performance Auditing," ensuring that every visual decision is backed by a data-driven energy outcome. Finally, it is proposed that the government host an annual "Green Design Biennale" to

showcase how energy-saving technologies are redefining the visual identity of Azerbaijan on the global stage. These steps will ensure that the "digital vernacular" and "aero-aesthetic" explored in this research continue to evolve, positioning Azerbaijan as a leader in sustainable design vernacular within the Turkic world and beyond. Through these strategic directives, the design community can continue to treat energy as a plastic medium, reflecting the technological aspirations of a nation committed to carbon neutrality and cultural excellence.

REFERENCES

1. Ministry of Culture & Ministry of Energy of Azerbaijan The Aesthetics of Sustainability: Architectural Guidelines for the 2030 Vision. Baku. 2025.
2. Hajili M. Technical Aesthetics in the Post-COP29 Era: A New Language for Baku. Journal of Design and Technical Aesthetics, 2026;22(1): 45–68.
3. State Agency for Renewable Energy. BIPV Design Integration: Aesthetics vs. Efficiency. Baku: AREA Publications. 2025.
4. UNESCO & ICOMOS Azerbaijan. Preserving Heritage through Energy Innovation: The Case of the Walled City of Baku. 2025.
5. Zadeh N., Aliyev T. AI-driven generative forms in modern Azerbaijani skyscraper design. Caspian Journal of Architecture and Engineering, 2026;(9).
6. International Council of Societies of Industrial Design. Sustainable Technical Aesthetics in Arid Coastal Regions. 2026.

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TİKİNTİ VƏ DİZAYNDA ENERJİ QƏNAƏTİ TEXNOLOGİYALARININ İNKİŞAFI

Xülasə

2026-cı ilin müasir reallığında texniki estetika və ekoloji məsuliyyətin kəsişməsi Azərbaycanda memarlıq diskursunun əsas katalizatoruna çevrilmişdir. Bu tədqiqat COP29 sammitindən sonra dizayn fəlsəfələrinin metamorfozunu araşdırır və enerji qənaəti texnologiyalarının funksional mənşəyindən çıxaraq vizual kompozisiyanın fundamental elementlərinə necə çevrildiyinə diqqət yetirir. İşdə binalara inteqrasiya edilmiş fotovoltaik sistemlərin (BIPV) estetik inteqrasiyası, ənənəvi "ağlay" əhəngdaşının maddiliyinin yenidən nəzərdən keçirilməsi və Bakının siluetinin aerodinamik formalarının formalaşmasında generativ süni intellektin rolu araşdırılır. İşğaldan azad edilmiş ərazilərdə "Ağıllı şəhər" layihələrini təhlil edərək, müəllif iddia edir ki, yeni Azərbaycan estetikası "forma enerjini izləyir" (form-follows-energy) paradiqması ilə müəyyən edilir; burada dayanıqlı performans göstəriciləri memarlıq mühitində ritmi, fakturanı və işığı diktə edir. Məqalə dizaynerlər üçün yerli mədəni semiotikanı karbon neytrallığının yüksək texnoloji tələbləri ilə uyğunlaşdırmaq üçün hərtərəfli çərçivə təqdim edir və nəticə etibarilə Xəzər regionunda texniki estetika üçün yeni bir standart təklif edir.

Açar sözlər: texniki estetika, dayanıqlı dizayn kodu, BIPV inteqrasiyası, "forma enerjini izləyir" paradiqması, biofil urbanizm.

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РАЗВИТИЕ ЭНЕРГОСБЕРЕГАЮЩИХ ТЕХНОЛОГИЙ В СТРОИТЕЛЬСТВЕ И ДИЗАЙНЕ

Резюме

В современных реалиях 2026 года пересечение технической эстетики и экологической ответственности стало основным катализатором архитектурного дискурса в Азербайджане. Данное исследование изучает метаморфозы дизайнерских философий после саммита COP29, уделяя основное внимание тому, как энергосберегающие технологии вышли за рамки своих чисто функциональных истоков, став фундаментальными элементами визуальной композиции. В работе рассматривается эстетическая интеграция фотоэлектрических систем, встроенных в здания (BIPV), переосмысление материальности традиционного известняка «аглай» и роль генеративного ИИ в формировании аэродинамических форм силуэта Баку. Анализируя проекты «Умных городов» на освобожденных территориях, автор утверждает, что новая азербайджанская эстетика определяется парадигмой «форма следует за энергией», где показатели устойчивой эффективности диктуют ритм, текстуру и свет в архитектурной среде. Статья предлагает комплексную основу для дизайнеров по гармонизации местной культурной семиотики с высокотехнологичными требованиями углеродной нейтральности, в конечном итоге предлагая новый стандарт технической эстетики в Каспийском регионе.

Ключевые слова: техническая эстетика, устойчивый дизайнерский код, интеграция BIPV, парадигма «форма следует за энергией», биофильный урбанизм.

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