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Adaptive Facade Systems: An Evaluation of Design Scales and System Principles

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Abstract

This study investigates adaptive facade systems as innovative architectural solutions that enhance building energy efficiency and occupant comfort in response to changing environmental conditions. By employing a literature review methodology, the research identifies key adaptive facade types—such as active, kinetic, smart, interactive, and biomimetic—and examines their classification, control mechanisms, and material characteristics. Particular attention is given to the environmental parameters (solar radiation, wind, humidity, and noise) that influence facade performance and the control parameters (thermal comfort, visual comfort, indoor air quality, acoustic comfort, and energy generation) that adaptive facades are designed to optimize. The study also categorizes adaptation methods as static or dynamic and highlights control strategies as intrinsic or extrinsic. Findings demonstrate that adaptive facades, through smart materials and responsive technologies, represent an integrated design approach that aligns energy efficiency with environmental responsiveness. The study provides a theoretical foundation for further research and application in performance-based, sustainable architecture.

Keywords: *Adaptive Facade, Dynamic Envelope, Climate Responsiveness, Smart Building.*

Adaptif Cephe Sistemleri: Tasarım Ölçekleri ve Sistem Prensipleri Üzerine Bir Değerlendirme

Öz

Bu çalışma, değişen çevresel koşullara yanıt verebilen ve böylece yapıların enerji verimliliğini ve kullanıcı konforunu artıran yenilikçi mimari çözümler olarak adaptif cephe sistemlerini incelemektedir. Literatür taraması yöntemiyle yürütülen araştırmada; aktif, kinetik, akıllı, etkileşimli ve biyomimetik gibi temel adaptif cephe türleri belirlenmiş, bu sistemlerin sınıflandırma biçimleri, kontrol mekanizmaları ve malzeme özellikleri analiz edilmiştir. Güneş ışınımı, rüzgâr, nem ve ses gibi fiziksel çevresel parametrelerin cephe performansı üzerindeki etkilerine ve bu etkileri optimize etmeyi amaçlayan kontrol parametrelerine (termal konfor, görsel konfor, iç hava kalitesi, akustik konfor ve enerji üretimi) odaklanılmıştır. Adaptasyon yöntemleri statik ve dinamik; kontrol stratejileri ise içsel ve dışsal olarak sınıflandırılmıştır. Çalışmanın bulguları, akıllı malzemeler ve duyarlı teknolojiler yoluyla adaptif cephelerin çevresel koşullara uyum sağlayan, enerji verimli ve entegre tasarım yaklaşımları sunduğunu ortaya koymaktadır. Bu çalışma, sürdürülebilir ve performansa dayalı mimarlık bağlamında kuramsal bir temel sunmaktadır.

Anahtar kelimeler: *Adaptif Cephe, Dinamik Kabuk, İklim Duyarlılığı, Akıllı Bina.*

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1. Introduction

Contemporary architectural design is increasingly defined by the need to address multifaceted challenges that extend well beyond traditional notions of aesthetics and function. In an era marked by rapid urbanization, global warming, rising energy consumption, and the depletion of natural resources, the built environment plays a critical role in shaping the sustainability agenda. Buildings account for a significant proportion of global energy use and carbon emissions, making it imperative that architects and designers examine innovative strategies to reduce environmental effect while enhancing indoor comfort (Wigginton & Harris, 2002; Loonen et al., 2015). In this context, the building envelope has come to be viewed not simply as a protective outer shell but as a dynamic, responsive interface that mediates the relationship between the interior environment and external climatic conditions. This shift in perspective has led to the emergence of adaptive facade systems, which are designed to respond to changing environmental stimuli—such as solar radiation, wind, humidity, temperature, and daylight—in real time. These systems enable buildings to operate more efficiently by adjusting their physical or functional characteristics according to external conditions, often through kinetic, smart, or interactive mechanisms (Romano et al., 2018).

Adaptive facades serve a dual purpose. On one hand, they improve the energy performance of buildings by regulating heat gain and loss, managing solar exposure, and supporting natural ventilation. On the other hand, they contribute to occupant well-being by enhancing visual, thermal, and acoustic comfort. Through the integration of smart materials, automated controls, sensors, actuators, and responsive geometries, these systems embody a convergence of architecture, engineering, and environmental science. As Aelenei et al. (2018) suggest, adaptive facades represent a paradigm shift in architectural practice—one that emphasizes performance-based, responsive, and intelligent design over static, prescriptive solutions. However, the successful implementation of adaptive facade systems is contingent upon a comprehensive understanding of their typologies, control principles, material properties, and the specific environmental parameters they are intended to address. Technological innovation alone is insufficient without an integrated design approach that considers the physical context, user needs, operational logic, and energy goals. Moreover, the architectural integration of such systems requires critical consideration of scale, adaptability, aesthetics, and long-term functionality.

This study aims to investigate adaptive facade systems through a holistic and multi-scalar perspective, focusing on their classification, functional components, control strategies, and interaction with environmental variables. In particular, the research seeks to examine how adaptive facades can respond effectively to physical environmental factors—such as solar radiation, wind, humidity, and noise—while simultaneously enhancing energy efficiency and occupant comfort. By analyzing both the theoretical system and real-world applications, this study contributes to the growing discourse on high-performance architecture and the role of responsive systems in the design of sustainable buildings.

2. Material and Method

This study was conducted with the aim of establishing a conceptual system for adaptive facade systems and evaluating their classification schemes, relationships with environmental parameters, and control strategies through a holistic approach. Within the scope of the research, one of the qualitative research methods, the literature review, was employed. A literature review is a research method that enables the systematic examination of previously conducted academic studies on a specific topic and the structuring of the existing body of knowledge through analysis and interpretation. In this context, theoretical approaches to adaptive facade systems, technical classifications, system components, environmental interaction strategies, and material-based applications were compiled from written sources and analyzed through a content-oriented perspective.

During the research process, both national and international publications were systematically reviewed, including academic journal articles, theses, conference proceedings, book chapters, and reports related to the subject. Various academic databases, digital libraries, and scholarly search engines were utilized during the scanning phase. The collected sources were categorized according to

themes aligned with the research questions and were evaluated within a coherent theoretical structure. Through this method, key approaches and trends in the existing literature were identified, and the characteristics of different facade types along with their adaptive strategies in response to environmental conditions were systematically revealed. Thus, the theoretical foundation of the study was strengthened, providing a solid basis for the analyses presented in the subsequent sections.

3. Findings and Discussion

3.1. Types of Adaptive Facades

In the literature, adaptive facade systems are categorized into various subtypes such as active facades, kinetic facades, intelligent facades, interactive facades, and biomimetic facades (Romano et al., 2018; Aelenei et al., 2018; Engin, 2022). These subcategories represent key criteria for defining a facade's adaptability potential. Adaptive facades, which are expected to respond to changing environmental conditions, demonstrate varying adaptation capabilities and methods depending on their inherent facade characteristics. An adaptive facade system can be designed based on the properties of a single facade type, or it can be developed as a hybrid system incorporating multiple characteristics from different facade categories. For example, the adaptive facade of the Campus Kolding building in Denmark represents a hybrid adaptive system. Thanks to its components and integrated technological features, this facade exhibits the combined functions of a kinetic, interactive, and responsive facade (Aelenei et al., 2018).

3.1.1. Active facades

Active facade systems are designed to help minimize the building's energy consumption while ensuring optimal indoor comfort conditions. These systems include facade components that can easily integrate with external environmental conditions. In response to changing environmental stimuli, active facades are capable of continuously controlling their formal or chemical deformations, either through automated control mechanisms or manual user input, depending on the needs of the occupants (Ruitenbeek, 2016; Ochoa & Capeluto, 2008; Romano et al., 2018). The responsiveness and activeness of these systems can be enhanced through the integration of smart sensors, automation technologies, and data analysis networks, which enable more precise environmental adaptation and energy efficiency as seen in Figure 1.

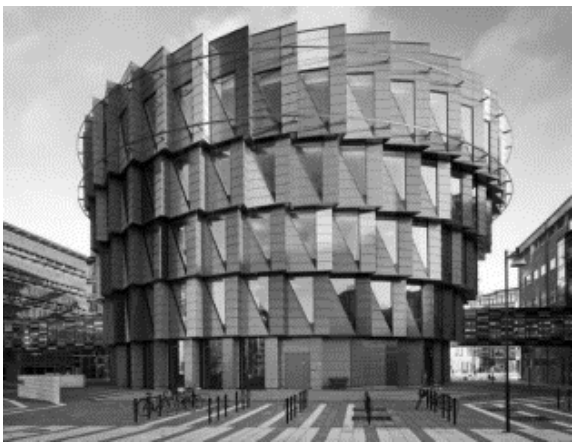


Figure 1. Kuggen Building's Active Facade (Sweden-Gothenburg, 2011) (Kuggen/Wingårdh Arkitektkontor, 2012)

3.1.2. Kinetic (dynamic) facades

Although the origins of kinetic facades—systems that incorporate movable facade elements programmed to respond to climatic or other environmental factors—can be traced back in architectural history, their integration with advanced technology is relatively recent (Ibrahim & Alibaba, 2019). These facades, often referred to as dynamic facades, are capable of altering their size, shape, orientation, or openings in response to physical parameters such as light, humidity, temperature, and wind (Kensek & Hansanuwat, 2011).

As shown in Figure 2, the ability of these systems to transform their form contributes significantly to improving indoor comfort conditions, while also helping to prevent energy losses and reduce energy-related operational costs within the building.



Figure 2. Carabanchel Social Housing's Kinetic Facade (Spain-Madrid, 2007) (Carabanchel Housing / Foreign Office Architects, 2008)

3.1.3. Interactive facades

The term interactive facade generally refers to technological or responsive elements embedded in a building's exterior that are capable of engaging with users or reacting to external stimuli. Interactive facade systems are typically designed to respond to various environmental changes or external inputs, and often require user engagement to operate (Velikov & Thün, 2013; Loonen et al., 2013).

These systems may incorporate technological components such as motion sensors or touch-sensitive interfaces, allowing the facade to temporarily alter its features based on user interaction as depicted in Figure 3. While supporting improvements in the building's energy performance, interactive facades also aim to enhance user participation and engagement with the architectural environment (Romano et al., 2018).



Figure 3. Cyclebowl Expo Interactive Facade (Germany, 2000) (Atelier Brückner, 2024)

3.1.4. Intelligent (smart) facades

Smart facade systems aim to enhance the building's energy efficiency through the integration of advanced technological components into the building envelope. These systems commonly include sensors, control mechanisms, automated lighting, and ventilation systems (Wigginton & Harris, 2002). By monitoring variables such as sunlight, temperature, air quality, and energy consumption, intelligent facades enable buildings to respond more sensitively and efficiently to changing environmental conditions.

In addition to artificial intelligence and computer-based technologies, smart facade designs often incorporate phase-changing smart materials and photovoltaic panels, which contribute to both passive and active energy strategies (Esgil & Yamaçlı, 2023).

3.1.5. Biomimetic facades

The term biomimetic, derived from the Greek words "bios" (life) and "mimesis" (imitation), was introduced by Frosch and Gallopoulos (1989) and refers to the use of biological and natural systems as sources of inspiration in design (Uç, 2023). Biomimetic facades, designed by emulating the structural and functional characteristics of nature, aim to enhance various comfort parameters such as thermal regulation, ventilation, light transmission, and acoustic performance. These facades represent a design concept that contributes to energy efficiency by integrating principles observed in living or natural systems (Zari & Storey, 2007). Through this nature-inspired approach, biomimetic facades provide sustainable solutions that harmonize with environmental conditions.

3.2. System Principles in Adaptive Facades

3.2.1. Environmental and control parameters influencing adaptive facade design

Environmental factors such as solar radiation, wind, sound, and humidity/precipitation present in a building's external environment are considered key physical parameters that significantly effect both indoor comfort and building performance. These physical environmental parameters have the potential to directly influence structural efficiency and interior environmental quality. In response to these external variables, a range of control parameters have been identified that mediate the interaction between the environment and the building (Loonen et al., 2015). These control parameters emerge as factors affecting visual, acoustic, thermal comfort, indoor air quality, and on-site energy production, all of which are critical to the holistic performance of adaptive facade systems (Belek & Yamaçlı, 2023). The accurate analysis of physical environmental parameters shaped by a building's geographical location plays a critical role in minimizing structural energy losses while also enabling the fulfillment of necessary control parameters within the interior space (Manioğlu, 2011). For example, the position and angle of solar incidence at a specific location affect both visual and thermal comfort conditions, and at the same time, solar energy can be utilized for on-site energy generation. When photovoltaic technologies are integrated into the facade, interaction with sunlight enables energy production through the building envelope (Voigt et al., 2023).

Wind is another physical environmental parameter that influences both thermal comfort and indoor air quality. When incorporated into adaptive facades, various elements can harness wind to generate kinetic energy, contributing to the energy demands of the building.Humidity levels in the outdoor environment directly affect thermal comfort and indoor air quality. High humidity levels may hinder evaporation processes, causing undesirable overheating in the interior. Additionally, excess humidity can negatively effect air freshness, reducing the quality of the indoor atmosphere. Another significant parameter is sound, which affects acoustic comfort. To prevent the transmission of unwanted external noise and to ensure a comfortable acoustic environment, adaptive facade designs can be developed to act as buffers (Başarır & Altun, 2017).

In this context, the main control parameters expected to be addressed by adaptive facade systems include visual comfort, thermal comfort, indoor air quality, acoustic performance, and energy production (Loonen et al., 2015). Adaptive facades have the capability to respond to these environmental parameters in real-time, allowing them to dynamically optimize performance in relation to varying external conditions (Romano et al., 2018).

3.2.2. Scales of adaptation

Adaptive facade systems consist of various architectural elements capable of modifying their characteristics to respond to changing environmental conditions (Ferguson et al., 2007). Sensitivity to external environmental factors can be achieved at different scales, including facade materials, individual components, or the entire facade system (Aelenei et al., 2018) (Table 1). These elements can function independently, or multiple adaptive components may be integrated simultaneously in hybrid adaptive facade systems. The selection of adaptive facade materials plays a crucial role in the interaction between the building and its environment and contributes significantly to the building's overall performance. A review of existing applications indicates that smart materials are often employed to achieve material-scale adaptability in adaptive facade systems (Looman, 2017). These

materials are designed to detect structural and environmental variations and respond accordingly to provide appropriate conditions within the interior space (Kroschwitz, 1992). Among the most commonly used smart materials in adaptive facade applications are photochromic, thermochromic, and electrochromic glasses (Oral & Karakoç, 2015). These materials can autonomously modify their optical and thermal properties in response to external stimuli such as light, heat, or electricity and revert to their original state. For instance, photochromic glass changes its color based on the UV intensity of incident light, helping to prevent glare and unwanted lighting conditions in the interior space (Ritter, 2007).

Thermochromic glass, unlike photochromic materials, responds primarily to the heat energy carried by sunlight. When exposed to solar radiation, it traps the heat and alters its optical properties through specific chemical reactions (Addington & Schodek, 2005). Electrochromic glass, on the other hand, requires an electric current to control its transparency level. This type of glass can be used in facade systems to provide dynamic climate control, significantly improving energy efficiency (Topal & Arpacıoğlu, 2020). In addition to smart materials, elements such as adaptive sun-shading devices, light shelves, photovoltaic panels, and wind turbines can also be integrated into facades. These components, often referred to as smart facade elements, are widely used to enhance energy performance and indoor environmental quality (Oral & Karakoç, 2015). Whether integrated in a static or dynamic manner, these components are capable of reacting to environmental stimuli to improve building performance (Çiftçi & Arpacıoğlu, 2021).

Through single- or double-skin facade systems, it is also possible to achieve adaptive functionality at the system scale without necessarily integrating specific adaptive components. For example, the adaptive facade of the Institut du Monde Arabe in Paris was designed with intrinsic adaptability, without the need for additional adaptive elements (Engin, 2022). The facade consists of a single layer that is perceptible from both the interior and the exterior, effectively responding to changing environmental conditions.

Table 1. Adaptation Scales and Functional Strategies in Adaptive Facade Design

Adaptation Scale	Description	Examples	Functionality
Material Scale	Materials that autonomously respond to environmental stimuli	-Photochromic glass -Thermochromic glass - Electrochromic glass	Alters optical/thermal properties in response to light, temperature, or electricity
Component Scale	Individual building elements with responsive or kinetic capabilities	-Operable louvers -Light shelves - PV panels - Wind turbines	Regulates daylight, ventilation, solar gain, and energy generation
System Scale	Entire facade system designed with integrated adaptive performance	- Double-skin facades - Smart curtain wall systems - Institut du Monde Arabe facade	Provides holistic environmental control (visual, thermal, acoustic, air quality, energy use)
Hybrid Integration	Combination of multiple adaptation strategies and elements across different scales	- Mixed use of smart materials and kinetic devices - Responsive facades with sensors + AI integration	Enhances dynamic adaptability and performance efficiency through multi-layered feedback systems

3.2.3. Adaptation methods

Adaptivity in facade systems can occur through two primary approaches: static or dynamic adaptation (Oral & Karakoç, 2015; Megahed, 2017) (Table 2). In static adaptive facades, the facade or its components remain in a fixed position relative to their original state while still responding to external environmental conditions. This type of adaptation is particularly evident in facade systems that integrate adaptive materials at the material scale. On the other hand, dynamic adaptive facades incorporate movable architectural components designed to respond actively to changing external conditions. These components may operate individually or collectively and exhibit kinetic behavior at micro or macro scales (Aelenei et al., 2018). At the macro scale, kinetic adaptability involves the movement of facade elements or entire systems through actions such as sliding, folding, rotating, or scaling (Moloney, 2011).In contrast, micro-scale movement is typically associated with material-level deformation, where morphological changes in smart materials lead to responsiveness (Loonen et al., 2013; Aelenei et al., 2018). When such materials are used across the whole facade, the entire system can exhibit micro-scale adaptive motion.

Table 2. Adaptation Method in Adaptive Facades

Adaptation Method	Features	Examples
Static Adaptation	- No moving parts - Material-based response - Low energy consumption - Typically occurs at the micro scale	Thermochromic glass, photochromic materials, phase-change materials
Dynamic Adaptation	- Involves physical movement - Kinetic systems at micro or macro scale - Can be controlled by automation systems - May require energy input	Movable sunshades, foldable panels, rotating facade components

3.2.4. Control Techniques in adaptive facades

Adaptive facades respond to external stimuli through integrated control systems. These systems are responsible for processing environmental data, activating system components, adapting to external conditions, and executing responsive operations (Moloney, 2011). The control techniques employed in adaptive facades can utilize both active and passive technologies (Tabadkani et al., 2020). In facades using passive control techniques, the system analyzes and responds to external environmental conditions independently, without the need for additional components or energy. In contrast, active control techniques require a combination of components and technological tools to facilitate and manage this adaptation.

There are two primary control strategies in adaptive facades: external (extrinsic) and internal (intrinsic) control systems (Velasco et al., 2015). The extrinsic control system represents an active control technique, consisting of sensors and actuators that are operated through automation and require energy input (Belek & Yamaçlı, 2023). These systems can only function through user input and typically utilize processors, data networks, and software to detect environmental variables and transmit them to a central control unit (Figure 4). However, these systems are usually designed to respond to predefined scenarios, which limits their adaptability to unpredictable changes in the physical environment (Loonen et al., 2013).

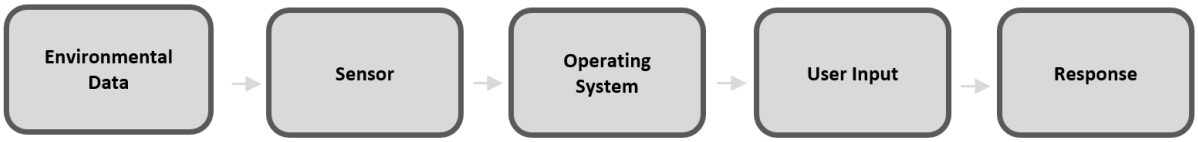


Figure 4. Data collection and response generation process in extrinsic control systems (Fox & Yeh, 2000)

On the other hand, intrinsic control systems operate with a much simpler mechanism. These systems do not require any external hardware, as they function based on inherent material or system

properties (Fox & Yeh, 2000). Moreover, intrinsic systems do not consume energy for adaptation, making them self-sufficient. They can perceive environmental stimuli and respond accordingly without intermediaries (Figure 5). Their flexibility allows for real-time adjustment to unanticipated conditions, enhancing their ability to adapt compared to extrinsic systems. When reviewing real-world adaptive facade applications, it is evident that intrinsic control techniques are more commonly preferred than extrinsic ones due to their greater adaptability and lower energy demand (Ghamari & Asefi, 2010).

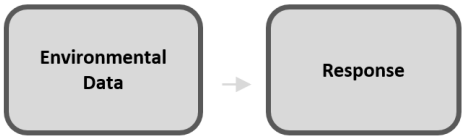


Figure 5. Data collection and response generation process in intrinsic control systems (Fox & Yeh, 2000)

4. Conclusion and Suggestions

In contemporary architectural discourse, sustainability, energy efficiency, and user comfort have evolved beyond conventional design concerns to redefine the role and function of the building envelope. Within this system, adaptive facade systems have emerged as dynamic and responsive architectural solutions capable of interacting with environmental variables and altering their physical or functional attributes in real time. Unlike static, passive envelopes, adaptive facades contribute not only to the reduction of energy consumption but also to the enhancement of occupant comfort, environmental responsiveness, and performance flexibility throughout the building's lifecycle.The findings of this study, based on an extensive literature review, reveal that adaptive facades are classified into various categories—including active, kinetic, interactive, smart, and biomimetic types—each defined by its mechanisms of environmental adaptation. These typologies represent a spectrum of responses to climatic stimuli, with some systems operating through singular technological strategies, while others function as hybrid solutions that integrate multiple adaptive features simultaneously. The increasing prevalence of hybrid systems indicates a growing tendency toward multi-functional, layered facade approaches in high-performance architectural design.

The successful response of adaptive facades to environmental inputs is largely dependent on the accurate analysis of physical environmental parameters—such as solar radiation, wind, humidity, and noise—and their correlation with critical control parameters, including visual comfort, thermal comfort, indoor air quality, acoustic performance, and energy production. The integration of smart materials (such as photochromic, thermochromic, and electrochromic glazing) and intelligent systems (sensors, actuators, and automation software) facilitates a continuous and optimized interaction between the building and its environment. These technologies enable the facade to function as a dynamic environmental interface, improving both performance and responsiveness. Furthermore, the control techniques employed in adaptive facades—categorized as either intrinsic or extrinsic—play a decisive role in determining the system's responsiveness, energy consumption, and sustainability potential. Intrinsic control strategies, which operate autonomously without external hardware or energy input, have proven particularly advantageous in terms of adaptability and energy efficiency. Their inherent ability to sense and respond to environmental stimuli allows for greater flexibility in addressing unforeseen conditions, making them increasingly preferred in practical applications.

Ultimately, adaptive facade systems signify a paradigm shift in architectural practice—one that reimagines the facade not as a static protective shell but as an active, intelligent, and performative mediator between indoor and outdoor environments. However, their successful implementation demands more than technological sophistication; it requires an integrated design approach that synthesizes contextual analysis, user behavior, climatic data, operational strategies, and architectural coherence. Interdisciplinary collaboration, holistic planning, and life-cycle-oriented design methodologies are essential to realizing the full potential of adaptive facades as a cornerstone of sustainable architecture. In this regard, further in-depth theoretical and practical investigations into adaptive facades are critical for advancing climate-responsive and energy-efficient architectural practices in the built environment of the future.

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The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The article was written by a single author. There is no conflict of interest.

References

Addington, M., & Schodek, D. (2005). *Smart materials and technologies*. *Architecture and Urbanism*, 5(3), 8–13.

Aelenei, L. E., Aelenei, D., Romano, R., Mazzucchelli, E. S., Brzezicki, M. & Rico-Martinez, J. M. (2018). *Case studies: adaptive facade network*. Netherlands: TU Delft Open.

Atelier Brückner. (2024). *Cyclebowl*. Access Address (28.04.2024): https://www.atelierbrueckner.com/en/projects/cyclebowl

Başarır, B. & Altun, M. C. (2017). A Classification Approach for Adaptive Façades. In *ICBEST Istanbul, Interdisciplinary Perspectives for Future Building Envelopes* (pp. 756–769). Turkey: Istanbul, May 15–18.

Belek, A. N. & Yamaçlı, R. (2023). Adaptif cephe sistemlerinin sürdürülebilir tasarım kriterlerine yönelik tasarım çözümleri. *Artgrid – Journal of Architecture Engineering and Fine Arts*, 5(2), 216–239.

Carabanchel Housing/Foreign Office Architects. (2008, May 30). *ArchDaily*. Access Adress (04.06.2024): https://www.archdaily.com/1580/caranbachelhousing-foreign-office-architects

Çiftçi, M. E. & Arpacıoğlu, Ü. (2021). Gün ışığı yönlendirme sistemleri. *Journal of Architectural Sciences and Applications*, 6(1), 59–76.

Engin, S. (2022). *Kinetik cephe sistemlerinin yapı performansına günışığı, kamaşma ve enerji performansı üzerindeki etkileri (Master's Thesis). Mimar Sinan Fine Arts University, Graduate School of Science and Technology, Istanbul.*

Esgil, M. & Yamaçlı, R. (2023). Akıllı cephelerin sürdürülebilirliğe etkisi: Türkiye ve dünyadaki örnekleri. *Sürdürülebilir Mühendislik Uygulamaları ve Teknolojik Gelişmeler Dergisi*, 6(1), 1–12.

Ferguson, S., Siddiqi, A., Lewis, K. & De Weck, O. (2007). Flexible and reconfigurable systems: Nomenclature and review. *ASME 2007 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. 249–263). United States: Las Vegas, September 4–7.

Fox, M. A. & Yeh, B. P. (2000). Intelligent kinetic systems in architecture. In P. Nixon, G. Lacey, & S. Dobson (Eds.), *Managing Interactions in Smart Environments* (pp. 91–103). London: Springer.

Frosch, R. A. & Gallopoulos, N. E. (1989). Strategies for manufacturing. *Scientific American*, 261(3), 144–153.

Ghamari, H. & Asefi, H. (2010). Toward sustainability by the application of intelligence building systems. *The Second International Conference on Sustainable Architecture and Urban Development* (pp. 245–248). Jordan: Amman, July 12–14.

Ibrahim, J. A. & Alibaba, H. Z. (2019). Kinetic facade as a tool for energy efficiency. *Engineering Research and Reviews*, 7, 1–7.

Kensek, K. & Hansanuwat, R. (2011). Environment control systems for sustainable design: A methodology for testing, simulating and comparing kinetic facade systems. *Journal of Creative Sustainable Architecture & Built Environment*, 1(11), 27–46.

Kroschwitz, J. (Ed.). (1992). *Encyclopedia of Chemical Technology*. New York: John Wiley & Sons.

Kuggen/Wingårdh Arkitektkontor. (2012, November 5). *ArchDaily*. Access Adress (04.06.2024): https://www.archdaily.com/289856/kuggen-wingardh-arkitektkontor#

Looman, R. (2017). *Climate-Responsive Design: a framework for an energy concept design-decision support tool for architects using principles of climateresponsive*. Netherlands: TU Delft.

Loonen, R. C., Rico-Martinez, J. M., Favoino, F., Brzezicki, M., Ménézo, C., La Ferla, G. & Aelenei, L. L. (2015). Design for façade adaptability: Towards a unified and systematic characterization. *10th Conference on Advanced Building Skins Economic Forum*, pp. 1284–1294. Bern, Switzerland, November 3–4.

Loonen, R. C., Trčka, M., Cóstola, D. & Hensen, J. L. (2013). Climate adaptive building shells: State-of-the-art and future challenges. *Renewable and Sustainable Energy Reviews*, 25, 483–493.

Manioğlu, G. (2011). Enerji etkin tasarım ve yenileme çalışmalarının örneklerle değerlendirilmesi. *Tesisat Mühendisliği Dergisi*, 126, 35–47.

Megahed, N. A. (2017). Understanding kinetic architecture: Typology, classification, and design strategy. *Architectural Engineering and Design Management*, 13(2), 130–146.

Moloney, J. (2011). *Designing Kinetics for Architectural Facades*. New York: Routledge.

Ochoa, C. E. & Capeluto, I. G. (2008). Strategic decision-making for intelligent buildings: Comparative impact of passive design strategies and active features in a hot climate. *Building and Environment*, 43(11), 1829–1839.

Oral, H. & Karakoç, E. (2015). Doğadan esinli tasarımda etkileşimli strüktürler. *IX. Mimarlıkta Sayısal Ulusal Sempozyumu, Sürdürülebilir Sayısal Ekolojiler* (pp. 156–166). Turkey: İstanbul, Özyeğin University, June 25–26.

Ritter, A. (2007). *Smart materials in architecture, interior architecture and design*. Basel: Birkhäuser, De Gruyter.

Romano, R., Aelenei, L., Aelenei, D. & Mazzucchelli, E. S. (2018). What is an adaptive façade? Analysis of recent terms and definitions from an international perspective. *Journal of Facade Design and Engineering*, 6(3), 65–76.

Ruitenbeek, S. T. (2016). *Structural Active Facade (Master's Thesis). Eindhoven University of Technology, Netherlands.*

Tabadkani, A., Roetzel, A., Li, H. X. & Tsangrassoulis, A. (2020). A review of automatic control strategies based on simulations for adaptive facades. *Building and Environment*, 175, 106801.

Topal, A. S. & Arpacıoğlu, Ü. (2020). Mimarlıkta akıllı malzeme. *Journal of Architectural Sciences and Applications*, 5(2), 241–254.

Uç, B. (2023). Ekolojik Mimarı Tasarımda Biyomimikri ve Ekomimikri. *YDÜ Mimarlık Fakültesi Dergisi*, 5(2), 1–20.

Velasco, R., Brakke, A. P. & Chavarro, D. (2015). Dynamic façades and computation: Towards an inclusive categorization of high-performance kinetic façade systems. In *Computer-Aided Architectural Design Futures. The Next City–New Technologies and the Future of the Built Environment: 16th International Conference, CAAD Futures 2015, São Paulo, Brazil, July 8–10, 2015. Selected Papers 16* (pp. 172–191). Germany: Springer.

Velikov, K. & Thün, G. (2013). Responsive building envelopes: Characteristics and evolving paradigms. In F. Trubiano (Ed.), *Design and Construction of High Performance Homes* (pp. 75–92). New York: Routledge.

Voigt, M. P., Roth, D. & Kreimeyer, M. (2023). Systematic classification of adaptive façades – Preparing a database. *Proceedings of the Design Society*, 3, 3295–3304.

Wigginton, M. & Harris, J. (2002). *Intelligent skins*. Oxford: Routledge.

Zari, M. P. & Storey, J. B. (2007). An ecosystem-based biomimetic theory for a regenerative built environment. *Sustainable Building Conference*, Vol. 7, pp. 1–8.

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