# Revitalization Of Unutilized Buildings Through Façade Retrofitting

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ABSTRACT-

With the rapid pace of urbanization driven by the need to meet ever-evolving infrastructural demands, construction industry often relies on materials like concrete to deliver large scale developments quickly and efficiently. However, their extensive use significantly contributes to the global carbon footprint. While much attention has been given to the environmental impact of active construction, the consequences of unutilized or abandoned buildings often go overlooked. These structures, rendered obsolete due to their inability to adapt to current occupational, economic, and social requirements, continue to burden the environment without serving any functional purpose. This paper explores the implications of such unutilized buildings and emphasizes the urgent need for sustainable strategies, such as façade retrofitting, to reintegrate them into the urban fabric.

KEYWORDS- *Urbanization, Carbon footprint, Unutilized building, Sustainable strategies, Façade retrofitting.*

## INTRODUCTION-

Through the 20th century, architecture has emerged as a widely recognized discipline gaining acknowledgement not only in professional circles but also among the broader public, with people realizing the significant value it brings to the needs of the society much beyond its aesthetic aspects but also in its crucial role in shaping spaces that effectively serve their intended purposes within communities. Growing awareness in regards to environment and climate change, each decade in architecture has since lead to focusing on achieving different sustainability goals.

The impact from the world wars and the damages done by industrialization has not only left an evident scar on the environment but also diminished the purpose of structures to be purely functional, operating more as mechanized systems run by the public. This is noticeable by the fact that Brutalism (emerged in the 1950s) is itself a utilitarian movement in architecture.

*Fig.1. From the Historic Photo Collection of the Milwaukee Public Library*

*Fig.2. Photograph by duncid via Wikimedia Commons*

As the conventional occupational patterns shifted from manual labour in factories and industries to desk jobs. Technological advancements lead to increasing automated industrial processes, significantly reducing the need for manual labour. Therefore, the infrastructural demands of the working class also changed with times.

In the United States, to accommodate this newly emerging corporate workforce, new technological advancements like vertical transportation systems (elevators and escalators) supported the construction of tall commercial buildings. Along with these, the development of heating, ventilation, and air conditioning (HVAC) systems became essential to ensure occupant comfort in these high-rise environments, facilitating the widespread adoption of climate-controlled office spaces .

Now, the question arises: in a world where work and technology are constantly evolving, what happens to the buildings that no longer serve the purposes they were built for?

BACKGROUND TO THE PROBLEM-

Scarcity of resources, the aftermath of disasters, and shifting occupational needs often compel communities to migrate toward urban centers in search of more stable livelihoods. Due to such circumstances, towns turn out to become unreliable in supporting long-term survival. Urban decline stands as a significant factor in rendering once-functional structures uninhabitable, as they no longer align with the evolving needs of the population. Structures that have lost purpose within the community contribute to economic stagnation and social deterioration. Though constant efforts have been made to include adaptive reuse in the revitalization process of unutilized buildings, hardly there's been a conversation with respect to revitalization of such buildings through façade retrofitting. Through surveys from previous researches, we know that façade retrofit is predominantly considered for aesthetic renewal of façade systems rather than improving energy performance of structures. Concurrently, 'retrofit' is often considered for integration of advancing HVAC systems in older structures to enhance occupant comfort indoors.

Large-scale structures designed for occasional or event-specific use often lose their functional relevance over time. A notable example is an Olympic stadium, which require substantial resources for construction and ongoing maintenance, yet frequently remain underutilized or vacant during non-event periods. Demolishing such structures would generate excessive amount of construction waste as well as account for the wastage of economic resources put into it's construction.

These examples highlight the need for careful consideration of post-event utilization during the planning phase of such structures. Façade retrofit is relatively a new area of practice and research. Façade retrofit is hardly ever considered as a strategy for the renewal of existing structures, due to the unavailability of energy-efficient retrofit data, methods, and unclarity of return on investment of the façade retrofit.

*Fig.3. Maracana stadium, Rio*

The theme though highly relevant to advocate for sustainability. The challenges it presents require much broader research to formulate comprehensive solutions for target issues. However, this paper primarily focuses on addressing the ever changing nature of workplaces through the integration of façade retrofit.

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METHODOLOGY-

Reimagining Industry: The Conversion of Industrial Spaces into Modern Offices


- Examining the architectural timeline following World War II offers critical insight into the specific changes that building typologies have
- Undestanding the environmental and functional repercussions of unutilized/ abandoned buildings.
- Focus-
  - Underutilized large scale buildings
  - Adaptive reuse through façade retrofitting
  - Workplace evolution as primary driver for change
- Establish the significance and evolving role of facades in building performance and sustainability.
- Analysis Parameters:
- Building Background and purpose
- Type of Retrofit
- Retrofit strategy
- Performance outcomes
- Technologies that could potentially change the conventional methods of upgrades during the renovation process.
- Design strategies tailored to adaptive reuse for evolving workspaces
- Highlight barriers and potential for future projects.

Since the 19th century, industrial facilities have stood as powerful symbols of growth and the emergence of previously isolated societies into an increasingly globalized world. Their contribution in completely transforming the face of such societies is undeniably remarkable—elevating social environments, stimulating local economies, and driving innovation through rapid engineering advancements and global communication networks. By facilitating a seamless flow of services across borders, they laid the foundation for modern globalization. However, despite their substantial historical and developmental impact, their significance is often understated in contemporary discourse.

Industrial revolution not only gave rise to massive commercial centers to accommodate complex machinery far from the comprehension of a common man, but also ushered in a wave of transformative ideologies that permeated every aspect of society. It led to the rise of cities like Manchester, Detroit, and Jamshedpur, turning them into economic powerhouses. The growth of socialist movements, feminist movements, fight for worker's rights and growth of labour unions were all a result of the industrial revolution.

The urgent need to 'design' emerging industrial societies in alignment with the mechanical ambitions of the era compelled philanthropists, architects, and engineers to devise rapid solutions to anticipated urban and social challenges. This momentum sparked a chain of technological innovations, as visionary minds across the globe collaborated on what would come next. While each wave of experimentation carried its own consequences—some advancing societal progress, others leaving enduring scars—the Industrial Age ultimately etched an indelible mark on history. However, many of the structures that once stood at the heart of this transformation were eventually rendered obsolete, left abandoned or underutilized as they no longer met the functional demands of contemporary workspaces.

Contemporary society is increasingly coming to terms with its past, prompting a renewed recognition of the social progress achieved over time. This reflection has led to the acknowledgment of former industrial structures as valuable components of our 'industrial heritage'.

Industrial Heritage- "*Industrial heritage refers to both the physical remains such as factories, machinery, and infrastructure and the intangible legacy, like the cultural and social practices, of past industrial activities. These elements are important because they reflect the historical, technological, social, and architectural developments that shaped modern society.*"

The following examples continues to showcase the well-preserved legacy of their industrial past, successfully morphing their once dilapidated forms into extraordinary spaces of renewed purpose and cultural significance. These structures are examples of revitalized modern offices.


Project Name: Domino Sugar Refinery

Location: Brooklyn, USA

Architects: PAU - Practice for Architecture and Urbanism

Year: 2023

Building Typology: Mixed Use

*Fig.4. Photograph by Max Tuohey via ArchDaily*

PAU's adaptive reuse of the Domino Sugar Refinery in Brooklyn transforms the historic industrial facility into a neighbourhood focal point. Once a prominent sugar production facility dating back to the late 1800s, the building now accommodates a range of contemporary functions.

Rather than altering the original façade, the architects introduced a new structure nested within the existing shell, separated by a 3.65-meter gap. This strategy preserves the building's historic character while allowing for modern floor heights and enhanced natural lighting. The design successfully blends heritage conservation with contemporary utility, creating a space for creative work and community engagement.

"The greenest building is... one that is already built." – Carl Elefante (Architect, FAIA)

However, the renewal of structures not originally designed to meet contemporary functional needs and regulations poses significant challenges. This becomes even more complex when dealing with industrial heritage sites, where historic landmark status imposes further constraints on the extent and nature of permissible interventions.

From Industry to Office: Challenges in Revitalizing Industrial Buildings for Contemporary Work Environments

1. Structural and Spatial Limitations

Industrial structures were designed for machinery, large open volumes, or heavy loads—not for occupant comfort, accessibility, or functionality of spaces.

Adapting these into offices often requires:

- Reinforcement of existing structural systems
- Floor plate subdivision
- Addition of HVAC and MEP systems in buildings that were never designed for thermal control or fine-tuned acoustics.

Mechanical systems such as elevators, electric lighting, and air conditioning were first introduced in 1902 and have continually evolved since then. While many older office buildings have replaced traditional HVAC systems to align with modern sustainability standards, industrial warehouses often constructed without any proper provision for mechanical services remain heavily reliant on mechanical retrofit solutions.

2. Facade and Envelope Inefficiency

Most industrial façades are non-insulated, glazing is minimal, and thermal bridging is common.

These buildings often donot meet current energy codes and also lack in providing efficient indoor environments, necessitating facades to:

- Improve thermal performance
- Allow daylight penetration for office work
- Enable natural ventilation where feasible

Industrial facilities usually have an appearance characteristic of their function—exposed structural elements, masonry walls, minimal ornamentation, chimneys, and an overall 'raw' personality. Large windows were typically built to exhaust smoke. The conditions within traditional industrial plants were only suited primarily for machinery.

3. Varying ceiling and flooring requirements

High ceilings and expansive interiors lead to poor acoustic control and uneven lighting distribution—inadequate for office tasks.

Revitalization must incorporate:

- Zoned lighting strategies

- Acoustic baffles for noise control
- Suspended ceilings and raised flooring systems are employed to accommodate the extensive cable networks required in data centers and offices, while also facilitating flexible spatial layouts.
- Controlled daylighting through adaptive façades

4. Accessibility and Building Code Compliance

Industrial facilities often lack proper egress routes, elevators, or accessible toilets, falling short of:

- Universal design standards
- safety and emergency exits
- Workplace comfort regulations

Industrial warehouses are often found in a state of disrepair long after their original period of operation. Without regular supervision or maintenance, these structures fall out of compliance with current building norms, making retrofitting essential. Such interventions typically require reconfiguration of entryways, staircases, and core infrastructure to align with modern building codes.

5. Environmental Remediation

- Legacy pollutants such as asbestos, lead paint, or soil contamination may still be present.
- Environmental remediation is both cost-intensive and legally mandatory before occupancy can begin.

6. Preservation vs. Intervention

Many industrial buildings hold heritage value, prompting a design tension between preserving historic elements and introducing new façade systems or spatial layouts.

Sensitive façade retrofitting requires:

- Balancing material reuse and visual identity
- Complying with heritage conservation guidelines
- Using reversible or non-invasive interventions

Example- The Tishman Building (now 10 Lafayette Square), located in Buffalo, NYC, serves as a notable example of how architects modified their façade retrofit strategies to comply with historic preservation criteria, due it being registered as a historic landmark in 2012.

7. Compatibility with different programs-

Offices require more privacy, networking spaces, and IT infrastructure compared to open-plan industrial halls.

The adaptation process must address:

- Zoning flexibility
- Introduction of modular interiors or mezzanines
- Workspace segmentation without compromising daylight or ventilation

8. Cultural Perception and Market Acceptance

Some industrial buildings are associated with decay or obsolescence. Turning them into attractive, functional workplaces involves:

- Rebranding strategies
- Public engagement
- Cultural programming (e.g., coworking hubs, creative industries)

## LITERATURE REVIEW-

Façades, traditionally perceived as mere envelopes or aesthetic expressions of architectural form have undergone a significant transformation in their functional and environmental roles. Facades serve as the primary interface between the structure's interior and the outside world. They are not merely aesthetic features but complex systems that play vital roles in a building's performance, sustainability, and identity. Moreover, they directly influence the energy efficiency, indoor comfort, and environmental footprint of buildings.

Project Name: Tri-Tesselate Building, Noida

Architects: AKDA

Area: 2350 $m^2$

Year: 2018

Building Typology: Office

*Fig.5. Courtesy of AKDA*

The project initially started of with an existing building located in the dense Hosiery complex of Noida, an industrial hub particularly allocated to the garment manufacturing business.

After careful deliberation, manufacturing and office spaces were to be accommodated in the same building. The façade was designed to play a pivotal role in distinguishing these zones vertically, based on the specific requirements for privacy and natural lighting associated with each function.

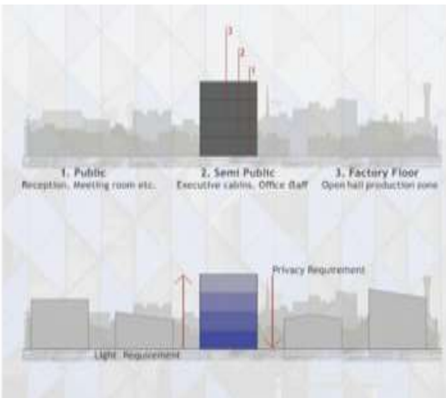



*Fig.6. Vertical Configuration of spaces*

*Fig.7. Manufacturing zone.*

The Tri-Tesselate building features a distinctive façade that combines cool grey glass with a gradient of blue, grey, and white aluminum panels. These materials are supported by a tubular aluminum frame with diagonal cross-bracing, creating precise six-sided joints that form the tessellated pattern.

Outcomes:- Darker panels at lower levels help absorb warmth in cooler areas or seasons, enhancing passive performance.


Project Name: Solar Facades in Trifolium

Location: Copenhagen, Denmark

Area: 13000m$^2$

Year: 2019

Building Typology: Creative Hub

*Fig.8. Solar façade by SolarLab (via ArchDaily)*

Originally, established as the city's largest dairy facility in 1966, the building has undergone significant transformation since. Now, rebranded as a creative hub by 'Rama studio', Trifolium serves as a multidisciplinary workspace, offering professional workshops, office spaces, a photo studio, event venues, and a showroom. It fosters a community of entrepreneurs, freelancers, and startups engaged in digital production, traditional craftsmanship, design, photography, and technology.

Along with adaptive reuse, the building has also taken over to incorporate a façade retrofit by integrating Kromatix high-efficiency energy-producing Building-Integrated Photovoltaics (BIPV) into its structure. This not only contributes towards a sustainable future for the building but also maintains the sentiment attached to the structure such that it resembles the original appearance of the building.

Project Name: A.J. Celebrezze Federal Building

Location: Cleveland, Ohio

Architects: Interactive Design

Area: 53605m$^2$ , Height: 128m Completion Year: 2015

Building Typology: Office

*Fig.9. A.J. Celebrezze Building - Courtesy U.S General Services Administration(GSA)*

Originally established as a 32 storey office building for the U.S. General Services Administration in the late 1960s. The building observed significant deterioration of the external wall due to moisture damage from failed drainage systems. This resulted in delamination of exterior wall panels, compromising the air and moisture barrier.

Facade Retrofit strategy: Double wall

Double wall technology is one of the most complex building envelope forms. Before the application of the double walls, it was a fundamental challenge to evaluate the effect of double wall on the existing superstructure. The design team ran an extensive series of simulation to analyse the impact in different weather conditions.

*Fig.10. Double Wall system*

The double-skin system became successful in significantly reduced heating and cooling demands, leading to an estimated 17% reduction in energy costs.

Project Name: China Resource Center Building

Location: Hong Kong

Retrofit Engineers: Arup

Gross Floor Area: 59460m$^2$

Height: 173m

Completion Year: 2015

Building Typology: Office

*Fig.11. China Resource Center Building - Courtesy of Arup*

After the completion of the China Resource Center Building in 1983, it became the tallest structure in Hong Kong. The building's 25$^{th}$ anniversary in 2008, marked the need for integration of innovative technologies to align the building with modern sustainability targets and corporate requirements.

The façade underwent a complete reclad type of retrofit of the original curtainwall with a high-performance façade. Daylight was optimized with a high-performance glazing that allows only 5% solar energy transmitted to interiors. Not only that, the façade also contributes in reducing the need for air conditioning

Energy reductions of about 1.65GWh/ were reported annually. The China Resource Center is the first green retrofit receiving LEED in Hong Kong.

Project Name: Kreditanstalt fur Wiederaufbau (KfW) Bank Building

Location: Frankfurt, Germany

Retrofit Architects: RKW Architektur

Gross Floor Area: 26000m$^2$

Completion Year: 2005

Building Typology: Office

*Fig.12. KfW Main Headquarters*

Constructed in 1968 as the new head quarters of the KfW Bankengruppe (banking group), a German state-owned investment and development bank, based in Frankfurt. KfW buildings have had their own share of history connected to the corporations growth and expansions. Time and again, their buildings reached the bursting point, and stopgap measures had to be undertaken.Just a decade later, the new building was no longer big enough. Expansion of the workforces into different buildings considerably disrupted business workflows.

In 2005, The main KfW building was a part of a retrofit project where in dynamic façade system has been applied as a retrofit.

*Fig. 13.*

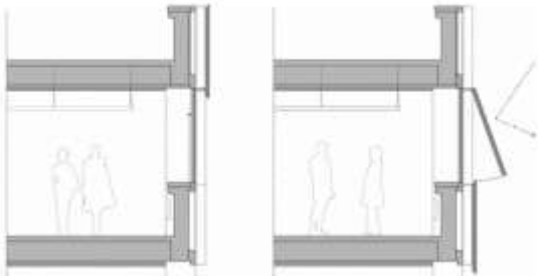


*Fig.14.*

The facade incorporates dual-pivot manually operable windows for natural ventilation, which are dynamically shaded by automated exterior sunshades that retract into the spandrel zone of the facade when not required. The KfW Bankengruppe now places considerable importance on user comfort with low energy consumption for all its buildings. For instance, the new facade controls the light, air and heat supply, and, together with new building services equipment, ensures primary energy savings of almost 50 per cent.

Today, multiple KfW buildings stand tall adjacent to each other in Frankfurt, Germany as a self contained block known as the 'KfW campus'.

- Case Study Analysis of global precedents-

*Table 1. Summary of the case studies*

| | Reutilized as | Retrofit Type | Retrofit strategy | Positive Impact |
|---|---|---|---|---|
| Tri-Tesselate Building | Factory to (Manufacturing + office Building) | Façade Enhancement | Passive Design | control over privacy and lighting |
| Trifolium | Dairy Facility to Creative Hub | Selective Replacement | Solar Façade (BIPV) | Energy generation |
| A.J. Celebrezze Federal Building | Office | Overclad | Double Wall facade | 17% reduction in energy costs |
| China Resource Center Building | Office | Reclad | High Performance glazing | Only 5% of solar energy transmittance |
| KfW Building | Office | Overclad | Dynamic Facade | Automated sun shading, energy savings of 50% |

Across all the projects, façades are no longer passive skins but active, responsive systems. Buildings like the KfW Bank and the Celebrezze Federal Building show how smart façades can adjust to changing weather and user needs, improving comfort while saving energy. There's also a growing trend of turning façades into energy producers, like at Trifolium, where solar panels are seamlessly built into the design. Many projects, such as Trifolium and the China Resource Center, manage to upgrade performance without losing the building's original character, showing a strong sensitivity to history. Advanced simulations, especially at Celebrezze, played a big role in predicting how new façades would perform, helping designers make smarter choices. Finally, façades are being used to organize space more clearly, as seen in the Tri-Tesselate Building, where the design visually separates the offices from the manufacturing areas.

Exploring Façade Innovations-

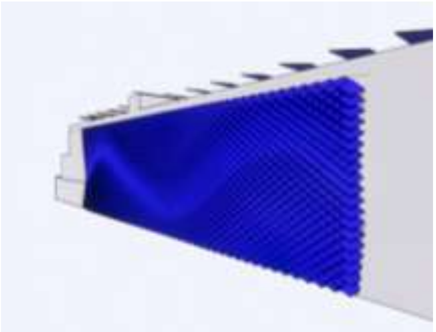
Heating and Cooling loads account for approximately 40% of the total energy consumption in commercial buildings. The growing reliance on active systems in society has significantly elevated the demand for fossil fuels and contributed to a rising carbon footprint.

*Fig.15. Courtesy of ETH Zurich (House of Natural Resources)*

Furthermore, their long-term impact poses a potential threat to the global climate, a concern that has become increasingly apparent in recent years.

Harvesting energy on-site is emerging as the next frontier in the pursuit of sustainable and energy-efficient design. Amalgamation of renewable energy and advancing technologies like BIPV (Building Integrated Photovoltaics) could really pave the way for achieving sustainability. While façade PV systems receive less irradiation than rooftop or ground units, they expand BIPV potential in urban areas and offer more stable output, especially in winter. *Fig. 16.*

Sustainable architecture prioritizes efficient resource use, and facades of prominent buildings offer valuable potential in this regard. Dynamic facades not only replace static shading by adapting to environmental changes—leading to up to 30% energy savings—but, when integrated with BIPV, they can also contribute to local energy generation. They further enhance indoor quality by adjusting to allow optimal daylight.



CASE STUDY: Adaptive solar facades at ETH House of Natural Resources, Zurich, Switzerland.

The following case study is a living lab experiment, that has been prototyped by ETH House of Natural Resources, Zurich.

Duration: 2018-2021

- The prototype was first demonstrated on the NEST HiLo Building in Zurich.

Future buildings will require significant improvements to adhere to 2050 greenhouse gas mitigation strategies. One method is to consider building components as multifunctional elements. At HiLo, the Architecture and Building Systems A/S group devised Adaptive Solar Facade (ASF): multifunctional elements that are delicate, movable photovoltaic modules that can be mounted onto a lightweight structure on the building envelope. Moreover, this type of modular system Moreover, this type of modular system is suitable for both restoration and new construction projects.

*Fig. 18.*

Beyond energy production, the modules enhance occupant comfort through adjustable shading, optimized daylight penetration, and personalized view control. The facade incorporates an energy storage system that converts excess energy into pressurized air, enabling module adjustment during periods of low generation. Its dynamic design allows continuous adaptation to environmental conditions.

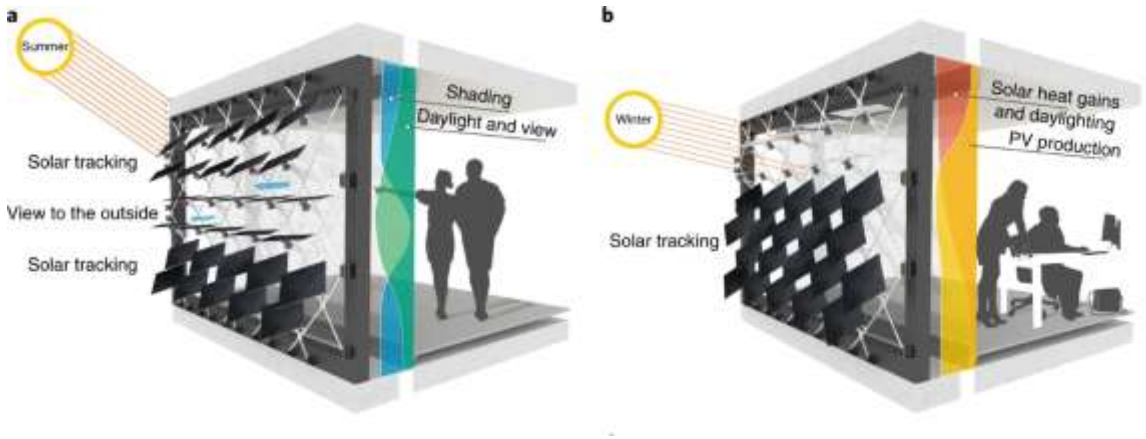
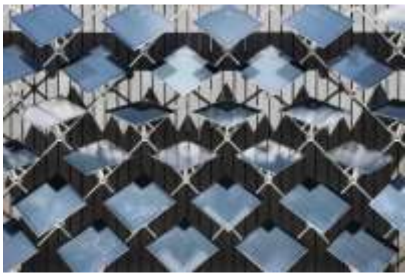



*Fig. 19. a) During summer season, b) During winter season*

The project integrates advancements in architecture, energy systems, and soft robotics. Individual modules are operated using the SoRo-Track—a soft-material actuator—guided by a custom orientation control algorithm developed by the research team.



The ASF consists of 50 modules on a modular frame installed at the façade of the HiLo unit of NEST, that is planned as a duplex penthouse apartment for visiting scientists and will show case ultra-lightweight construction as well as smart and adaptive building systems.

Design of the module-

1. The ASF is composed of individual modular units, each equipped with a photovoltaic (PV) panel.
2. The CIGS photovoltaic cells are laminated directly onto 400 x 400 mm aluminium panels.These modules are arranged in a grid-like configuration on the building's facade and can be controlled independently.

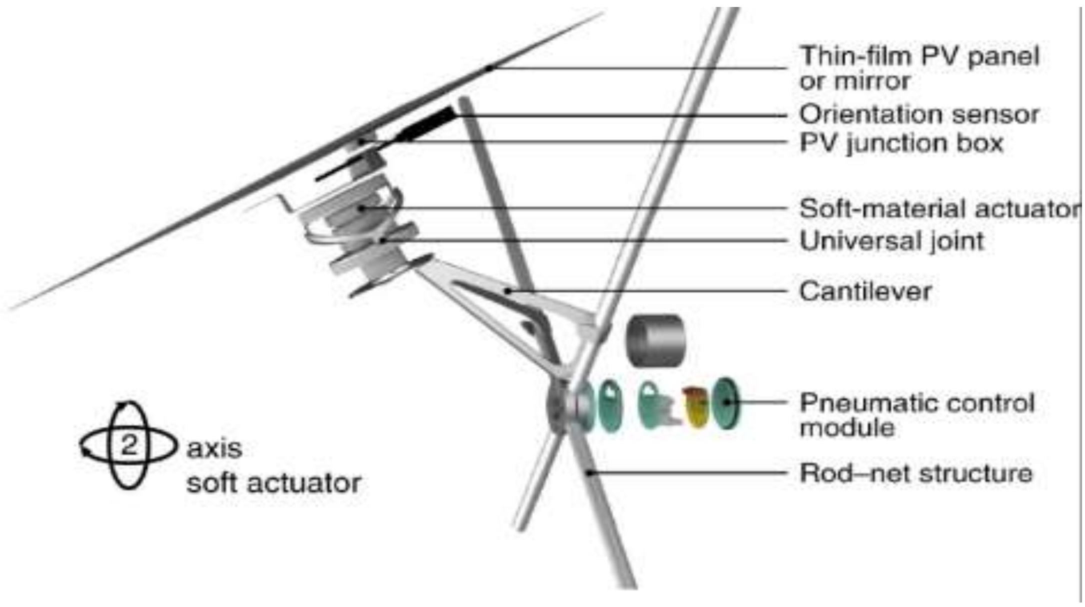



*Fig.20. Adaptive solar panel Module*

3. Soft-material pneumatic actuator (SoRo-Track) expands and contracts based on pressurized air, allowing for smooth and energy-efficient motion.
4. Simulation environments were created using Rhinoceros 3D and its Grasshopper plugin.

Post-Experiment Analysis of the Adaptive Solar Façade (ASF)-

1. Solar production can be increased by up to 40 percent compared to conventional solutions, heating and cooling energy savings of up to 80 percent are possible compared to conventional non-PV, non-adaptable shading systems.
2. The ASF allowed controlled daylight admission into the interior, contributing to reduced reliance on artificial lighting.
3. The analysis showed that this approach enabled low-energy, responsive actuation, even in low solar conditions (e.g., cloudy days or nighttime), by utilizing previously stored energy.
4. Beyond its application in new constructions, ASF is also well-suited for retrofitting existing buildings, offering significant potential to enhance the energy performance of the broader building stock.
5. The Adaptive Solar Facade has been commercially launched under the name 'Solskin' and is now available to consumers, having also secured several major contracts.

- CONCLUSION-

The revitalization of abandoned buildings through façade retrofitting presents a compelling opportunity to blend architectural heritage with contemporary environmental and aesthetic goals. This research highlights how façade interventions—whether through selective replacement, overcladding, or complete enhancement—can transform underutilized structures into sustainable, functional, and culturally relevant spaces. It also explores the integration of different technologies, modified into conventional façade systems.

This research demonstrates that a well-considered façade retrofit can do much more than improve energy performance. Projects like the Trifolium Creative Hub illustrate how façade enhancement, when grounded in principles of reuse and material honesty, can foster inclusive public spaces and creative economies. In contrast, the KfW retrofit reveals how even highly functional upgrades—such as overcladding for thermal performance—can be integrated in a way that respects urban fabric while supporting healthier indoor environments for occupants. Even in the case of the Tri-Tessellate Building, the façade strategy offers insights into how geometry, material gradients, and passive design increases the efficiency of the building.

Façade retrofitting of abandoned buildings offers more than just a technical solution to urban blight—it serves as a catalyst for architectural renewal and social revitalization. By reactivating forgotten structures, façade interventions not only extend the life of buildings but also reinvigorate neighbourhoods, encourage community engagement, and promote cultural continuity in evolving urban landscapes.

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