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Alive dynamic covers

From Static to Dynamic Covers: Reimagining the Building Skin

In modern architecture, the concept of the building envelope has evolved significantly, moving away from traditional static facades to the more innovative dynamic systems. Traditional facades function as a simple barrier, creating a rigid separation between the outside and inside environments. However, these static solutions often fail to address the complex and ever-changing climatic conditions, resulting in increased energy consumption for heating, cooling, and ventilation. One compelling way to think about this evolution is by considering the building skin as not just a separator, but as a multilayered, dynamic system, similar to the layers of an onion. These layers provide more than just thermal insulation and acoustic protection; they also mediate the flow of light and air, ensuring a gradual and seamless transition from the public exterior to the intimate private spaces within. This dynamic response enables buildings to be more energy-efficient, improving comfort levels without relying heavily on external heating or cooling systems. Traditional static facades lack the thermal inertia necessary to moderate temperature changes effectively, exposing the interior life of the building to the outside world. This limitation not only impacts energy consumption but also the privacy and comfort of the occupants. As discussed in my doctoral thesis, "Envelope Optimization for Energy-Efficient Office Buildings," these problems are compounded in buildings that adopt outdated facade solutions, often overlooking both traditional climatic contexts and modern sustainability principles.

The Need for Multi-layered, Adaptive Facades

In response to these challenges, the solution lies in creating adaptive, dynamic covers that are more responsive to environmental conditions. These dynamic systems, using advanced technologies such as ETFE air cushions, movable shading, and smart materials, offer flexibility that static facades cannot. These dynamic "skins" regulate the flow of heat and light, optimize the building's thermal performance, and mediate the transition between exterior public spaces and the private, intimate interior.

Moreover, the incorporation of multiple translucent layers allows natural light to filter through, creating a more gradual transition from outside to inside, enhancing both aesthetic and functional qualities. This kind of responsive facade serves not just as an energy-efficient solution but also as a design element that contributes to the overall well-being and comfort of the occupants.

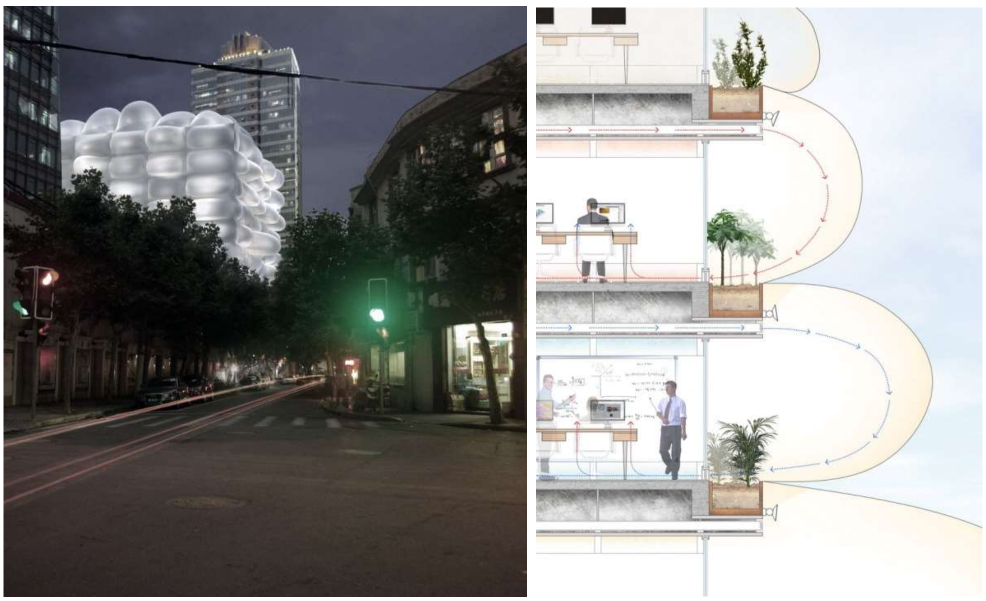

Figure1 – 3Gatti Architecture Studio, Bubble Building © 3Gatti Architecture Studio

Sustainability and Dynamic Building Envelopes

In today's context of climate change and resource scarcity, sustainable building practices have become essential. Dynamic envelopes help reduce reliance on non-renewable resources, as they are capable of adjusting to climatic variations in real-time, without the need for significant energy expenditure. This adaptability makes them ideal for achieving energy efficiency goals, addressing the limitations of traditional facades which consume vast amounts of energy to maintain comfortable indoor climates.

Dynamic facades function as alive organism, regulating thermal and solar gains by adjusting their shading mechanisms throughout the day and across seasons. For instance, during peak summer hours, the facade can limit solar penetration to reduce cooling loads, while in colder months, it can allow more sunlight to enter the building, providing natural heating and reducing the need for artificial climate control systems. By actively managing these factors, dynamic facades reduce reliance on non-renewable energy sources, lowering the overall energy consumption of the building.

Unlike static facades, which may perform well in certain conditions but poorly in others, dynamic skins can provide a tailored indoor environment by adjusting to specific user requirements. For example, different rooms in the same building may have distinct lighting, heating, and ventilation needs. A dynamic system can

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respond to these individual requirements by controlling the amount of natural light, airflow, and temperature, ensuring maximum comfort for each space. This customization improves not only thermal comfort but also enhances user satisfaction, morale, and productivity.

An example of the superiority of dynamic systems can be seen in the implementation of adjustable shading devices, such as operable louvers or retractable awnings which transform the building and its behavior similar to flowers behavior. A fixed shading device, while capable of blocking sunlight during the hottest times of the day, cannot adjust to allow for solar gains during the cooler months. A dynamic shading system, however, can move and adjust in real-time, maximizing energy efficiency by letting in sunlight when it’s needed for heating and blocking it when it's not.

Figure2 – El Dorado, Leawood Speculative Office © El Dorado

Research shows that these systems can achieve near-zero energy usage for heating and cooling in temperate climates for most of the year. Dynamic shading devices can significantly reduce the energy required for cooling during the summer and, when properly integrated with other building systems, can also improve heating efficiency during the winter months.

Due to advanced technologies incorporated into dynamic covers, like sensors, actuators, and control systems that monitor external factors such as solar radiation, temperature, wind speed, and even humidity, the facade is able to respond instantly to changes in weather, maintaining a stable and comfortable indoor climate. In contrast, static facades are limited in their ability to mitigate extreme weather conditions, often resulting in higher energy usage and reduced occupant comfort.

For example, ETFE air cushion systems—as seen in projects like the Ed Kaplan Family Institute —allow buildings to maintain optimal internal conditions with minimal energy use. These flexible systems can adapt to changes in internal and external pressure, making them highly effective in controlling temperature and light without relying on heavy mechanical systems.

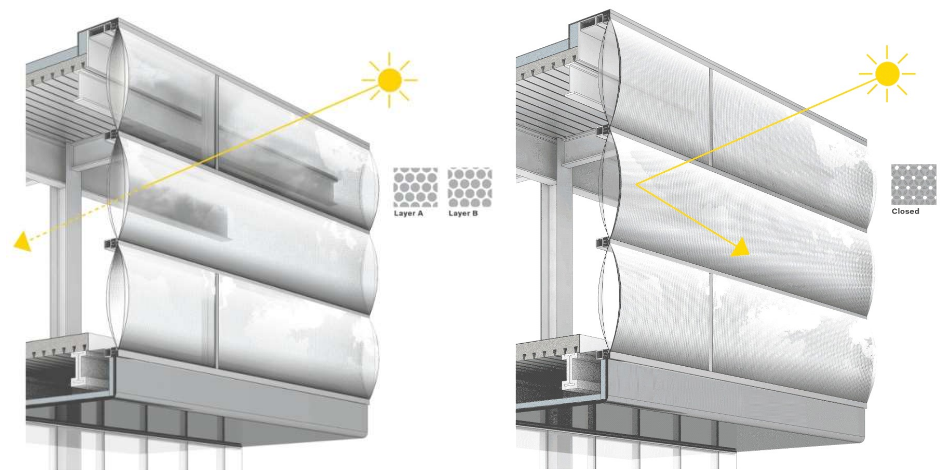

Figure3 – John Ronan Architects, Ed Kaplan Family Institute © John Ronan Architects

Figure4 – John Ronan Architects, Ed Kaplan Family Institute © Steve Hall

In addition to their energy-saving potential, dynamic facades can incorporate bioreactor systems, like those being developed in Germany, which utilize algae to produce biomass and reduce CO_2 emissions. These systems not only help regulate temperature and light but also contribute to generating renewable energy, enhancing the overall sustainability of the building.

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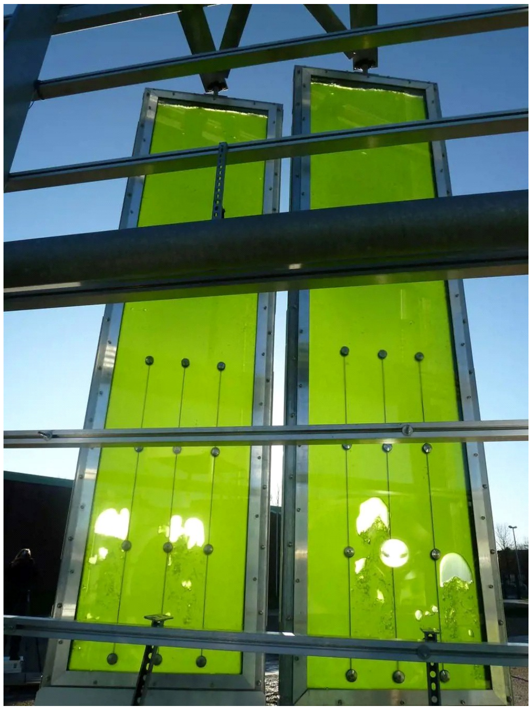
Figure5 – BIQ House © Colt International, Arup Deutschland and SSC StrategicScience Consult

The potentioal of integrating renewable energy solutions, such as photovoltaic panels or bioreactor systems, offer the possibility of shading and thermal control but also generate clean energy that can be used to power the building. For example, bioreactor facades, which utilize algae to create biomass and reduce CO2, provide adaptable shading and solar control, enhancing energy efficiency while producing renewable energy. This level of integration is far superior to static facades, which generally lack the ability to harness renewable energy sources effectively.
As the demands of modern buildings evolve, dynamic facades offer greater flexibility compared to their static counterparts. They can be programmed to meet the changing needs of the building over time, adjusting to new occupancy patterns or environmental changes. This adaptability ensures that the building remains efficient and functional for a longer period, delaying the need for costly renovations or upgrades that are often necessary with static facades. Furthermore, the lifespan of materials and components in dynamic facades can be maximized, as they are used more efficiently, reducing wear effects.

Integration of New Technologies and Smart Materials

Incorporating smart materials like electrochromic glass into dynamic facades enables further customization of the interior climate. Electrochromic glass changes its transparency based on external conditions, such as sunlight exposure. This

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capability allows buildings to automatically regulate heat gain and light penetration, adjusting throughout the day to provide maximum comfort without manual intervention. This technology has been employed in cutting-edge structures like The Helios Building in Paris, which combines electrochromic materials with other adaptive technologies for enhanced energy performance.
By layering advanced materials and systems, these dynamic building skins not only respond to external stimuli but also provide a visual transformation, adding to the aesthetic dynamism of the building. This visual and functional adaptability reflects the modern need for continuous transformation, aligning architectural innovation with environmental responsibility.
Regarding the building transformation into a responsive organism, the researches of Doris Sung from DO|SU Architecture Studio are inspiring. Experimenting with oftware, materials and nature, these applications help anticipate the human needs. This level of responsiveness cannot be matched by static facades, which often require manual intervention or fail to adjust to the changing needs of the interior environment, but can be futher enhanced by applying an external translucent skin that integrates smart materials and new technologies.

Figure6 – dO|Su Studio Architecture © Brandon Shigeta

Also, a distinctive aspect of these dynamic envelopes is the integration of renewable energy solutions. For example, modern buildings can incorporate photovoltaic systems into their dynamic façades, providing protection against solar radiation while generating clean electricity. Bioreactor façades, such as those developed in recent projects in Germany, use algae to produce biomass and reduce CO2 emissions, while simultaneously offering efficient temperature control and energy generation potential.

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Conclusion: The Future of Building Envelopes

As architecture continues to evolve, the building envelope must transition from a static, underperforming element to a dynamic, living system that actively engages with its environment. The principles outlined in my research emphasize the need for dynamic systems that can adapt to fluctuating climatic conditions while improving energy efficiency and enhancing occupant comfort. By integrating smart technologies, renewable energy sources, and advanced materials, we can create building facades that not only respond to the present challenges but are also equipped for the future needs of a sustainable and transformative built environment.