EXECUTIVE BOARDROOM COMMENTARY

More with Less + Less with More

Adapting our approach to design and delivery

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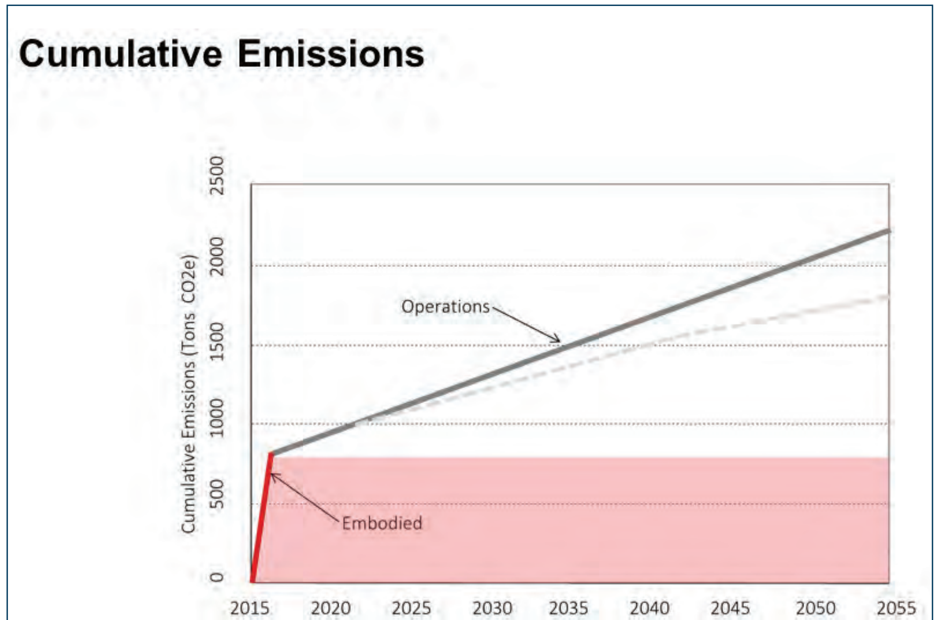
Are the good times really over for good? I often think about these lyrics to the Merle Haggard song of the same name when faced with the challenges presented by increasingly stringent codes and sustainability trends. Trends like carbon neutrality are becoming driving parameters in the design of our enclosure systems. Gone are the days where building designs utilizing expansive glazing, with questionable thermal performance go unfettered by the governing bodies overseeing what we build or occupied by tenants apathetic and ill-informed about the impact these buildings have on our environment. I'm not old enough to give "Back in the Day stories", nor did I start my career in a period where performance was not a concern, but I can say that what we have experienced in the realm of energy codes and sustainability initiatives in the last few years is markedly more intense than when I started my career seventeen years ago. Accountability is now the driving force behind how buildings are expected to perform and how their performance is proven and documented in the design and construction phases. And it's about time.

Uber Mission Bay Headquarters

Three related trends have been recurring through our recent work, all of which address project's embodied or operational performance and involve the central concepts of doing More with Less or using Less with More. The term "performance" can be interpreted in many ways, but in the context of this article it is meant to define the amount of resources (energy, cost, carbon, etc) a building uses in its creation (embodied) and through it's lifespan (operational). When it comes to architectural glazing, the concept of using Less with More adopts the precept that the beauty of expansive glazing will forever be central to the architectural vision despite increasingly strict energy codes and sustainability initiatives, and puts the onus on glazing manufacturing industry to keep finding ways to increase the performance of glazing systems in order to meet the increasingly stringent targets. Alternatively, More with Less addresses the growing trend towards carbon neutrality and Net Zero Carbon (NZC) design by limiting the carbon intensity of our glazed systems. Finally, incorporating both these tenets, is the concept of designing for adaptability, that addresses designing easily adaptable enclosure systems in order to allow for minimally invasive and wasteful retrofits to respond to future technologies and increasing energy use limitations.

MORE WITH LESS

The concept of quantifying a building's impact from a carbon perspective rather than one from energy use or energy cost has been a welcome change. Energy codes and sustainability rating systems have traditionally used site energy use or Energy Use Intensity (EUI), all of which are easy metrics to grasp and to quantify, but do not capture the full impact that carbon does. Quantifying impact through carbon, not only captures the quantity of energy but also the impact from which that energy came. The fact that 40-50% of the global greenhouse gas emissions emanate from the building industry has become widely accepted by the building industry. The amount of that percentage that is a result of embodied impacts is constantly evolving as our buildings become more operationally efficient, but currently is believed to be 25% of the total. If you look at how a typical project impacts build over time, there is the initial burden of emissions that occur during construction, the embodied impacts, as well as the operational impacts that occur over the life of the building. The operational "curve" representing the buildings impact over the course of its occupation is influenced by how much energy the building consumes over time, where the building's energy is sourced, and how efficiency of the building throughout it's life. As the world's buildings get designed to meet more strict energy code, built with accountability, and operate with cleaner energy sources or through renewables, we will see the embodied carbon impact of 25% get as high as 50% of the total building-generated carbon impact. With fully electrified buildings, powered by clean energy sources and renewables, all



Cumulative Carbon Emissions of a Typical Building

Louis Armstrong New Orleans International Airport
©LEO A DALY | Creative Sources Photography / Rion Rizzo

the carbon of our future buildings will come from materials, refurbishment, and commuting. As a result, the area under the curve is getting harder to ignore.

The two primary recommendations for carbon reduction in construction are simplistically, use less materials, and use less impactful materials. In the context of the building enclosure, the material to which this publication is focused, and the materials that support it have huge targets on their back. As Mic Paterson of the Façade Tectonics Institute speculates, unless the manufacturers or glass and aluminum find ways to reduce their carbon footprint, increase their performance, and extend their service life, "restrictions on their use are ultimately unavoidable" .

Is it heresy to suggest the use of less glass in a glass publication? As a fan of many well-designed transparent skins, I lament the day when code all but outlaws the design of large expanses of glass. However, we all should embrace the responsibility of creating low-embodied carbon and highly performative buildings and be excited about the design challenges it offers. While some jurisdictions, like New York City, have been leading the charge of code changes that would limit glass use, most others will be slow to adopt similar goals. The burden falls on us as designers and engineers to lead the way to using less, or should I say emitting less, not through limiting the total area necessarily, but by limiting the quantity and being more creative with the application of its use.

PERFORMANCE BASED DESIGN

The first method for reducing the quantity of glass used on any given project is to only utilize the amount necessary to meet any given project's construction codes. A number of engineering efforts, including structural design and fire design, have increasingly adopted Performance Based Design (PBD). PBD procedures skirt the inefficiencies and design limitations of prescriptive approaches. What this means in regards to glass and glazed enclosure systems, is that we as designers and engineers need to gain a better understanding of the code requirements that drive glass sizing and utilize more sophisticated analysis techniques than what is traditionally used. Furthermore, rather than designing for the worst case wind pressures and applying the resulting thickness to the entire project, we need to mandate more sophisticated calculations methods than ASCE7 to determine our components and cladding pressures as to optimize the glazing thicknesses to the specific loads determined at each orientation and each floor of the building. A recent study performed by our team on a new heavily glazed 440 foot tall tower indicated that a 30% reduction of glazing tonnage could be saved if the glass assembly was tailored to the specific loads indicated in the wind tunnel results rather than the worst case pressures determined by ASCE7-10. This approach is atypical, but if utilized could result in substantially reduced embodied carbon use in buildings with no impact on the occupant experience.

ALTERNATIVES TO GLASS

A second consideration to using less quantity of glass is to look at alternatives. While no one can discount the benefits of traditional insulated glazing in vertical and overhead applications from a thermal, clarity, aesthetic, and acoustic perspective, in order to reduce the embodied carbon contained in the making of our envelopes, we have to think about alternatives. Furthermore, we have to make informed decisions regarding the use of triple pane glazing as the benefits are minimized when you consider cost payback. In a 2014 article for Building Magazine and Circular Ecology, author Craig Jones outlines a study into the embodied and operational carbon payback of triple pane glazing compared to double pane glazing. His article concludes that regardless of framing type, it would take almost twenty years for triple pane glazing to pay back the additional embodied carbon. Depending on the framing type, the carbon cost payback will never be realized when considering the lifespan of the window itself .

Products such as Heat Mirror® Insulated glazing by Eastman have been commercially available since the early 2000's. This product is marketed as an alternative to triple pane glazing, offering similar or superior performance while being 30% lower in weight and 33% less in energy use from cradle to grave. While often ignored due to size and coating limitations as well as the lack of competitors, technologies like this are important if our goal is to limit our embodied carbon. If more members of the glass supply chain stepped up to meet the aesthetic challenges raised by designers, the entire industry could build with less of a carbon impact.

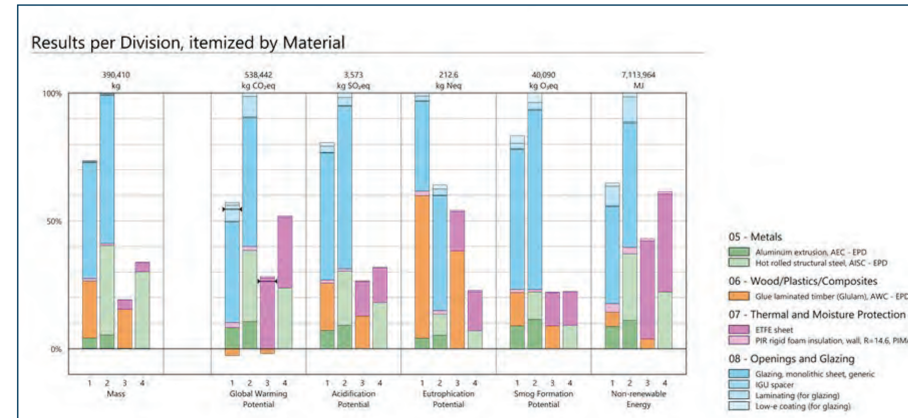
As our company works on a number of large scale projects containing long span roofs with a need for extensive roof fenestration, we have become well-versed in alternatives to glazing that would allow for greater spans, while increasing the transparency and reducing the structural weight of the fenestrated area. A material that has become increasingly popular in these types of applications is ethylene tetrafluoroethylene (ETFE). This lightweight, transparent film can be used in a single layer or inflated multi-layer application to achieve long spans with minimal supporting structure. The hope in using this material is that it could offer a lightweight alternative to glass while still offering the transparent views and high performance, however conventional ETFE has some unavoidable limitations which often result in the return to traditional glazing or even costly roof mechanisms. The limited mechanical strength capacity and flexibility of the material often results in costly and visually obtrusive cable reinforcement. Furthermore, ETFE film, in a single skin or inflated cushion has very limited thermal properties compared to traditional insulated glazing (IG), resulting in the need to provide fritting to achieve comparable Solar Heat Gain Coefficients to IG. The result of this fritted treatment is substantially compromised clarity, often defeating the purpose of having overhead fenestration. To address these challenges, researchers within Walter P Moore are partnering with MADICO to develop the next generation of ETFE that incorporates higher mechanical strength and increased thermal performance. Designed as a composite film of multiple laminations, ViewScape™, already being considered for large scale projects, will be able to be customized to a specific product and incorporate a number of technologies that will enhance its performance. The first generation of this film will be eight times stronger than conventional ETFE and will incorporate Low-E coatings that will significantly increase the thermal performance without compromising views through the material. Early prototypes are being tested that will incorporate electrochromic and thermochromic technologies that will allow for climate responsive performance, light-emitting diodes (LED's) and Organic light-emitting diodes (OLEDs) to allow for the material to become a source of light or media, and even technology that allows for solar harnessing.

While unlikely to ever replace glazing, the advances in this material will allow films to expand into markets typically reserved for glass and metal. This potential for carbon reduction on projects can not be ignored. In a study performed on a recently completed indoor water park we were involved in, the switch from glazing to ETFE alone resulted in a 48% reduction in CO_2 for the enclosure and a 40% reduction of enclosure construction cost. These results do not even include the knock-on benefits to the primary structure. The final realization of the project did not adopt

ViewScape™ Mockup

Comparison of ViewScape™ with 0.3 SHGC to fritted ETFE with SHGCs of 0.47 and 0.41

Soundwaves at Gaylord Opryland



Soundwaves LCA Options Analysis

the full savings indicated by the study as the design team and ownership opted for a hybrid approach that maintained insulated glazing for the vertical facades and ETFE for the roofs, proving that there are still intrinsic benefits to glass that the film material cannot yet match.

Alternatives to Aluminum Framing

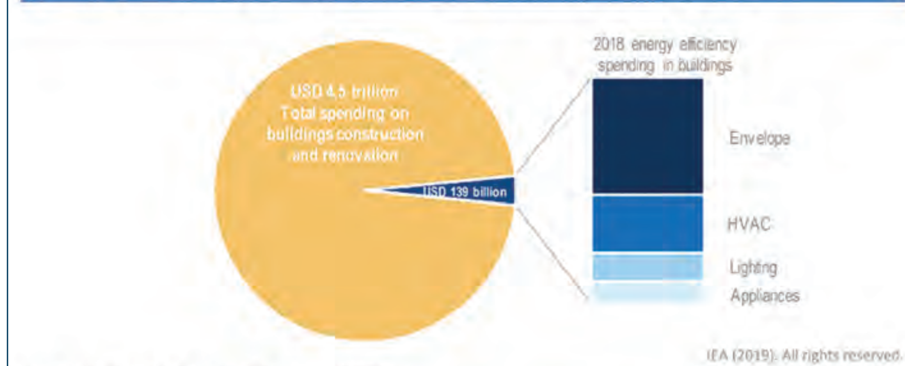
In the aforementioned research by Craig Jones, he reveals that the results of his research indicate that the glass frame type is more important than the choice of double versus triple glazing. Over a 20 year timescale, the choice of double vs triple pane becomes almost irrelevant (from an embodied + operational carbon perspective) when comparing the impact of the frame alone. Wood framing, naturally, outperformed uPVC and aluminum framing. He states that it would take 40 years for an aluminum-framed triple pane window to be a lower-carbon option than a uPVC-framed double glazed window. Similarly it would take 50years for a uPVC framed double pane window to out perform a wood-framed double glazed window. When looking at a traditional curtain wall system from a commercial perspective it can be surmised that the impact on carbon payback through a move from aluminum framing to another material such as wood or fiber reinforced plastic (FRP) would significantly impact the carbon footprint of any given project. PVC, Vinyl and uPVC have been used primarily in the residential market, however uPVC has been seeing increased use in commercial projects demanding high performance, such as those pursuing Passive House certification. While FRP has been used in limited capacity for increased thermal performance in fenestration framing, it's use as a primary element in curtain wall framing has been non-existent due to fire code limitations and perhaps aesthetics. Similarly, wood use in curtain walls have been limited to stick-framed feature facades or in the case of the Tower at PNC Plaza in Pittsburgh, Pennsylvania, the interior skin of the double skin façade. Italian façade fabricator GEM srl METAL WOOD & GLASS, has developed a unitized curtain wall system called "WOODY" which utilizes a primarily wood frame that supports insulated glazing secured through a carrier frame to the wood backup. As building codes become more receptive to heavy timber in commercial construction, technologies like this system should be increasingly considered as viable alternatives to the pure aluminum framed curtain walls.

Less with More

The increasingly stringent energy codes, even those that are introducing backstops to the percentage of vision glazing will force designers to become more creative with their opaque areas, but will likely not lessen the desire for large expanses of vision glazing or the appeal of the sleek glazed skin. The all glass building is not going away anytime soon. The goal however will be how to use Less energy and emit less carbon through the building's operational life with More glazing. New options for low-E coated glass types are still in development. Companies like AGC-Interpane have even begun to offer customizable low-E coated glass the designer can make specifically for a project to meet desired architectural and performance targets. The conventional 1-inch thick insulated unit has seen some improvements in the past decade that has not changed its overall makeup or it's general availability. These include technologies such as triple-silver, room-side low-E and electrochromic coatings. The future of energy codes however will likely put additional pressure on glazing manufacturers to find the next generation of commercially available glass technology. While Vacuum Insulated Glazing (VIG) appeared to hold some promise, their size limitations and high cost has prevented penetration into the market. In the meantime, while the technology to limit energy transfer through glazing is making incremental gains in performance, glass suppliers will likely double down on integrating technologies within glazing that will capture and reuse that energy. Technologies such as transparent organic photovoltaic coatings, electrochromic glazing, and glazing with integrated adaptive shading technology will likely become a heavy focus in the near future.

When it comes to the all glass façade, even if a project met the strict limit on vision glazing we are finding that the spandrel glazing within an aluminum framed system does not have nearly the limited performance we thought it had. New procedures that supplement the NFRC 100 calculation method for determining system U-factors have changed the "edge-of-spandrel" from 2.5-inches previously assumed by NFRC 100 to 6-inches. Often, this doesn't leave much of that nice center-of-spandrel U-factor area remaining. As this procedure becomes universally adopted, the glazed spandrel will have to be re-tooled. While this doesn't fall fully on the shoulders of the glazing industry, manufacturers who can offer solutions to this challenge will find themselves in the driver's seat. Already known for their specialty and oversized glass capabilities, Sedak, has developed a product called Isomax, which incorporates a Vacuum-Insulated-Panel (VIP) within the insulated glass cavity that can achieve a U-factor as low as 0.04 depending on the percentage and buildup of the vision area.

Figure 11 • Global energy efficiency investments and total spending on buildings, 2018

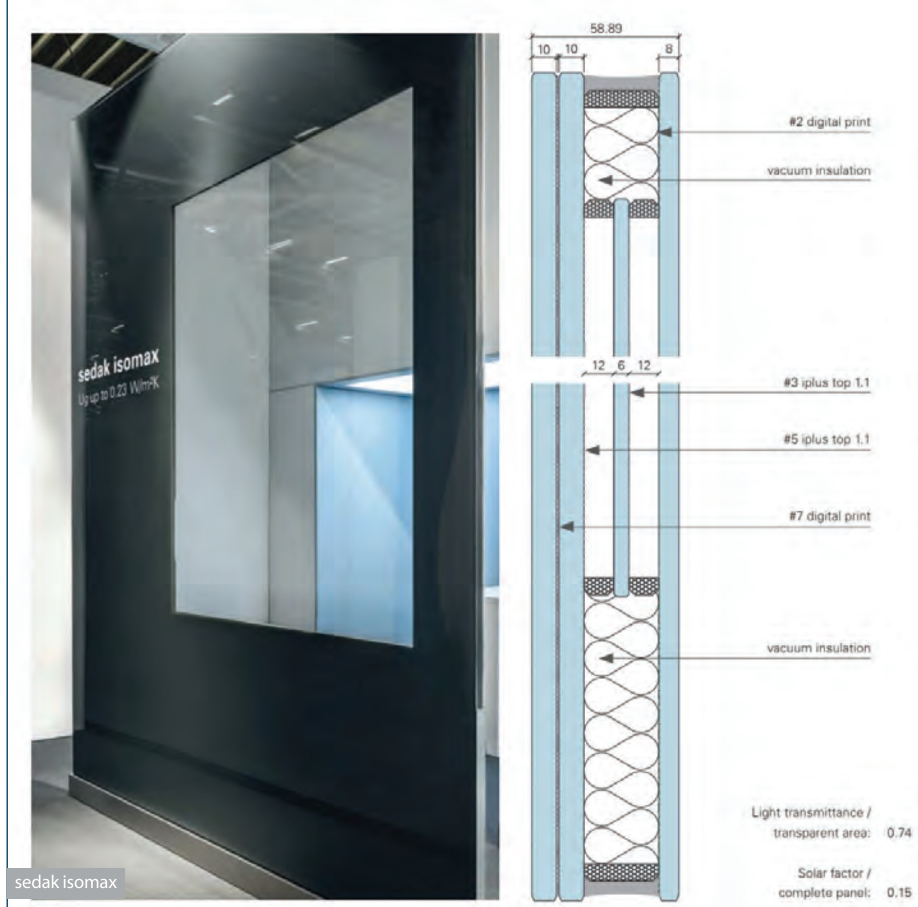


Note: HVAC = heating, ventilation and air conditioning.

Source: Adapted from IEA (2019d), *Energy Efficiency 2019*, https://www.iea.org/efficiency2019/.

Furthermore, through the use of their oversized units, vision openings can essentially be a void in an otherwise vacuum insulated insulated panel, eliminating the thermally-challenged framing that usually exists at the interface between vision and spandrel.

Example glass structure with 30mm VIP



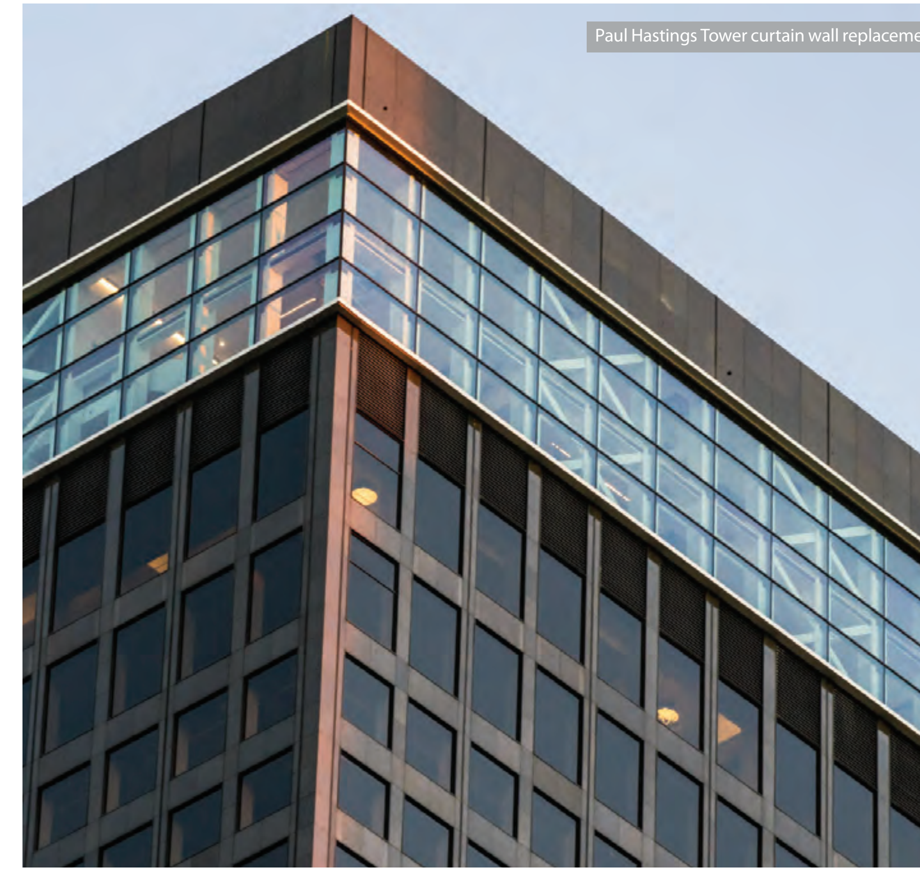
sedak isomax

While many of these technologies are cost prohibitive for most conventional projects and have limited suppliers, they highlight the next-generation of glazing that will have to be adopted by more manufacturers if they are to meet the demands imposed by the ever increasingly stringent energy codes.

Design for Adaptability

While I was writing this article, I watched Terminator Genysis with my two sons. Don't judge me, I'm a childhood Terminator fan. In it, an aged model T-800 Terminator Cyborg , played by Arnold Schwarzenegger repeatedly made the comment that he was "old but not obsolete" after experiencing some technical glitches. At the end, spoiler alert, he falls into a vat of liquid metal and emerges as an "upgraded" model. While ridiculous in many ways, if you suspend disbelief completely, you can get excited about the future promise for performance upgrades. Unfortunately, at this time, our collective inability to easily upgrade something as straightforward and static as a curtain wall is one of the major shortcomings of our industry. A shortcoming that will have to be addressed if we are to design buildings that exist through multiple generations of code upgrades, material lifespans, and architectural styles.

In a 2019 study entitled Energy Efficiency, the International Energy Agency (IEA) highlighted that 4.5 Trillion US dollars were spent on building construction renovation. USD 139 billion of that amount was dedicated to "energy efficiency" spending in buildings, of which more than 50% was dedicated to the building envelope. This alludes to a few potential takeaways that building envelope upgrades: 1) seen as having the largest

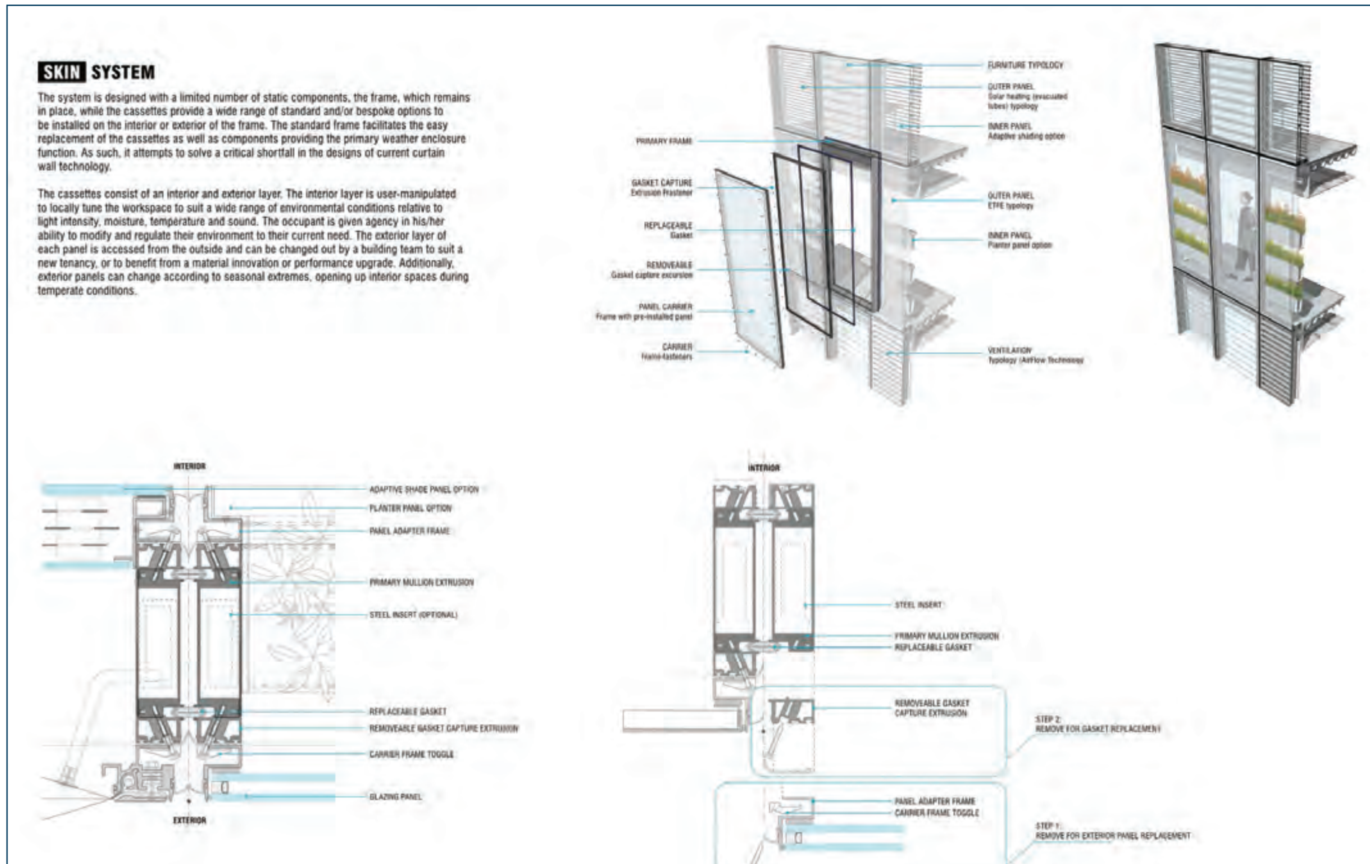


Paul Hastings Tower curtain wall replacement

return on investment, 2) are potentially easier and less disruptive to undertake than other building system upgrades, 3) are potentially the most incentivized to be upgraded.

While the study didn't go into detail on what types of envelope systems were upgraded, it did surprise me considering how envelope systems and assembly designs do not easily allow for upgrades or adaptability.

In the Façade Tectonics article Beyond Glass, author Mic Paterson states "The most effective measure to reduce lifecycle embodied carbon is extending the service life of a material, component or system, including a building and its facade system. This will bring considerations of durability and adaptability to the forefront as design drivers." This quote speaks early generation curtain wall systems 'lack of 'abilities' -- maintainability, repairability, upgradability and adaptability-- that has compromised durability, resiliency and has left us with a large building stock in need of retrofit without viable options for upgrading resulting in the need for complete removal. Perhaps façade system designers and



2019 Metals in Construction Competition Entry (Studios Architecture and Walter P Moore) manufacturers are counting on complete re-skins as a form of future job-security, because the systems we install these days are not any more maintainable, repairable, upgradable, or adaptable than those installed 70 years ago. This state of affairs is not limited to enclosures. In a lecture entitled 'Are Highly Efficient Buildings Sustainable, Andrew Marsh, maker of the Ecotect environmental analysis software since acquired by Autodesk, spoke of his 1969 Land Rover LLE as an analogy of a sustainable vehicle. While not as operationally efficient as a newer hybrid model, he posits that the fact that the vehicle is still running and serving as his primary means of transportation now 51 years after it was built is likely more sustainable than newer models that are fully expected to be out of service and replaced in much less time. His Land Rover's extended life is in large part due to the ability for it to be maintained easily and inexpensively by its owner .

It is inevitable that any building will undergo envelope upgrades, perhaps multiple times in the course of its lifespan, for various reasons. Weather performance, energy performance, and stylistic upgrades are a few of these reasons. A well-designed façade for today's energy codes or today's climate may not be sufficient within a decade of its life. New York City's recently adopted Local Law 97 takes compliance a step further by introducing hefty fines to owners of buildings exceeding a certain size that do not meet the energy use expectations defined by the city. The local law defines maximum energy use criteria that a particular building typology must meet by 2025, but then makes the criteria even more strict by 2030. Owners of existing buildings and developers of new buildings, who plan on owning any particular property for the next ten years will all have to look at design or upgrade their buildings to meet an energy use requirement that is likely above and beyond what the current prescriptive code requirements achieve. Whether it's mandated by local law, or just acknowledging that one's building will need to be upgraded at one or more points during it's lifespan, the need to design façade systems that facilitate performance upgrades that are not only minimally invasive, but also extend the service life and allow for recyclability of the high embodied carbon components used in the making of facades is critical. Mic Paterson's body of research includes finding ways to make facades more like Andrew Marsh's 1969 Land Rover or perhaps the Terminator, imbued with the ability for minimally invasive performance upgrades that extend the façade's useful life so we are not, as he states, building tomorrow's problems today. If the enclosure systems of the future could be designed as a kit of upgradable parts, maintainable (like the Land Rover), and these parts could be disassembled and have the ability to extend their life beyond the life of the buildings themselves, their impact is reduced significantly. This ability perhaps starts a novel industry where owners contract with enclosure service providers who can easily upgrade, swap, or dismantle enclosure systems based on performance, architectural or tenant goals. This concept was developed by the joint team of Studios Architecture and Walter P Moore for the 2019 Metals In Construction competition. This concept included a novel unitized curtain wall frame that allowed for ease of replacement the internal gaskets while also allowing for the ability to swap out the infill to the frame with a myriad of cassette types that could be supplied by any vendor who utilized the same carrier frame that system supported.

The formula for quality, responsible, and sustainable design is constantly evolving. While the opinion on what the metric or the resultant of this formula has evolved as well, the underlying belief is that we as an industry have to be more conscious of the resources we use to construct our buildings and scrutinize not only selected components but also the holistic view of how those constituent parts fit into the system of our planet. Through recent advances in digital technologies, our ability to analyze, assess, and quantify our design decisions is unlike any time in the history of our industry. What we are still lacking however is the understanding and adoption of a holistic approach as well as accurate data on various system comments we use in buildings. In the hands of the designers, LCA assessment tools will empower the industry to make positive change in our resource consumption and environmental impacts regardless of governmental mandate or incentive. Just as operational energy efficiency and occupant wellness became a recent design driver, carbon impact will soon become as big and a potentially more impactful change agent. Acknowledging material and system impact, quantity and adaptability in addition to performance characteristics is a necessary next step for our industry. The good times aren't over. They are just beginning.

Erik Verboon
Principal
Structures
Erik Verboon is the Co-Founder and Managing Director of Walter P Moore's New York office. Trained in both architecture and engineering, Erik brings a deep global experience with a focus on the design of complex and high-performance building envelopes for a wide range of building types. Erik also has experience working with a wide variety of façade applications including high-performance, double-skin façades, geometrically complex composite façades, and custom unitized enclosures for both new buildings and existing building retrofits and additions.
His experience in digital design, geometric rationalization, and environmental analysis allows him to bring the highest level of value to his clients while also helping designers deliver projects to the highest level of design sophistication while maximizing performance and minimizing cost. Erik's portfolio expresses both national and international work with extensive experience in the New York market, bringing expertise in buildings old and new, across academic, commercial, and cultural sectors. In addition to Erik's professional accolades, he teaches enclosure design at a number of leading universities.

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