Pushing the Envelope:
A New Methodology for Facade Attachment

A Thesis

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Grant Griffith

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Advisor___________________________
Mary Rogero

Reader____________________________
John Becker

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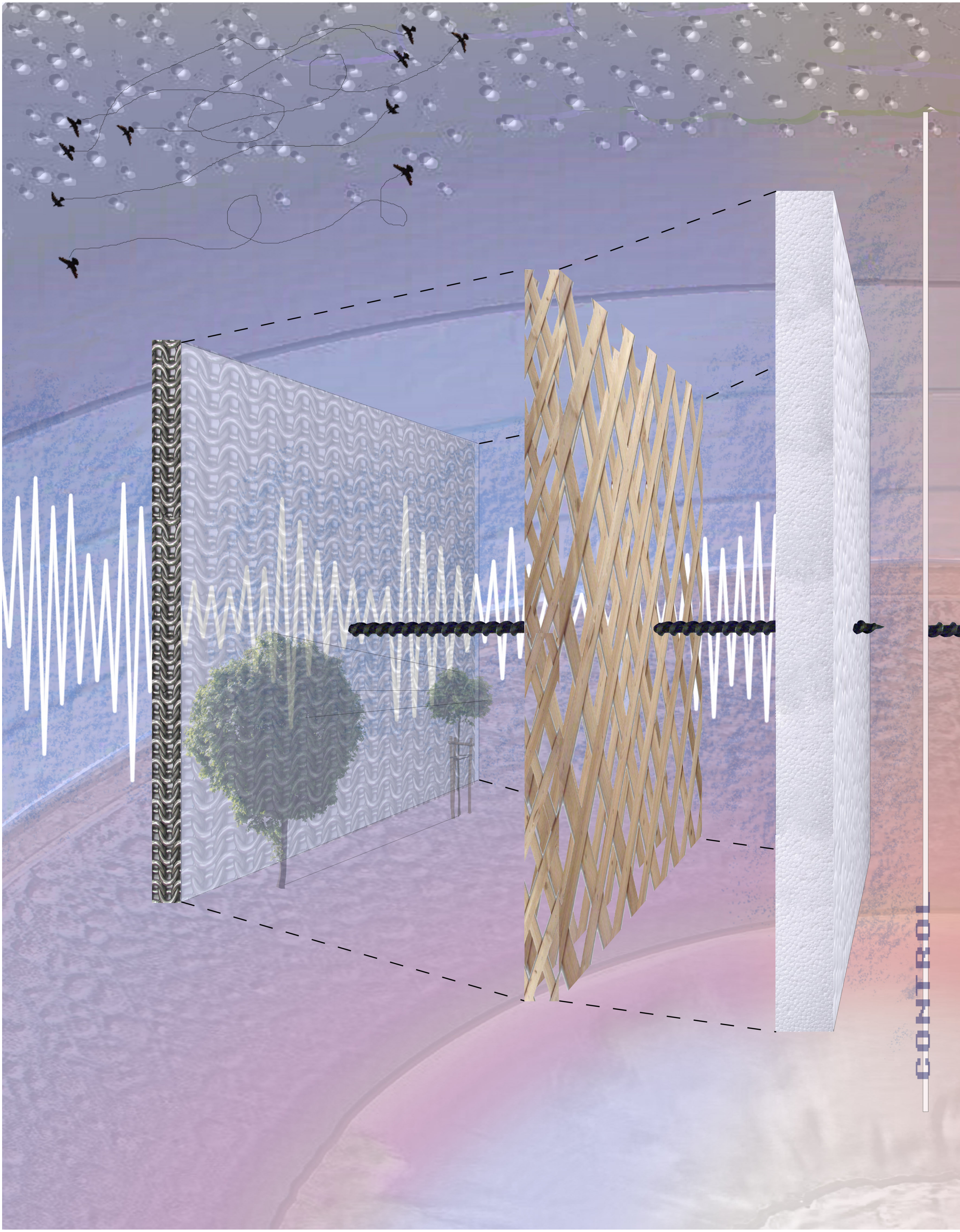
Thank you Momma Biggs!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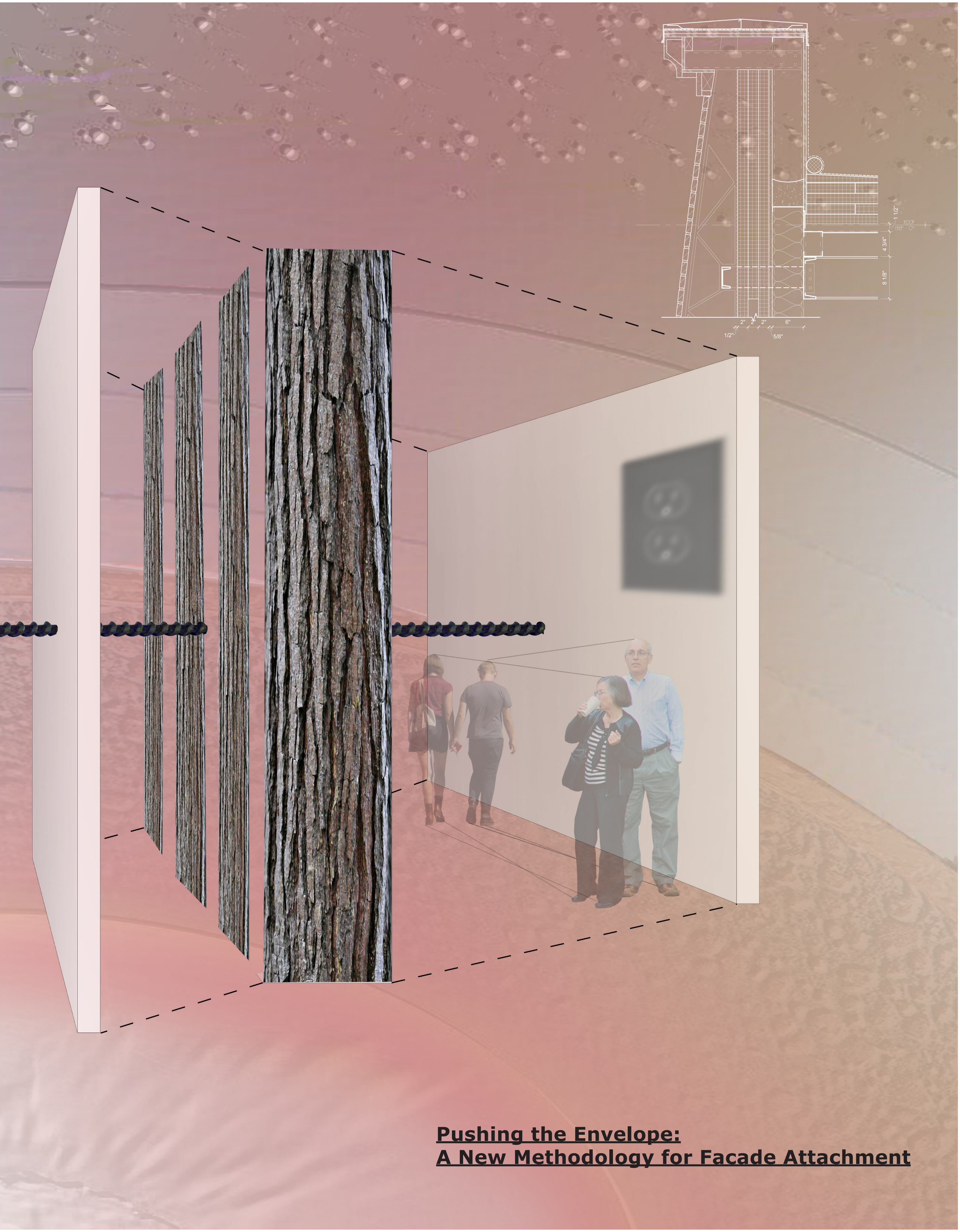

Pushing the Envelope:
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Introduction

One of the most fundamental aspects of architecture is the act of enclosure. In the built environment, the walls, roofs, and floors of a building become thresholds between physical realms, separating space and function, interior and exterior, and become part of a whole building enclosure. The essence of a building enclosure is the enveloping layers of materials that serve to control the environmental conditions of interior spaces. These control layers mitigate air, heat, and water vapor flows into and out of a building and is where the most care must be taken by architects and contractors to ensure interior comfort, energy performance, and durability. Ever evolving and adapting to many diverse climates and geographic regions, humans have continuously sought to improve their building envelopes. Despite continuous advancements in architecture and construction practices, there remain opportunities for improvement in areas of energy performance, durability, and labor costs associated with the construction of building envelopes, particularly with the methods of attachment that are used to attach various control layers and cladding systems. In 2019, the cost of materials and labor dominate the budget of most projects and new products, materials, and labor techniques are constantly being sought to help reduce the overall project cost. While important, the financial costs of building pale in comparison to the ecological costs of irresponsible design and building practices. Human impact on the natural environment is greater than ever and immediate steps must be taken to ensure future generations have the ability to meet their own needs. The need for high performance buildings that can serve as figurative organisms in a greater ecosystem cannot be overstated.

Through technical analysis, case studies, and discussions with construction technologists, this paper asks the following: why does current construction methodology need improvement and what do these potential improvements mean for the building industry, owners, and architects. In response to the discoveries made during the course of these investigations, a new construction method for exterior envelopes is presented that has the potential to change many paradigms in how buildings are envisioned, built, and maintained.

The Case for High-Performance Buildings

THE TIPPING POINT OF THE 21st CENTURY LIFESTYLE AND CONSUMERISM

Human impact on the natural environment is greater than ever. Since the industrial revolution, population growth rates have increased exponentially along with industrial production per person.[1] In the rapidly approaching future, there will not be enough resources on earth to support this growth. Concurrent to population growth, the health of the earth's ecosystems are rapidly declining resulting in fewer resources to go around. Whether one considers the supply of fresh water and food, the regulation of climate, or air quality and pollution, there have been countless studies that have found that humans are having a negative impact on the earth. This is a global problem with the most dire consequences humanity has ever faced. With human population increasing exponentially and earth's resources decreasing ever faster, humanity is headed for crisis.

MASS EXTINCTION

Since the 1800s, the number of species of plants and animals disappearing per year has increased dramatically and correlates directly to population growth and the impact of humans on the environment. According to the Threatened Species Red List released by the international union for the Conservation of Nature and Natural Resources in 2008, 40.1 percent of all species, approximately 19.2 percent of animals and 20.9 percent of the plants are classified as "threatened". These threats are directly linked to the loss of habitats due to destruction, modification, and fragmentation of ecosystems as well as from overuse of chemicals, intensive farming methods, hunting, and general human disturbance.[2] If looking solely at species loss resulting from tropical deforestation, extinction rate forecasts climb as high as 75 percent.[3]

POLLUTION AND CLIMATE CHANGE

The twentieth century brought about a globalization of pollution through exponential population growth and the use of industrial processes. Today, harmful emissions into the air and water from urban, industrial, and agricultural sources affect over a billion people around the world by making natural resources either unusable or unhealthy.

The World Bank estimates that about of 20 percent of health concerns in developing countries can be traced to environmental factors and 40 percent of a deaths resulting from exposure to environmental pollutants and malnutrition. This problem is incredibly exaggerated in developing industrialized countries such as China and India which boast the 10 most polluted cities in the world. Air pollution effects the environment as a whole also by influencing climate change. Greenhouse gases such as carbon dioxide, sulfur, and nitrogen dioxide have measurable effects on global surface air temperatures. In the past 100 years, global surface air temperature has risen 1 degree.[4] The average atmospheric carbon dioxide concentration reached 387 parts per million, which is an increase of 35 percent since the industrial revolution and the highest for at least the last 650,000 years.

SCARCITY OF RESOURCES

As the world population continues to grow exponentially, the earths natural resources are under increasing pressure, which is exaggerated by pollution and climate change. With more people and even less resources, there is a growing demand for natural resources. This has caused living conditions to worsen worldwide and will continue to worsen exponentially. The depletion of resources is an inevitable result of overpopulation and the need to have buildings to house these people. There is an unsuitable demand for the earths natural resources, materials, and energy. Each year, three billion tons of raw materials, which equates to 50 percent of the total amount consumed by the global economy, are used in the manufacturing of building products and their components.[5] The architects of the future must recognize this disproportionate use of resources and begin to devise new strategies for construction. All three of the above topics, mass extinctions, pollution and climate change, and scarcity of resources all have architectural implications that designers can have immediate effect on. By practicing principles of sustainability and integrating these principles to common thought patterns of humans around the world, there may be hope for the future.

THE NEED FOR HIGH-PERFORMANCE

Currently in the United States, buildings account for 40 percent of all energy used. This staggering percentage is in addition to 15 percent of all water use, 70 percent of all electricity use, and 40 percent of all carbon dioxide emissions. This is unsustainable and the first step to alleviate some of the above problems is to mandate high performance buildings.

High Performance Building Principles

THE BUILDING ENVELOPE

High-performance building practices revolve around the envelope of a building. How well a building maintains internal temperature, humidity, and lighting levels are all tied to envelope design. Heat, air, and moisture are all constantly acting on a building and it is the function of a building envelope to control how much or how little each of these elements can travel from interior to exterior or vise versa. This control is achieved through a layering of various materials and components that perform specific functions. The three main control layers that will be discussed are the thermal layer, air control layer, and water vapor control layer and each controls exactly what its name suggests. The layers can be constructed of a wide variety of materials and techniques but share the same goal, to control flows of heat, air and vapor.

In the United States, prescriptive building codes set regulations for minimum envelope assemblies in various climate zones. Prescriptive building codes vary according to construction type, either commercial or residential, and by climate zone. In the United States, the most challenging climate zones to design for are regions that experience high humidity and freezing temperatures, specifically climate zones 4,5, and 6 as categorized by the U.S. Department of Energy.[6] These climate zones are referred to as "mixed-humid" because they receive "more than 20 in. (50 cm) of annual precipitation, have approximately 5,400 heating degree days (65°F basis) or fewer, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.[7] It is in these climate zones, where the temperature gets very cold, that additional insulation is needed. When additional insulation is needed to reduce heat flow out of the building, the method of attaching cladding becomes crucial to the overall performance of the envelopes various control layers. If there is insufficient insulation thickness in any region of the envelope, or if cold air is allowed to flow freely, condensation can occur and cause significant damage to the building.

Predicting condensation potential is, therefore, crucial to the durability and safety of a building. Typically, condensation can occur anywhere a surface temperature is at least 7.2 degrees below the mean radiant temperature of the interior ambient air temperature of a building. This natural phenomenon is localized in contemporary construction at places where thermal bridging occurs. It is, therefore, logical to minimize all thermal bridging. THERMAL bridges are locations in a building envelope where greater than average heat loss is experienced and are categorized into two types: linear thermal bridges (Ψ), and point thermal bridges (X). Linear thermal bridges are typically located along joints between building assemblies such as between walls and roof, walls and floors, etc. or around openings such as doors and windows, but they can also be located within walls along the studs or structural members. Point thermal bridges can occur at various penetrations in an exterior wall, such as at plumbing vents, HVAC exhausts, or even at places in walls where cavity insulation is reduced, such as behind electrical outlets and light switches. In most contemporary construction methodologies, the most overlooked point thermal bridging is located at the individual fasteners that attach exterior cladding and insulation to exterior walls. An individual point thermal bridge created by a fastener is negligible when compared to the overall thermal performance of an entire wall assembly, however, multiple point bridges become problematic when considered aggregately. More importantly, any thermal bridging, regardless of size, dramatically increases the risk of condensation.

ATTACHMENT SYSTEMS

The individual fasteners used to attach exterior insulation or cladding systems, are usually highly conductive materials such as steel or aluminum and penetrate through cladding, exterior insulation, exterior sheathing, and into various backup wall construction. In an average exterior code minimum wall, there is some type of fastener every two feet horizontally and vertically that attaches cladding systems to backup walls and even more fasteners required to attach exterior insulation to the backup walls based upon the type of exterior insulation used. (Figs.1-3) (Fig. 10) These fasteners, colored red in figure 2, have to be located with precision to ensure that they attach directly to structural members in the backup wall and then are sealed to prevent potential air leakage. This procedure demands special care and craftsmanship and in some large buildings can equate to hundreds of hours of manual, repetitive labor. The length and cost of fasteners also increases simultaneously with increases in sheathing thickness, exterior insulation thickness, and cladding weight. When considering the potential for thermal bridging, condensation, labor costs, and material costs, it becomes clear that fasteners are the weakest link in exterior wall assemblies.

There are currently a plethora of systems and products available to attach the various envelope layers that use a variety of new materials such as fiberglass and polyurethane that attempt to minimize thermal bridging, but all of these products still rely on fasteners to penetrate back into the supporting studs. The problems with this methodology is that it is impossible to adequately seal these penetrations once successive layers are added and increasing the continuous exterior insulation becomes prohibitive. (Fig. 2)

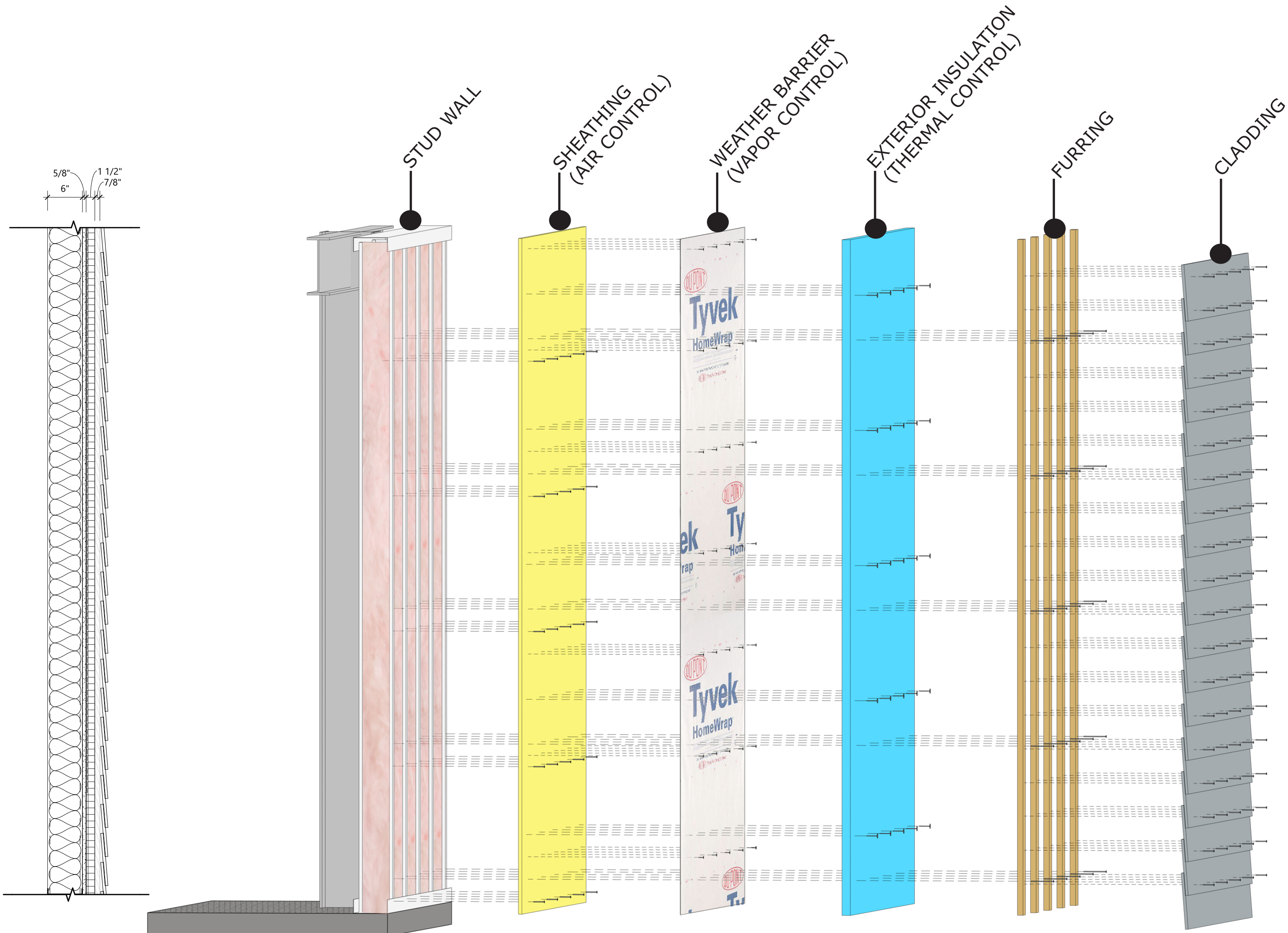


FIG. 1
Exploded view of typical commercial wall.
Notice all of the fasteners.

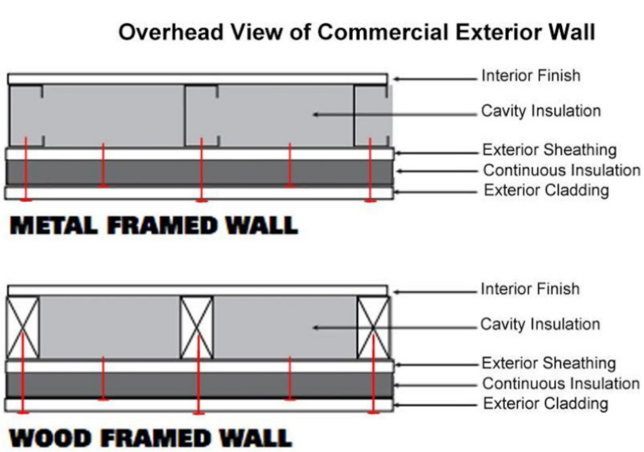


FIG. 2
Fasteners in RED, must be long enough to achieve safe penetration of studs.

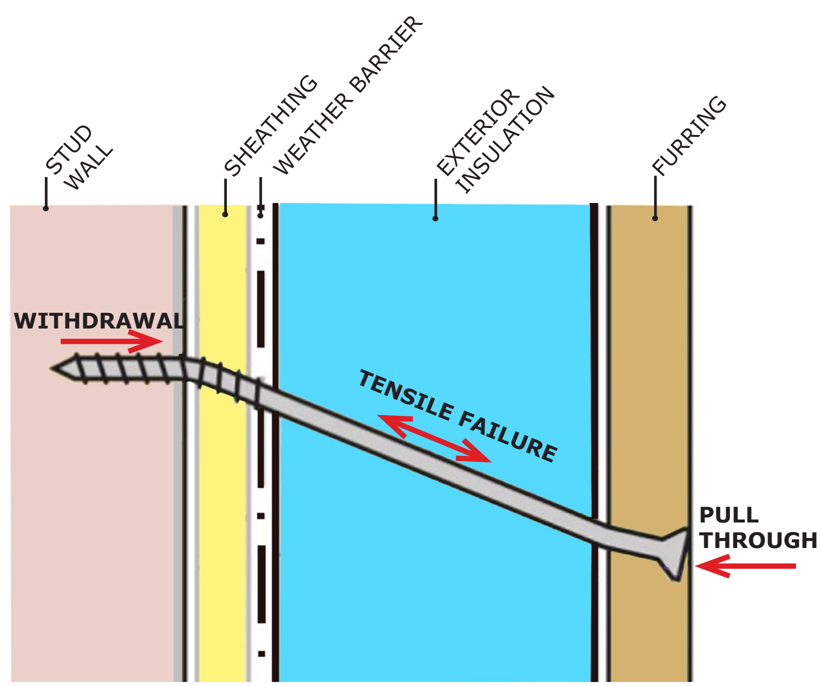


FIG. 3
Potential fastener failures are compounded by increasing exterior insulation thickness.

Fig. 4
This analysis by Steven Winter Associates Inc. shows how even thermally broken clips de-rate the overall effectiveness of the continuous exterior insulation.

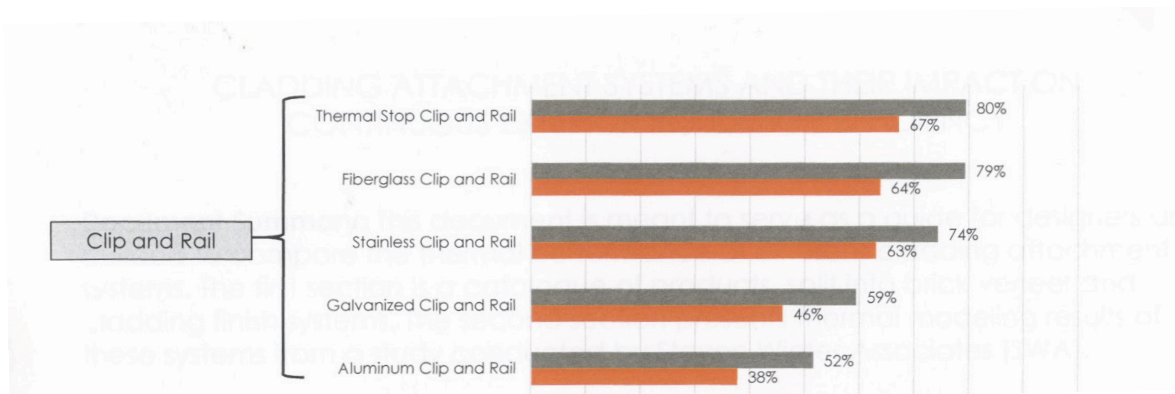


Fig. 5
Comparison of systems specifically designed to reduce thermal bridging still shows overall reduced performance. Steven Winter Associates Inc.

CMU Backup Wall
Metal Stud Backup Wall

Despite being relatively small in comparison to an entire wall, the effect of a single point thermal bridge created by a fastener in an exterior wall assembly can be disproportionate when compared to the wall it is fastened to. "Repetitive metal penetrations may increase nominal U-factors (compared to assemblies without fasteners) and heat flow through assemblies by as much as 44% in typical wood, steel, or concrete/masonry assemblies."[8] In most building and energy codes there are not considerations for repetitive metal penetrations possibly due to the range of possibilities and conditions, however, as stated above, a 44% performance decrease is obviously worth investigating. Appendix A of ASHRAE 90.1 is the first attempt to account for the impact of metal clips, but only on concrete/masonry backup walls. Figures 4 and 5 illustrate clip and rail systems designed to replace furring strips. These clips penetrate through the continuous insulation layer and the loss of effective thermal protection is shown in the images. Regardless, thousands of screw, nail, or clip penetrations in the thermal envelope of a building is an antiquated practice that severely needs improvement. The infrared and thermographic images seen in figures 6-7 illustrate the effects of point thermal bridges and their potential for heat loss.

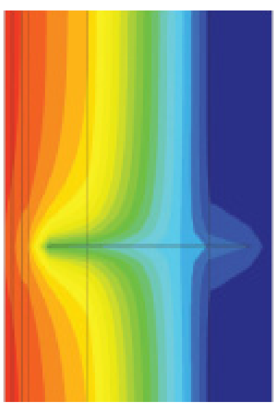


Fig. 6

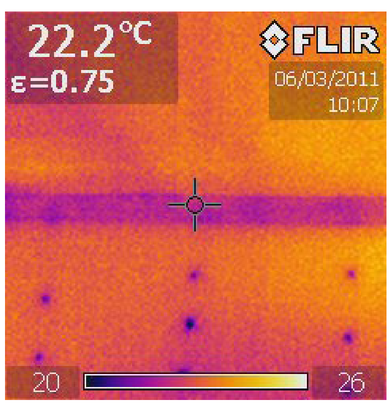


Fig. 7

CONDENSATION RISK

Condensation occurs where the temperature of air drops to the point that it can no longer hold water vapor. This point where air becomes saturated is called the dew point. When warm, moist air comes into contact with something cold enough that it reaches it's dew point, condensation forms. This relates directly to what is known as the vapor profile of a wall assembly. In contemporary wall construction, impermeable vapor barriers, composed of various materials, inhibit the passage of water vapor through walls. Water vapor moves by what is known as vapor drive, and can be caused by several natural phenomena such as air pressure, temperature differential, and absolute humidity differences.

A fastener that holds exterior cladding to a wall has a higher heat conductance than the building materials surrounding it, therefore, a fastener is essentially a cold penetration into an exterior wall assembly. In figures 6-7 the temperature difference is shown graphically. If this difference of temperature is great enough and occurs within the allowable vapor profile of an assembly, condensation can occur. When this phenomena is coupled with thermal bridging, it becomes crucial to carefully design and plan for uncontrolled condensation.

HEAT LOSS

As illustrated in any of the figures 1-7, there are simply too many locations where the thermal envelope is penetrated. Disproportionate heat loss will occur at places where there is not sufficient insulation causing condensation risk and making the buildings mechanical systems work harder to maintain comfortable temperature levels. The exploded wall illustration in figure 1 shows an industry standard code minimum wall for a type 5 climate zone and is designed to mitigate condensation and vapor penetration. Notice the vapor profile is located between the exterior rigid insulation and exterior sheathing, which is typical, industry standard for code minimum commercial construction. What is missing from the code calculations are the fasteners. Table 704.3 – Note V of the international building code states that "minimum nail length must accommodate sheathing and penetrate framing a minimum 1- 1/2 inches." This means that there is a cold fastener penetrating into the thermal envelope 1-1/2 inches and effectively pushes the vapor profile "inside" the wall. This cold fastener will not only cause heat loss, but also has the potential to cause unwanted condensation inside the wall cavity.

AIR AND WATER INFILTRATION

Another major issue with fasteners penetrating through several layers of a building envelope is that there is no good way to seal the penetrations behind successive layers. For instance, a screw used to attach furring strips or clips can not be adequately sealed at the vapor or air barrier. New systems such as the AeroSeal system, release vaporized polymers into the interior of a building and use positive pressure to coagulate at sites of air leakage. This system, originally designed for mechanical duct sealing is now being adapted to whole building applications but is expensive and still does not solve transmission heat loss problems, only air infiltration. All of the penetrations also provide a path for water and water vapor to enter an envelope assembly. Unmitigated air infiltration or leakage is the leading cause of performance loss and condensation and obviously any water and water vapor can have devastating effects. By eliminating fasteners that penetrate through the control layers, this problem can be eliminated.

DURABILITY

Regardless of climate zone, buildings experience the diurnal cycle of expansion and contraction caused by exposure to solar insolation. When building components become warm, they expand and shrink when they cool. This natural phenomena is heightened during different parts of the year when solar insolation increases but typically occurs daily. There are not any currently available materials that do not experience this phenomena, therefore the effects of expansion and contraction must be taken into consideration when designing an envelope. Figures 3,8,9 illustrate potential issues that fasteners may experience from expansion and contraction. As cladding expands, the fasteners will move to accommodate this expansion. The movement of fasteners will lead to increased penetration widths causing even further heat loss and air infiltration. This problem is further increased when insulation thickness is increased for high-performance buildings which may require upwards of 8 inches of continuous exterior insulation compared to code minimum 1.5 -2 inches.

Fig. 8

Fig. 9

Figures 8 and 9 show the effects of expansion and contraction on a roof surface that was not designed to accommodate the amount of movement that can occur. Underlying layers also suffer from this inescapable force and therefore envelopes must be designed with this in mind. The additional expenses associated with the repair and replacement of damaged envelope assemblies can be spent on better design and higher quality assembly details.

24”x 16” Fastener Spacing
Insulation and Cladding Attachment Only
(48) #10 Screws @ 3/16” Diameter; Area .028 SQ.IN Each
+
(48) 6Dx2” Cap Nails @ 1/8” Diameter; Area .012 SQ.IN Each
=
Total point area for 100 S.F. Wall Segment
1.92 SQ.INCHES

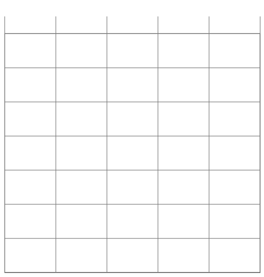


Fig. 10

CASE STUDIES OF WALL ASSEMBLIES

In addition to the analysis of code minimum wall construction for type 5 climate zones, ultra high-performance wall assemblies were analyzed to locate potential areas of improvement. These case studies are from certified Passive House projects and utilize very high levels of continuous insulation.

Madrona House
Seattle, WA
SHED Architecture & Design

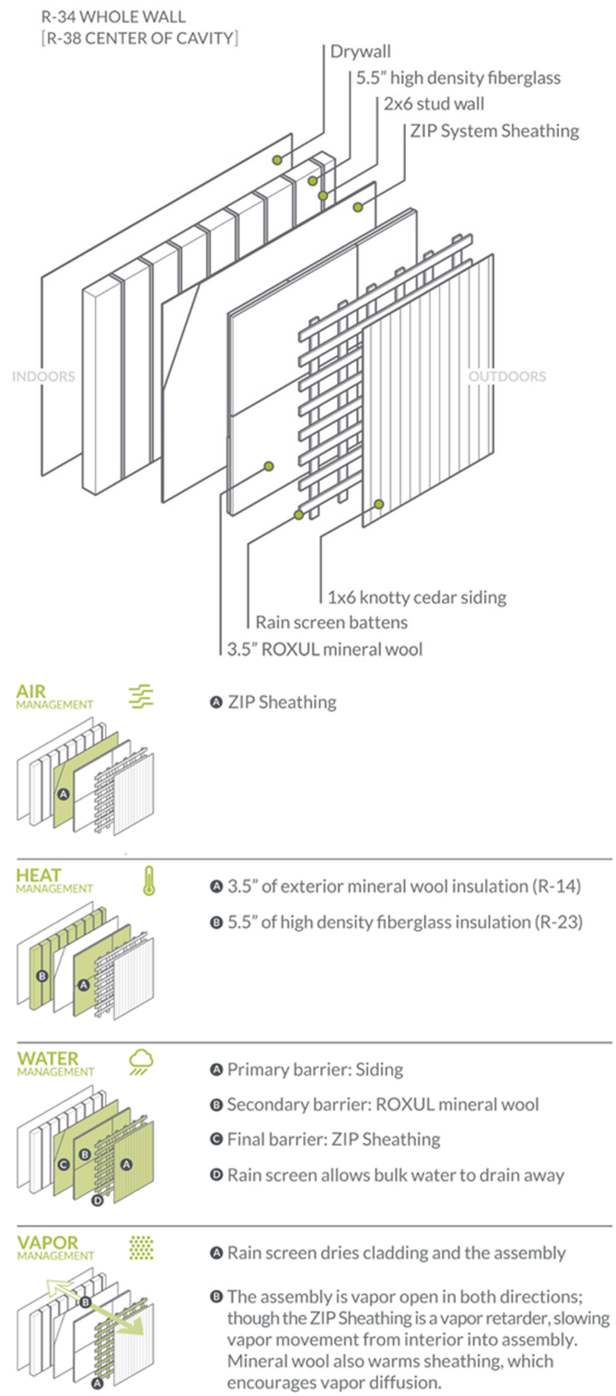


Fig. 11

Fig. 12

The Madrona House in Seattle, WA is an excellent example of the extra long fasteners required to attach cladding through thick layers of insulation. As the fastener length increases, so too does the diameter of the penetration and the potential risk of infiltration and durability issues discussed previously. With all of the care devoted to creating air, water, heat, and vapor barriers, they are all penetrated by screws every two feet that cannot be adequately sealed.

Glasswood House
Portland, Oregon
Scott|Edwards Architecture

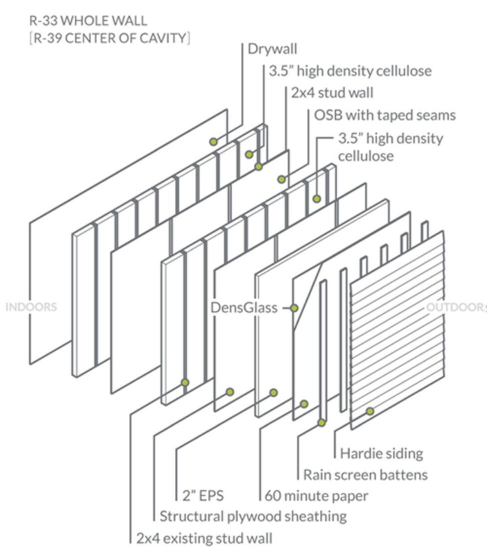


Fig. 13

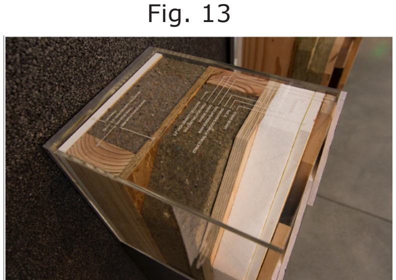


Fig. 14

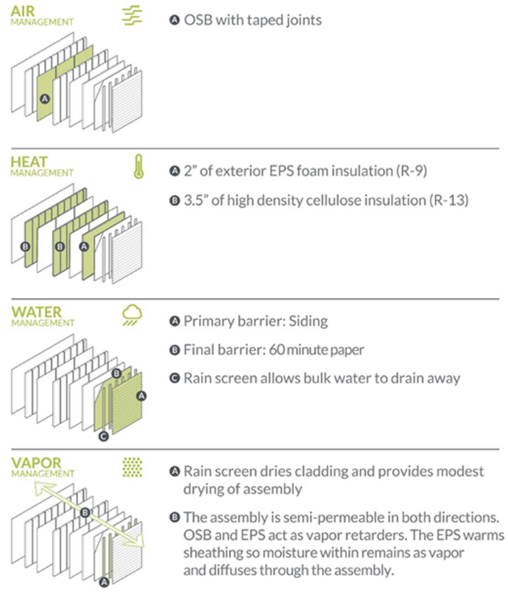


Fig. 15

The Glasswood House in Portland Oregon uses 3 separate layers of insulation which requires a high level of vapor permeability. The water vapor that enters the assembly is supposed to dry adequately from the sun heating the rainscreen but this does not take into account north facing facades. In addition the risky vapor permanance, long fasteners also must be used in this case to attach through all of the 8 layers.

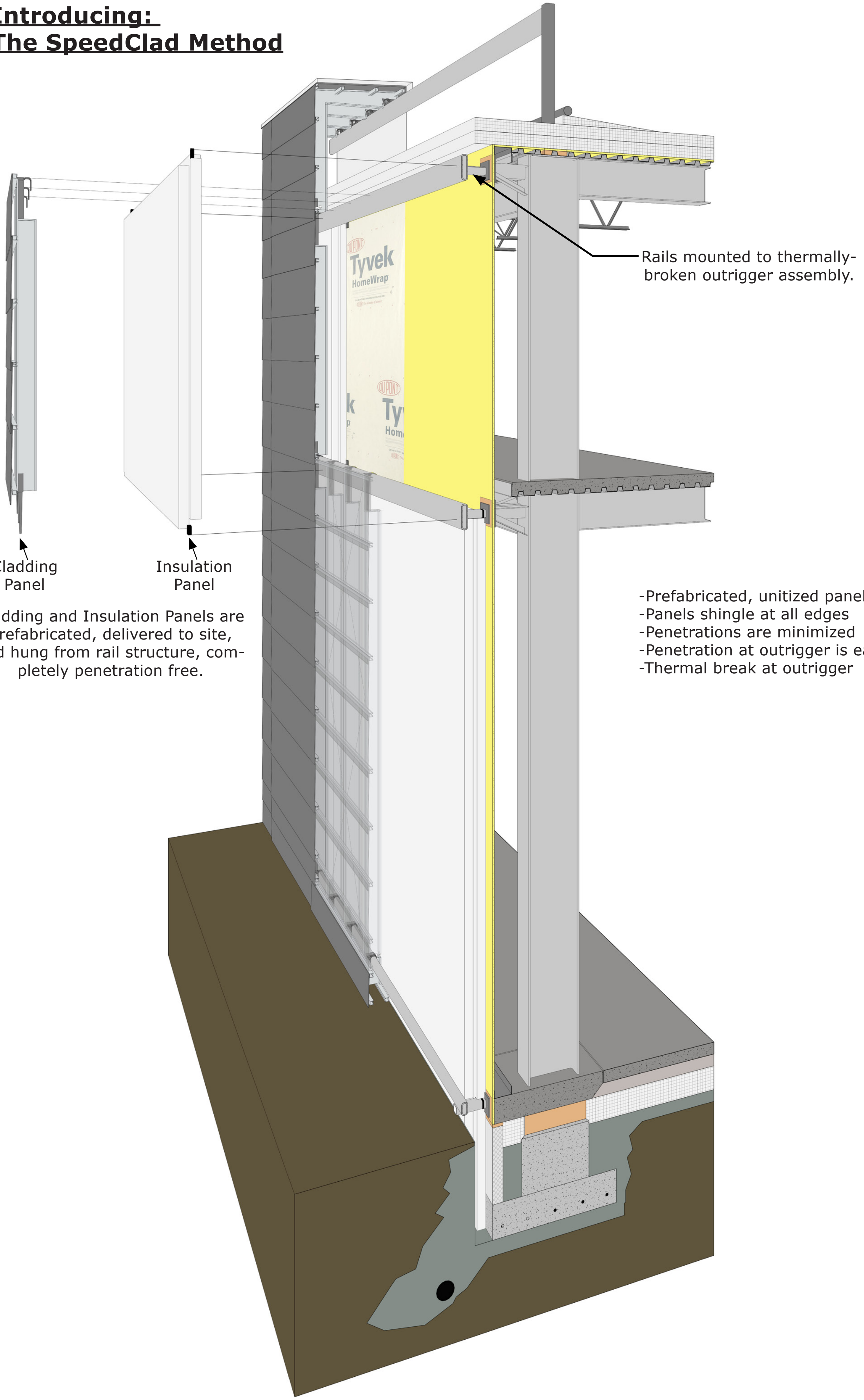
In each of these examples a large quantity of long fasteners is required to hold the assembly together. Another drawback to extra large fasteners is the equipment and care needed to install them. Current pneumatic nailers have maximum fastener lengths of 3" to 3.5" which limits insulation thicknesses to 1.5" max (3.5" fastener, 1/4" to 1/2" siding, 1 1/2" embedment into framing, 3.5-0.5-1.5 = 1.5" max insulation). Longer fasteners are also more difficult to ensure that they make contact with framing members, resulting in increased installation time. Not only does the length of fasteners need to be increased, but also the diameter which creates a larger "hole" per each screw or nail resulting in greater thermal bridging and air sealing problems. Figure 9 gives recommended vertical faster spacing for typical exterior cladding systems. It is useful to note that as the cladding weight increases, more fasteners are required.

Another significant problem related to the cost of traditional fasteners is maintenance. For example, a building with wood cladding will eventually need to have the cladding replaced due to aging and weathering. To replace the cladding a contractor has to pull out all of the fasteners that once held it to the wall, leaving thousands of holes in any insulation, sheathing, and framing members. Even if these holes are adequately sealed, which obviously takes a large amount of labor, the framing members can never be repaired to "as new" condition and will be weakened from the forces of removing the fasteners and adding new ones.

In an age where humanity is rapidly approaching a crisis of environmental disaster, exponential population growth and widespread extinction of plant and animal species, every watt of energy is important. Architecture is always evolving. New technology, trial and error, and new design strategies all push the frontier of the built environment into the future. By studying history, designers have the ability to see that the simultaneous progression of architecture and technology has not always been steady or even beneficial to humanity. At some points in history, great strides have been made toward an architecture that improves lives by seeking harmony with the earth and stars, using the highest level of available technology. At other times, architecture and technology can have adverse effects on one another and produce works that bring imbalance and waste.

The modern passive building represents the pinnacle of high performance building techniques. Despite relatively simple exterior appearances, there is an extraordinary amount of complexity built into the envelope assemblies to create air and water tightness. Breathable membranes strategically placed within wall and roof assemblies ensure that any water accidentally admitted can thoroughly dry without causing mold or rot. Since this building is so air tight, documented and certified with blower-door tests, the ability to dry is very important. Preventing condensation, bulk rain infiltration, or other sources of water vapor from moving freely through the building is equally important. It is among these issues that there is additional room for immediate improvement, especially in how exterior cladding systems are attached to the building envelope. The attachment systems used in this case study are potential problems highlighted in figures 3-9. Any unplanned condensation on fasteners can lead to water moving into a wall assembly by means of capillary action and therefore create a plethora of problems for the durability of a building. We must continue to push the envelope of construction methodology and devise better assembly systems to usher in a new era of high performance buildings. The stakes are too high to sit on our laurels and be content with the antiquated construction systems of the past.

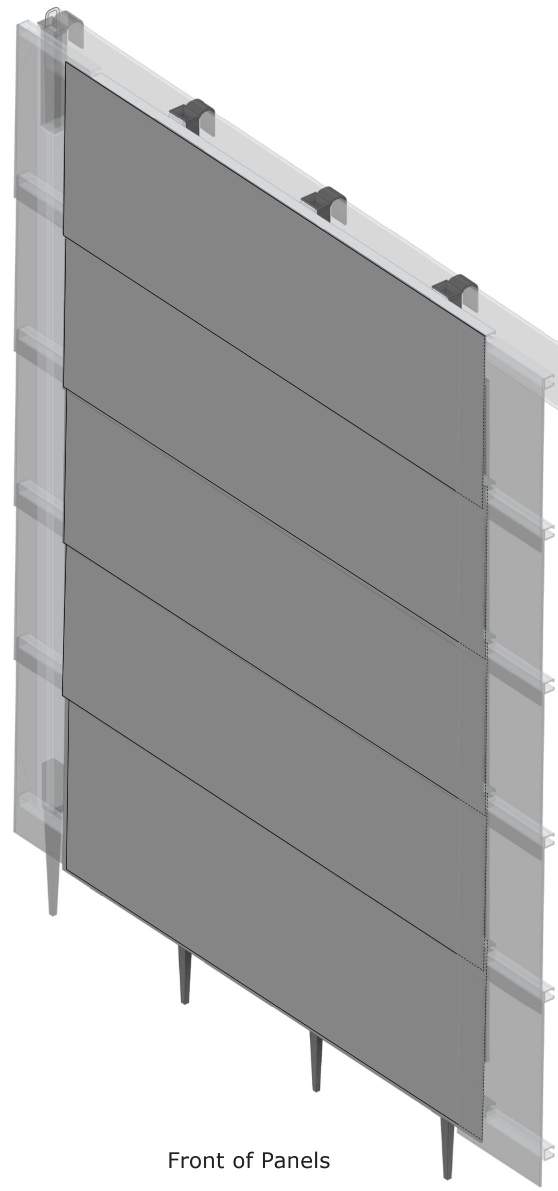
Introducing: The SpeedClad Method



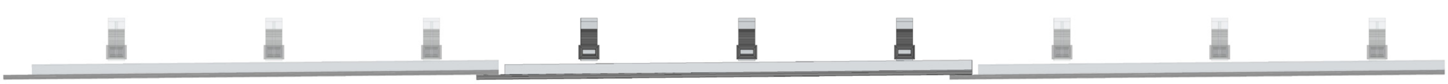
Cladding and Insulation Panels are prefabricated, delivered to site, and hung from rail structure, completely penetration free.

- Prefabricated, unitized panels
- Panels shingle at all edges
- Penetrations are minimized
- Penetration at outrigger is easily sealed
- Thermal break at outrigger

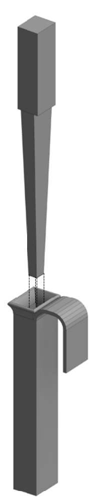
Back of Panels



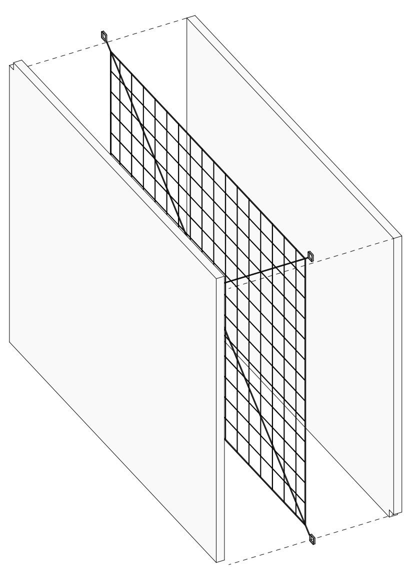
Front of Panels



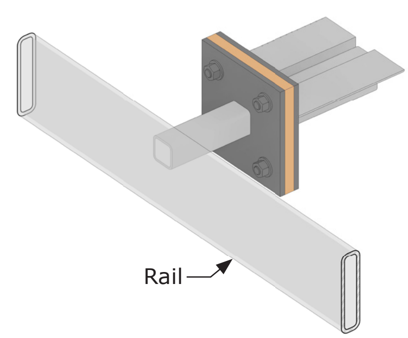
Top View of 3 Panels Shingled



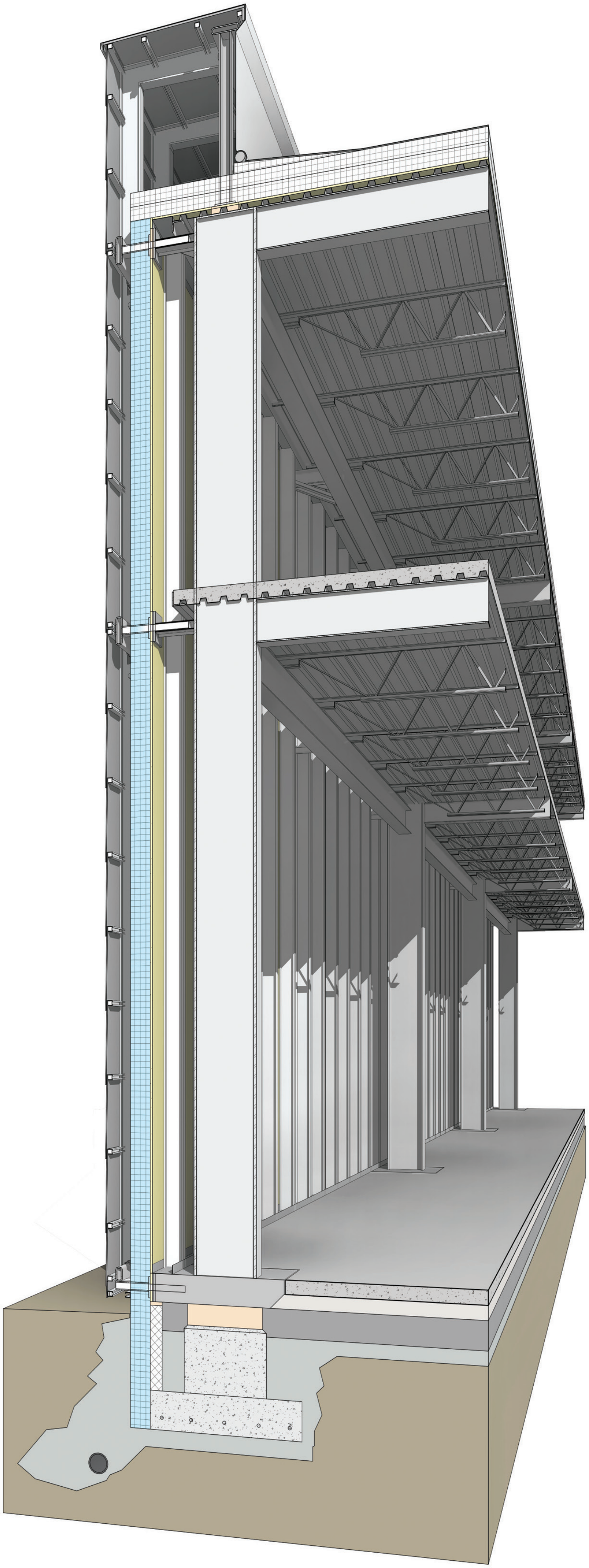
Top panel slides into bottom hanger. Also functions as hoist attachment point.



Fiberglass screen suspended in insulation sandwich. Insulation edges overlap with surrounding panels.



Thermoset polyurethane thermal break at outrigger attachment.



Methodology

OUTRIGGER

The systems shown has structural members sized to hang a total panel weight of 10lbs./s.f. but can easily be adjusted for various cladding weights. The outrigger itself is composed of two parts: 1-the interior component that attaches to the main structure of the building, and 2-the exterior component that is bolted from the exterior once the sheathing layer is in place. Once bolted in place, the edges can be properly sealed for the air and weather barriers. In the system shown, outriggers are placed 12’-0” O.C. to accommodate the weight of two panels, but can be adjusted to a maximum of 16’-0” O.C. The spacing of outriggers is constrained by the size of truck that will deliver the panels to the site. A common semi-truck trailer can fit an 8’-0” wide panel.

RAIL

Functioning much like a curtain rod, the rail spans between outriggers and is used to hang the panels. The rail shown is a section of HSS and can be sized according to total cladding weight. The rails are individually leveled to account for structural deflection and can be oriented horizontally, vertically, or diagonally depending on design intentions, type of cladding, or exterior accoutrement/equipment to be attached.

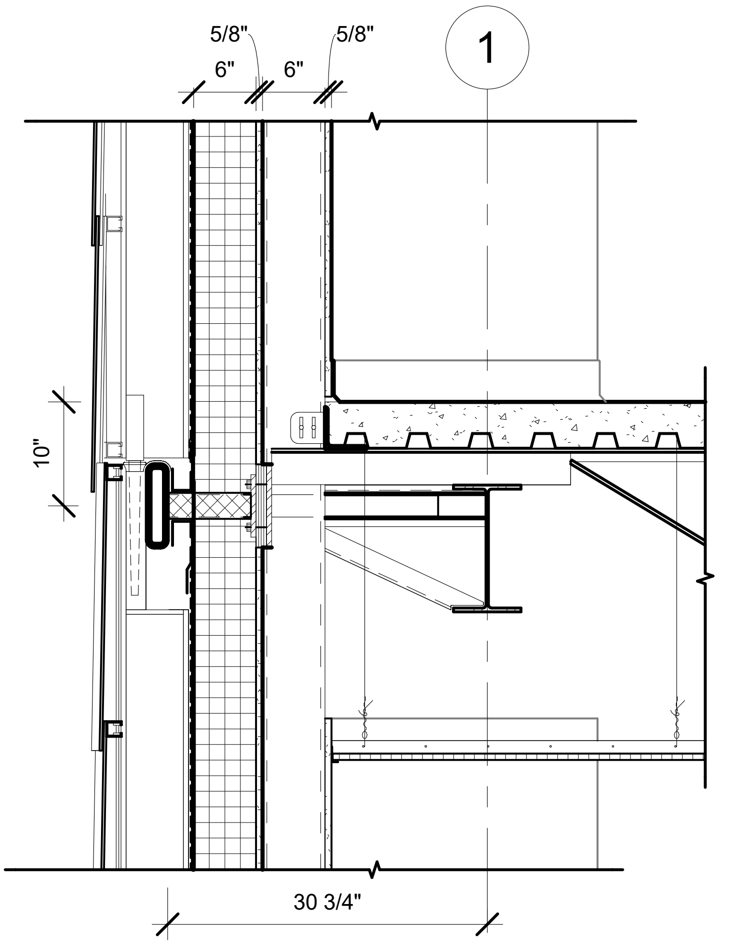
HANGER/RECEIVER

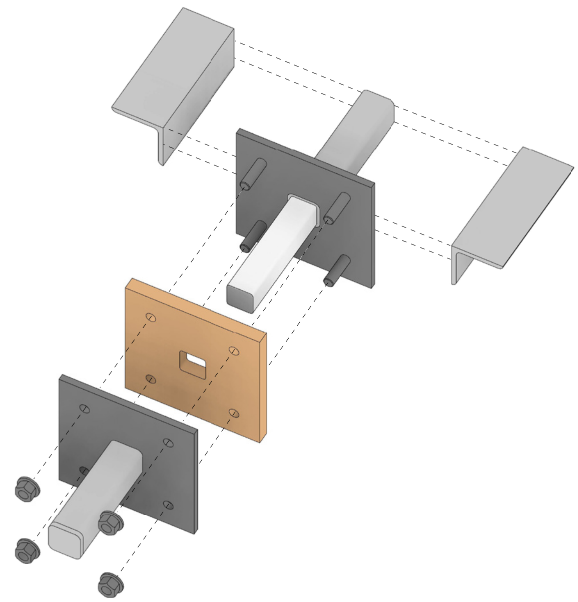
The hangers are designed to be free floating, held in place by the weight of the panel directly above to mitigate any movement caused by expansion/contraction of the cladding elements. As illustrated in the above figures, each hanger also acts as a receiver for the panel above. Located on each hanger is a leveling bolt that can enable installers to fine tune the alignment of each panel if necessary. Each hanger is also designed to receive standard crane hoist equipment.

STRUT

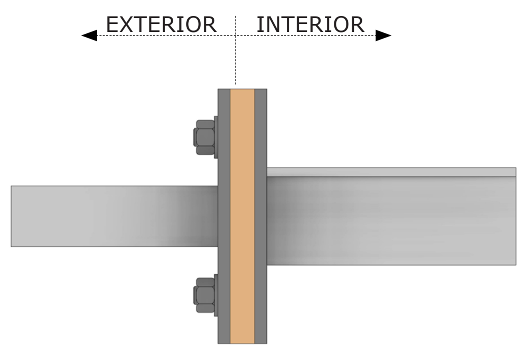
In the systems shown the struts are conventional 6” cold formed metal studs spaced 2’-0”O.C. but can also be sized according to cladding specifics. The strut profiles can take on various shapes if envisioned as a wire truss or a custom built truss lattice. This freedom of expression in the shape and profile of the struts can enable designers to articulate facades while maintaining a planar backup wall. The space between the struts functions as a vented cavity, allowing air flow to dry any moisture that gets through the rainscreen cladding.

OUTRIGGER DETAILS



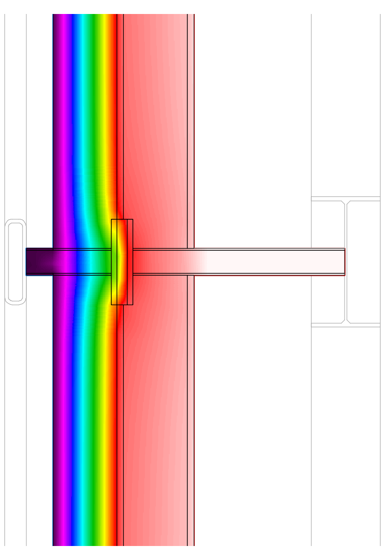


EXPLODED VIEW OF OUTRIGGER



SIDE VIEW OF OUTRIGGER WITH VAPOR PROFILE LOCATION

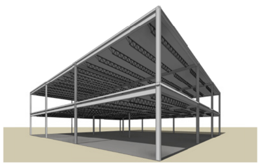
Each part of the outrigger assembly can be adjusted according to accommodate various cladding weights. The exterior and interior elements are separated by a proprietary product developed by ARMATHERM. The product ARMATHERM FRR, consists of a hardened thermoset polyurethane material that combines low thermal conductivity and high compressive strength. The product can support up to 40,000 psi and has an R value of 1 per inch and is ideal for transferring load in moment and shear connections.



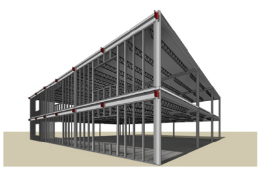
Isothermal Analysis created with THERM 7.6 software shows temperature gradient through outrigger. Condensation potential occurs outside of the air and vapor barrier due to the thermal break gasket.

SCHEDULING

A major benefit to using a unitized panel system is that the building envelope can be "dried-in" very quickly once the structure is in place. The time from erection to fully enclosed envelope is short due to the pre-manufactured cladding panels.

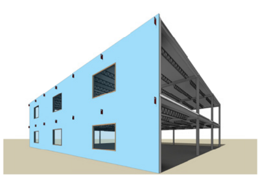


1. Structure is Erected

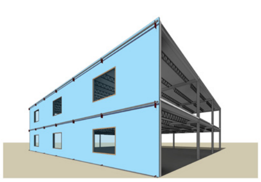


2. Backup wall stud spacing can be increased to 24"O.C. because it only carries sheathing load, not cladding or insulation.

3. Sheathing is attached to backup stud wall. Outriggers are bolted in place. Windows and Doors installed.



4. Insulation is installed. Seams taped at overlapped insulation edges.



5. Rails are leveled to compensate for structural deflection and welded to outriggers. Panels can begin to be hoisted into place.

HOPE FOR THE FUTURE

As gloomy and depressing as the introduction to this paper may seem, there is still a chance to heal some of the wounds humanity has made to the earth. Hopefully new methodologies like the SpeedClad system can continue to develop and become part of tougher energy standards in future buildings. Using a system like SpeedClad to retrofit existing buildings also offers unique opportunities to increase the energy performance of some of the biggest energy wasting structures around the world.

Even if all new demand for resources was significantly slowed or even halted, the ecosystems of the earth would not recover without drastic remediation and recovery efforts on a scale and scope that still lies outside the current psychological grasp of most humans. A complete paradigm shift in thinking and theories of sustainability is needed. "Almost all previous attempts at sustainability are linear, like making cars more efficient rather than crating a more diverse system of getting around"[8] Sustainability is not a deliverable, it is not a thing, or a prescriptive set of steps to follow, sustainability is a complex weaving of interconnected systems and ethos with the ability to sustain life. Until the fundamental approach to sustainability that views humans as an integral and symbiotic part of nature there is no way to guarantee the ability for future generations to meet their own needs.

In architectural terms, sustainability can best be described as the act of creating buildings that function as an approximated ecosystem. As will be discussed, all of the ecosystems on the planet are connected to form the larger Ecosystem of the earth. This is the vision of the future that architects must embrace to affect any real change in the face of impending globality and ecological catastrophe. Our buildings and cities must mimic and, wherever possible, outperform the natural systems that make up their surrounding environment. Our buildings and cities must be analogous to swamps, rainforests, prairies, and reefs if future generations are to be afforded the ability to meet their own needs. All of this is within our grasp through the use of technology and responsible design. This is not to say that our cities must become literal rainforests or marshlands, but they must emulate the natural functions of these ecosystems through the implementation of technological systems. (See figure 1) This approach, as mentioned before, is not prescriptive, linear, or algorithmic. Nature is complex with countless living and nonliving components that interact and architects must respond with broad understanding and multiple solution paths.

THE NEED FOR AN ECOLOGICAL ARCHITECTURE

An ecosystem is defined as a natural unit, consisting of all plants, animals, and microorganisms in an area functioning together, along with nonliving factors of the area to produce flows of energy This relationship of living and nonliving components of the environment at a given site has very real and applicable architectural implications. The living components of a site are easy to define and identify. The nonliving components such as temperature, light, moisture, air, stone etc. have just as much importance and effect on their immediate ecosystem. An ecosystem is not a single, autonomous entity with a constant shape or size. The entire earth is covered with a wide range of overlapping ecosystems that combine to create an ecosystem as large as the entire planet. The key to ecosystem health is interconnection and relationship to other ecosystems. All parts of an ecosystem are interrelated through a complex set of self regulating cycles, feedback loops, and linkages between different parts of the food chain. If one part is removed or disrupted, there are ripple effects throughout the entire system. These descriptions are invaluable to the future of a sustainable architecture. If buildings and cities can be imagined to be parts of an ecosystem that contribute to the wellbeing and health of a larger whole, then architects can make a legitimate argument that we need more buildings to solve the problems of the environment.

Buildings and cities can become better ecosystems. As discussed earlier, in the current paradigm, our buildings and cities are one of the main causes of environmental damage and act as autonomous, disconnected entities that consume disproportionately more than they produce in terms of energy and resources. When compared to how a natural ecosystem functions, our cities are simply wasteful and dumb. Nature provides all the examples an architect needs to envision an ecological architecture. As much as a stand of trees in a forest can sustain themselves indefinitely with adequate quantities of sun and water, the trees also provide for the ecosystem around them by creating food, oxygen, nutrients for the soil , and filter water through transpiration. Why then can we not design buildings and cities in this manner, to improve their surroundings and work together to create a system of connected architectural organisms with symbiotic relationships.

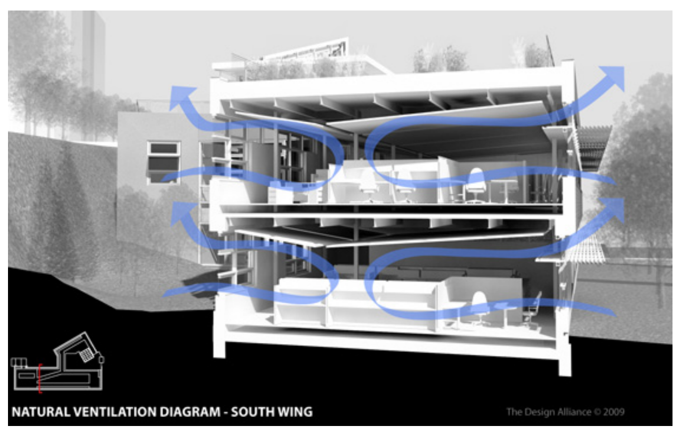
Not every ecological function might be accomplished in entirety in each individual building, but, these separate buildings can work together to form a complete system. For example, a residential building which on average uses 40 percent more water than an office, might be tailored to become a water purification and filtration hub while the office building which typically inhabits a larger footprint, might become a solar energy collector and air purification hub. These two building types, traditionally separate and disconnected, can become symbiotic partners. When taken at the scale of a city, the implications are much larger and complex but it is easy to see potential relationships between already established programs. Once the scale of a city has been envisioned and quantified, the same principles can be applied.

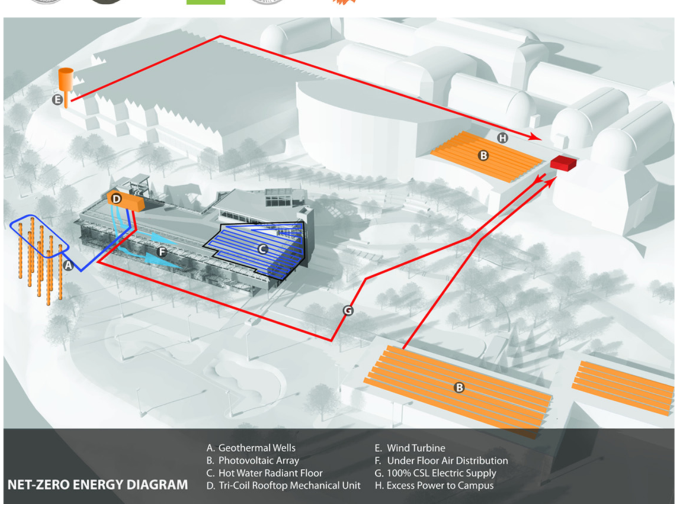
Perhaps a city with more solar insolation per year can work with other cities that have more overcast days and each city can contribute to the overall system in their greatest potential. The most important connection that our buildings and cities must make is the connection to nature. If we only envision buildings and cities working together without their relationship to natural ecosystems we are doomed to failure. Buildings and systems must also form symbiotic relationships with their immediate and global environments. Architects must envision the built environment as an extension and active participant in the natural world and contribute as much to nature as they consume. Providing habitats for wildlife, purifying air and water, producing food and nutrients, and enriching the lives of all who inhabit them are how designers can envision the future of the built environment. Luckily there have been many examples of architects enacting these principles.

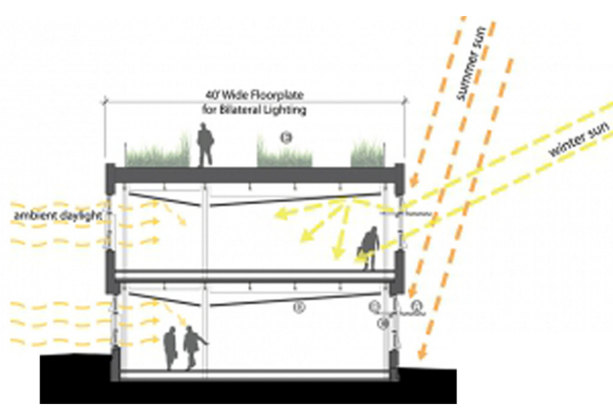
CASE STUDIES OF ECOLOGICAL ARCHITECTURE

The Design Alliance

The Phipps conservatory Center for Sustainable Landscapes in Pittsburgh, Pennsylvania was designed by The Design Alliance in 2012. The Center generates all of its own energy from photovoltaic panels and trans all storm and sanitary water captured on site. In addition to these strategies, the center uses a desiccant wheel energy recovery ventilator coupled with a ground sourced geothermal heat pump to heat and cool the building. The 22,000 square foot building was designed with an energy use intensity of 18.7 kBtu/sf/year and with the photovoltaic array, ends up with a net EUI of -1.6, making it a net producer of energy. Light shelves, a 40 foot wide footprint, and exterior bris soleil help achieve daylighting goals while minimizing overheating. Under floor air distribution and radiant hydronic heating are supplemented by a single air handling unit that conditions the entire building. Exposed exterior walls are steel framed with three inches of continuous exterior insulation with eight inches of cellulose between the stud cavities. Even the windows have been optimized and use triple pane, argon filled operable casement type windows to minimize heat loss and provide opportunities for natural ventilation. These technological systems are impressive and show a refined scientific approach to the built environment but the real and lasting effects are how the building operates as a whole to enrich the lives of the occupants and the surrounding environment. The people who work there love the building and the natural daylight and ventilation that the building provides. Green roofs that act as daily respites provide relaxing spaces for workers, habitat for birds and microorganisms, and help filter rainwater and oxygen. The environmental control systems would be pointless if this was not a pleasant building to inhabit. This building is LEED platinum, NetZero, Living Building Challenge, PassivHouse, Energy Star, and Architecture 2030 certified, making it one of the most environmentally sensitive buildings ever built.



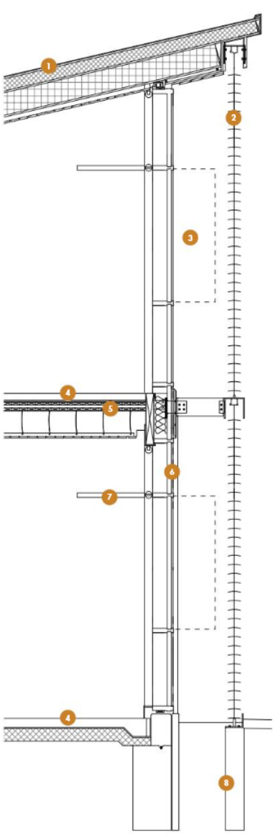


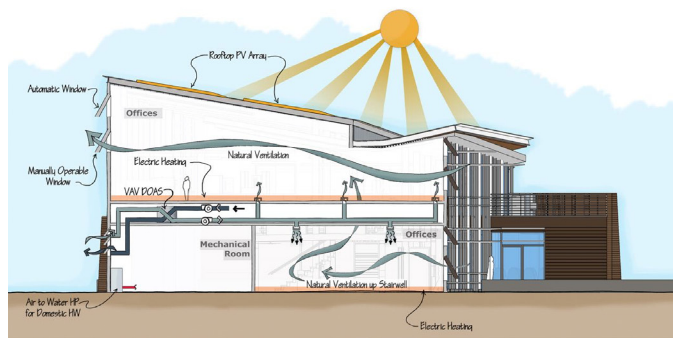


Figs. 15-19

ZGF Architects

The Rocky Mountain Institute Innovation Center is the highest-performing building in the coldest climate zone in the U.S. and produces more clean energy than it uses on an annual basis plus enough energy to power six electric vehicles. At 15,610 square feet, the RMIIC is similar in size to 90 percent of U.S. commercial offices. Over half of all commercial buildings are owner occupied and office space is the largest use type. The innovation center is intended to serve as a ground-breaking model to push the boundaries of what's possible with integrative, passive design and the business case for net-zero energy use. The building includes and advanced level of automation, metering, and controls that unfortunately have had glitches and software issues, but these kinks are inevitable when pushing the envelope. The long and narrow profile of 52 feet places most of the windows in a southern orientation to provide great daylighting opportunity. This is another building that has surveyed the occupants and has had resounding success in the wellbeing statistics of employees. People love to be in the building and knowing that it is a net producer of energy and clean water. This satisfaction carries over to performance at work and life. This building also carries the same certifications of the Phipps





Exterior Venetian Sunshades

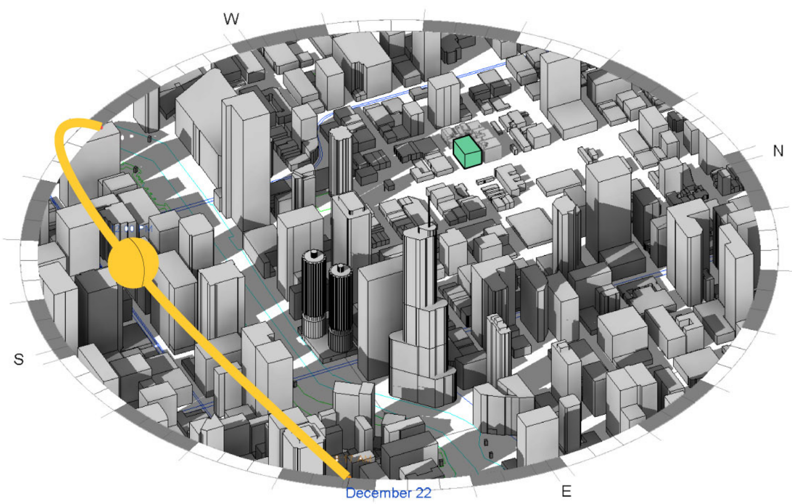
The sunshades control solar heat gain and retract to maximize views when shading is not required. The automatic sunshades are controlled by building system software that responds to the climate and changing weather conditions.

South Wall Section

1 Structural Insulating Panels (SIPs)
2 Exterior Venetian Sunshades
3 Quad Pane Operable Windows
4 Concrete Slab
5 Cross Laminated Timber (CLT) Floor
6 High Performance Curtainwall System
7 Light Shelves with Bio Phase-Change Material (PCM)
8 Exterior Sunshade Anchor

Figs. 20-24

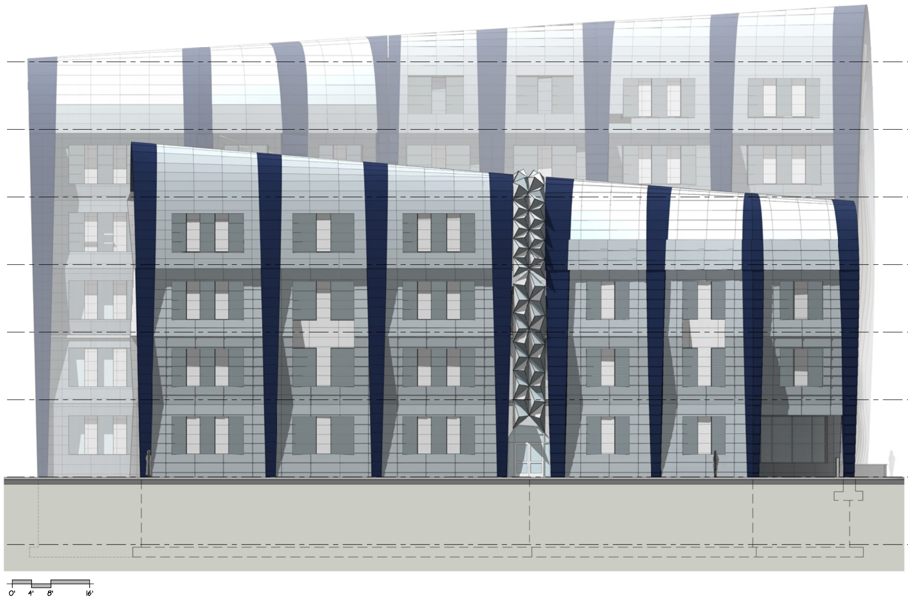
Chicago Center of Sustainable Building Innovation

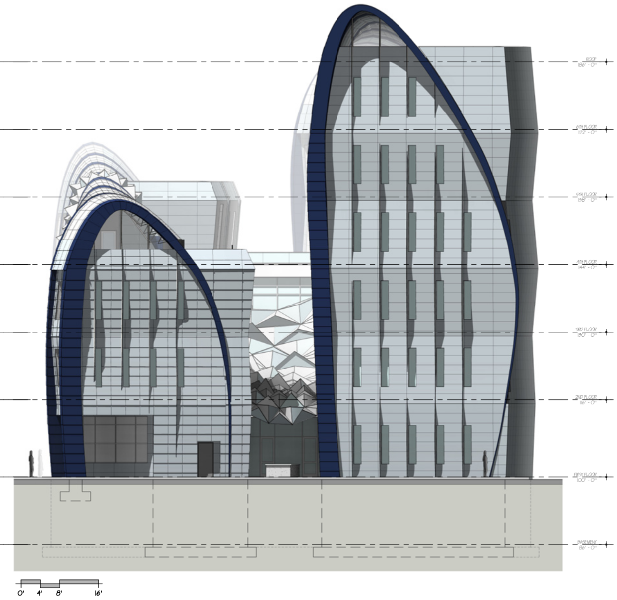


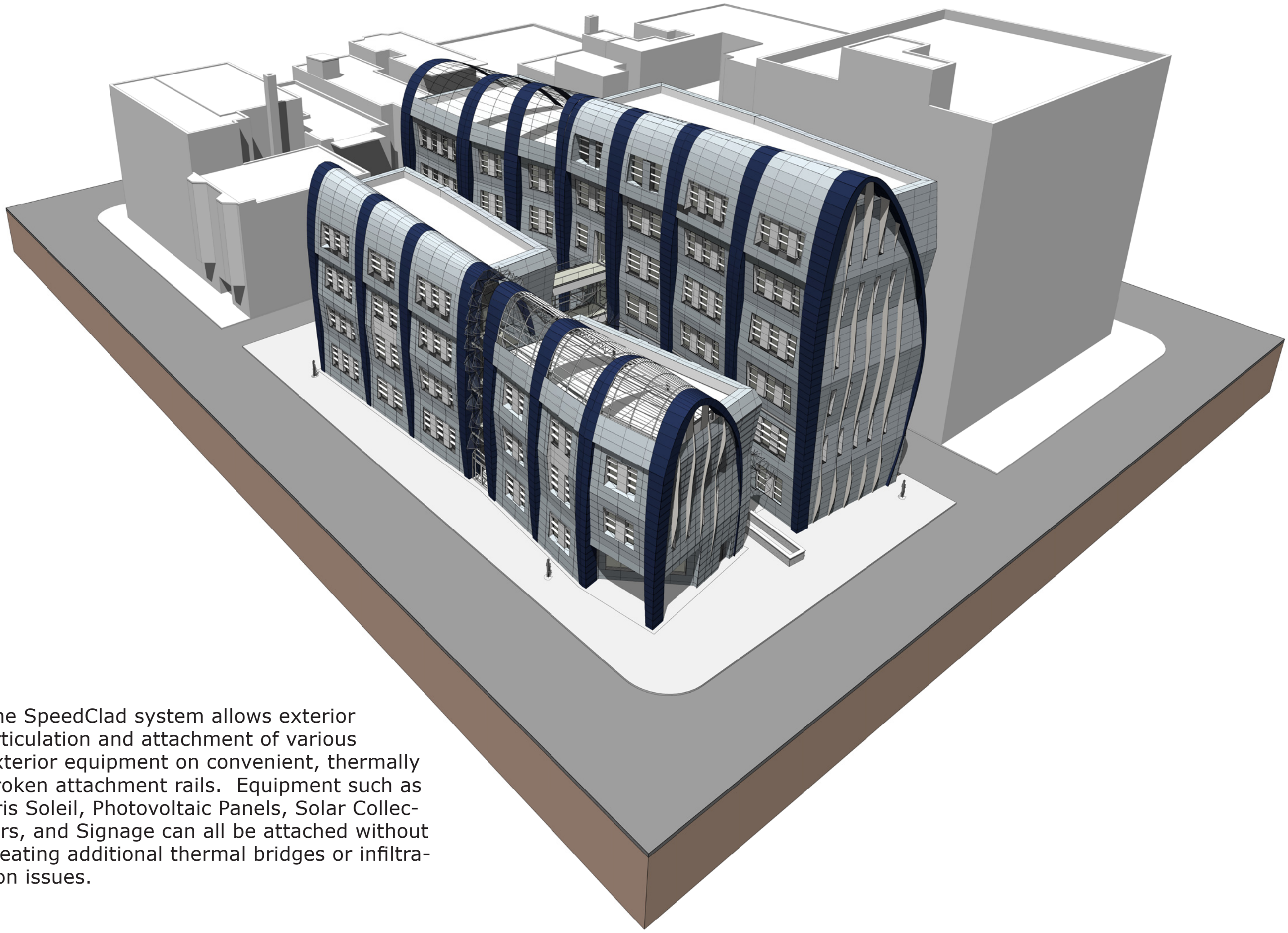
Midrise office building accounts for the largest percentage of new construction by square feet in the United States for the past 3 years. Since this typology is the most common type of floor area built, it was logical to develop an ecological approach for future midrise buildings. The site was carefully analyzed for solar insolation and a building footprint with a maximum depth of 40 feet was decided upon so that occupants receive a desired amount of daylight during working hours.

The SpeedClad system is utilized to illustrate how a facade can perform multiple functions while staying thermally-broken from main structural members, keeping the envelope control layers free of unmitigated penetrations.

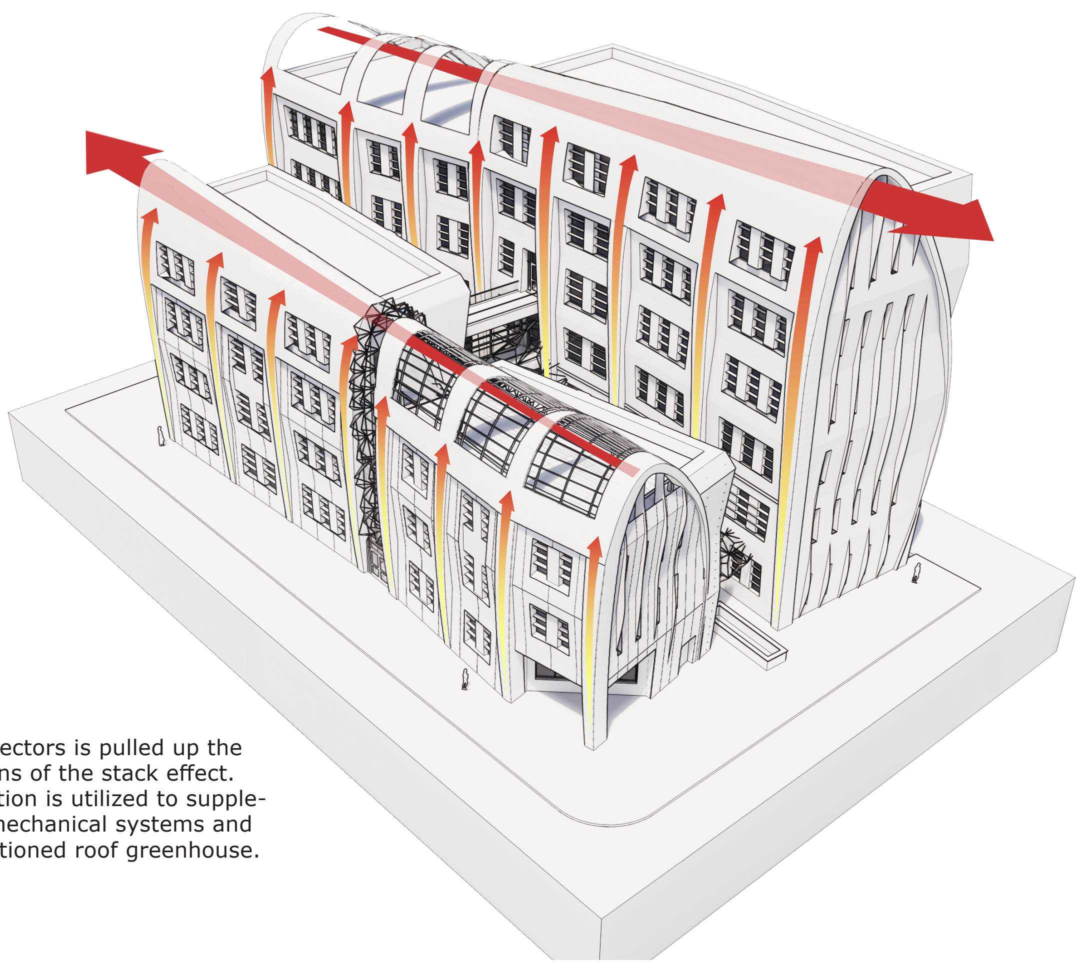
This 80,000 S.F. building is intended to house several medium tenants with sustainable business interests, as well as roof gardens, a workshop and rentable desk space in a business incubator for startup companies.


0' 4' 8' 16'

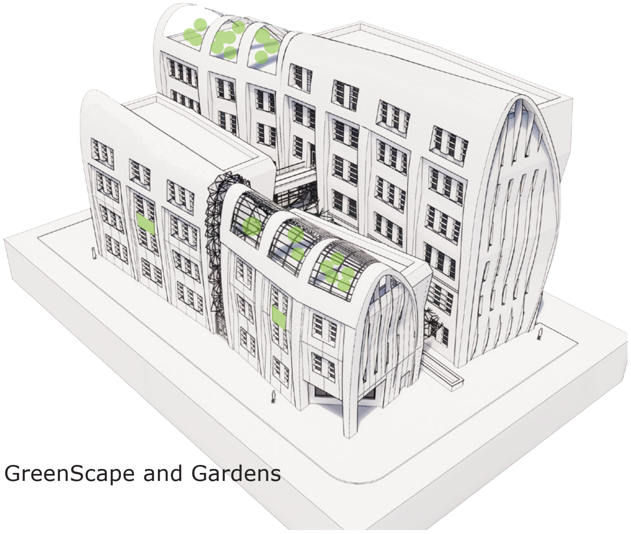

0' 4' 8' 16'



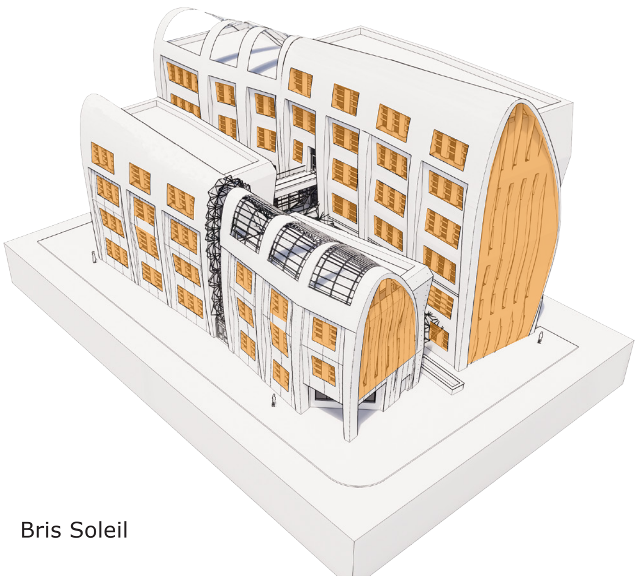
The SpeedClad system allows exterior articulation and attachment of various exterior equipment on convenient, thermally broken attachment rails. Equipment such as Bris Soleil, Photovoltaic Panels, Solar Collectors, and Signage can all be attached without creating additional thermal bridges or infiltration issues.



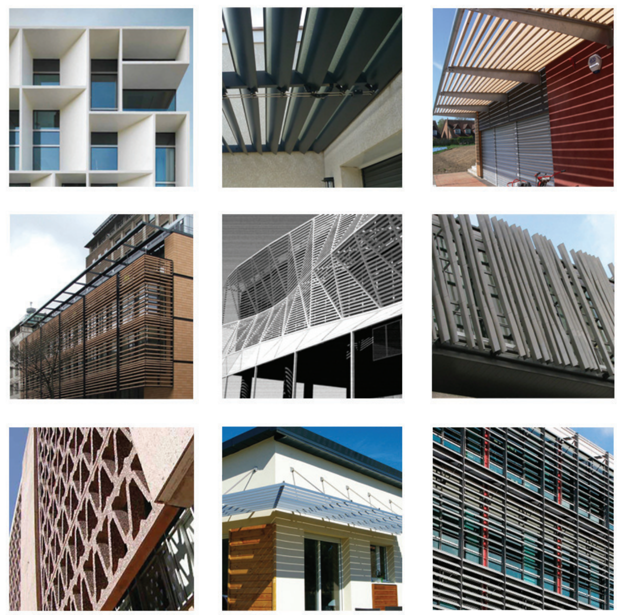
Heat from solar collectors is pulled up the strut cavity by means of the stack effect. This passive circulation is utilized to supplement the building mechanical systems and temper the unconditioned roof greenhouse.

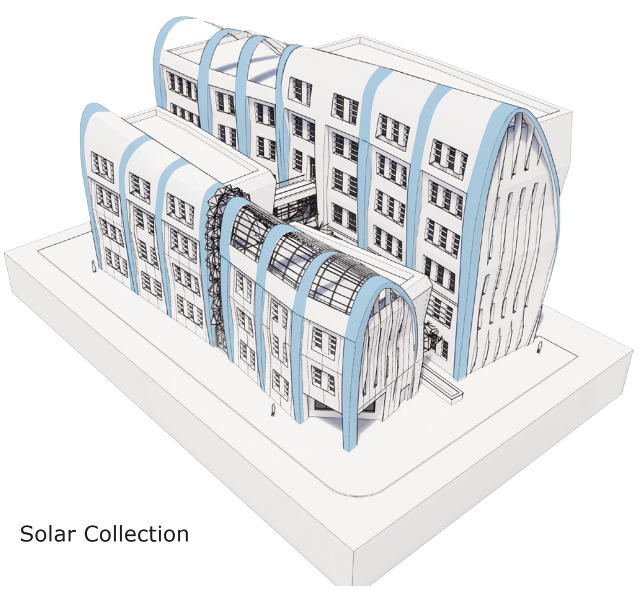


GreenScape and Gardens



Bris Soleil

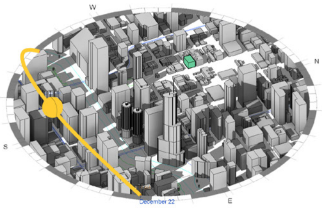


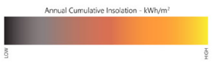


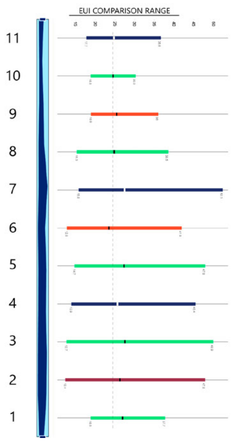
Solar Collection

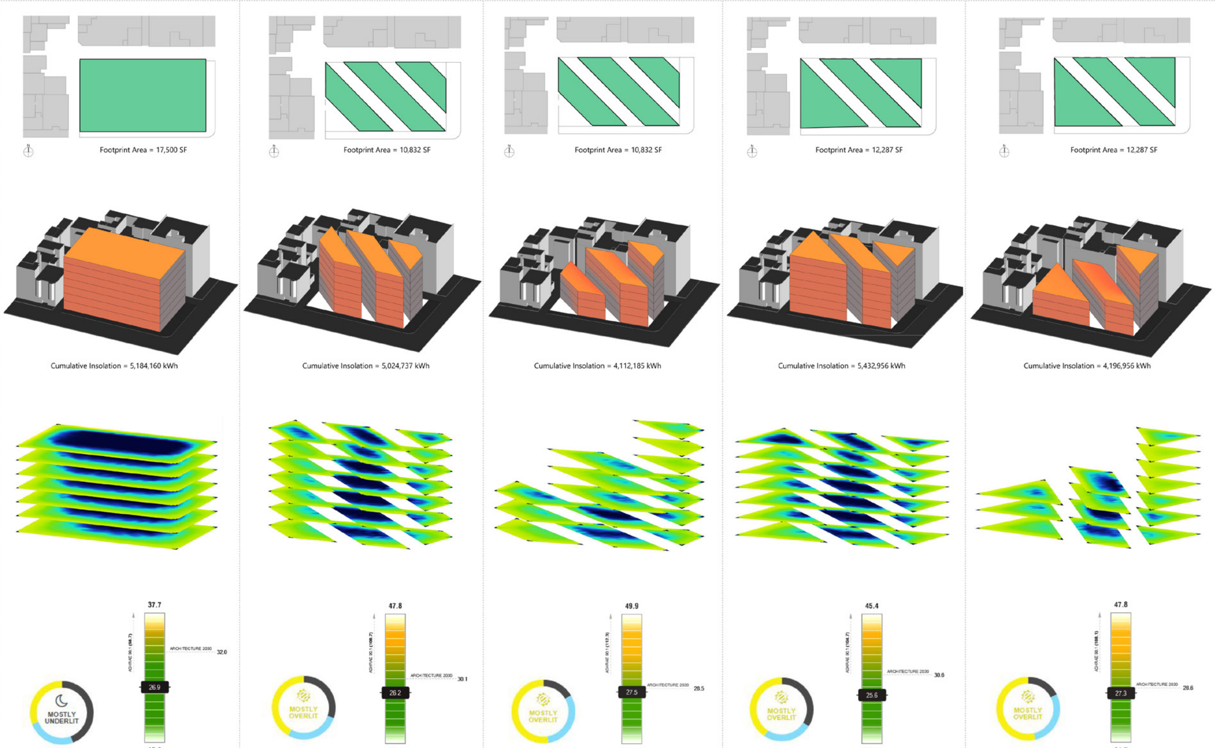
Chicago Center of Sustainable Building Innovation

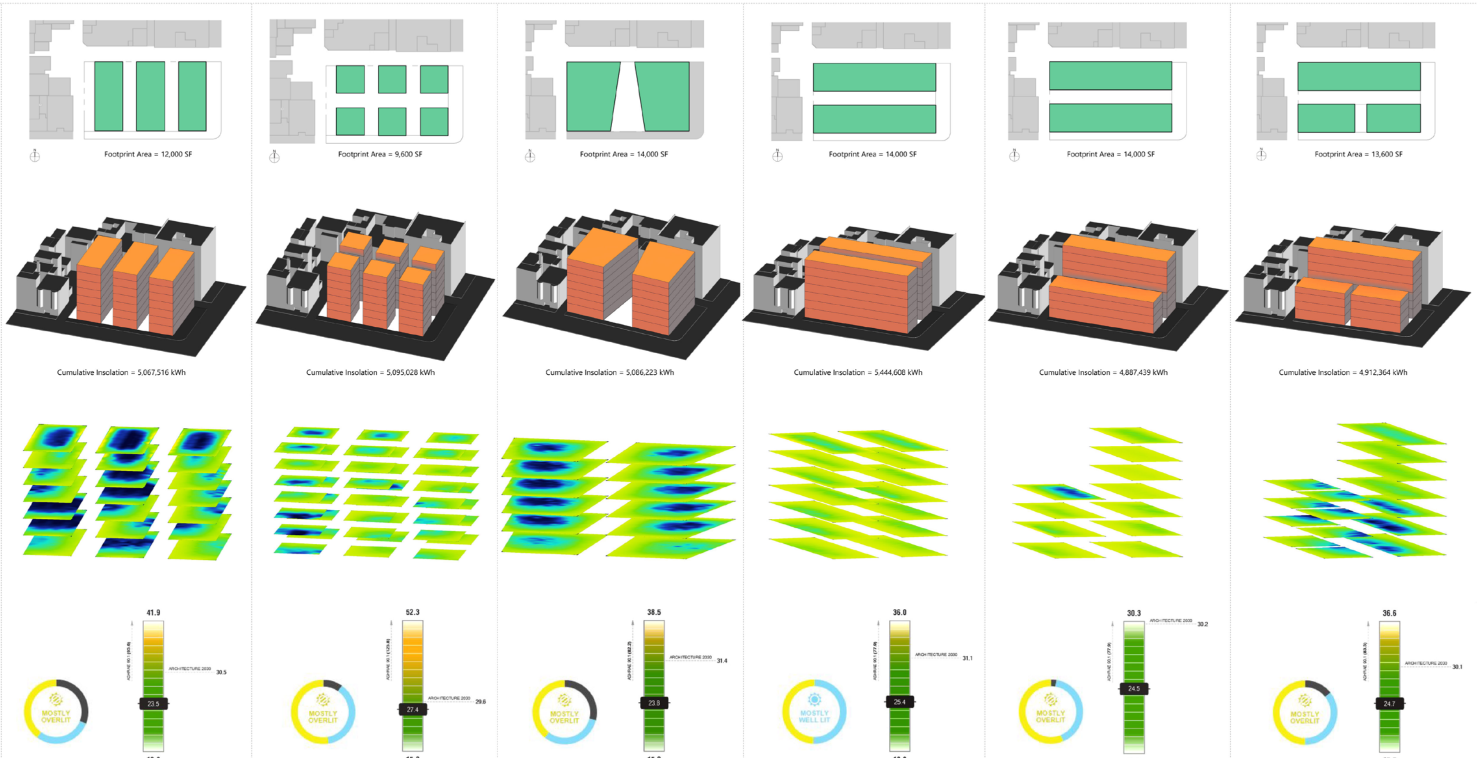
Daylight and Energy Analysis











Option	Footprint Area	Cumulative Insolation	EUI (kBtu/sf/year)	Gross Surface Area	Gross Volume	Gross Floor Area	Roof Area	Direct South Exposure	Cumulative Insolation
1	17,500 SF	5,184,160 kWh	**26.9**	88,900 s.f.	1,715,000 c.f.	122,500 s.f.	17,500 s.f.	17,150 s.f.	5,184,160 kWh
2	10,832 SF	5,024,737 kWh	**26.2**	111,709 s.f.	1,061,596 c.f.	51,624 s.f.	10,832 s.f.	9,616 s.f.	5,024,737 kWh
3	10,832 SF	4,112,185 kWh	**27.5**	86,979 s.f.	706,249 c.f.	51,624 s.f.	10,832 s.f.	5,656 s.f.	4,112,185 kWh
4	12,287 SF	5,432,956 kWh	**25.6**	118,602 s.f.	1,203,313 c.f.	85,950 s.f.	12,278 s.f.	14,409 s.f.	5,432,956 kWh
5	12,287 SF	4,196,956 kWh	**27.3**	90,988 s.f.	823,104 c.f.	52,242 s.f.	12,278 s.f.	6,972 s.f.	4,196,956 kWh
6	12,000 SF	5,067,516 kWh	**23.5**	106,320 s.f.	1,176,000 c.f.	84,000 s.f.	12,000 s.f.	11,760 s.f.	5,067,516 kWh
7	9,600 SF	5,095,028 kWh	**27.4**	113,280 s.f.	940,800 c.f.	67,200 s.f.	9,600 s.f.	11,760 s.f.	5,095,028 kWh
8	14,000 SF	5,086,223 kWh	**23.8**	95,200 s.f.	1,379,000 c.f.	98,000 s.f.	14,000 s.f.	12,312 s.f.	5,086,223 kWh
9	14,000 SF	5,444,608 kWh	**25.4**	112,280 s.f.	1,372,000 c.f.	98,000 s.f.	14,000 s.f.	17,150 s.f.	5,444,608 kWh
10	14,000 SF	4,887,439 kWh	**24.5**	93,360 s.f.	1,064,000 c.f.	77,000 s.f.	14,000 s.f.	17,150 s.f.	4,887,439 kWh
11	13,600 SF	4,912,364 kWh	**24.7**	96,045 s.f.	1,045,700 c.f.	75,400 s.f.	13,600 s.f.	16,692 s.f.	4,912,364 kWh

Buildings need to be living, symbiotic participants of nature that enrich the lives of inhabitants. Any act of building essentially destroys a part of nature, encapsulates soil, and requires vast energy and material to construct, so how can this seemingly malignant yet necessary act become a net gain for both society and the earth. A fundamental change to our thinking and lifestyle stemming from nothing less than a paradigm shift in sustainability ethos is necessary and will not be possible without a completely new pedagogy. I simply don't think that we are capable of this kind of drastic change overnight without some cataclysmic event that forces our hand. A few architects building a few projects here and there isn't going to have the widespread effect our psychological core. Perhaps the best definition of sustainability that we can approach now is 'providing the education and training to tomorrow's generation so that they can deal with the mess we have left them.' By utilizing every available technology and lessons learned from the past, architects must become the face of change.


INTRODUCING...
THE SPEED-CLAD SYSTEM
BACK OF PANEL
FRONT OF PANEL
TOP VIEW


EXIT

Figs. 25-26


HANGER AND PIN
OUTRIGGER
THERMAL BREAK AT OUTRIGGER
INSULATION PANEL
BRIS SOLEIL
GREENSCAPE


STUD WALL
SHEATHING
WEATHER BARRIER
EXTERIOR INSULATION
FURRING
CLADDING
INTRODUCING...
THE SPEED-CLAD SYSTEM
BACK OF PANEL

Figs. 27-28

REFERENCES:

1. Bovill, Carl, Sustainability in architecture and urban design, New York: Routledge, 2015 (pg 5).

2. Attmann, Osman, Green Architecture, McGraw-Hill, 2010 (pg 6).

3. United States Department of Energy www.energy.gov.

4. Attmann, Osman, Green Architecture, McGraw-Hill, 2010 (pg 9).

5. Roodman and Lenssen 1995; Anink et al. 1996.

6. Bovill, Carl, Sustainability in architecture and urban design, New York: Routledge, 2015 (pg 2).

7. Schröpfer, Thomas, Ecological Urban Architecture, Basel: 2012 (pg 58).

8. Garcia, Emilio Jose., Unravelling Sustainability and Resilience in the Built Environment Florence: Taylor and Francis, 2017 (pg 14).

9. PHIUS.org Passive House Institute US.

10. JLC Online www.jlconline.com Journal of Light Construction.

11. Ehrlich 1985; Clark, Reading and Clarke 1994; Broswimmer 2002.

12. Building Science Corporation.

13. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

14. International Code Council.

FIGURES:

4-5. Steven Winter Group Associates, Inc.

6-7. Getty Images

8-9. www.exteriorproinc.com

11-14. Hammer and Hand Construction

15-19. The Design Alliance

20-24. ZGF Architects

25-28. Diane Fellows