
Kingspan
Light+Air
THE BUSINESS CASE FOR DESIGNING WITH LIGHT AND AIR
THE PROFITABILITY OF HEALTHY SPACES

Program Registration

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Course Overview

Natural light and air in the built environment are vitally important to the well-being of the occupants and their productivity, and to the profitability of businesses and building owners. But not all daylighting designs are created equal. The designer must understand not only the importance of natural light in the workplace, schools, and retail environments, but also how to bring it about for optimal function, performance, and durability. This course discusses the factors to consider.

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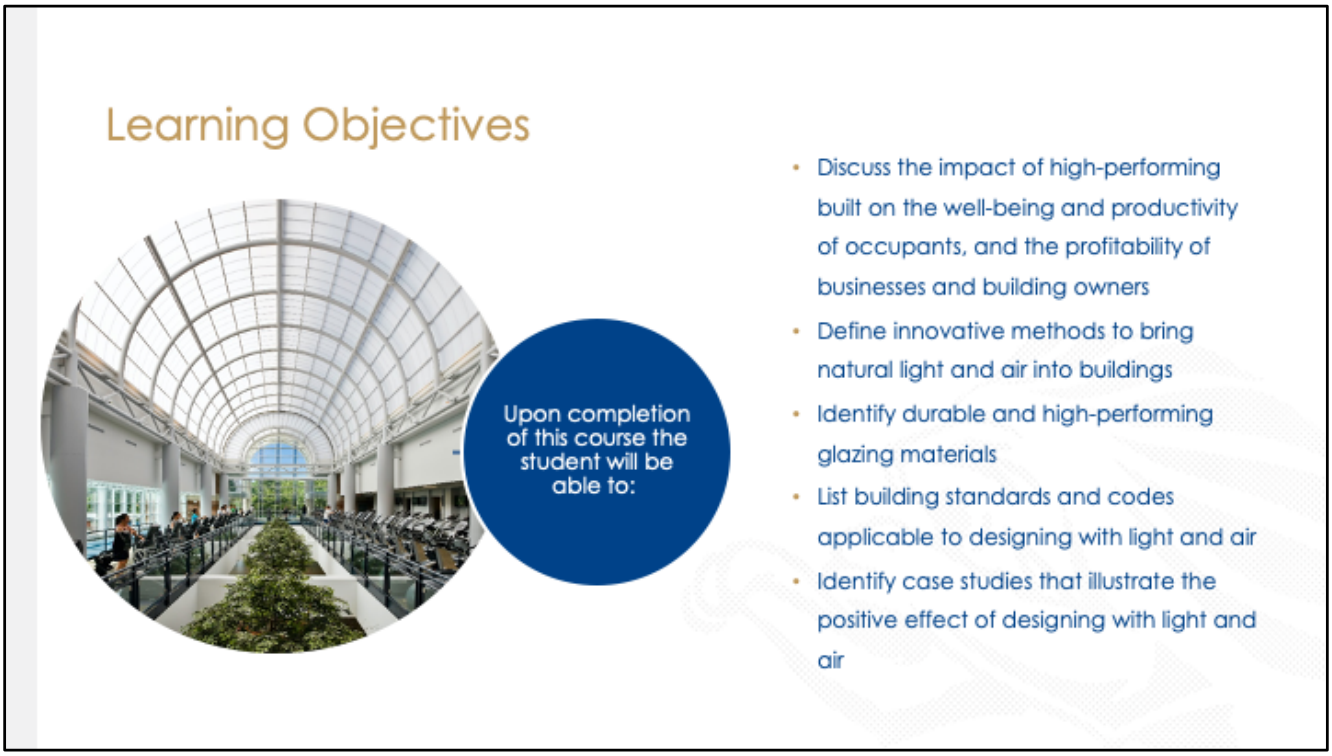


Upon completion of this course the student will be able to:

Discuss the impact of high-performing built environments on the well-being and productivity of occupants, and the profitability of businesses and building owners
Define innovative methods to bring natural light and air into buildings
Identify durable and high-performing glazing materials
List building standards and codes applicable to designing with light and air
Identify case studies that illustrate the positive effect of designing with light and air

Introduction

Setting the priorities at the beginning of a project

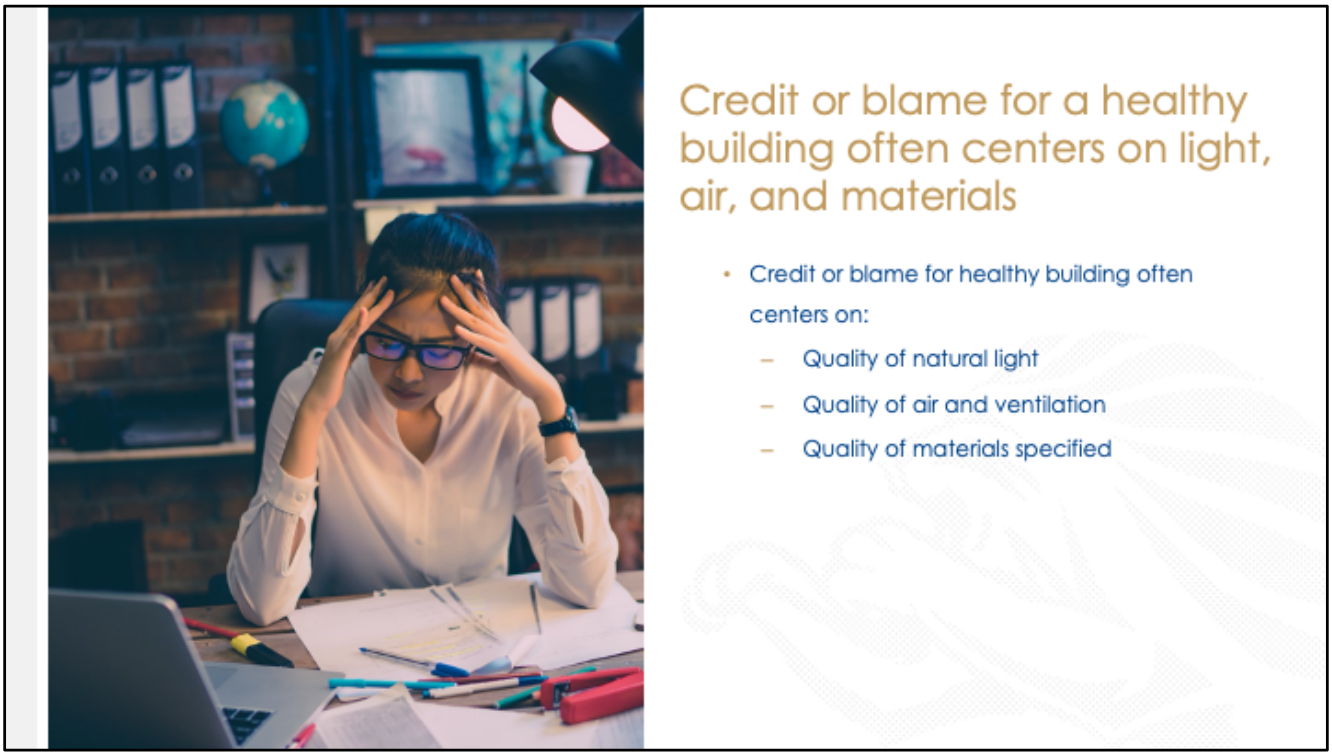
- What do we want this building to accomplish?
  - How much square footage?
  - What is the layout?
  - What is the volume?
  - What are the technical features?
  - How do we weatherize it?
- But what about vitality, health, and well-being of the occupants?
  - Should that be a primary concern?

When an architect and developer/owner meet for first time to discuss a new project, foremost on everyone's agenda is: What do we want this building to accomplish? It will need certain square footage, layout, volume, technical features, and weatherization to accommodate the needed program.

But what about the vitality, health, and well-being of the occupants of the building? Should that be a primary concern?

Occupant wellbeing is often seen as wishful thinking, and simply impractical or impossible due to budget and timing.

In reality, designing a building with human health as a primary concern is often not only doable, but preferable for all the benefits it also brings to the owner of the building, the business occupying the building, and the operator of the building.



Much of the credit or blame for a healthy building centers on the quality of natural light and air in the building, and the quality of the materials specified.

When natural light and ventilation are not part of the program, the negative effects on occupants hurt the occupants' productivity, the business, profits, and potentially the value of the building when compared to higher performing buildings a buyer might be considering.

This course demonstrates the benefits of natural light and air to all stakeholders, and offers innovative strategies with quality materials to make that part of the design program from the very beginning of the process.

This section discusses how the built environment affects occupant health.

Workers in offices lacking natural daylight have been shown to sleep on average 46 minutes less than their light-receiving counterparts[1]. They also reported lower scores on quality of life measures related to physical problems and vitality, and had worse overall sleep quality and sleep efficiency, with more sleep disturbances and daytime dysfunction. This can result in an increased likelihood of missing work or making errors. Additionally, lack of sleep is linked to many psychological conditions such as depression and anxiety. The impact daylight can have on our mood is further evidenced by a research poll of 1,614 North American employees in which 43 percent report feeling sad or depressed because of lack of daylight[2].

[1]Boubekri, M. et al. (15 June 2014). Impact of windows and daylight exposure on Overall health and sleep quality of office workers: a case-control pilot study. Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine vol. 10, no. 6 pp.603-11 Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4031400/Meister, J. C. (5 September 2018).

[2]World Green Building Council. (25 October 2016). Building the Business Case: Health, Well-being and Productivity in Green Offices. Retrieved from https://www.worldgbc.org/newsmedia/ building-business-case-health-well-being-and-productivity-green-offices (accessed 01/09/2019)

Daylighting helps create a well-regulated circadian system, which controls the body's sleeping and waking cycles and core temperatures with the external day and night cycle. It leads to reduced symptoms of Seasonal Affective Disorder (SAD), such as depression, low energy, tiredness, increased appetite and weight gain. Daylighting aids maintenance of healthy levels of vitamin D, positively linked to healthy bones, and to reduced amounts of bacteria and virus associated with respiratory infections common in winter. Daylighting has a positive impact on mood for those who spend a lot of time indoors.

[1]https://shop.bsigroup.com/ProductDetail/?pid=000000000030157088

Access to good quality air is also fundamental to health and wellness. Spending too much time in a space with poor air quality can result in respiratory problems, manifesting in symptoms such as headaches, irritated eyes, nose and skin, and difficulty concentrating.

Replacing stale, polluted indoor air with fresh air through natural ventilation systems can not only prevent these issues, but lead to dramatic improvements in cognitive performance. For example, a study published in *Harvard Magazine* showed employees in environments with optimized ventilation scoring 31 percent better in crisis-response questions, and nearly 300 percent better on information usage[1]. Fresh air is also important for our emotional well-being. Opening a window or activating a natural ventilation system gives us a direct connection to the outside world, helping us to feel refreshed. Meanwhile, the sensation of a breeze against our skin can have a calming effect.

[1]Babür, O. (14 April 2017). Cognitive Benefits of Healthy Buildings. Harvard Magazine. Retrieved from https://harvardmagazine.com/2017/05/cognitive-benefits-ofhealthy-buildings (accessed 02/09/2019)

Healthy buildings attract quality workers. According to the Harvard Business Review, a poll of 1,614 North American employees, found that "access to natural light and views of the outdoors are the number one attribute of the workplace environment, outranking stalwarts like on-site cafeterias, fitness centers, and premium perks including on-site childcare[1]."

An occupant-focused workplace can be a powerful recruitment tool. A survey released by the U.S. Green Building Council (USGBC) shows that the majority of office workers want to work for a value-orientated company that has a reputation for showing commitment to both environmental and human sustainability.[2]

Prioritizing employee well-being enhances corporate reputation, which research has indicated has a significant impact on jobseekers' decision to accept or decline an offer of employment. One study found that 75 percent of Americans would prefer to stay unemployed rather than work for a company with a bad reputation, and that 87 percent of currently employed workers would consider leaving their job to take on a role with a company that has an excellent reputation.[3]

[1]The #1 Office Perk? Natural Light. Harvard Business Review. Retrieved from https://hbr.org/2018/09/the-1-office-perk-natural-light (accessed 08/31/2020)

[2]U.S. Green Building Council. (16 October 2018). Employees are Happier, Healthier and More Productive in LEED Green Buildings. Retrieved from https://www.usgbc.org/articles/employeesarehappier-healthier-and-more-productive-leed-green-buildings (accessed 12/09/2019)

[3]ReputationManagement.com. (9 July 2019). Indeed & Glassdoor Reviews Influence Your Company's Reputation. Retrieved from https://www.reputationmanagement.com/blog/employee-reviews-influence-company-reputation/ (accessed 01/09/19)

Investing in a healthy, happy workplace can have an impact on the market value and desirability of a building. The World Green Building Council found that building owners consider healthy buildings to be worth 7 percent more than standard buildings, while 46 percent said they were easier to lease, and 28 percent said they commanded premium rents[1].

With renters saying they'd pay 6.1 percent more for a space with ample natural daylight[2]

[1]World Green Building Council. (25 October 2016). Building the Business Case: Health, Well-being and Productivity in Green Offices. Retrieved from https://www.worldgbc.org/news-media/building-business-case-health-well-beingand-productivity-green-offices (accessed 01/09/2019)

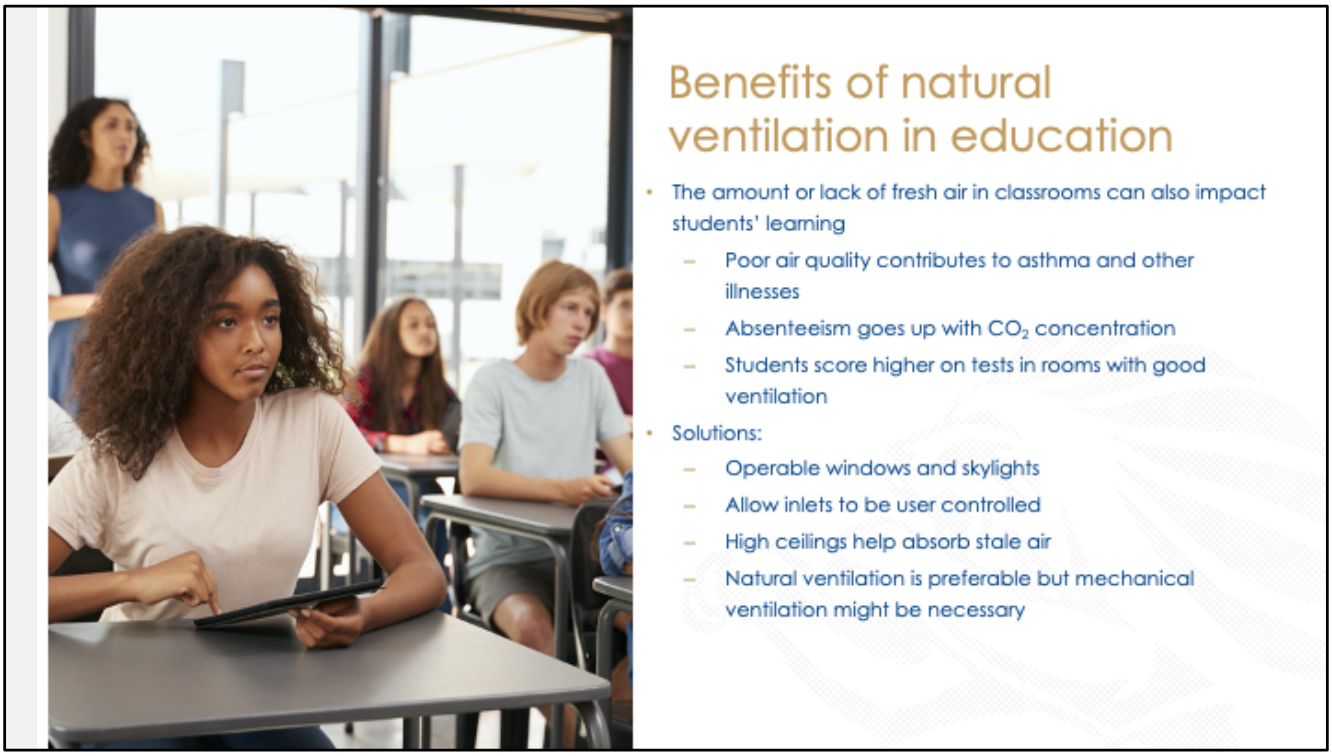
[2]https://www.sciencedirect.com/science/article/abs/pii/S0360132319307152

A comprehensive study by Heschong Mahone Group analyzed the connection between daylighting levels in classrooms and the academic performance of over 21,000 primary school pupils in the U.S. It found that students who worked in spaces with high levels of daylight progressed 20 percent faster in math tests and 26 percent faster on reading tests[1].

There are several reasons for this:
Daylight through windows and skylights is more diffused than artificial ceiling lights, providing a more even illuminance of objects and people.
Natural daylight contains all the color wavelengths visible to the human eye. It is the ideal lighting source for color rendition, allowing pupils to identify colors and shades more clearly and engage better with educational resources.
Access to high levels of natural light will reinforce the children's natural circadian rhythms, making them feel more awake and ready to learn during the day and to sleep better at night.
Artificial lights, particularly those containing fluorescent tubes, can have a noticeable flicker that is distracting. This can also result in headaches and eye strain.
Of course, it is not a case of simply flooding the space with as much daylight as possible. Excessive levels of sunlight can cause disruptive and even disabling glare and increase the room temperature beyond what is thermally comfortable. These issues need to be managed by designers through careful consideration of the maximum and minimum light levels a room will receive, and implementation of

shading measures or the selection of diffusive materials such as nano-prismatic polycarbonate glazing.

[1]http://h-m-g.com/downloads/Daylighting/schoolc.pdf (Accessed 08/31/20)



The amount or lack of fresh air in classrooms can also impact students' learning.

Poor indoor air quality due to airborne pollutants from both in and outdoors can cause a range of issues. These include symptoms from headaches and itchy noses, throats and eyes to lethargy and difficulty concentrating, as well as potentially aggravating more serious issues such as asthma. Children are particularly vulnerable to these concerns as they have a higher breathing rate, resulting in them inhaling more pollutants per body weight than adults. This issue is compounded in classrooms, which often have a high occupancy density. A study found that every 100 parts per million increase in CO_2 resulted in school attendance decreasing by approximately one-half day per year[1].
A 2012 research program improved the ventilation rates of 16 classrooms[2], monitoring over 200 pupils' performance on computerized tasks before and after. It showed a marked improvement in the speed and accuracy of responses for Choice Reaction, Color-Word Vigilance, Picture Memory, and Word Recognition at the higher ventilation rates compared with the low ventilation conditions.

There are several ways architects can help to ensure good levels of natural ventilation, such as:
Considering different types and sources of ventilation. Windows are an obvious inlet for fresh air. Openings that are high in the room, such as skylights, allow for the hottest, stalest air to escape more efficiently.

Allowing for these inlets to be user controlled as far as possible. This enables teachers to manage the classroom environment under different circumstances. For example, varying numbers of students or colder weather.

High ceilings can also help to absorb stale air. However, this is not the only effective solution, and good ventilation is still necessary.

While natural ventilation is preferable, mechanical ventilation may be necessary in some cases. Utilizing mechanical ventilation with a heat recovery system can help to increase energy efficiency.

[1] https://pubmed.ncbi.nlm.nih.gov/25117890/ (Accessed 08/31/20)

[2] https://www.sciencedirect.com/science/article/abs/pii/S0360132311002617 (Accessed 08/31/20)

A healthy building can actually increase profits for retail stores as natural light has been proven to increase sales in a retail setting. A report titled "Skylighting and Retail Sales: An Investigation into the Relationship Between Daylighting and Human Performance"[1] was prepared by Pacific Gas and Electric Company and funded by California utility customers under the auspices of the California Public Utilities Commission.

"Skylights were found to be positively and significantly correlated to higher sales," the report stated. "All other things being equal, an average non-skylit store in the chain would likely have 40 percent higher sales with the addition of skylights, with a probable range between 31 percent and 49 percent. This was found with 99 percent statistical certainty.

"After the number of hours open per week, the presence of skylights was the best predictor of the sales per store of all the variables that we considered. Thus, if a typical non-skylit store were averaging sales of $2 per square foot, then its sales might be expected to increase to between $2.61 and $2.98 per square foot with the addition of a skylighting system."

Employees and shoppers in a retail setting respond favorability to fresh air.

Now that we have explored *why* natural light and air are important for human health and well-being, and for profitability, let's discuss *how* it's done.

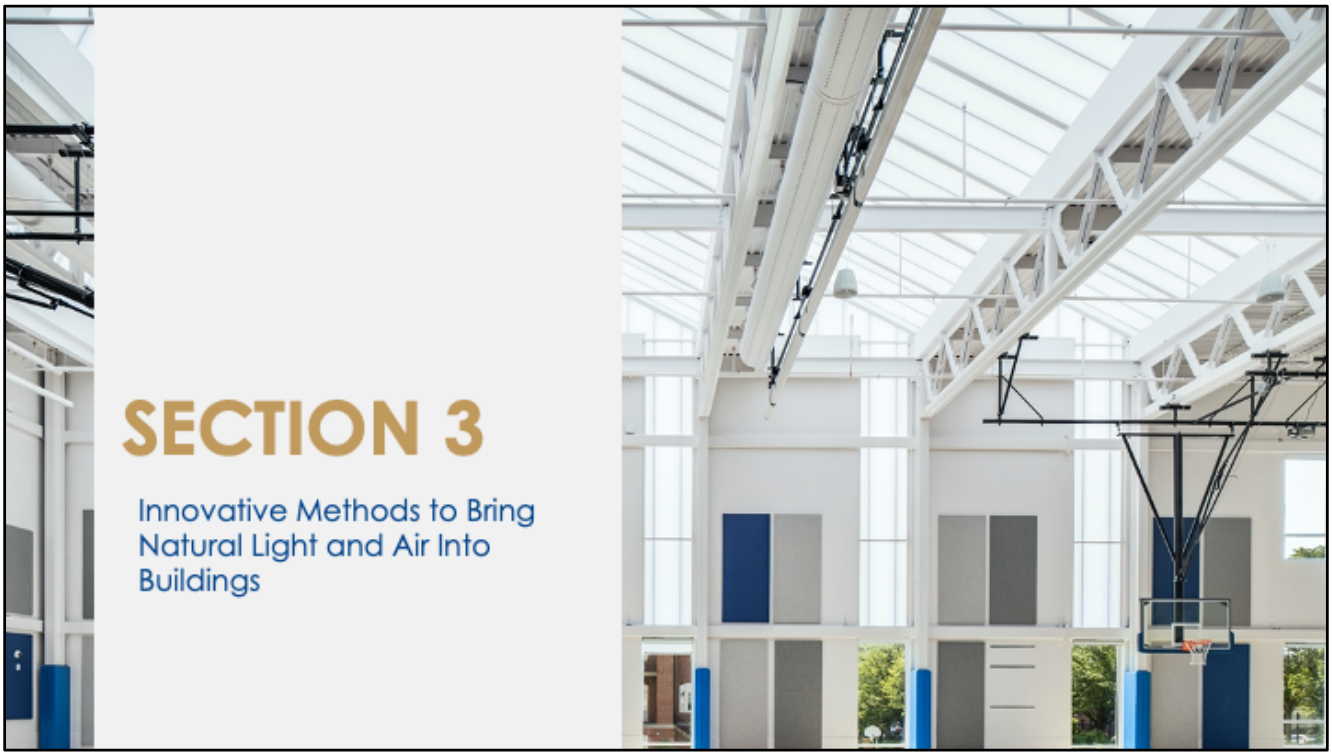
[1]https://www.pge.com/includes/docs/pdfs/shared/edusafety/training/pec/daylight/R

etailCondensed820.pdf

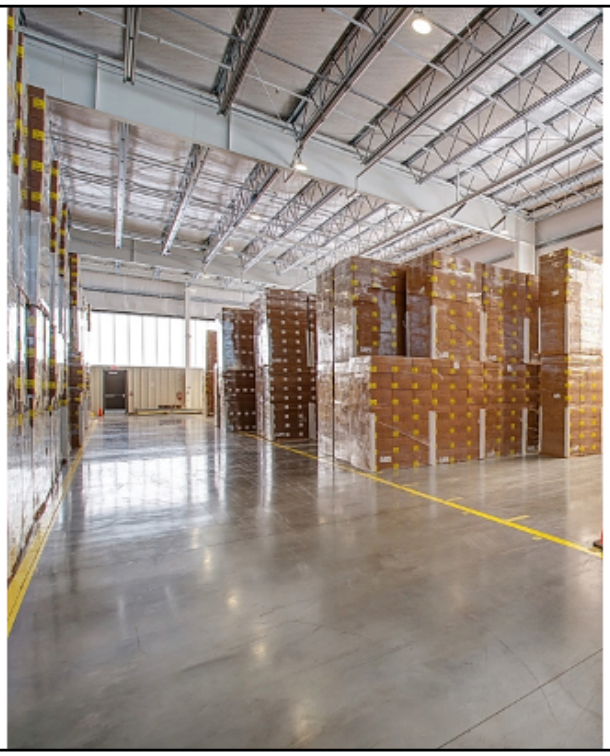
Despite growing evidence to support increased worker function in buildings with natural light and air, healthy design interventions are often excluded from proposals due to the perceived cost of implementing them, with many clients considering them a luxury rather than a necessity.[1]

Therefore, the challenge for building designers and architects lies not only in finding the best ways to create healthy, happy buildings, but also in how to present the business case for doing so. To do this effectively, it is vital to educate stakeholders on the benefits that basic environmental factors, such as light and air, have on people's well-being and performance, and how these elements contribute to a holistic, sustainable, and cost-effective building concept that will increase asset value and support ongoing business success in the long term.

[1]Hunstone, K., Mesari, A., and Pinchera, E. (2018). Healthy Placemaking. Design Council and
Social Change UK. Retrieved from
https://www.designcouncil.org.uk/resources/report/healthyplacemaking-Report



This section discusses innovative methods to bring natural light and air into buildings.



Strategies needed early in design stages

- Bringing natural light and air into building must be priority from beginning
  - Not features to add on as budget allows
  - Must be fundamental to entire design program

Bringing natural light and air into a building must be a priority from the earliest design stages. These are not features added late in the game if the budget allows. Rather, these strategies and factors are fundamental to the entire design program.

There are many ways to bring natural light and air into a building. Here are some of the most innovative and effective methods.

Two-panel translucent wall systems have become the benchmark for what's possible when imagination meets innovation, enabling architects to achieve the highest levels of building performance without compromising on the aesthetic qualities of their designs. These may be the most versatile daylighting system on the market, which can be the showcase feature of the design rather than just a utility product.

Essential to this system are the concealed aluminum support members between the panels that create an efficient and effective unitized system, allowing for a continuous, flush, and clean aesthetic similar to channel glass but with less weight and lower costs.

Benefits to this system include longer clear spans of up to 12 feet (depending on loading conditions), which minimizes costly support structures. The unitized design enables fast and easy installation. In this system, panels are preassembled at the factory, which maintains superior quality control. The building owner can count on a durable assembly as the system creates superior protection against water and air infiltration.

Translucent skylights

- Two-panel translucent skylights offer enhanced thermal performance
- Even distribution of glare-free, diffused natural daylight
- Shapes include:
  - Vaults
  - Ridges
  - Single slopes
  - Pyramids
  - Polygons
  - Domes
  - Completely custom designs

Forward-thinking two-panel translucent skylight systems enable architects, designers, and specifiers to achieve the highest levels of building performance while enhancing the environments where occupants will work, live, and play for decades to come. These skylights not only offer superior thermal performance but also provide an even distribution of glare-free, diffused natural daylight.

Two-panel translucent skylights generally are available in a variety of options, ranging in scale from small and simple to monumental and complex. These skylights are available in a variety of standard shapes, including:

Vaults
Ridges
Single slopes
Pyramids
Polygons
Domes

The systems also allow for totally custom designs.

Translucent canopies and walkways

- Canopies can create a more vibrant walkway
- Innovative clear span designs eliminate need for cross bracing
- Opens up space below to create more comfortable and pleasant environment
- Creates shelter
- Low slope polycarbonate provides economical alternative to glass

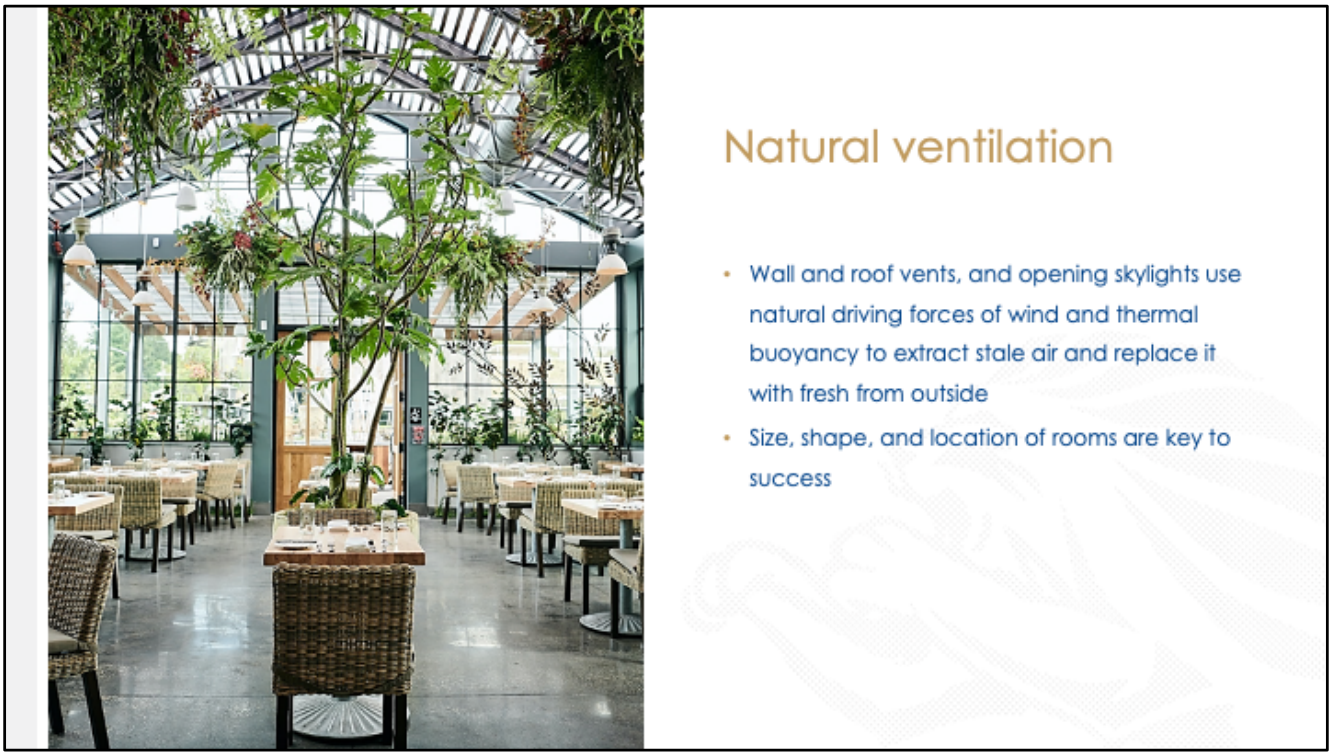
Translucent canopies and walkways are a stylish method of allowing natural light for passersby. Innovative clear span designs eliminate the need for cross-bracing, which opens up the space below the canopy structure to create a more comfortable and pleasant environment for pedestrians. These canopies not only provide shelter but also allow diffuse natural light to pass through, resulting in a more vibrant walkway. Low slope canopies made of translucent polycarbonate can provide an economical alternative to glass canopies. Glass systems are often cost prohibitive and require a more complicated installation. The simplicity of a polycarbonate system and the lightweight nature of the materials enable the system to be installed quickly and with ease. The glazing material is inherently flexible and will not shatter upon high impact. The extreme durability of light glazing panel helps to ensure the longevity of the system, curbing future costs.

Dynamic shading is a cutting-edge system used in skylight and wall applications to optimize daylight levels and improve energy efficiency. The key element of the design is a series of blades that are inserted into the two-panel glazing system and act as internal louvers with the freedom to rotate a full 360 degrees. The louvers adapt based on sensor data and user settings to effectively regulate and optimize light levels throughout the day, while simultaneously reducing heat gain and eliminating glare. The system's ability to control light transmission levels results in lower peak load demands and significantly improves a building's energy efficiency, leading to predictable energy consumption and associated cost savings.

Such a system can be zoned, enabling larger aperture sizes that can be scaled down during peak daylight hours. A system like this can adapt to accommodate multiple daylighting scenarios, and harvests both direct and indirect light to ensure a comfortable and well-lit environment throughout the day and year. For locations where a dark sky is desired or regulated, dynamic daylighting systems can significantly reduce light pollution from interior lighting at night.

Spaces with dynamic shading can be used for a variety of different functions. While a company conference room or open space may require a lot of natural light for day to day work, the natural light may need to be dimmed to show video presentations or conduct Zoom video conferences. The system can be automated or operated manually. The process of completely opening or closing the system's internal louvers

can be done in less than a minute.



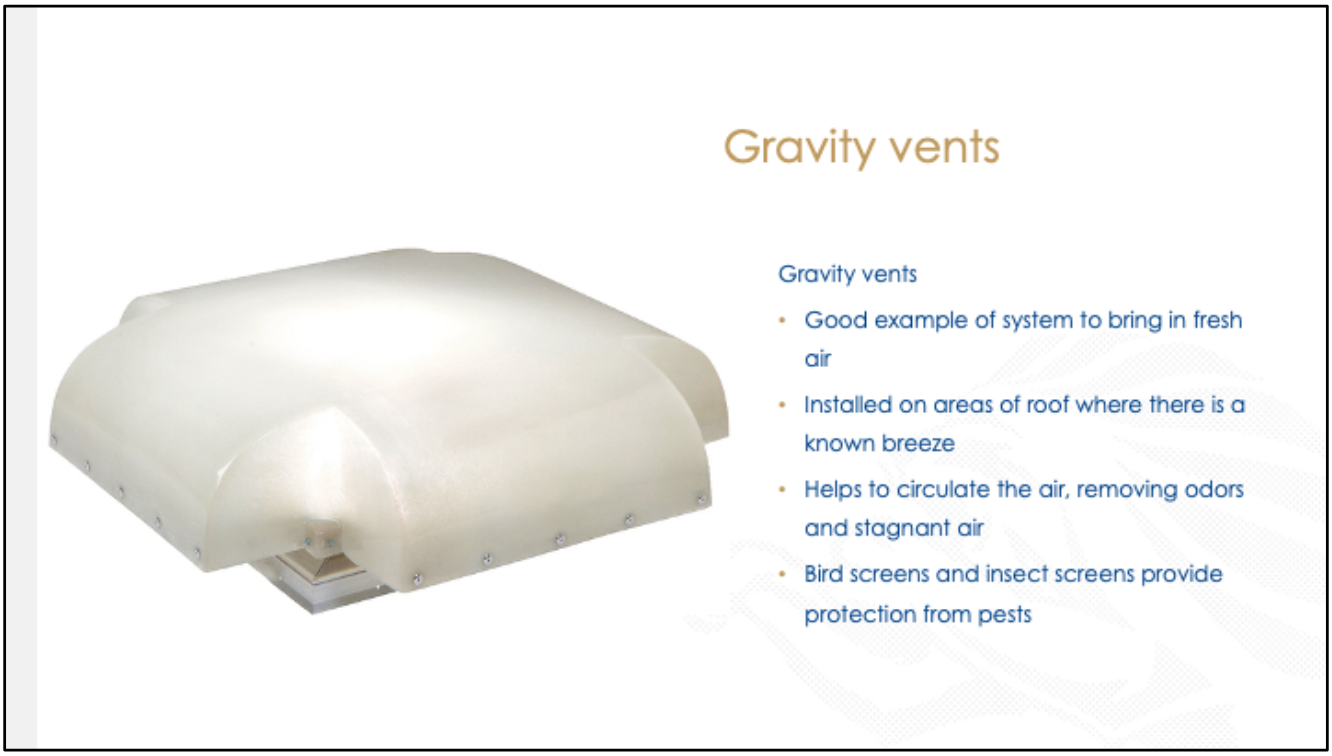
Natural ventilation systems, such as wall and roof vents or opening skylights, use the natural driving forces of wind and thermal buoyancy to extract stale air and replace it with fresh air from outside. This oxygenates the room, dilutes and disperses pollutants, reduces odors and humidity, and can help to regulate internal temperatures.

Natural air can be provided through cross or stack ventilation, and both should be integrated where possible. This means designing buildings to be dual aspect, or to have a connection with the sky. Various airflow modeling software platforms can help to determine the best ventilation types or products for a particular project. A system manufacturer's technical design team can often conduct this modeling.

The shape, size, and location of rooms are key to how successfully they can be naturally ventilated. In principle, narrower rooms are easier to ventilate (and easier to introduce daylight), and they often have more external aspects to bring in fresh air. Higher ceilings can also help to improve air quality because there is more space for air particles to circulate. Higher ceilings also bring a greater sense of psychological freedom.

Of course, the effectiveness of natural ventilation systems is reliant on the outdoor air quality being higher than the indoor air. If the outdoor air pollution levels exceed local guidance, mechanical solutions with air filtration will need to be employed to

reduce the concentration of particulate matter in indoor air. Undertaking an assessment of the potential external and internal sources of pollution at the design stage can help to determine what method is appropriate.



Gravity vents are a good example of a system to bring in fresh air, greatly improving the health, mood, and productivity of building occupants. Gravity vents are installed on areas of the roof where there is a known breeze. This natural ventilation can enter the building and help to reduce odors, eliminate stagnant air, and provide cleaner oxygen to breathe improving the lives of the occupants inside the building. Bird screens and optional insect screens can be installed for protection from pests while still allowing fresh air into the building.

SECTION 4

Factors to Consider for Incorporating Natural Light and Air

Daylighting Strategies

- Daylight design must start at the beginning of the design
  - Look at the sun patterns on the site
  - Consider building orientation
  - Consider shade and shadows from adjacent buildings and areas
  - Consider building massing compared to available sunshine
- Space planning
  - Different spaces require different lighting levels
  - Arrange spaces to benefit from daylight
  - Allow services to be internal
  - Allow public spaces and workspaces to benefit from daylight from exterior walls
  - Locate skylights for interior spaces

Daylight design must be considered from the very beginning. The site, adjacent structures, orientation, and building massing will all have an impact. In the northern hemisphere:

Northern exposure is great to introduce diffused light while mitigating heat gain, without requiring significant shading.

Southern exposure is also good for introducing diffused light as the sun angle is high and easily shaded against direct penetration.

Eastern and western exposure can be difficult. At some time during the day, these will receive low-angle direct sunlight that will need to be mitigated.

For space planning, daylight levels should be based on the task (office vs lobby vs manufacturing vs conference room).

If possible, arrange spaces based on the type of light and views you want.

Hide service spaces (restrooms, closets, server rooms)

Put offices, lobbies, or any high use areas along the exterior to bask in sunlight

Another common strategy is to layer the fenestration to do different things in a facade.

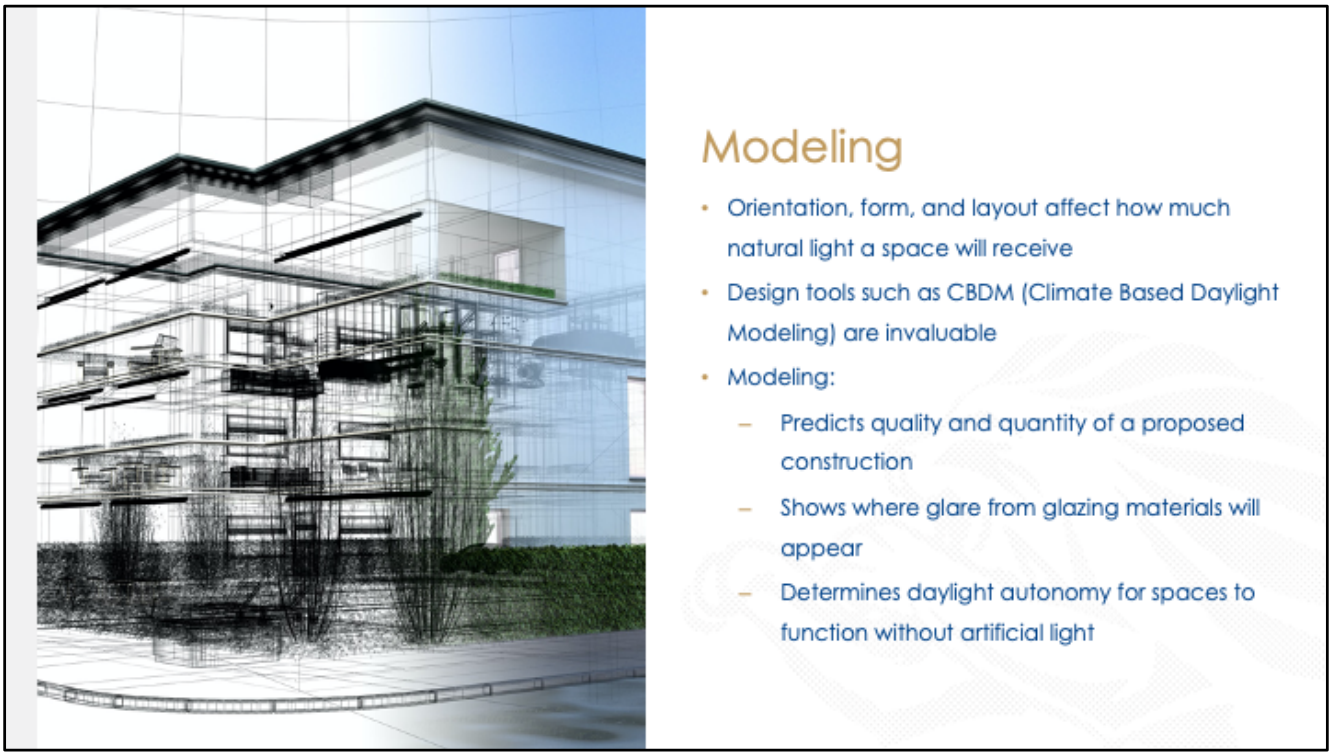
This strategy utilizes the different benefits of transparent and translucent systems broken down into “daylight” and “view” zones.

Down below, (blue arrows) vision glass with a large exterior canopy allows for views to the outside while minimizing the associated glare/heat gain.

Up top, (orange arrows) a translucent glazing system performs better thermally, but is also introducing more diffused and pleasant light deep into the space. All without any additional shading devices.

Be sure to analyze your layouts to ensure appropriate light/glare levels throughout the year.

Note that layering can increase costs if additional exterior elements are used for transparent areas.



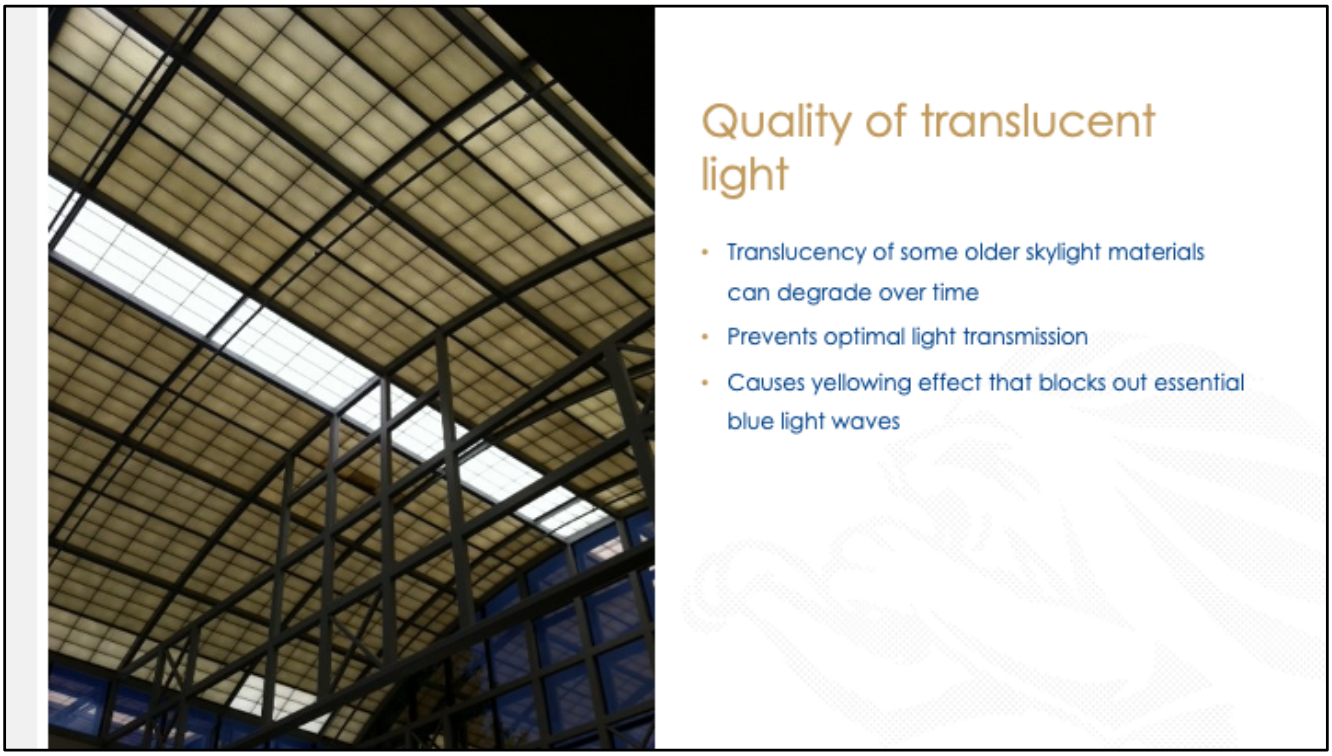
Orientation, form, and layout affect how much natural light a space will receive at any given time of the day. Therefore, daylight should be considered from the outset of a design proposal. Design tools such as Climate Based Daylight Modeling (CBDM) are invaluable for effective daylighting strategies. This method predicts the quality and quantity of daylight a proposed construction will receive in its exact geographical location, using realistic sun and sky conditions drawn from standardized climate data.

Modeling provides foot-candle levels at various heights and surfaces in a space. These include:

Glare analysis—Can show an architect where glare from certain glazing materials might appear in a design.
Daylight autonomy—Defined as a specific portion of the interior spaces being able to function without the need for electric lights for a minimum number of hours each year. This type of modeling can help earn LEED credits.

Weather files from the project location are used to provide accurate lighting analysis. A building in the Southern United States will have very different daylighting needs and requirements than a building in the Pacific Northwest. This can impact the amount of daylighting and the materials used in the design of a space. Considerations should be taken to account for thermal performance as well as light.

If unmanaged, direct sunlight can cause a disruptive or disabling glare, or a build-up of heat in the space below. As well as being uncomfortable for occupants, these issues can cause health problems such as eyestrain and exhaustion. Both can be difficult and costly to rectify retrospectively; therefore, the type of products used to introduce daylight into a space, how they are positioned, and how the light is transmitted and diffused, all play a part in how effective a daylighting strategy is. Climate-controlled glazing which can filter out ultraviolet (UV) and infra-red (IR) rays, or uses nano-prismatic technology to diffuse light beams and create a soft, even light can provide simple solutions to these issues.



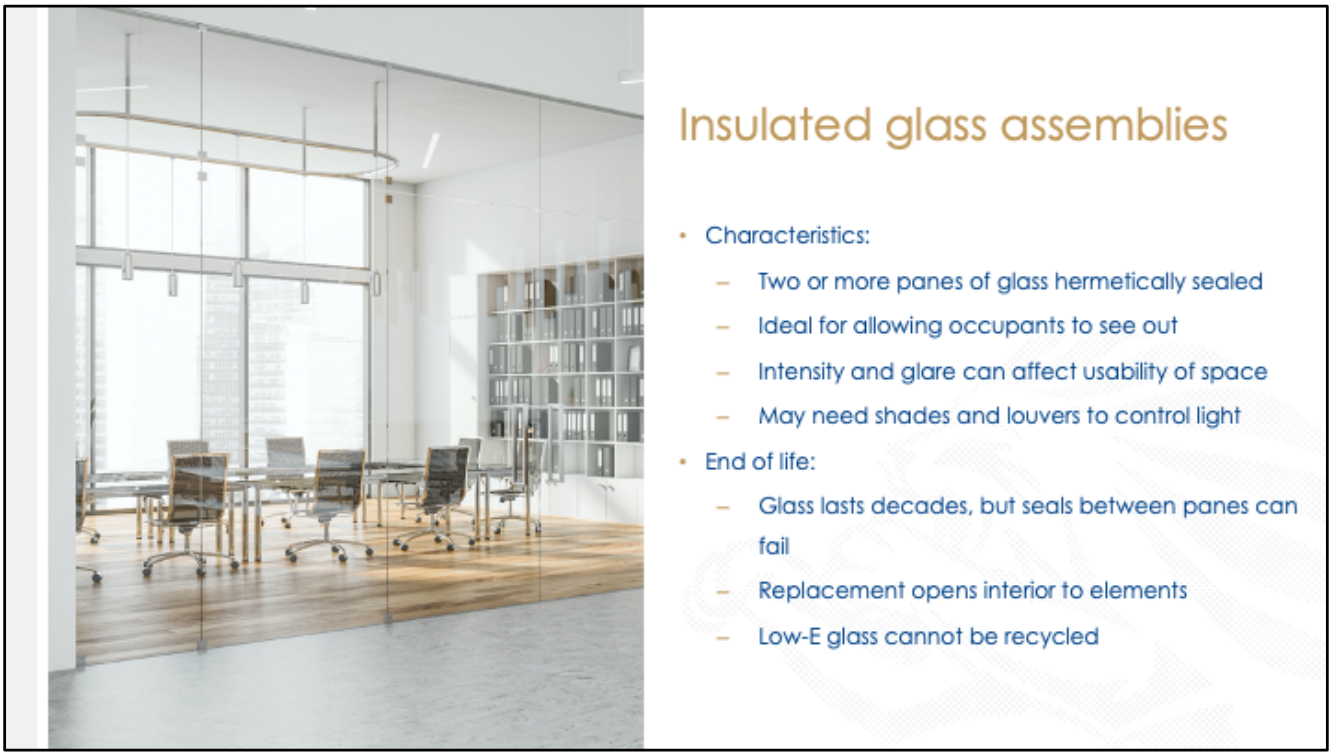
The translucency of some older skylight materials can degrade over time, either preventing optimal light transmission or causing a yellowing effect which blocks out essential blue light waves. This can have a negative effect on the way that colors are perceived and how people feel in a space. As we mentioned earlier, there are more blue light waves in the morning, making us feel active, alert and ready for the day, tiring as it becomes darker and the light moves towards the yellow and red end of the spectrum. It is therefore important not to filter out the blue light in places of work, as this can disrupt the circadian rhythm and reduce productivity.

Staff performance can fall by 6 percent when workspaces are too hot and 4 percent if too cold, so it is important to maintain a comfortable and stable ambient temperature. Once the average optimum temperature has been calculated, it can be kept as close to this level as possible with effective air circulation and night purge strategies, where air is introduced through windows and vents during the night to cool the internal spaces.

The financial success of natural daylighting and ventilation strategies depends significantly on the use of high-quality materials. In the next section we'll take a deep dive into the best glazing materials for the vast range of daylighting designs.

This section discusses materials for daylighting systems.

The most common choices available for daylighting strategies include: insulated glass assemblies, fiberglass reinforced polymer (FRP), and various types of polycarbonate glazing, including commodity polycarbonate and unitized polycarbonate. We'll look at the characteristics and life cycles and end-of-life issues for each.



Characteristics

Insulated glass assemblies can be described as two or more panes of glass hermetically sealed with argon/other gas/vacuum in between, and usually supported by aluminum/steel structure.

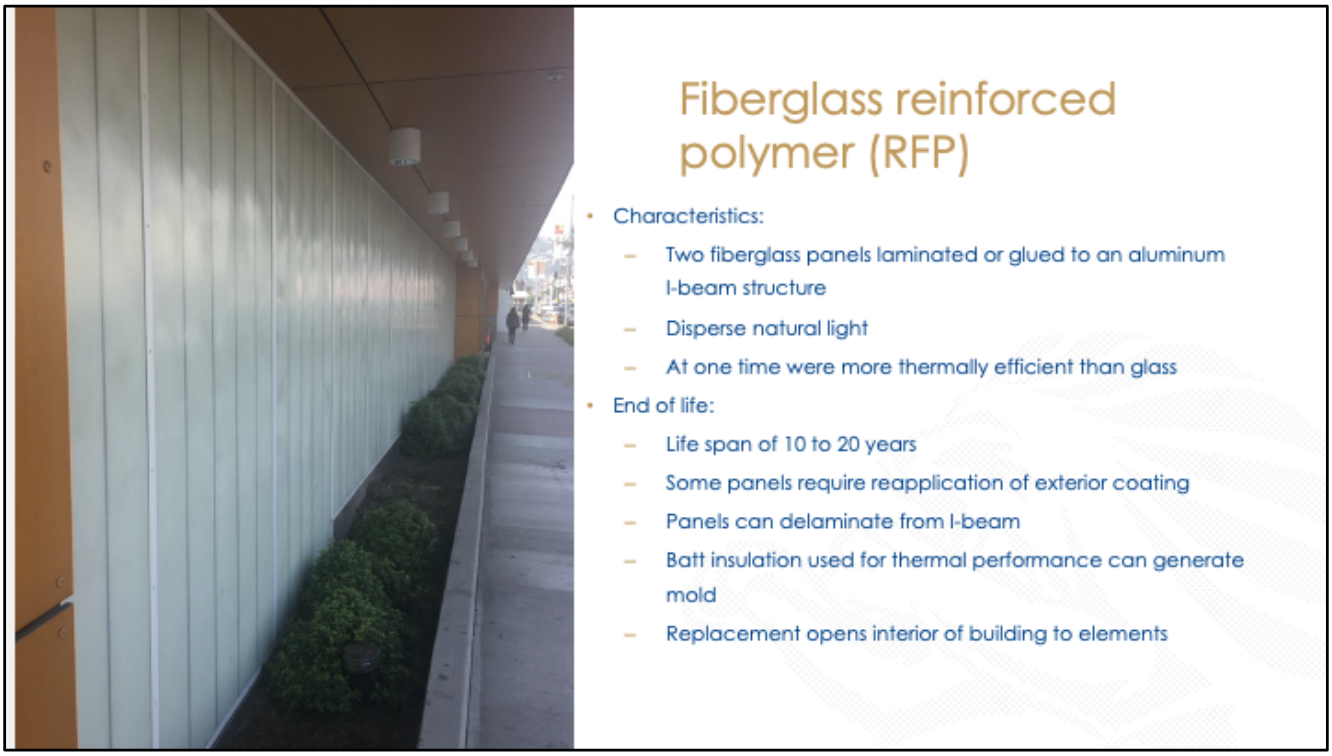
Glass is ideal for allowing occupants to view what's around them. However, intensity and glare can affect the usability of the space. Additional systems—such as shades and louvers—may be needed to effectively control light, which increases overall design cost. Even when those are implemented, there may be times of day that the space is unusable.

Thermal performance can be lacking, though performances are constantly improving. At this point, in order to get a high thermal performance, there will be an extra cost.

End of service life/life cycle

In terms of life cycle, modern glass systems are known to last decades. What fails, however, is the seal between the panes of glass. When the seals fail, thermal performance is lost. Envelope integrity may also be lost, which allows for water and air infiltration.

To replace the assembly, the structure or framing can potentially remain, but both the internal and external glass panes must be replaced. This process opens the interior spaces to the elements and this can have a huge monetary impact on the building's owner. At the end of its service life, some glass can be recycled, but not if it contains Low-E coatings, which are increasingly popular.



Characteristics

Fiberglass-reinforced polymer can be described as two fiberglass panels laminated or glued to an aluminum I-beam structure.

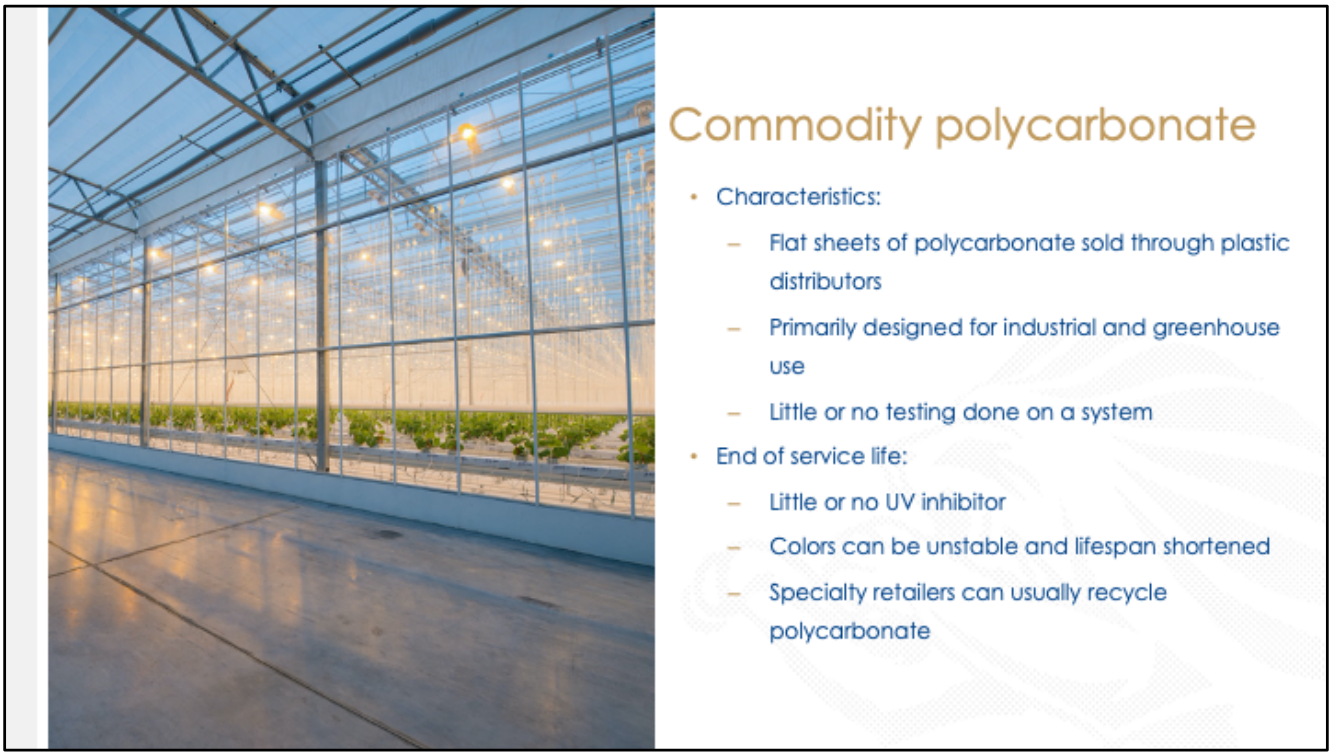
With the light control and thermal performance issues of older glass systems in mind, fiberglass systems were introduced to the market in the 1950s. They eliminate outside views, but they control intensity by dispersing light, which allows for more usable natural light. At one time, they moderately improved upon the thermal performance of glass; however, modern insulated glass systems have caught up.

End of service life/life cycle

The major challenge with fiberglass is its life cycle. With reliance on adhesives and sealants, the multi-decade life span of glass is cut to 10 to 15 years, and possibly up to 20 years.

Over that lifetime, some systems require a reapplication of the exterior coating in order to prevent “fiber blooming.” That means disintegration of the panel material. As the product ages, the fiberglass delaminates from the I-beam core, allowing water and dust to accumulate internally. As with insulated glass with failing seals, thermal performance and envelope integrity begin to fail. Uneven discoloration can occur. The

batt insulation these systems rely on to meet thermal performance can stimulate the growth of mold and can create unpleasant odors. In terms of replacement, there are the same issues as glass. The entire panel, inside and out, must be replaced, opening up the building envelope to the elements, and likely necessitating the business inside the structure to pause operation.



Characteristics

Polycarbonate glazing is a third option for daylighting. Wide cell commodity polycarbonate is sometimes considered, but it may not be the most desirable for daylighting in many buildings. The flat sheets of polycarbonate are sold through plastic distributors and are primarily designed for industrial and greenhouse use. Because polycarbonate sellers often buy from multiple distributers, there is often little to no testing done on a system. The wide-cell structure reduces structural loading capacity. There are no structural systems designed by extruders.

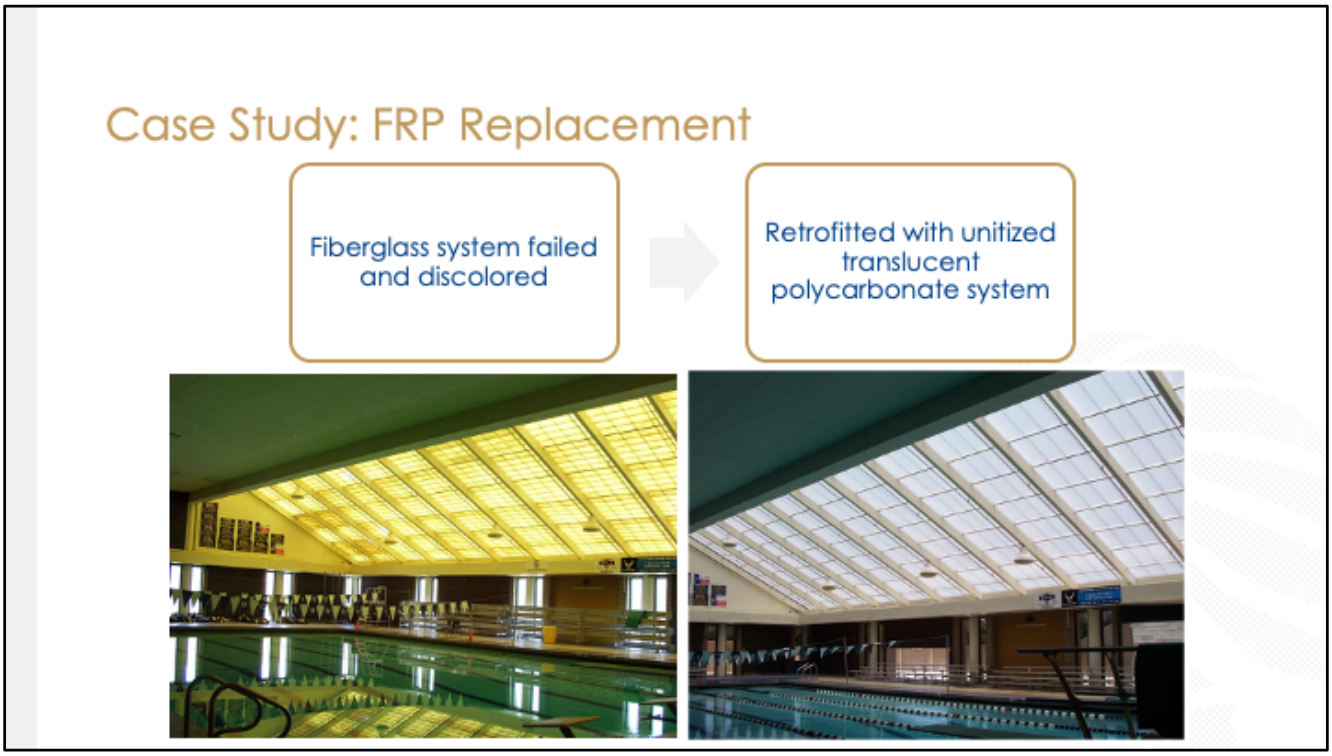
End of service life/life cycle

Commodity polycarbonate typically contains little or no UV inhibitor. That means the color can be unstable, and the lifespan shortened. In architectural use, the third-party warranties may be insufficient. Specialty recyclers can usually recycle polycarbonate.

Characteristics

Perhaps the best choice for daylighting in buildings is unitized translucent polycarbonate panels. They are made of two architectural-grade polycarbonate panels mechanically assembled with an internal back-to-back standing seam aluminum frame. This creates large air cavities that can be used for augmentations.

Polycarbonate has been developed specifically for its high-quality optics. Most modern eyeglass lenses, car headlight housings, and bulletproof glass are all made of different grades of polycarbonate. Translucent polycarbonate eliminates glare while maximizing useful natural light. All this occurs without additional shading systems.

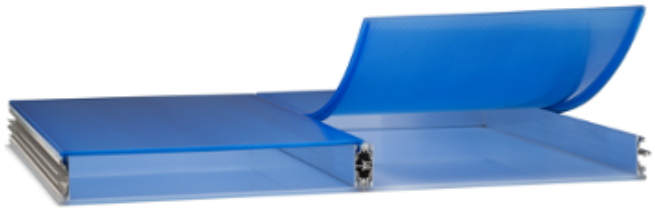


In this indoor pool enclosure, the fiberglass system has failed and discolored from white to yellow. The yellowing of the panels prevents beneficial blue light from entering the space.

After the retrofit with unitized translucent polycarbonate, which was done over spring break, the space looks and feels cleaner. In fact, students and faculty didn't realize that the skylight had been replaced, but thought pool had been drained and painted blue.

It's important to note that all products will eventually deteriorate, but how their performance changes as they wear over time should be considered.

Recycling fiberglass materials can theoretically be done, but it can be nearly impossible to achieve. And fiberglass can only be recycled into other fiberglass products.



Unitized translucent polycarbonate

- End of life:
  - Removable skin technology
    - Exterior panel can be independently replaced
    - Building envelope remains intact
    - No costly downtime for business
  - Panels and aluminum frame 100% recyclable

Thanks to advances in translucent wall and ceiling technology, a removable skin option is now available. That means that the exterior panel can be independently replaceable while the aluminum frame and the interior panels remain untouched and continue to perform. This way, the building envelope stays sealed with no costly downtime for the building. Polycarbonate also has an endlessly renewable life cycle because the panels and aluminum frame are 100 percent recyclable.

Unitized polycarbonate product features and options include:
Long spans
Additional insulation augmentation
Sound transmission blocking augmentation
Protective inserts augmentation
Thermal performance
Curtain wall system
Nanotechnology
Specialized performance options

Let's look at each separately.

Long spans

- Some of the design options for unitized polycarbonate include panels up to 40 feet long
- May be installed with purlin supports spaced as per ASTM E 330
- Longer spans can save on support structure and additional installation costs

Some of the design options for unitized polycarbonate include panels up to 40 feet long, which may be installed with purlin supports spaced as per ASTM E 330, with a factor of safety of 1.5 for determination of allowable design load. Longer spans can save on support structure and additional installation costs.

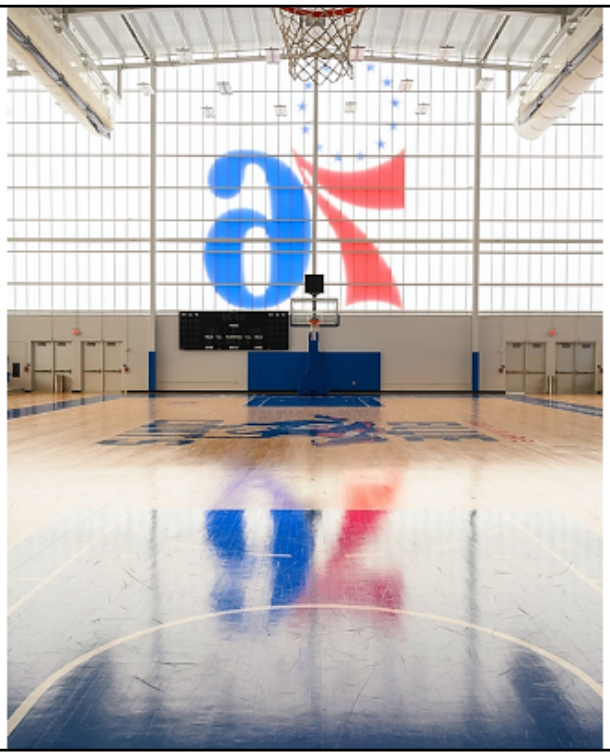
Additional insulation augmentation—Additional layers of polycarbonate/light transmitting insulation may be used. This can create maximum/minimum U-values of .23 to .07.

Additional layers of transparent polycarbonate can reduce sound transmission. This can create minimum/maximum STC (Sound Transmission Class) ratings of 26 to 43.

Protective inserts augmentation

- Inserts can be included that will pass U.S. Dept. of Defense requirements for:
  - 5-minute forced entry
  - Terrorism blast
  - 2000 foot pound of human impact

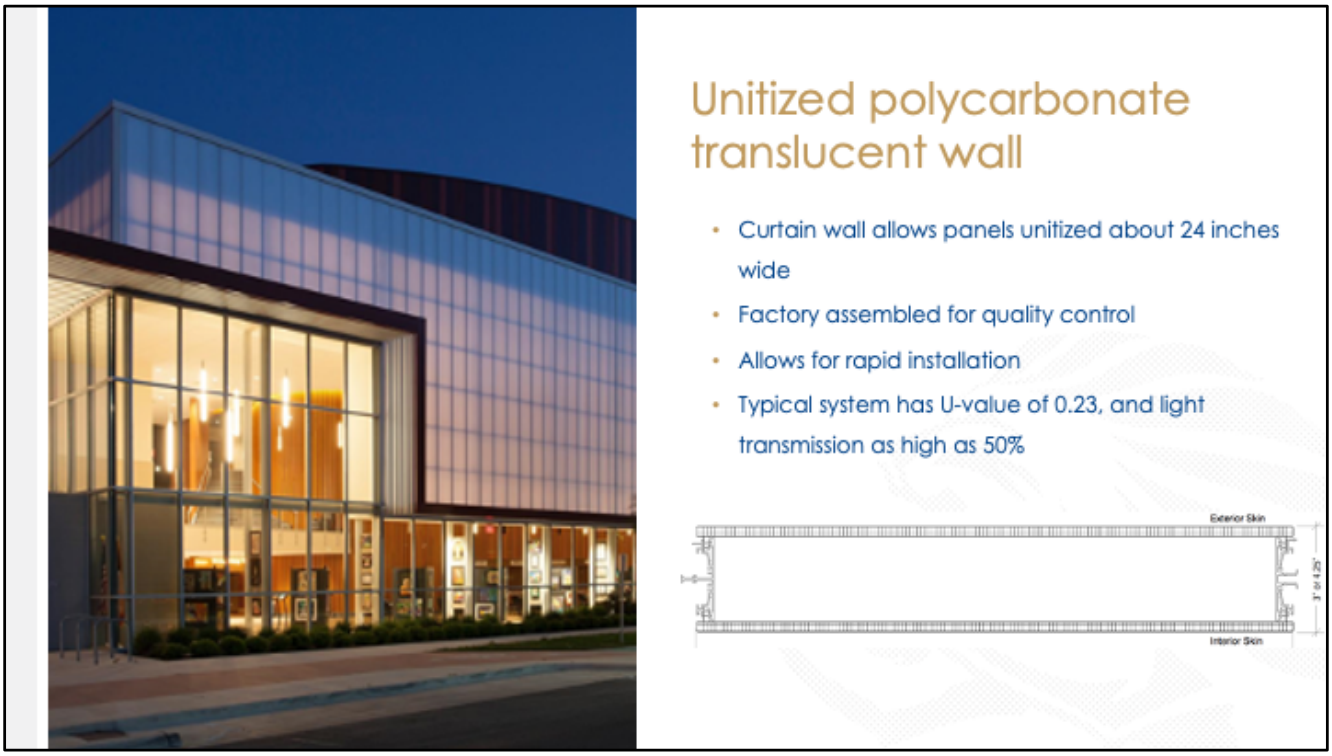
Inserts can be included that will pass U.S. Dept. of Defense requirements for five-minute forced entry, terrorism blast, and 2000 foot pound of human impact.



Thermal performance

- Double panels dramatically increase assembly's thermal performance
- Panels inherently broken with no exposed aluminum bridging at panel joints
- Non-sealed system allows panels to breathe

Double panels dramatically increase the assembly's thermal performance. It's important to note that the panels are inherently thermally broken with no exposed aluminum bridging at panel joints. The non-sealed system allows panels to breathe while maintaining air and water infiltration requirements.



A curtain wall system made with unitized polycarbonate allows for panels unitized about 24 inches wide that are all factory assembled for the highest quality control. This allows for rapid installation that does not hold up the timeline or other trades. A typical system such as this has a U-Value of 0.23, with a light transmission as high as 50 percent.

An advanced option uses nanotechnology to maximize the characteristics of the polycarbonate. The cell size of .18 inch provides improved impact/weathering resistance and light diffusion. The assembly is dry glazed with no caulks or sealants, which means that systems avoid long-term degradation of air and water seals.

The scalability of the internal cavity resulting from a system's unique two-panel design offers versatility. Such a system can be modified with a range of inserts to customize the system's performance to meet the needs of any project, including:
High-Velocity Hurricane Zone (HVHZ)
Class-A & Class-B Roof Construction
Forced Entry Resistance

This section discusses building standards and codes applicable to designing for light and air.

Building Standards and Codes

LEED® (Leadership in Energy and Environmental Design)

- Categories where translucent wall systems and skylights can earn points:
- Sustainable Sites
  - Heat Island Reduction—Non-roof and roof (2 points)
  - Light Pollution Reduction (1 point)
- Energy & Atmosphere
  - Minimum Energy Performance (1 point)
  - Optimize Energy Performance (Up to 20 points)
- Materials & Resources
  - Building Life-Cycle Impact Reduction (Maintain Existing Walls, Floors, & Roof) (1-3 points)
  - Building Product Disclosure and Optimization – Environmental Product Declarations (1-2 points)
- Indoor Environmental Quality
  - Enhanced Indoor Air Quality Strategies (Increased Ventilation) (1 point)
  - Low-Emitting Materials (Adhesives & Sealants) (1 point)
  - Interior Lighting (1 point)
  - Control and Design (1 point)
  - Daylight (1-3 points)
  - Quality Views (1 point)
  - Acoustic Performance (1 point)
- Innovation (1-5 points)

LEED® (Leadership in Energy and Environmental Design) is a voluntary program of the U.S. Green Building Council and has gone through several evolutions. The latest version is LEED v4.1. Fenestration and daylighting have an impact on several LEED categories. Good daylighting design is one of the easiest ways to earn LEED points. Here are categories where translucent wall systems and skylights can earn points.

Sustainable Sites

Heat Island Reduction—Non-roof and roof (2 points)
Light Pollution Reduction (1 point)

Energy & Atmosphere

Minimum Energy Performance (1 point)
Optimize Energy Performance (Up to 20 points)

Materials & Resources

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Indoor Environmental Quality

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- Interior Lighting (1 point)
- Control and Design (1 point)
- Daylight (1-3 points)
- Quality Views (1 point)
- Acoustic Performance (1 point)

Innovation (1-5 points)

The WELL Building Standard is another voluntary rating system for buildings that is gaining in popularity. It is similar to LEED but with much more emphasis and focus on wellness and indoor environmental quality.

WELL has a specific criterion for daylighting specifically related to light color. It recognizes that the blue portion of the visible light spectrum is responsible for triggering our natural circadian rhythms that regulate when we feel sleepy or alert. They have identified this as a health issue when our circadian rhythms are disrupted causing ill effects. Therefore, WELL v1 provides illumination guidelines related to providing the right amount of blue spectral light at the proper times as found in daylight, rather than the warmer or non-blue lighting of most artificial lighting. The impact is directly related to proximity to windows or other daylighting and healthier occupants who are more productive.

BREEAM

Created in the 1990s, the Building Research Establishment's Environmental Assessment Method (BREEAM) was the world's first sustainability rating system for the built environment. It measures sustainable value in a series of key categories, awarding points that contribute to the overall BREEAM rating. Applicable under both new construction and refurbishment schemes, the health and well-being category aims to enhance quality of life by recognizing the key design aspects that must come

together to create a healthy and safe internal environment for occupants. These include addressing issues such as Visual Comfort and Indoor Air Quality. For more information, visit: https://www.breeam.com

Building Standards and Codes

- International Building Code (IBC) fenestration integrity
  - IBC is most concerned with the integrity or inherent strength of the products used in a building envelope
  - ASTM E-330 is the standard test for all fenestration used for daylighting
- IBC Fire Codes
  - Roof fenestration also needs to be capable of Class A/B or C roof construction
- Occupational Safety and Health Administration (OSHA) Life Safety
  - These are the tests that OSHA requires for ensuring the assembly is safe:
    - Sand Bag test—Involves impact loading of the system with a 500-pount blunt object as per ASTM E 695.
    - Walk Through test—The daylighting system is exposed to a 300-pound point load as per Standard 29 CFR 1910.23 (e) (8).
    - Must support at least twice the weight of an employee and materials.

The IBC (International Building Code) is most concerned with the integrity or inherent strength of the products used in a building envelope. ASTM E-330 is the standard test for all fenestration used for daylighting. There is also a code requirement to limit deflection of flexible materials. Table 1604.3 requires a maximum of L/120 for deflection.

IBC fire codes

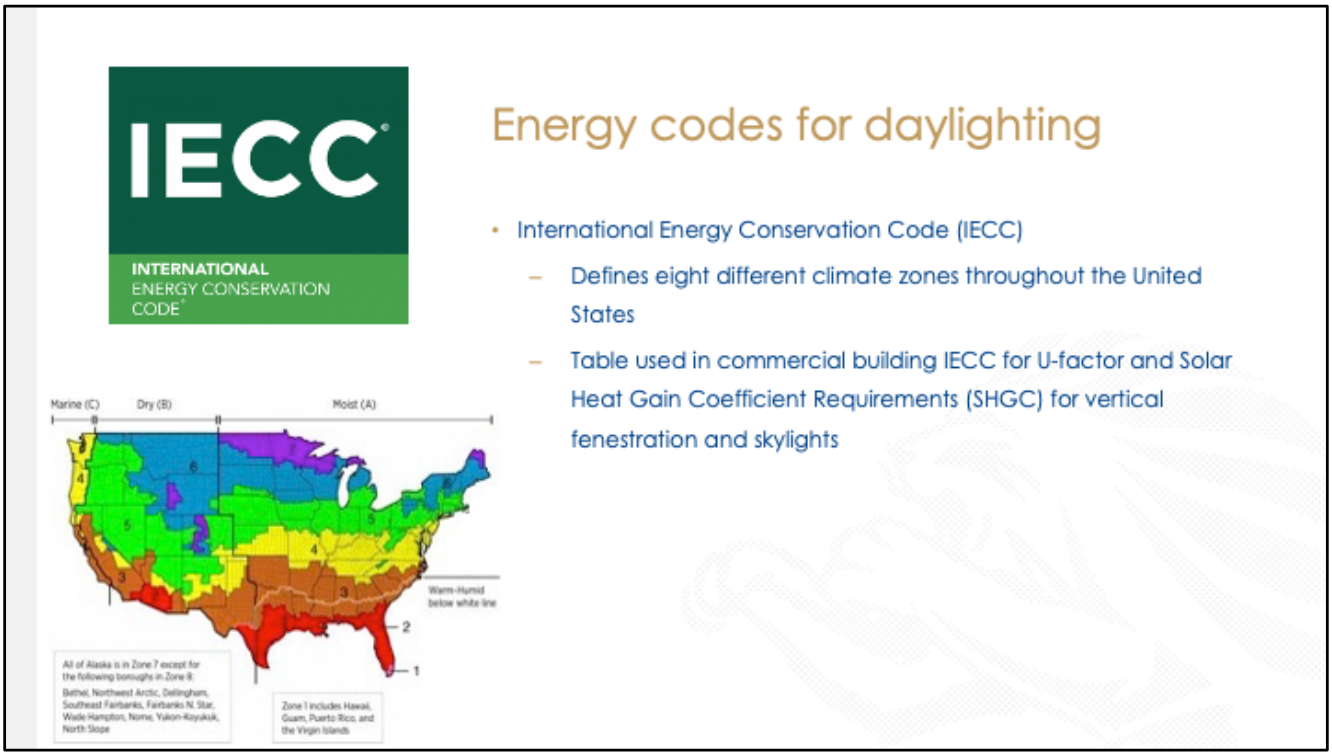
Roof fenestration also needs to be capable of Class A/B or C roof construction. Note this is different than a standard Class A for *interior flame spread*. As such, the roofing area of the system is no longer limited to the 300 square feet of skylight per the IBC, this is now the roof, in and of itself. This allows much greater flexibility. Classification is met by introducing other materials into the system; minimum classification is Class C.

Some manufacturers will indicate that the “Class A Burning Brand” test is sufficient for this type of application. You must specify “Class A Roof Construction,” which is a combination of three different tests that must be passed to achieve certification.

OSHA Life Safety

These are the tests that OSHA requires for ensuring the assembly is safe:

Sand Bag test—Involves impact loading of the system with a 500-pount blunt object as per ASTM E 695.
Walk Through test—The daylighting system is exposed to a 300-pound point load as per Standard 29 CFR 1910.23 (e) (8).
Must support at least twice the weight of an employee and materials.



International Energy Conservation Code

The International Energy Conservation Code (IECC) defines eight different climate zones throughout the United States. The thermal performance requirements under the IECC will vary based on what climate zone a particular building is located in.

This is the table that is used in the commercial building IECC for U-factor and Solar Heat Gain Coefficient Requirements (SHGC) for vertical fenestration and skylights.

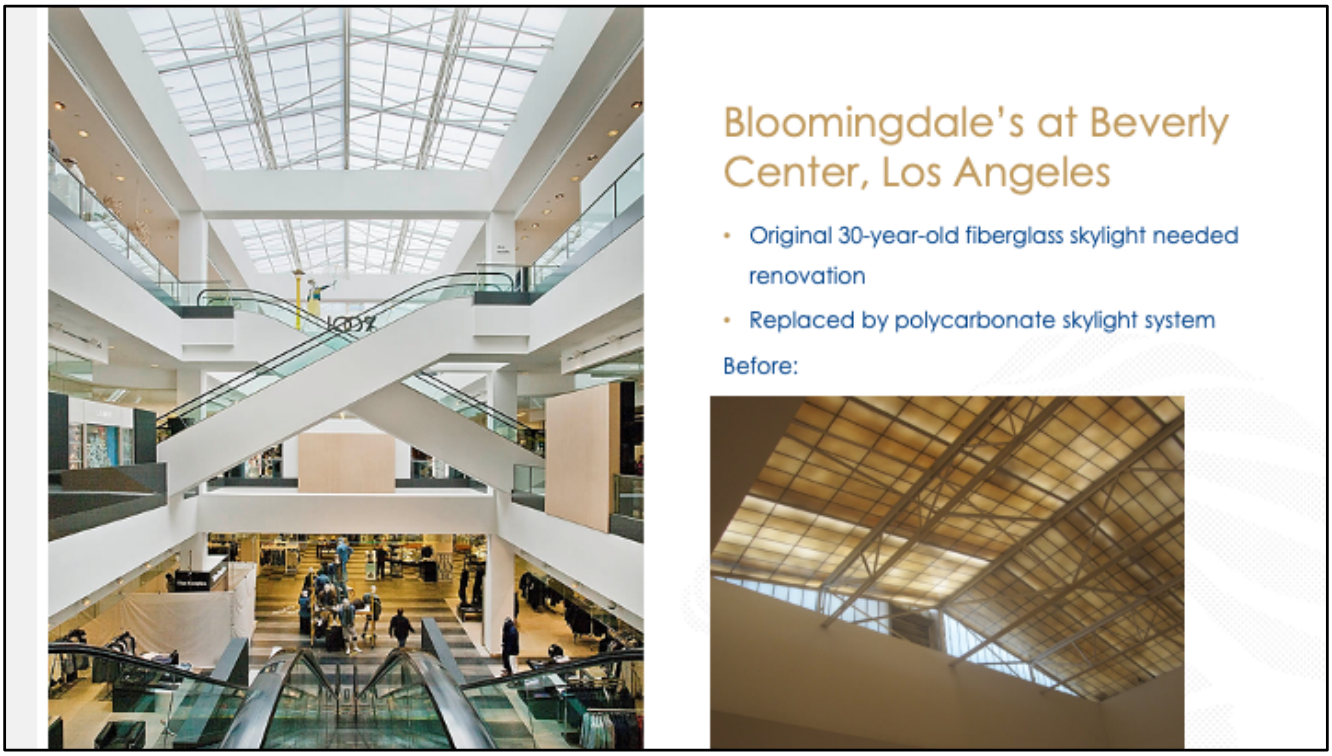
The IECC requires independent, certified testing of fenestration products. One of the most commonly recognized sources of that testing is the National Fenestration Rating Council (NFRC) using a standard known as NFRC 100. Manufacturers work through NFRC to receive independent certification of their products

The importance of an NFRC rating

When a commercial fenestration product is tested under NFRC 100, it considers each of the specific components in that product—framing, glazing, spacers, and so on. It then determines an overall fenestration system performance based on the size and shape of that system.

In particular it uses the NFRC 100 program to certify the U-factor, SHGC, and Visible Light Transmittance of the system. These values are then compared with the minimums required under the IECC to determine code compliance. If a product is used without any certification, then the IECC will require the use of very low performance default values that make it more difficult to show compliance with the code. Products without NFRC ratings should be specified only with great caution, if at all.

This section discusses case studies for designing with light and air.



At Bloomingdale's at the Beverly Center fashion mall in Los Angeles, the original 30-year-old fiberglass skylight needed renovation and a polycarbonate skylight system was the solution the mall was looking for. Specified in ice white and white matte glazing, the new skylight was installed above the 41,000 square foot main floor in just seven days to meet the store's unveiling deadline. And it was done while the store was fully occupied, thanks to the system's innovative removable skin technology.

Hologic Gen-Probe

- Molecular diagnostics products and services company
- After 20 years the original skylight weathered beyond repair
- Yellowed so severely that light not able to penetrate through glazing
- Replaced with 14,385 square feet of Class B fire-rated polycarbonate skylight system

After only 20 years, the original skylight in this molecular diagnostics products and services company had weathered beyond repair and yellowed so severely that light was no longer able to penetrate through the glazing. What was once a design focal point had become an eyesore and maintenance nightmare. The failed system was replaced with 14,385 square feet of Class B fire-rated polycarbonate skylight system, which completely rejuvenated the atrium space.[1]

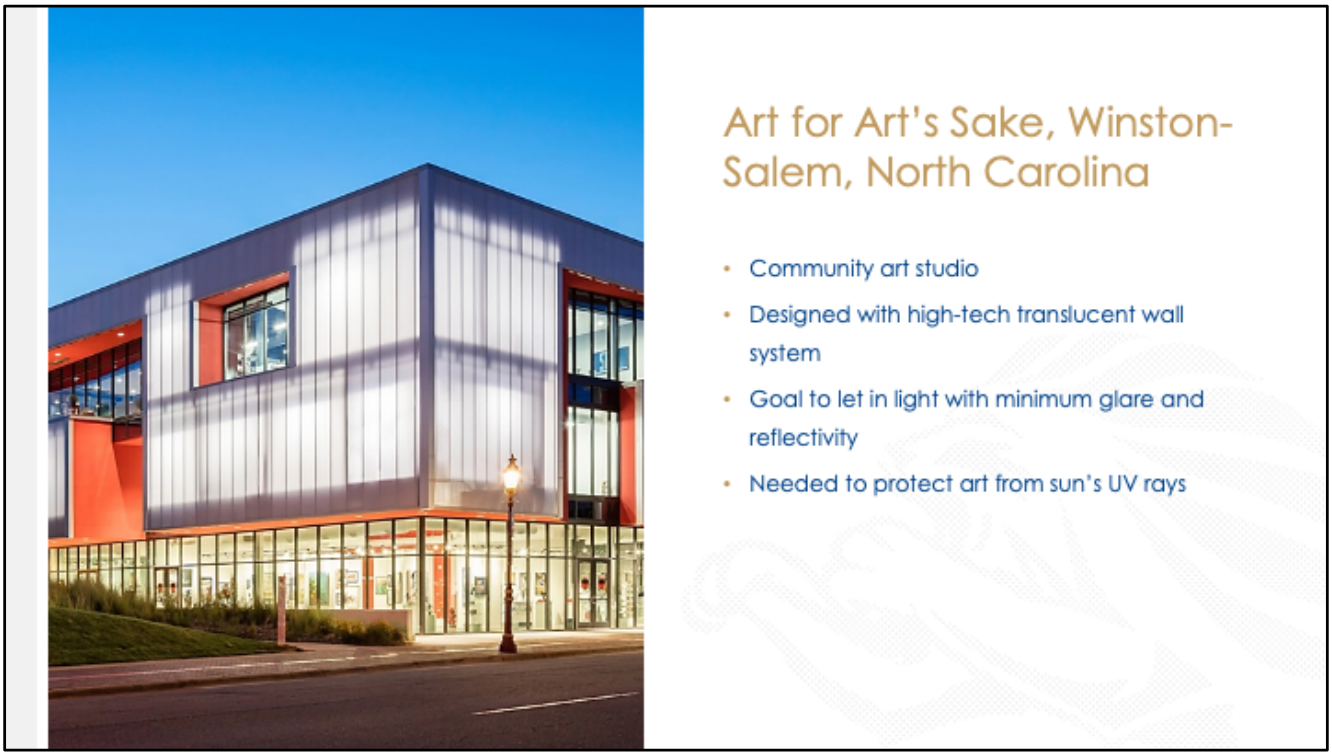
[1]https://www.kingspan.com/us/en-us/product-groups/architectural-daylighting-systems/renovations/renovation-projects

Office complex, Jacksonville, Florida

- Fiberglass entry canopy had weathered and yellowed
- Replaced with blue translucent polycarbonate glazing

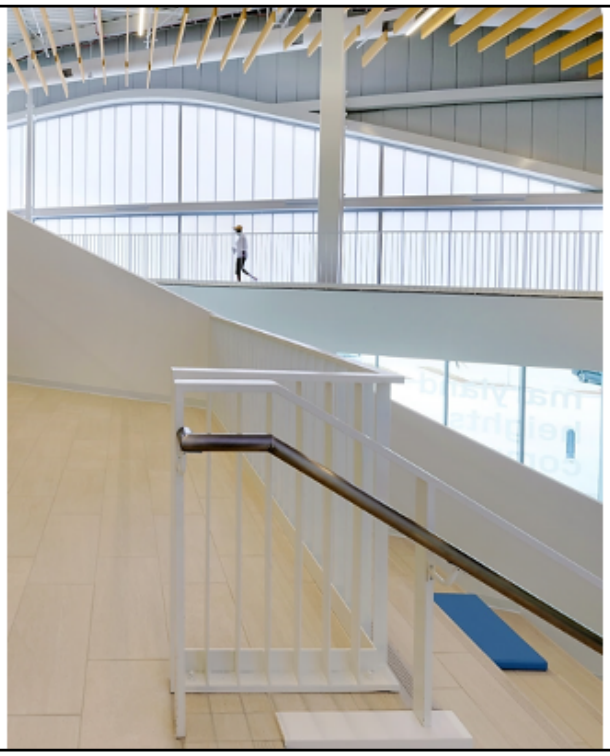
The fiberglass entrance canopy at this corporate office complex in Jacksonville, Florida had deteriorated and significantly yellowed. To solve the problem, a structural low-rise vault canopy system was designed to replace the existing fiberglass system. The existing structure remained in good condition, so it was repainted and reused. The blue translucent polycarbonate glazing provides a fresh new look and makes the entryway much more inviting.

https://www.kingspan.com/us/en-us/product-groups/architectural-daylighting-systems/renovations/renovation-projects



The Art for Art's Sake (AFAS) community art studio in North Carolina was transformed into its own work of art in May of 2017, thanks in part to a high-tech translucent wall system. The goal for this project was to create an environment that let in as much light as possible with minimal glare and reflectivity, while also protecting the art from the sun's UV rays given the light sensitivity of certain mediums.

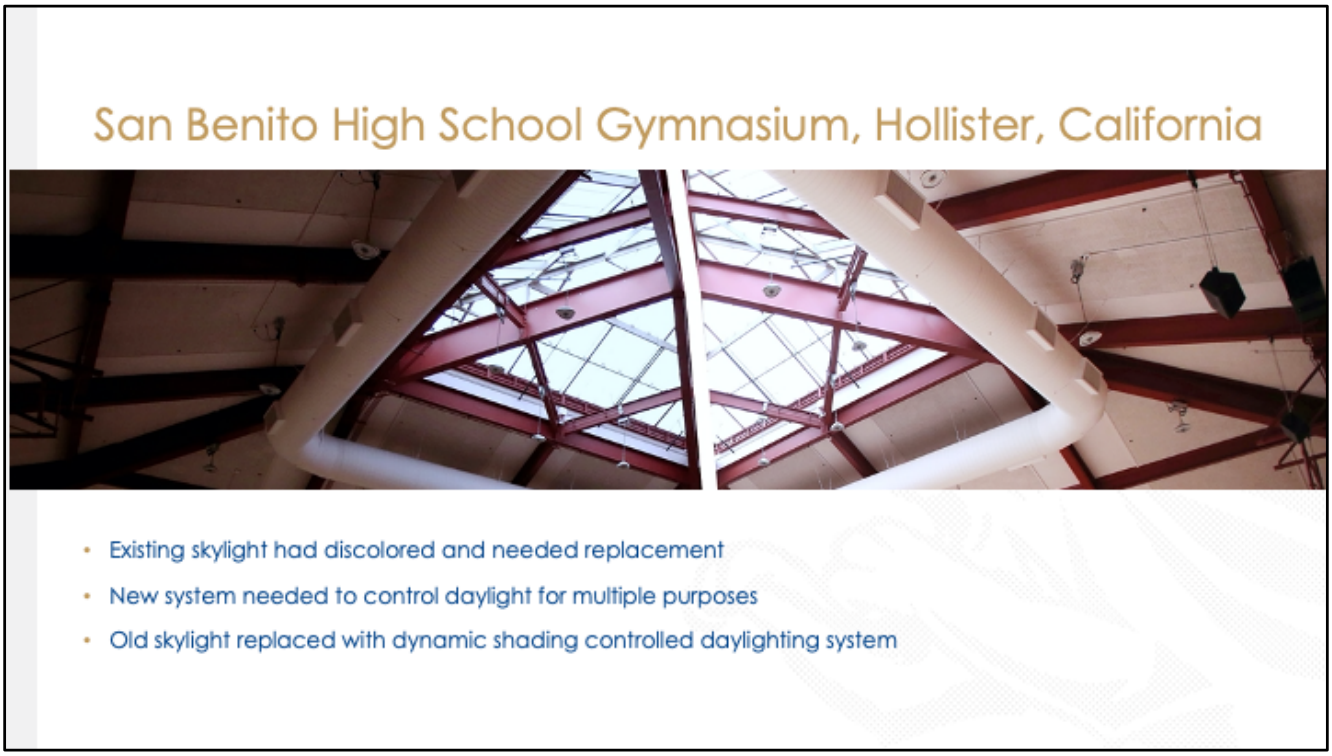
The high-tech panels of architectural grade polycarbonate were selected because of their ability to effectively block 99.9 percent of UV rays and for their ability to diffuse natural light into the space to reduce artificial lighting costs. STITCH Design Shop, the project designer, loved the space so much that they now reside in the office space the building offers. The studio has become an art feature itself for the sculpture park outside due to its unique aesthetic, and provides a new venue for the city that furthers the AFAS mission to "build, educate, and celebrate the community through art."



Maryland Heights Community Center, Maryland Heights, MO

- Translucent wall system of architectural polycarbonate solved these problems:
  - Blocked unsightly views of freeway and strip mall
  - Reduced noise from freeway
  - Met aesthetic needs of curved and tapered walls
  - Allowed in natural daylight

When the City of Maryland Heights, just outside of St. Louis, committed to replacing its original community center, the city had big aspirations for the impact it would have on the community. A variety of design goals were specified for the new center, ranging from blocking unsightly views and reducing noise to finding a translucent facade that could meet the aesthetic needs of the building's curved and tapered walls. The architect was able to meet, and go beyond, all of the design challenges with the help of a translucent wall system made of architectural polycarbonate.
The center, sandwiched between one of the area's busiest highways and a strip mall, was particularly concerned with noise levels around the facility. The specification of translucent panels was critical to blocking the noise coming from the highway. Views of the unsightly freeway was masked with 9,284 square feet of polycarbonate panels, specified in clear over white matte colors, a strategy that still allowed in natural daylight.



The existing skylight at Sen Benito High School was severely discolored and needed replacement. Because the gym is used as a multipurpose space for a variety of different functions, the new system needed to be able to control the amount of light entering the space, while keeping glare and heat gain to a minimum. The old skylight was replaced with a dynamic lighting controlled daylighting system, which features a series of internal blades that rotate to control the amount of light within the space below.

https://www.cpidaylighting.com/san-benito-high-school-gym/

By now it is clear that natural daylight and air are good for the building occupants, the businesses in the building, and the bottom line of the building owner. However, not all daylighting and natural ventilation systems are not created equal. To achieve the most successful daylighting and natural ventilation designs, it is suggested that the designer:

- Understand and use the fundamentals of daylighting in building designs.
- Incorporate appropriate strategies for building facades and for overhead daylighting solutions.
- Acknowledge code requirements and green building standards related to fenestration.
- Specify the most appropriate material to meet project needs.
- Use other projects for inspiration.

Thank You

This concludes the continuing education unit on the **The Profitability of Healthy Spaces** course.

Please take the quiz to receive your credits.

Thank you for your interest in Kingspan Light + Air.

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