High Performance Meets History

Optimizing Pittsburgh's Historic Benedum Trees Building Through Systems Integration

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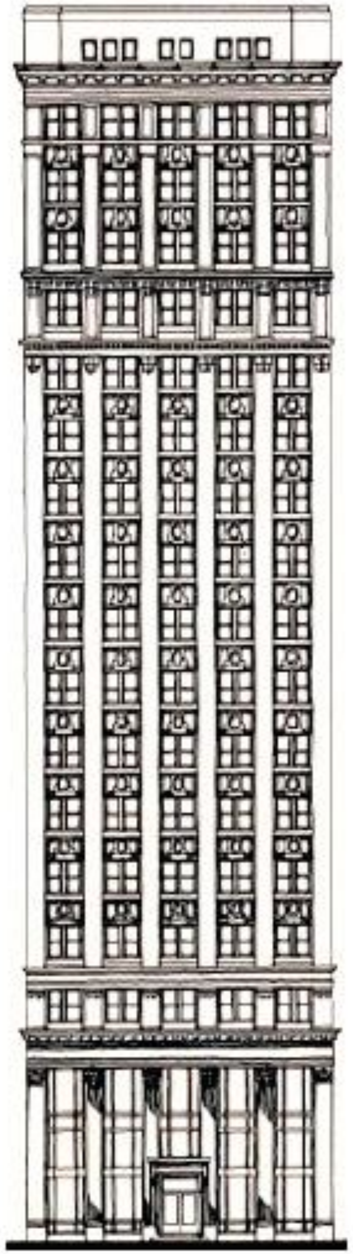
Carnegie Mellon University
School of Architecture
Professor Volker Hartkopf

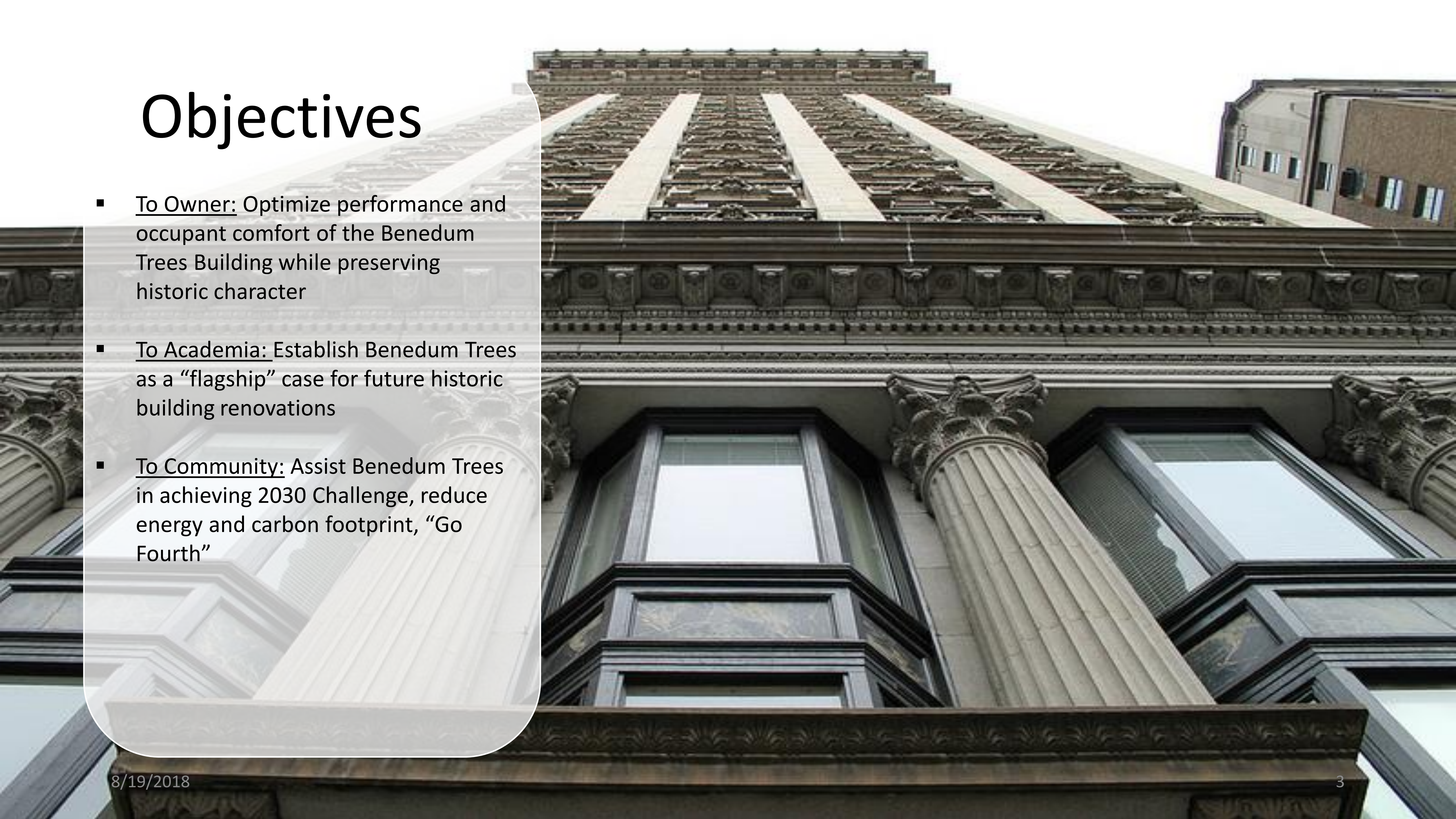
48-723: Performance of Advanced Building Systems

Carnegie Mellon University



Background

- Location: 223 Fourth Avenue, Downtown, Pittsburgh PA
- Built in 1905
- 19 stories tall
- Originally known as Machesney Building
- In 1911, became headquarters for Benedum Trees Oil Company
- Designed by: Thomas H. Scott
- Project addresses the 16th, 17th, and 18th floors of the building.

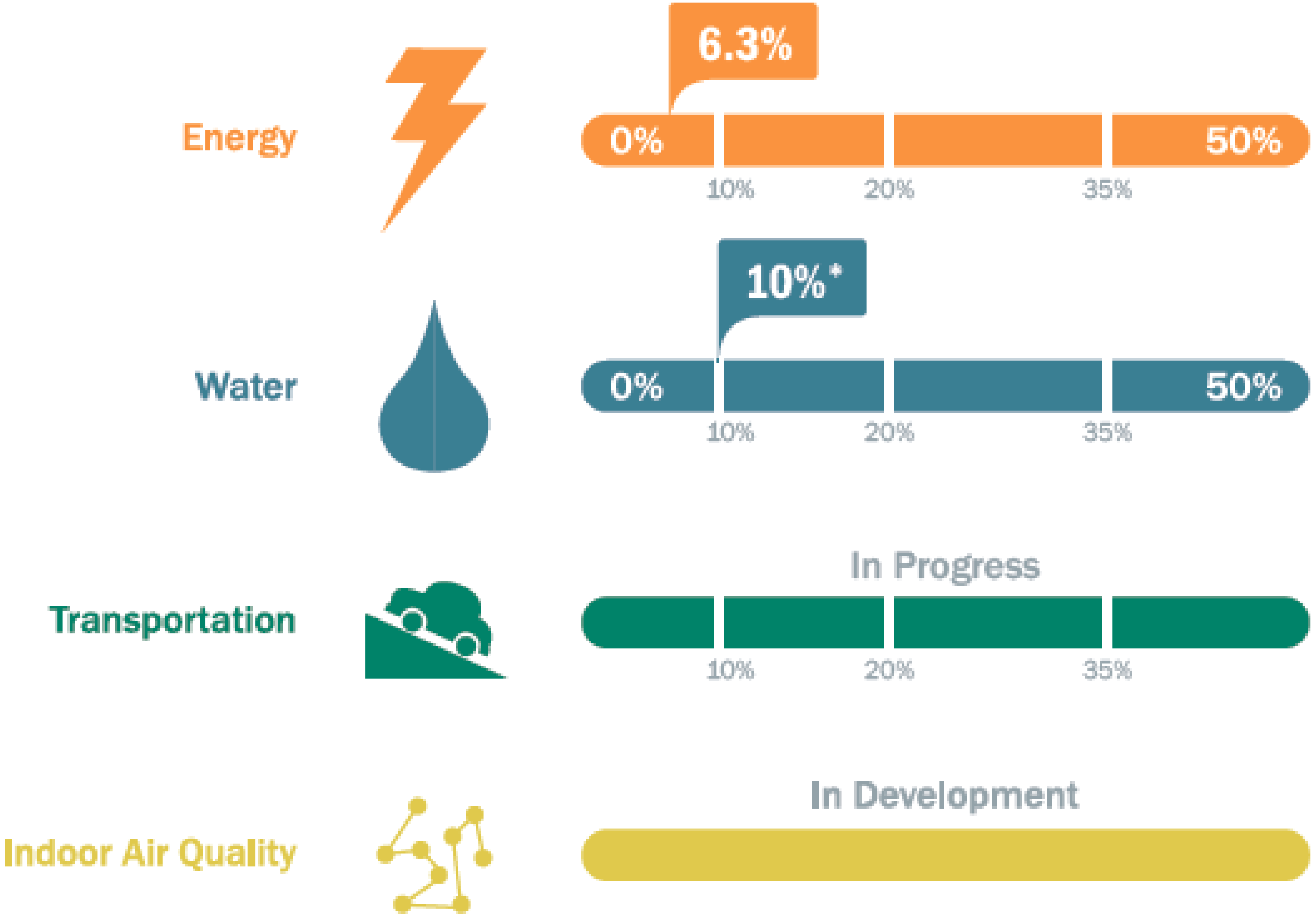


Objectives

- To Owner: Optimize performance and occupant comfort of the Benedum Trees Building while preserving historic character
- To Academia: Establish Benedum Trees as a “flagship” case for future historic building renovations
- To Community: Assist Benedum Trees in achieving 2030 Challenge, reduce energy and carbon footprint, “Go Fourth”

Pittsburgh 2030 Initiative

PITTSBURGH 2030 DISTRICT



Challenges

- <u>Capital Cost</u>: Although many retrofits will reduce operating cost, improve productivity and well-being, and increase energy efficiency, most require significant upfront cost for procurement and installation.

- <u>Historic Building</u>: Historic building requirements limit what can be done to the exterior façades of the building and require preservation of "historical character"

- <u>Client Preferences</u>: New technology may not be compatible with rich, traditional aesthetic desired by client.

Success Story

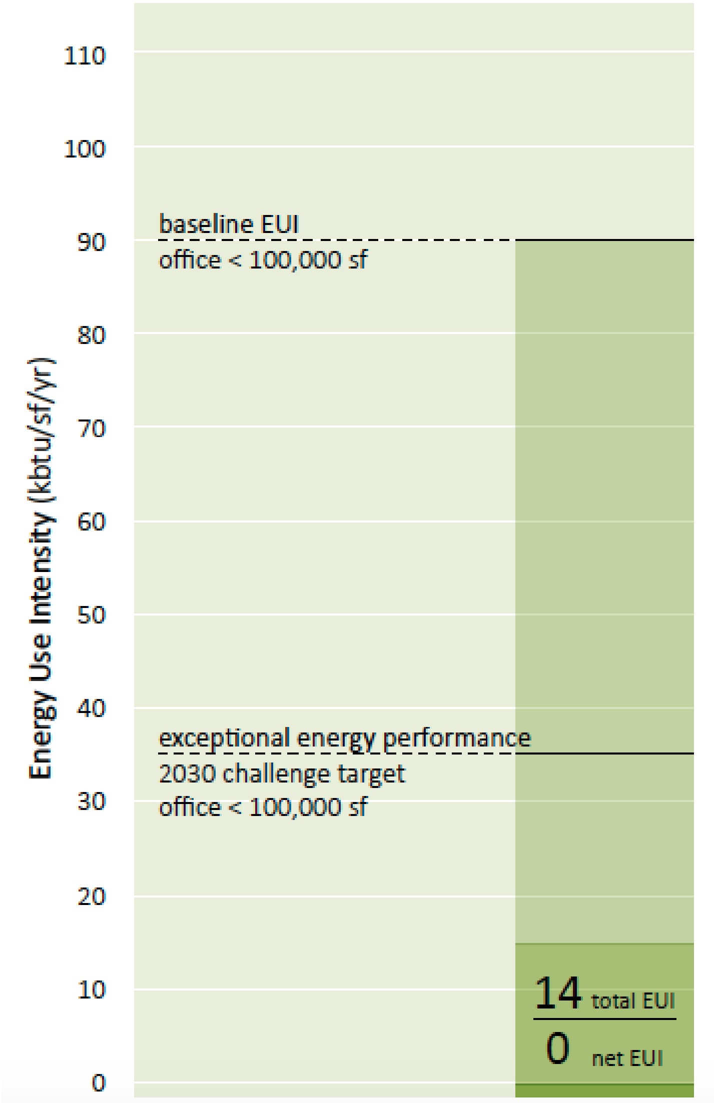
Wayne N. Aspinall Federal Building and U.S. Courthouse

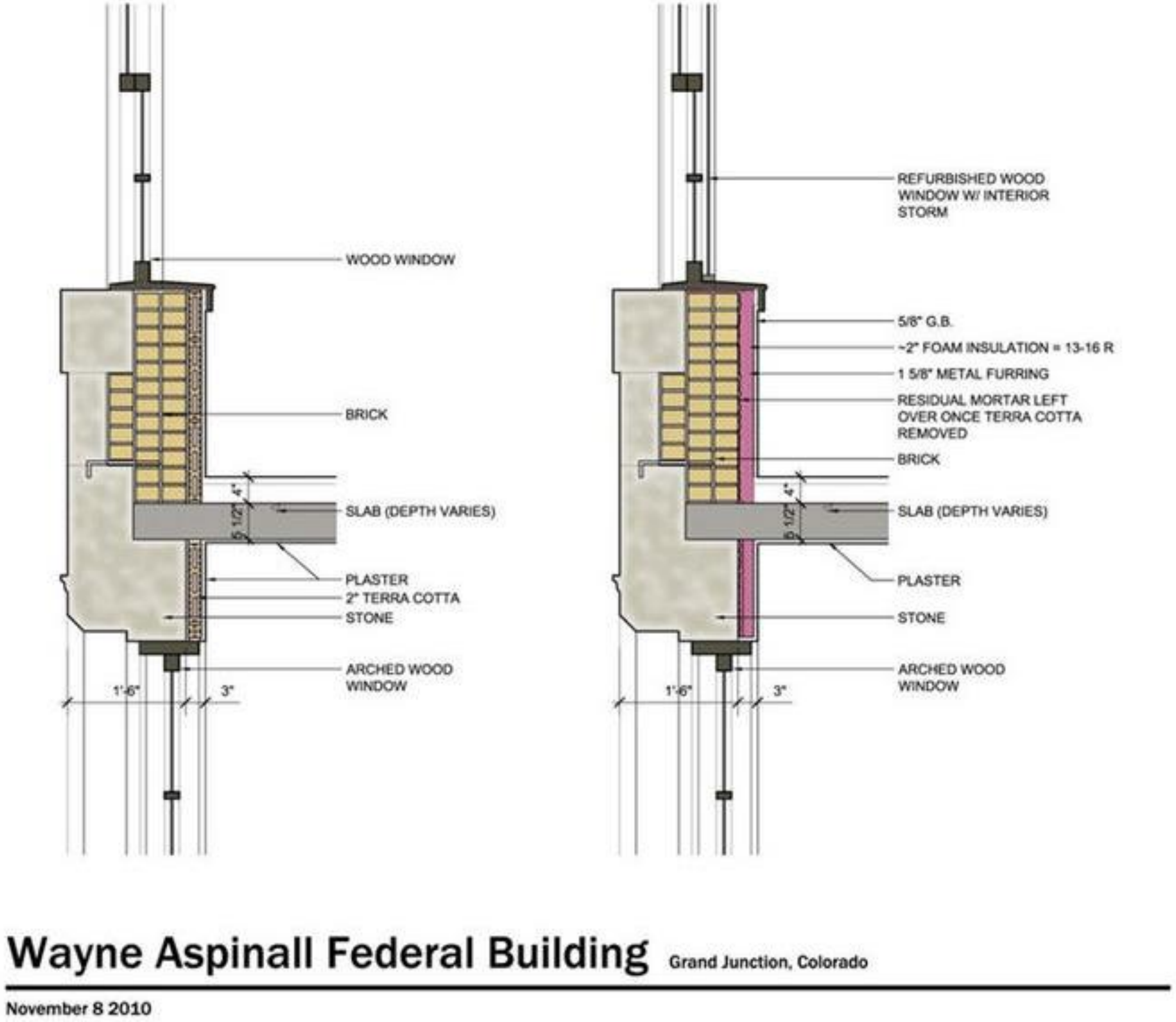
American Institute of Architects. (2016). *Wayne N. Aspinall Federal Building and U.S. Courthouse*. Retrieved April 15, 2016, from AIA Top Ten : http://www.aiatopten.org/node/367

1st Net Zero Historical Bldg.

- Wayne N. Aspinall Federal Building and U.S. Courthouse
- Grand Junction, Colorado
- Built in 1918
- Net producer of energy
- $15 million renovation
- 41,562 square feet
- $360 per square foot

An Improved Enclosure – Interior Insulation





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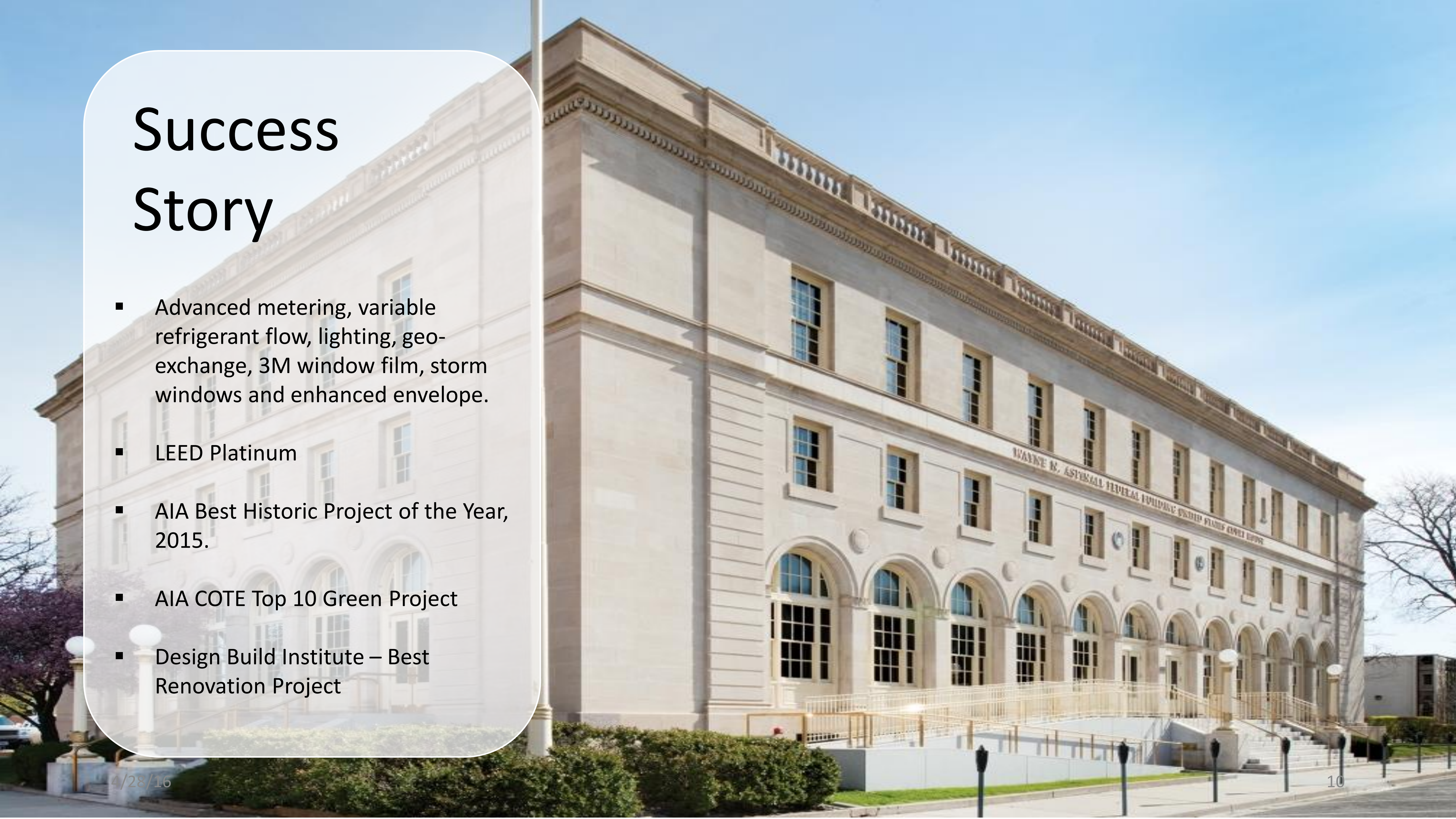


Success Story

- Advanced metering, variable refrigerant flow, lighting, geo-exchange, 3M window film, storm windows and enhanced envelope.
- LEED Platinum
- AIA Best Historic Project of the Year, 2015.
- AIA COTE Top 10 Green Project
- Design Build Institute – Best Renovation Project

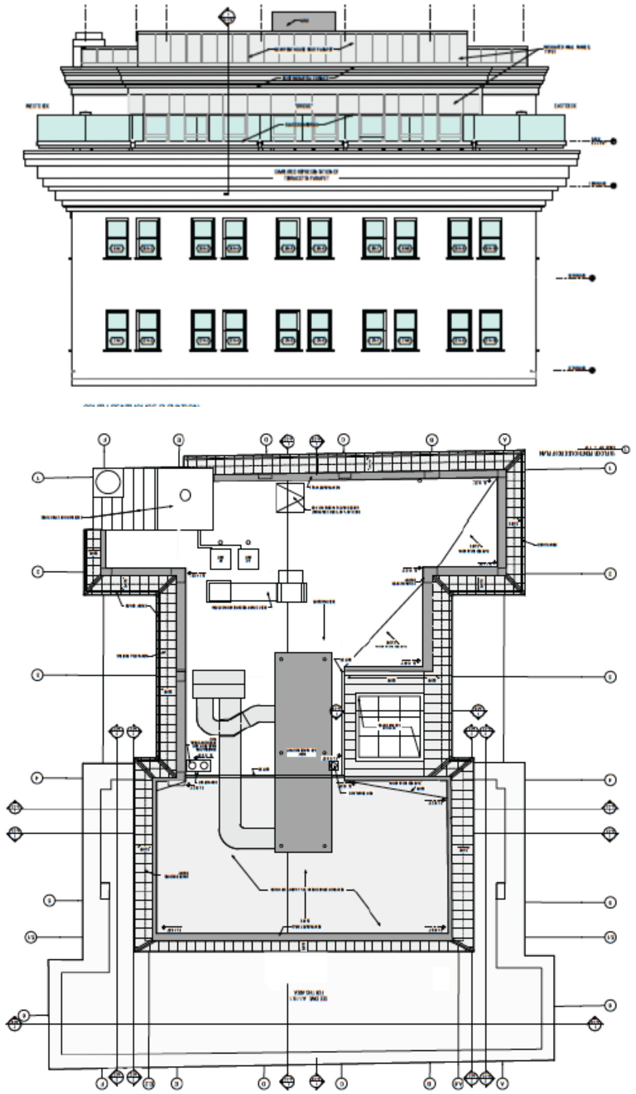
High Performance History

Benedum Trees Building

Existing Conditions – Steel Structure and Flat Arch

Existing Conditions – Steel Structure and Flat Arch

Existing Conditions – Rooftop

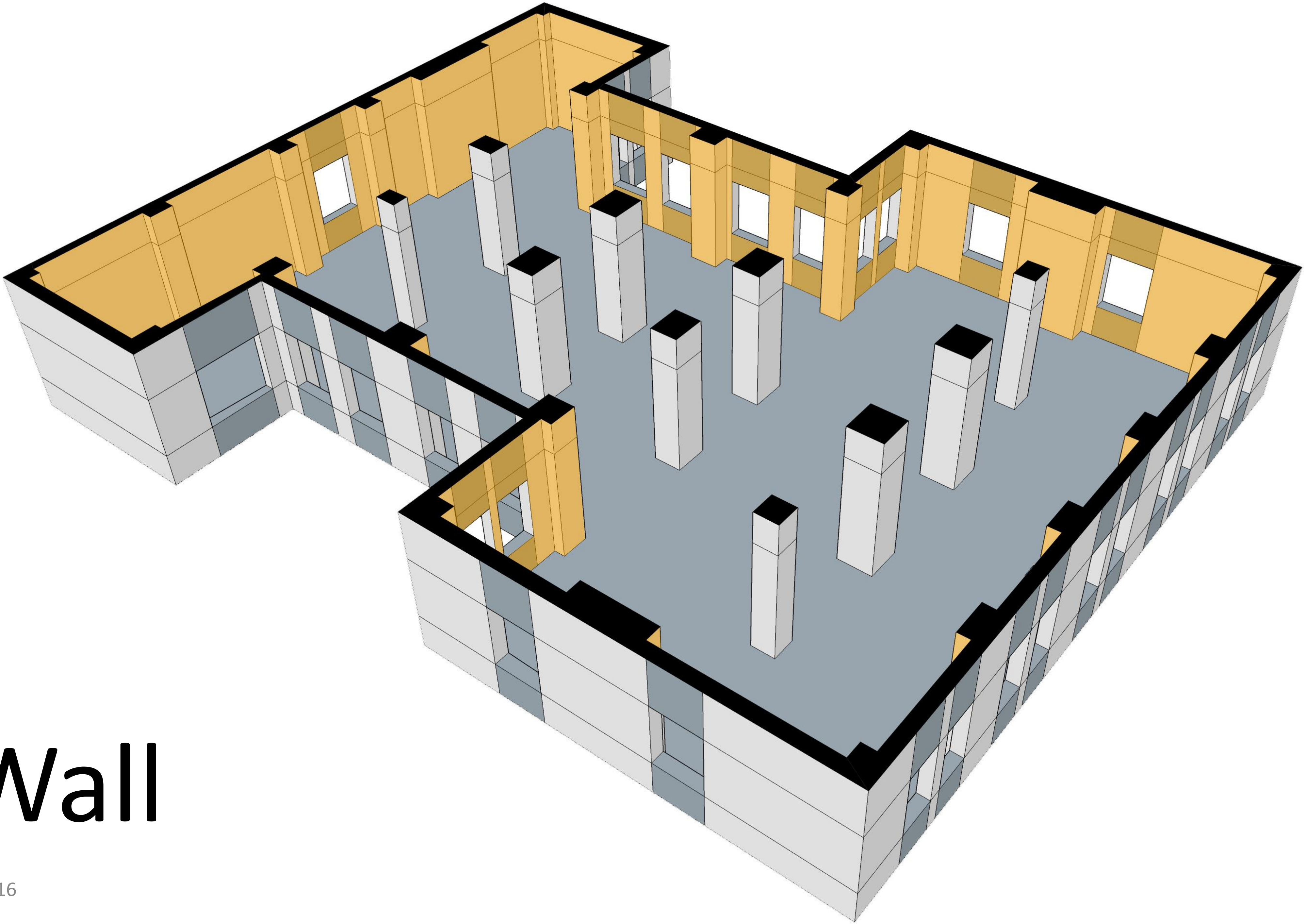


Existing Conditions – Windows

PROPOSED DESIGN

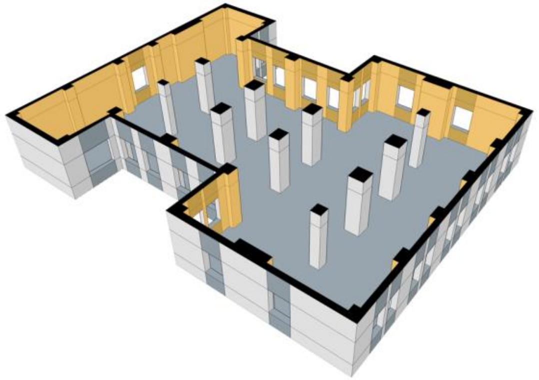
Performance Matrix – Systems and Mandates

		Spatial Performance	Visual Performance	Acoustic Performance	Thermal Comfort	Air Quality	Building Integrity
Floor	Raised Floor System						
	In-Floor Radiant Beam						
	EcoCore Phase Change Panels						
	Displacement Ventilation						
Enclosure	Schuco Parallel Windows						
	Warema External Shades						
	RetroSolar Internal Blinds						
	Window Sensors						
	Foamglass Interior Insulation						
Ceiling	Chilled Sail Radiant Cooling						
	Solar Tube Coffered Ceiling						
	Foamglass Roof Insulation						



Wall

Wall Systems – Foamglas®



A1 rating for sustainability from Masdar Future Building Initiative

2010 Building Green Top 10 Product

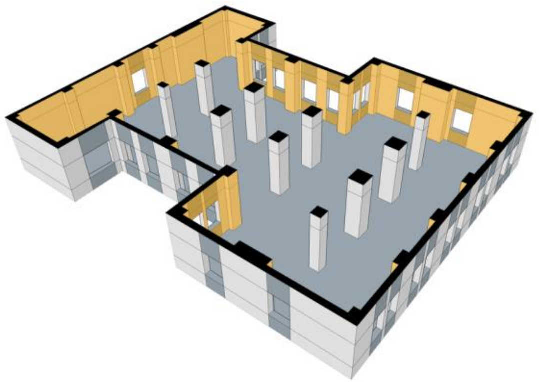
Awarded Nature-Plus quality label

NFPA 285 Standard fire test approved
pure glass → zero flame or smoke spread

Wall Systems – Foamglas®

Better Than XPS and EPS

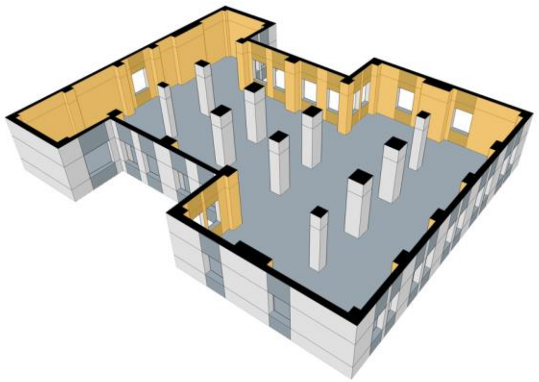
	XPS or EPS	Glass Foam Insulation
Price per BF	$0.40	$1.00
R-value per inch	5.0	3.4
Adjusted cost ($/R-in)	$0.08	$0.29
Blowing Agent	HFC-134a	None
Flame Retardent	HBCD*	Glass
Absorbs liquids	Yes	No
Off-gassing	Yes	No
Compressive Strength	45 psi	90 psi
Thermal Contraction		X
Thermal Expansion		X
Thermal Resistance	X	
Health Impact		X
Environmental Impact		X
Durability		X

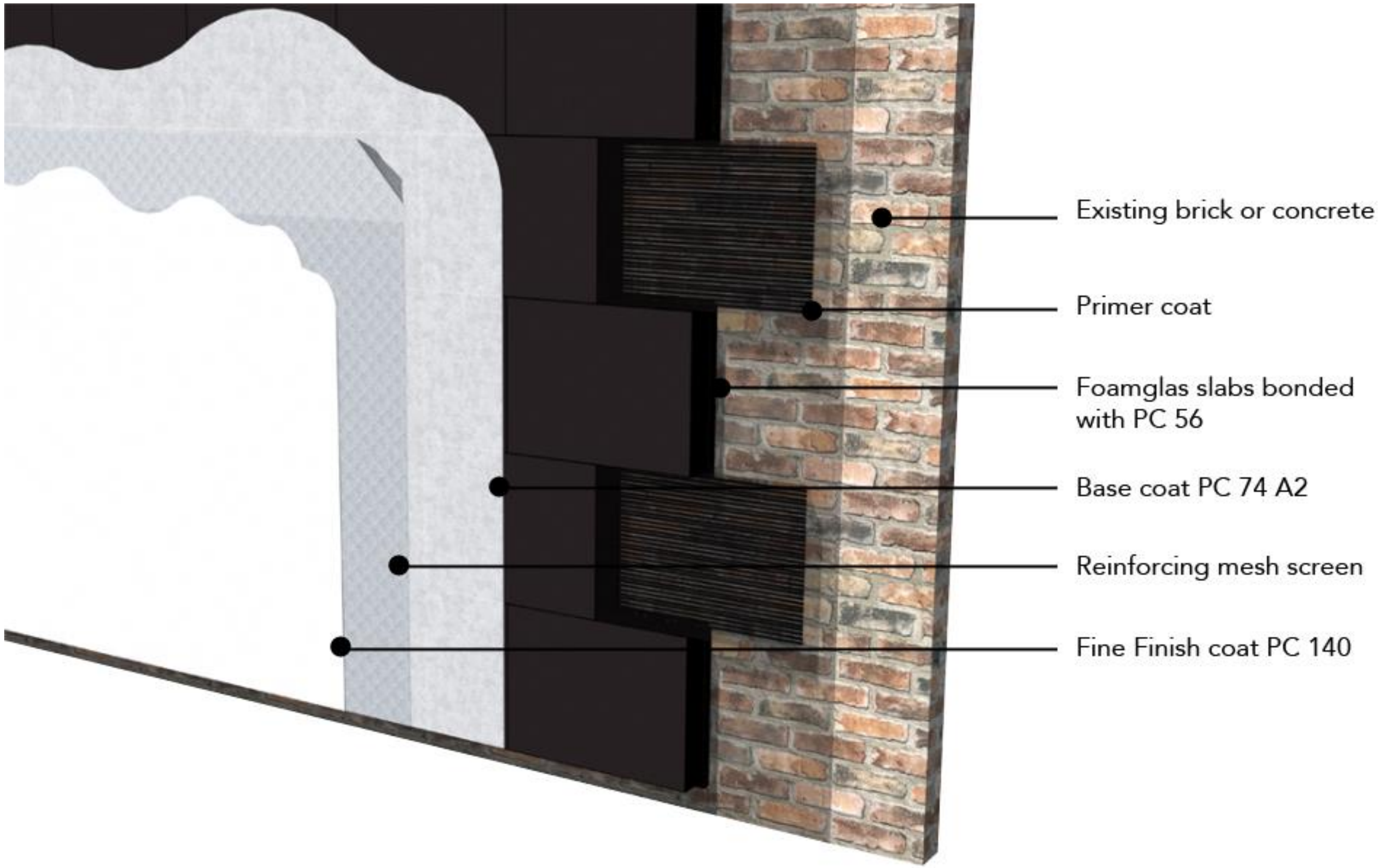


- 2” rigid board (50mm)
- + R-7.0 to exterior assemblies
- < $30 per square meter section
- Exterior wall area: 2,606 SF (per floor)
- Retrofit: $7,207 (per floor), $5,670 top floor
- Manufacturing process is 1,400 times better for the environment (no GWP or ODP).

1. Foamglas. (2015). *Interior Wall Insulation*. Retrieved from Foamglas Building Applications: http://www.foamglas.com/en/building/applications/interior_insulation_systems/interior_wall_insulation/#3-2-4
2. Pittsburgh Corning. (2016). *Foamglas Insulation*. Retrieved from www.pghcorning.com: http://www.pghcorning.com/products/foamglas/
3. Wilson, A. (2012, November 29). *Green Building Advisor*. Retrieved from On the Jobsite with Foamglas: http://www.greenbuildingadvisor.com/blogs/dept/energy-solutions/jobsite-foamglas

Wall Systems – Foamglas®





Heat Loss Calculation

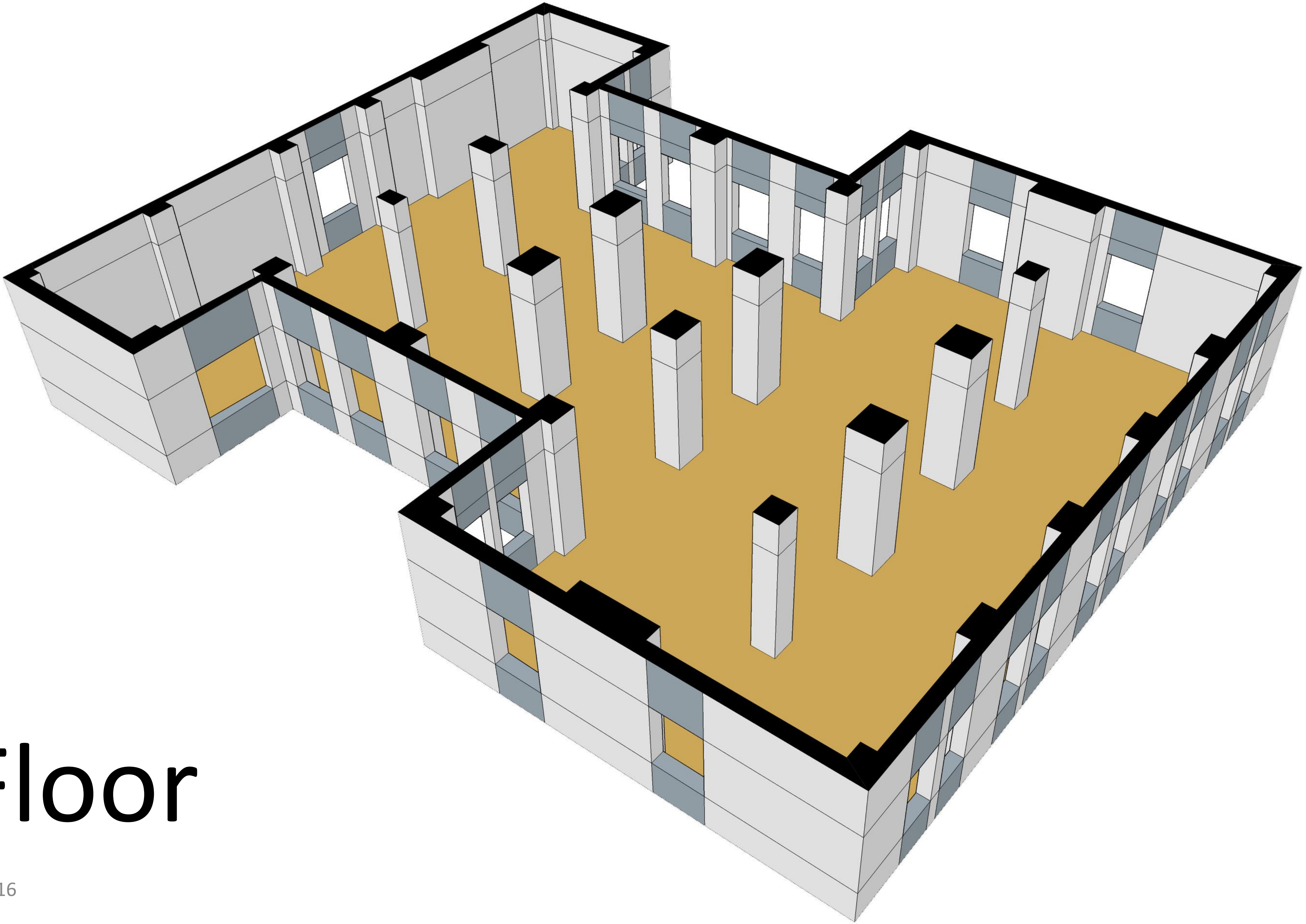
Current Walls

uA▲T = .100 X 7316 X 60F
= 44 kbtu/hr

After retrofit:

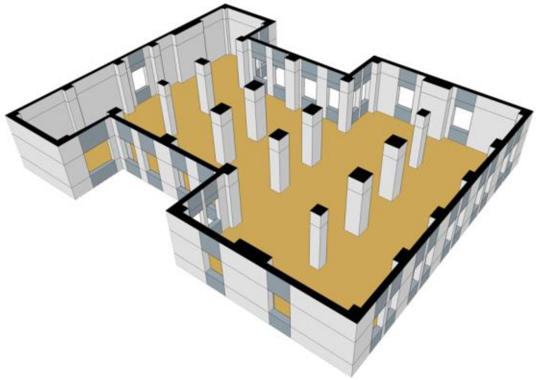
uA▲T = .059 X 7316 X 60F
= 26 kbtu/hr

Heat Loss through the walls
: **41% Reduction**



Floor

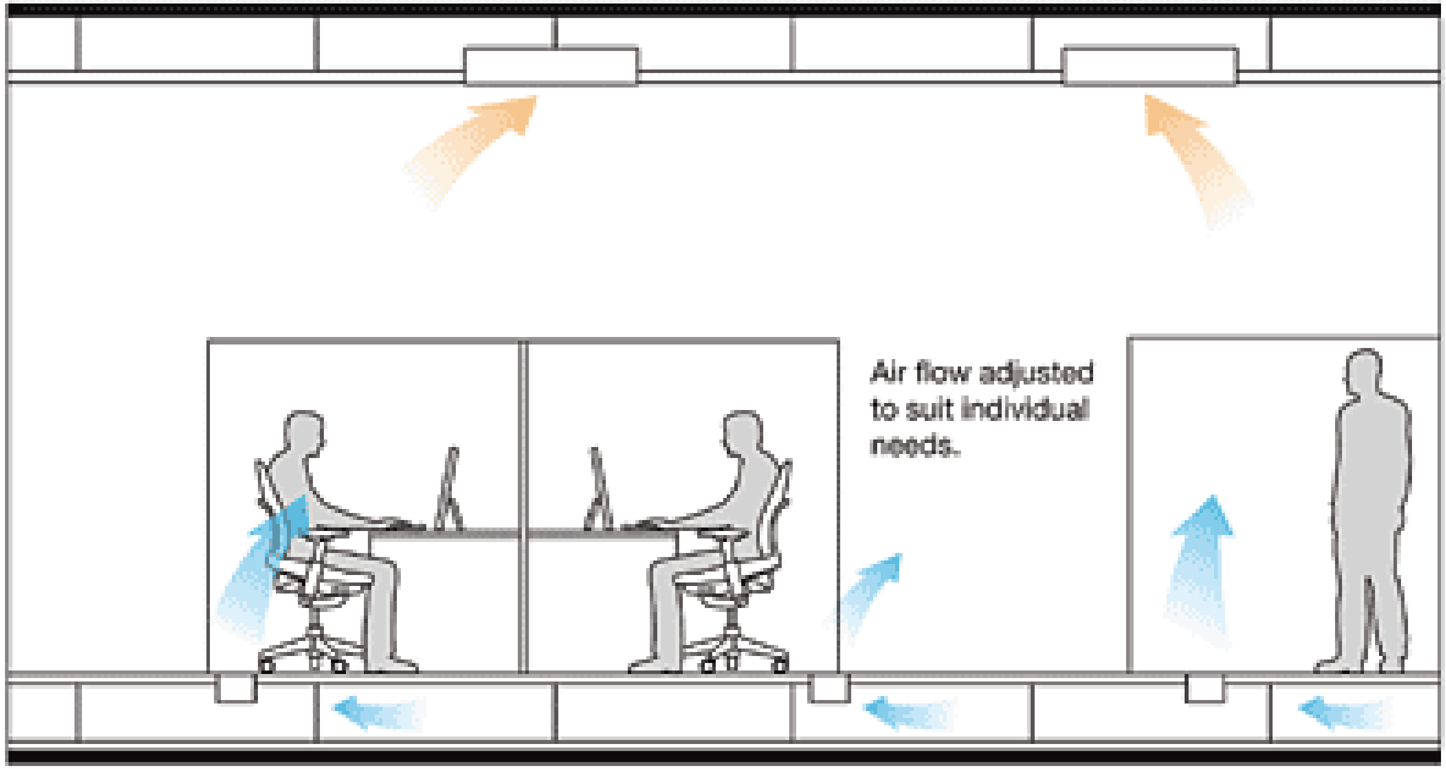
Floor Systems - Underfloor Air Distribution



Under Floor Air Distribution systems use an underfloor supply plenum located between the structural concrete slab and a raised floor system to supply conditioned air through floor diffusers directly into the occupied zone of the building.

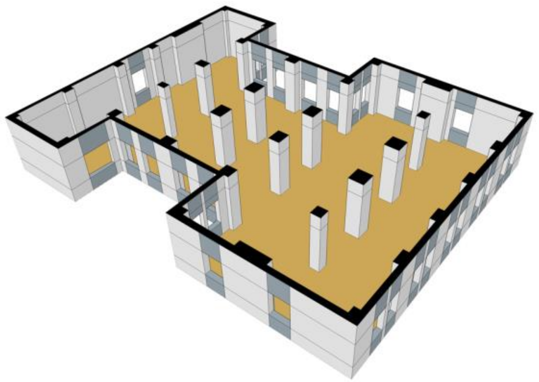
ADVANTAGES

- **Layout flexibility**
- **Improved thermal comfort**
- **Improved ventilation efficiency**
- **Improved energy efficiency**
- **Reduced life cycle costs**

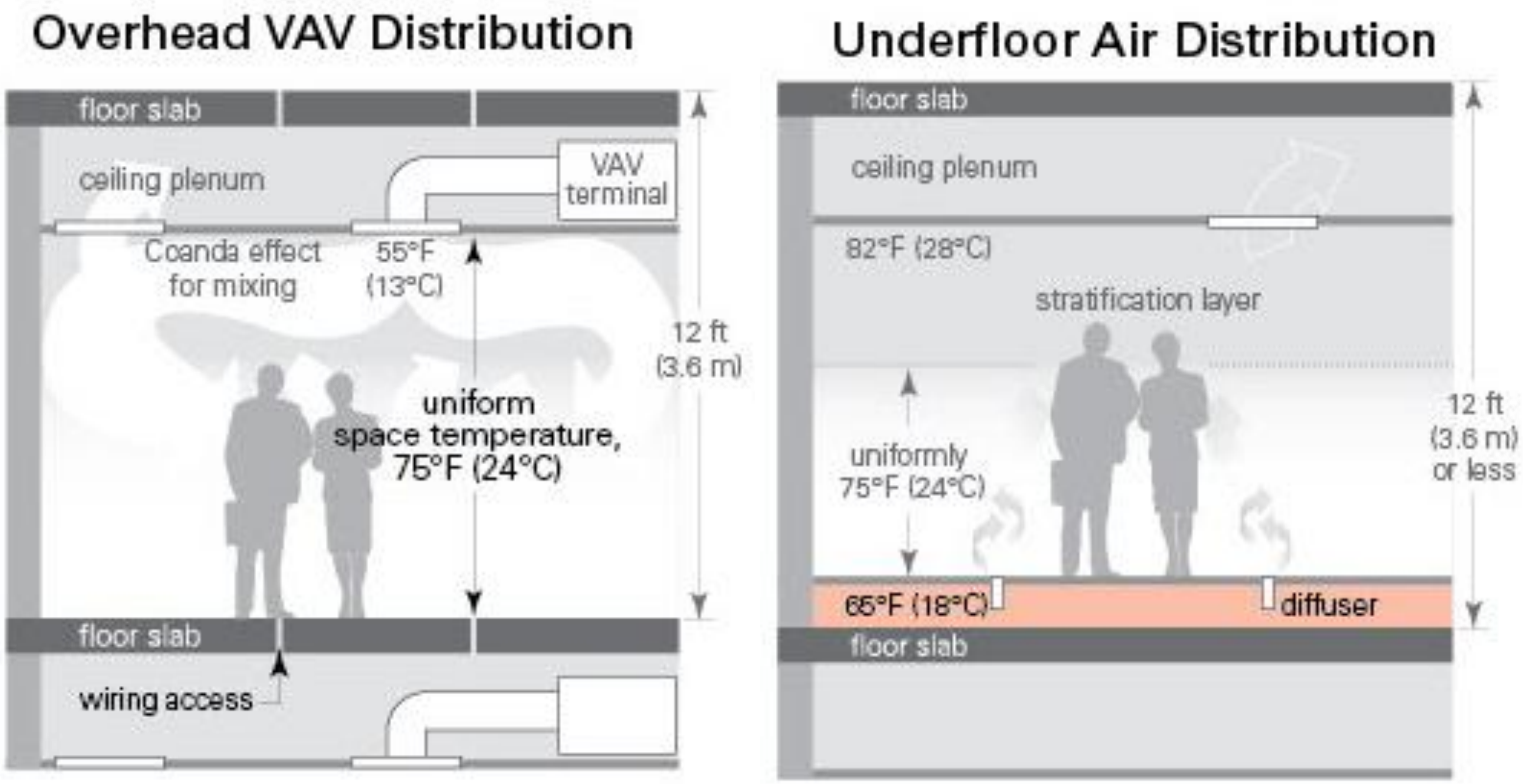


Source: UnderFloor Air Technology. (n.d.). Retrieved from : *http://www.cbe.berkeley.edu/underfloorair/techoverview.htm*

Floor Systems - Underfloor Air Distribution



UFAD Human Benefit



Underfloor: Thermal stratification

Natural stratification occurs when warm air rises due to thermal buoyancy.

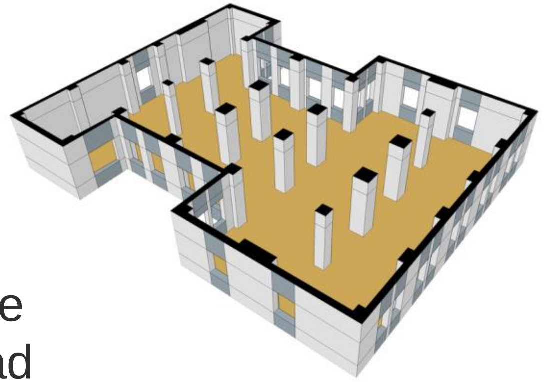
Conditioned air stays in the lower, occupied part of the room

Heat sources such as occupants generate thermal plumes, which carry warm air towards the ceiling and are exhausted through the return air ducts.

Source: UnderFloor Air Technology. (n.d.). Retrieved from : *http://www.cbe.berkeley.edu/underfloorair/techoverview.htm*

Floor Systems - Underfloor Air Distribution

UFAD Energy Savings



In a study comparing the thermal environment of two air distribution systems in an office setting, Rosario et al found that underfloor system is better performing than an overhead system in contaminant removal and energy saving while maintaining thermal comfort.

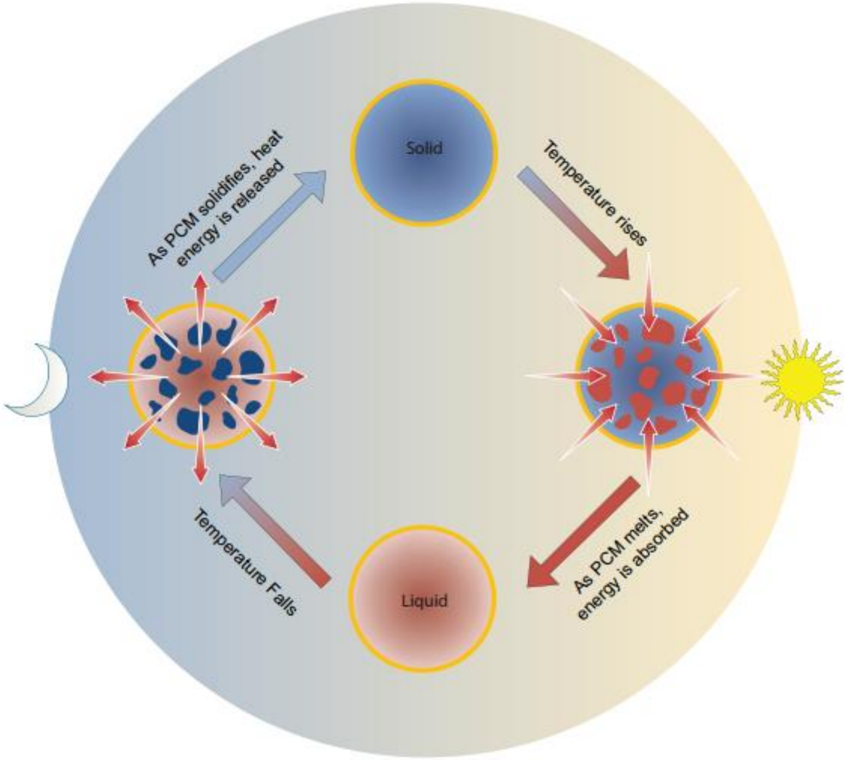
Comparison of energy consumption of the two air distribution systems and energy saving by using a UFAD system.

(a) Power of refrigeration required for cooling and dehumidifying supply air		
Overhead (simulation 4)	Underfloor (simulation 1)	Energy saving
1.01 kW	0.80 kW	21%
(b) Power consumption for cooling the occupied space		
Overhead (simulation 4)	Underfloor (simulation 1)	Energy saving
47 W	33 W	30%

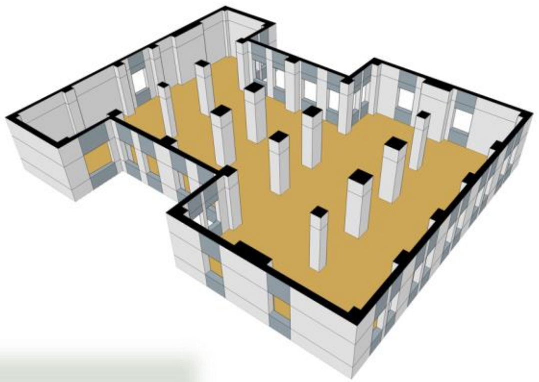
Source: Ho, S., Rosario, L., & Rahman, M. (2011). Comparison of underfloor and overhead air distribution systems in an office environment.

Floor Systems - EcoCore™ Panels by Tate

Phase Change Technology



Phase Change Materials

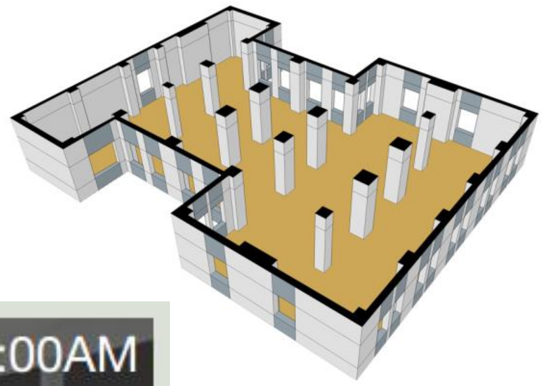


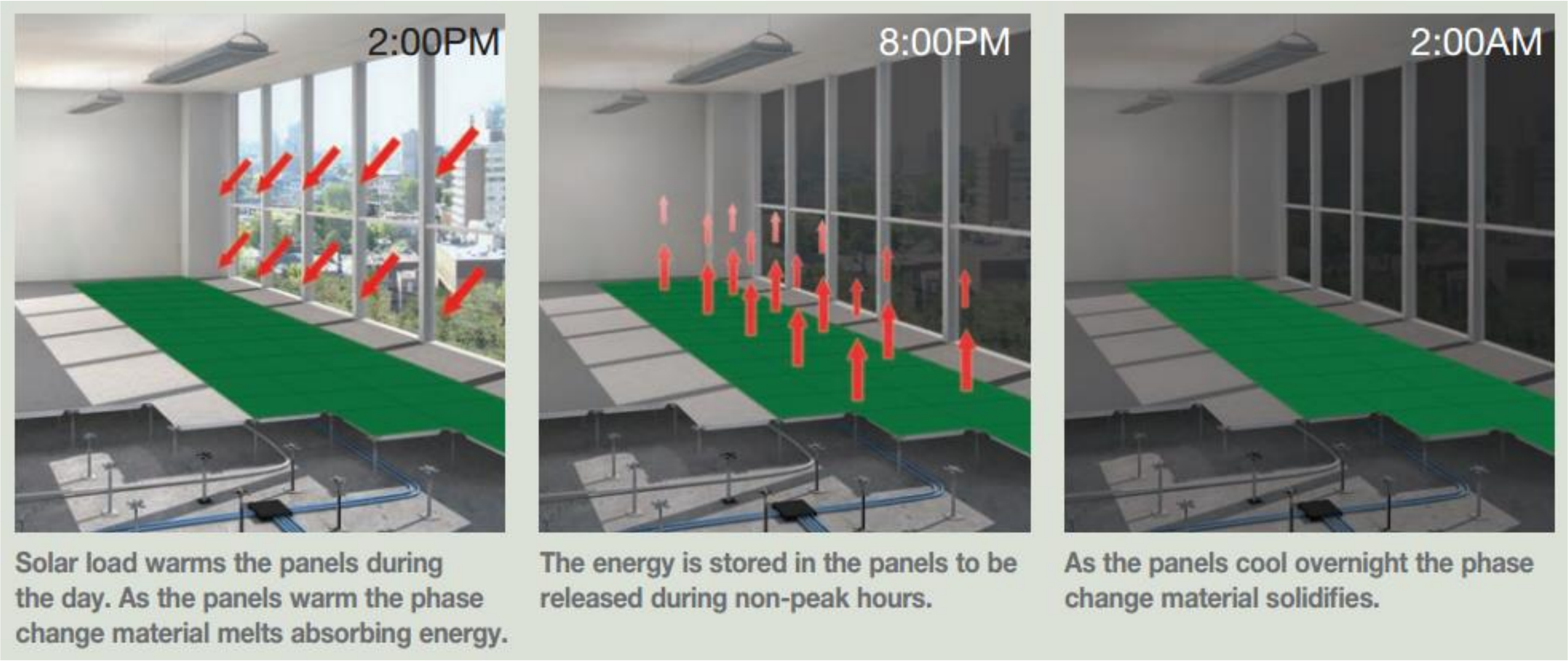
Panels with phase change material that can seamlessly integrate into a raised floor installation

Source: EcoCore: Phase Change Technology for Access Floors. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

Floor Systems - EcoCore™ Panels

Phase Change Technology



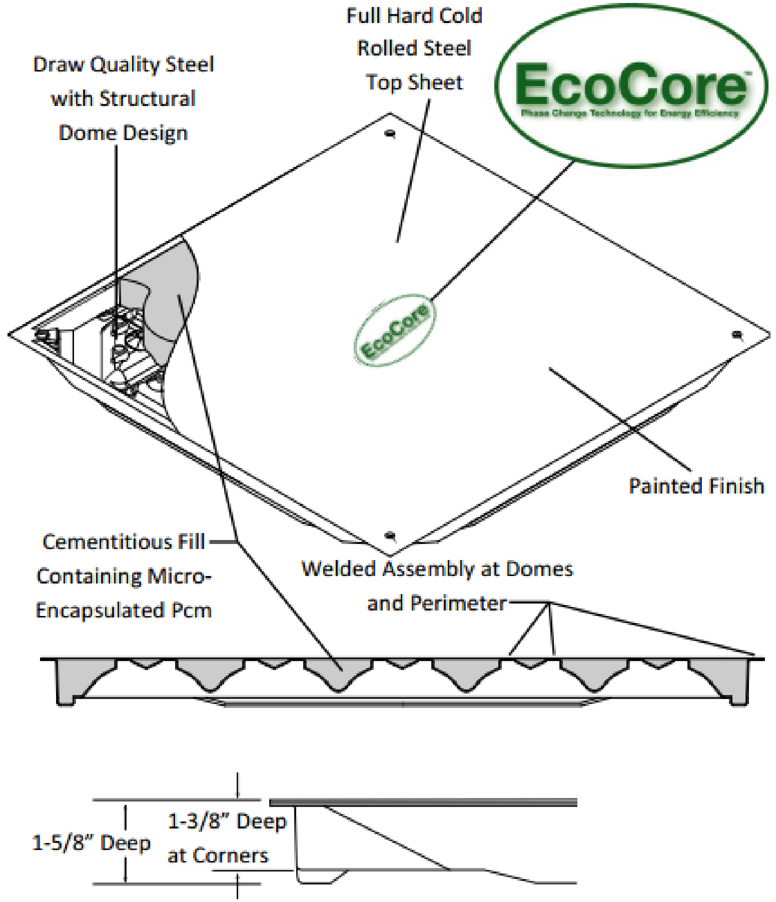


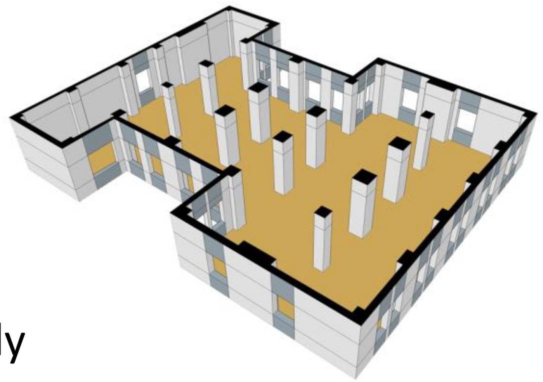
Source: EcoCore: Phase Change Technology for Access Floors. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

 spatial thermal air quality acoustical visual building integrity

Floor Systems - EcoCore™ Panels

Phase Change Technology





- ❖ Steel Welded Construction Filled Internally
- ❖ Phase Change Material Activates at 75.2°
- ❖ Absorbs up to an Additional 141 Btu during Phase Change
- ❖ Additionally Absorbs 6.73 Btu/°F

The typical rule of thumb:

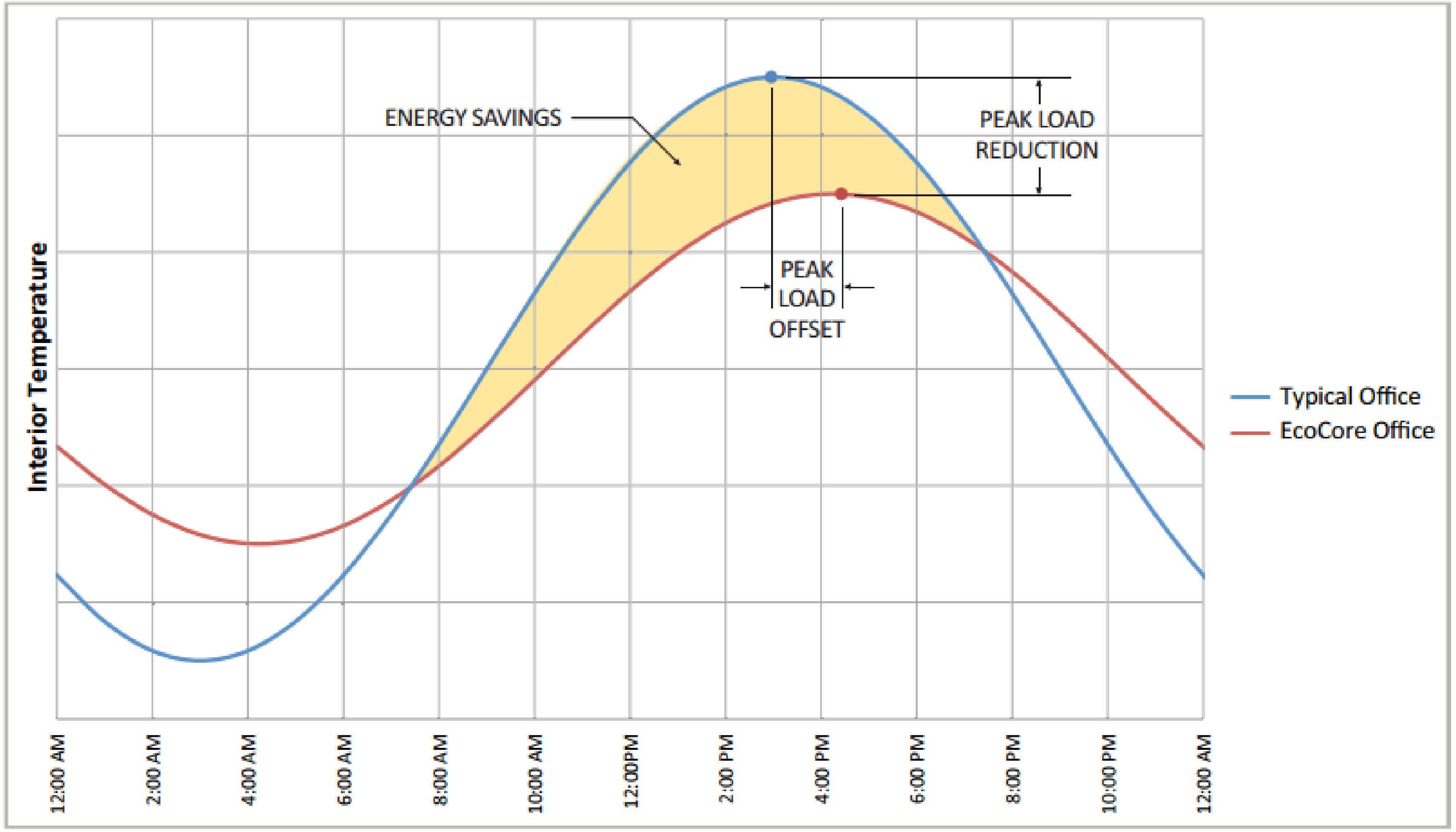
For every 65 Btu/lf of solar loading for a given perimeter area a single row of EcoCore to achieve maximum load offsetting.

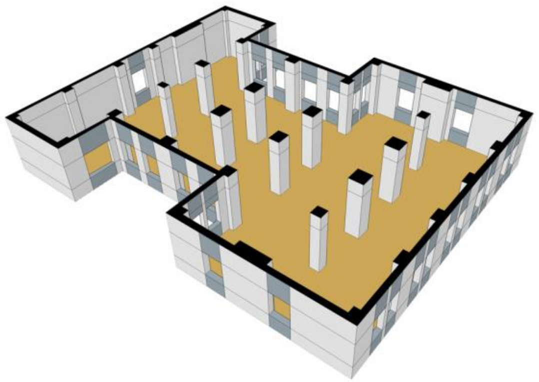
Source: EcoCore: Phase Change Technology for Access Floors. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

Floor Systems - EcoCore™ Panels

Peak Load Reduction

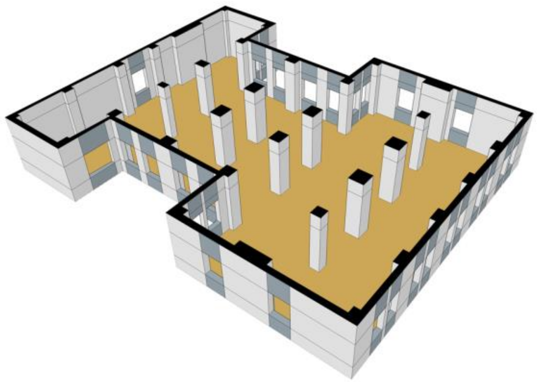
EcoCore Reduces and Offsets Peak Load to Save Energy





Source: EcoCore: Phase Change Technology for Access Floors. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/floor-active-chilled-beams*

Floor Systems - EcoCore™ Panels



Other Benefits

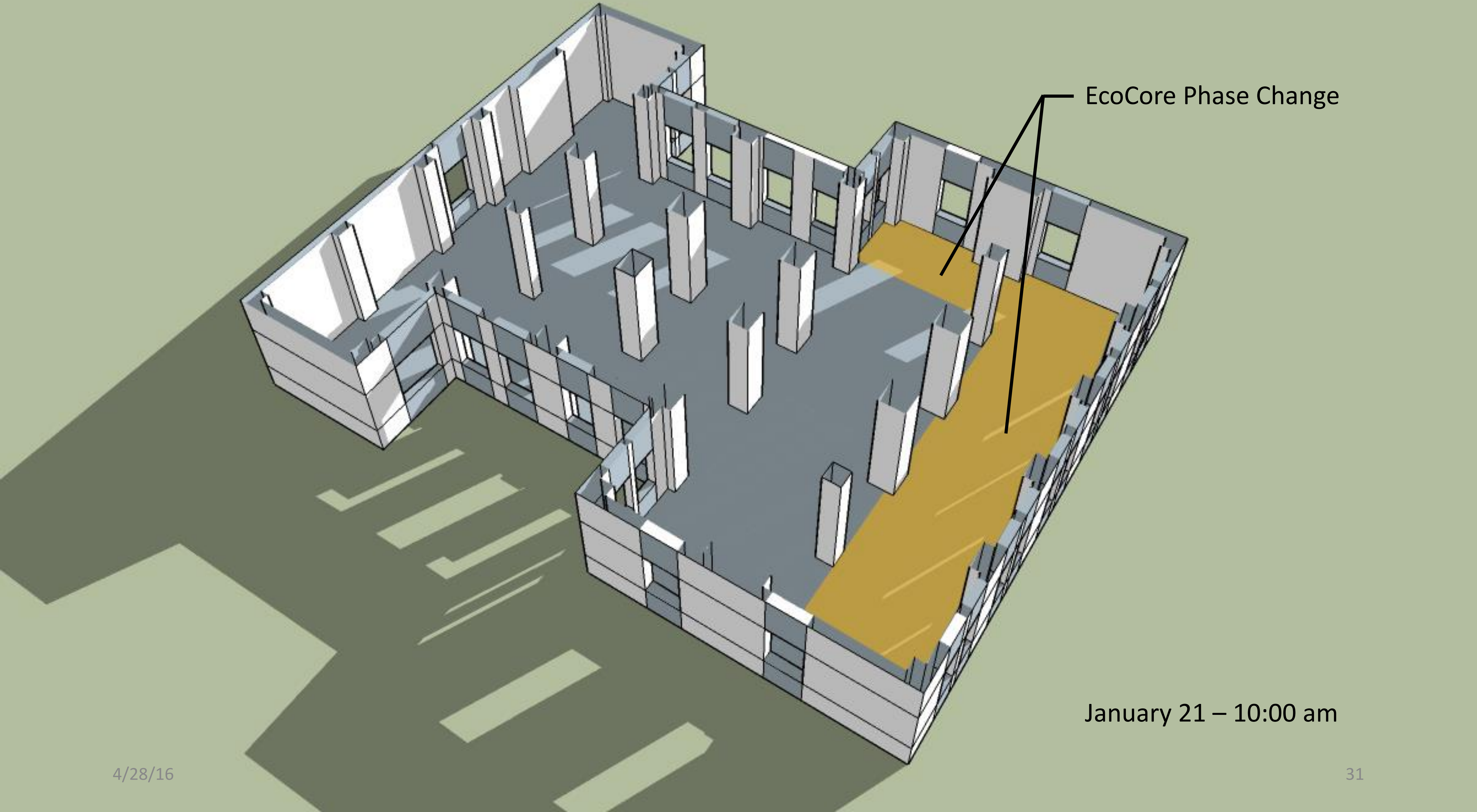
•Reduces perimeter heating and cooling loads during normal business hours

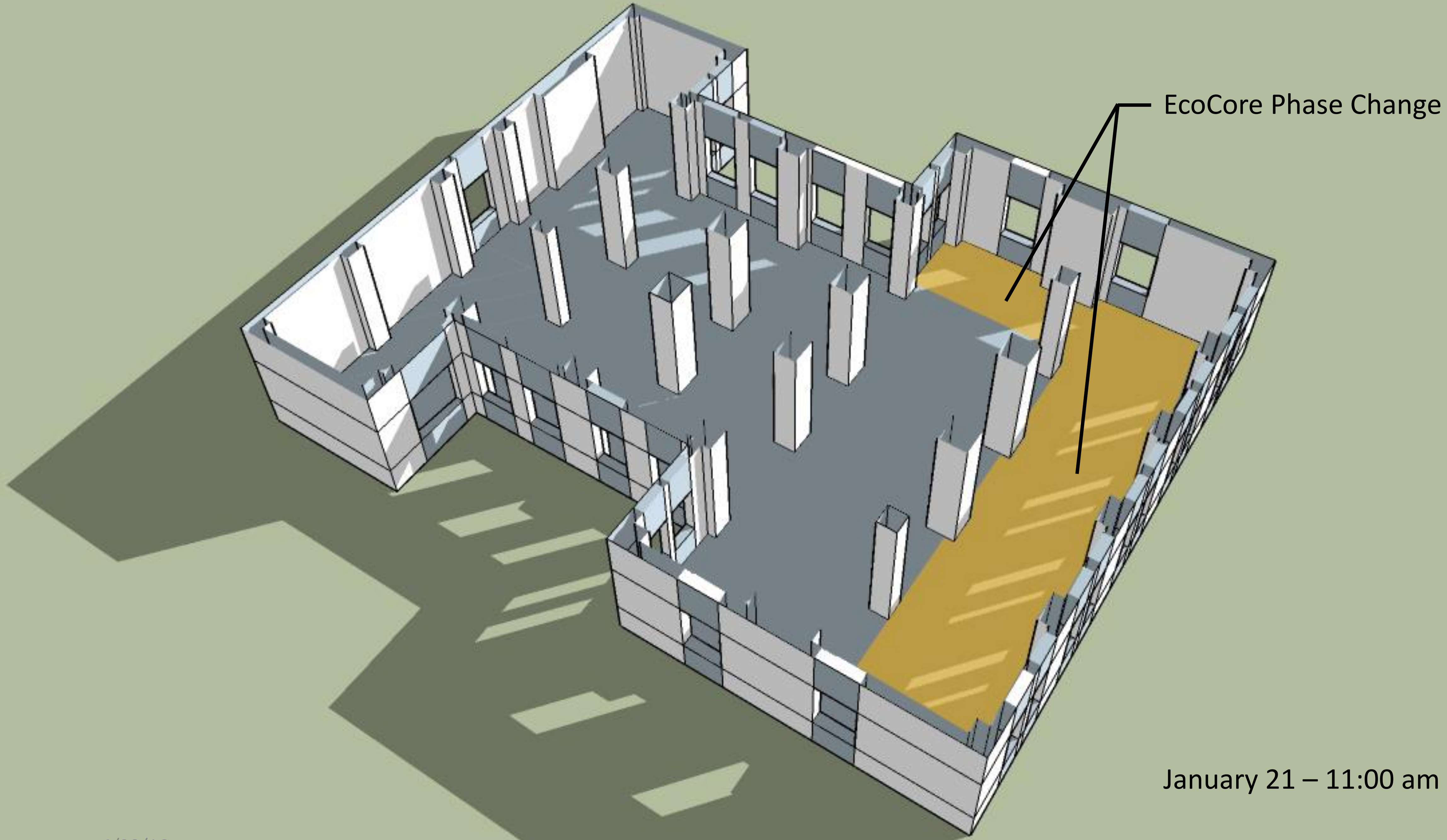
•Uses free or low cost cooling to handle the thermal load stored in the panels during non-business hours

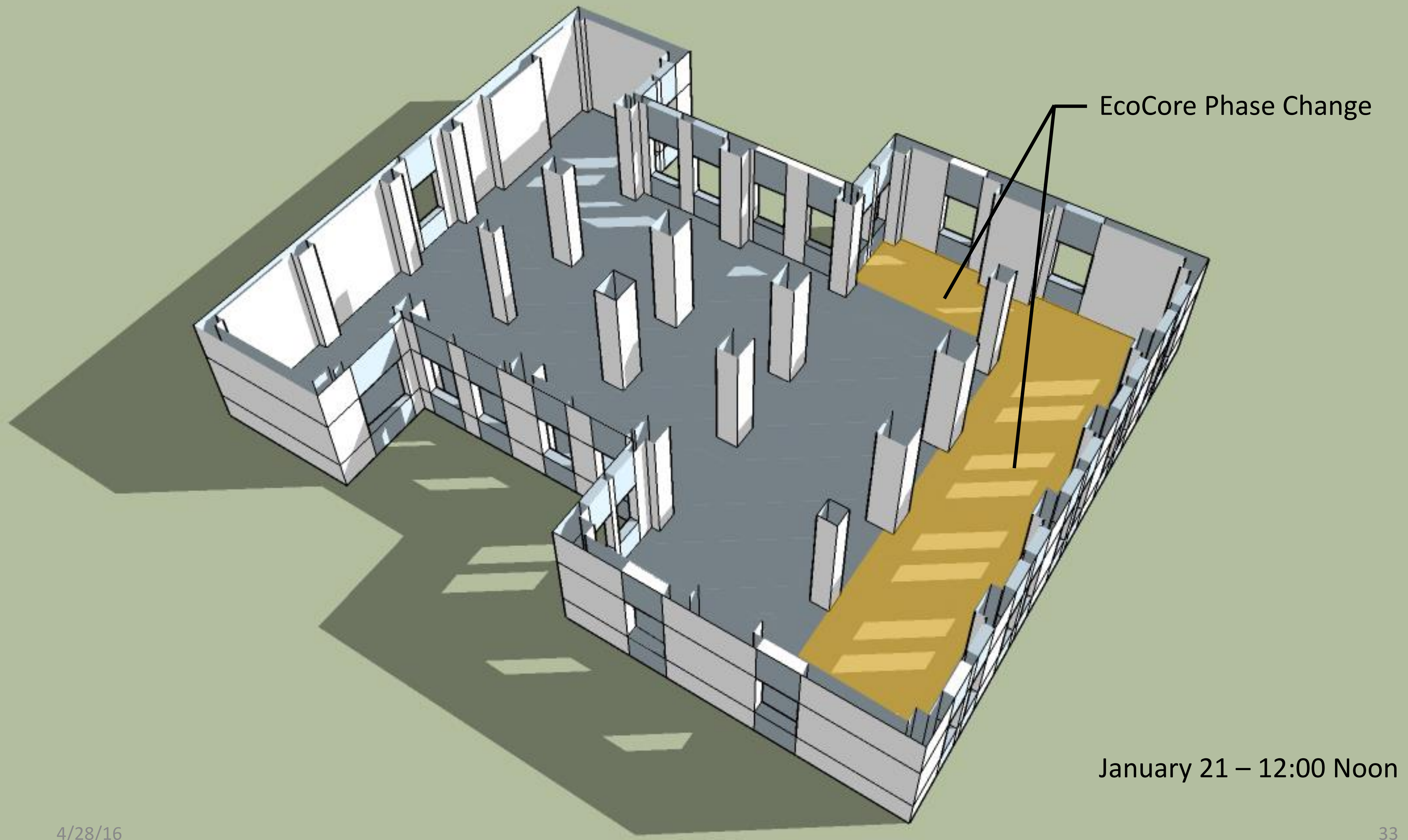
•PCM lasts the life of the building (over 100,000 changes)

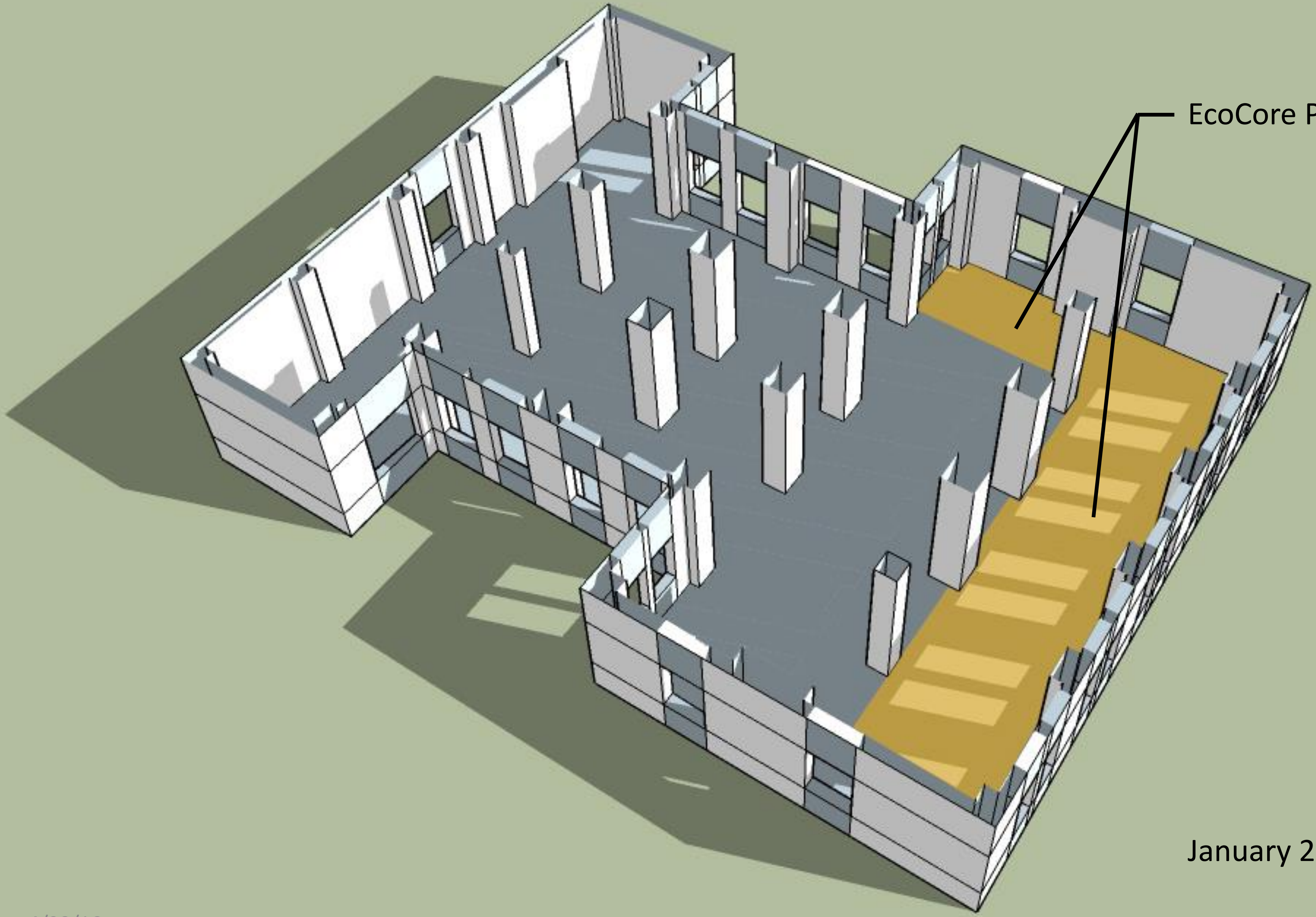
• By embedding the material in cement and they fully encapsulating it in a steel welded shell, the material is protected from the external environment

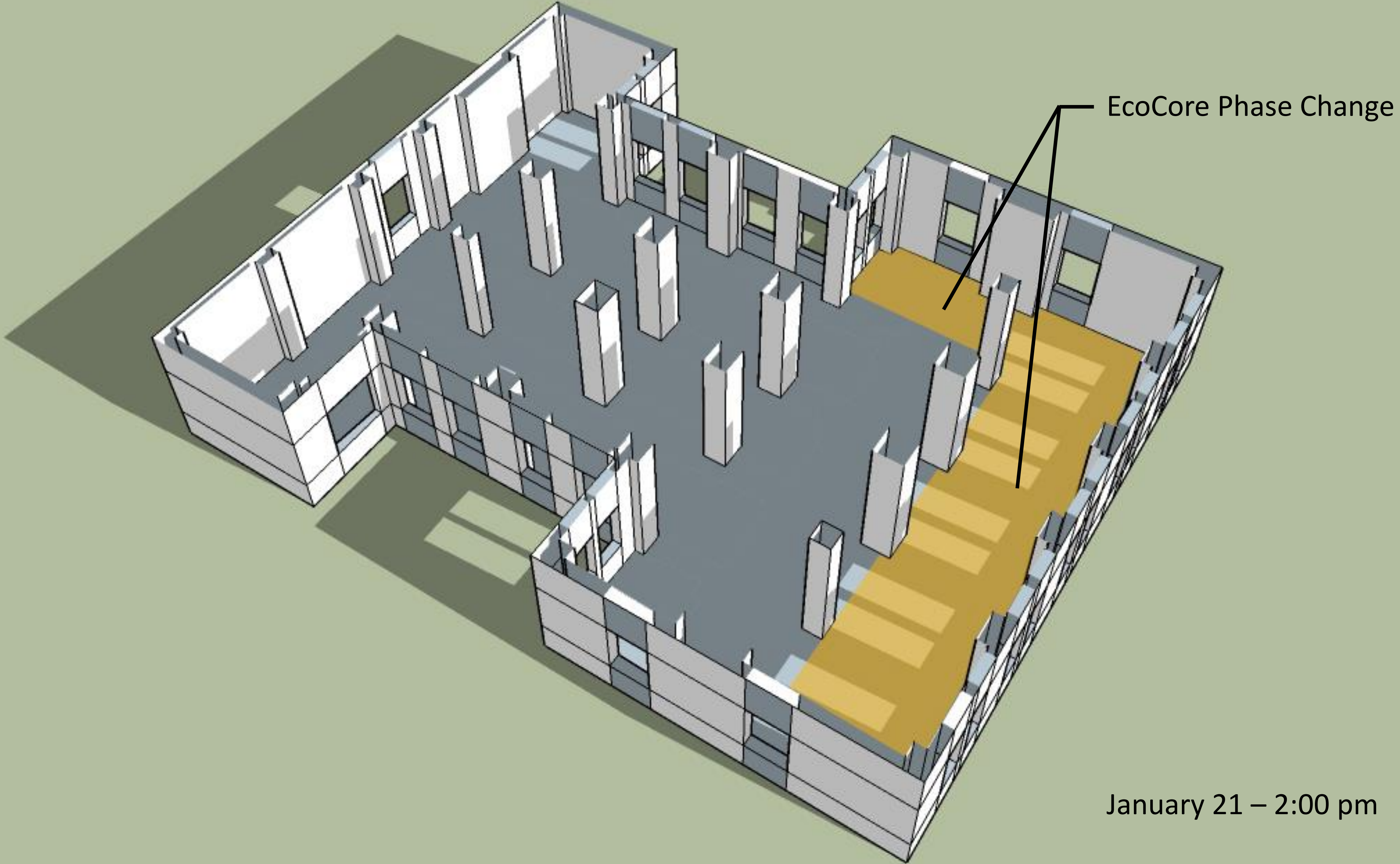
•Possesses the numerous advantages of a raised floor system


EcoCore Phase Change
January 21 – 10:00 am

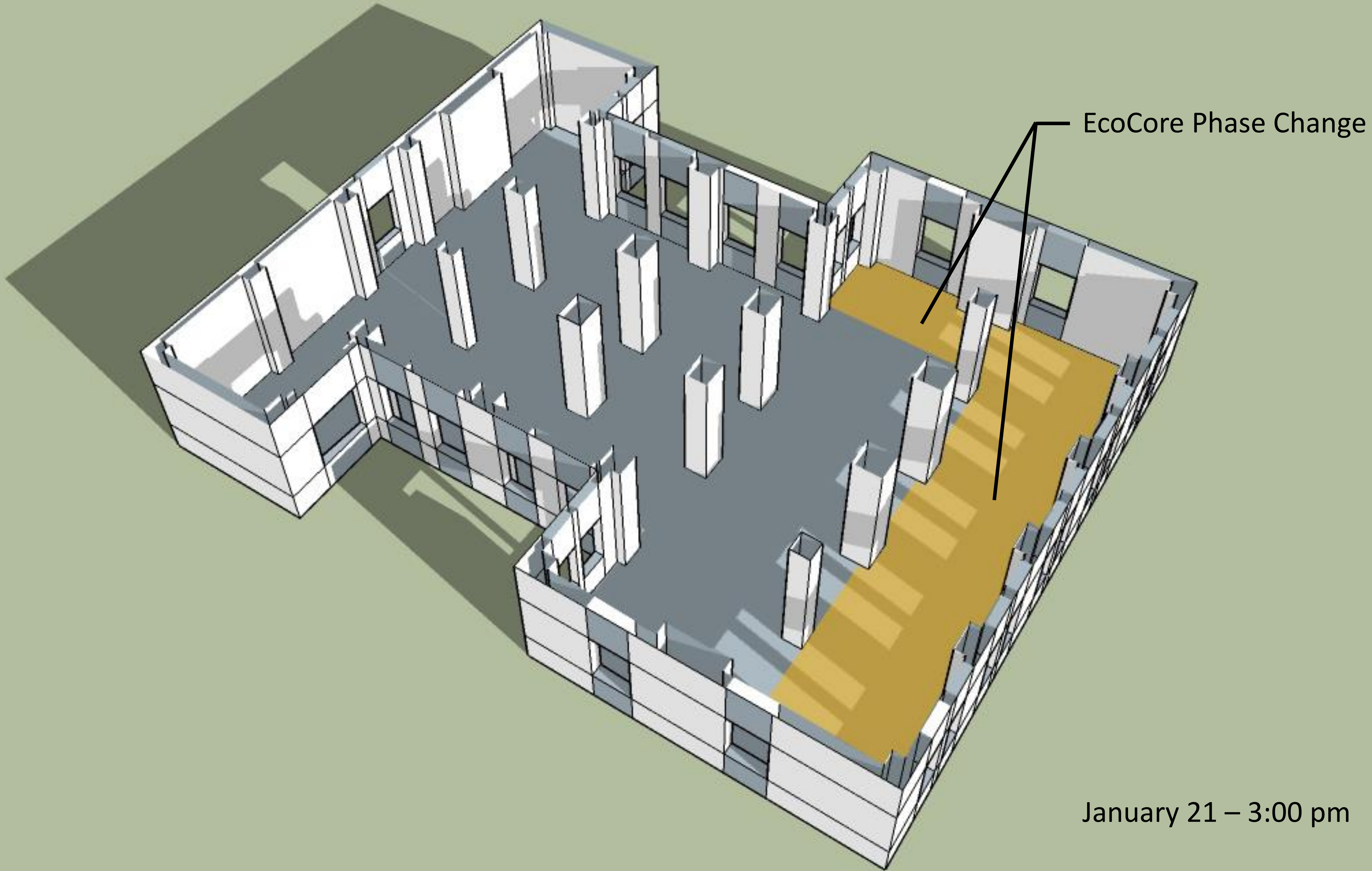

EcoCore Phase Change
January 21 – 11:00 am

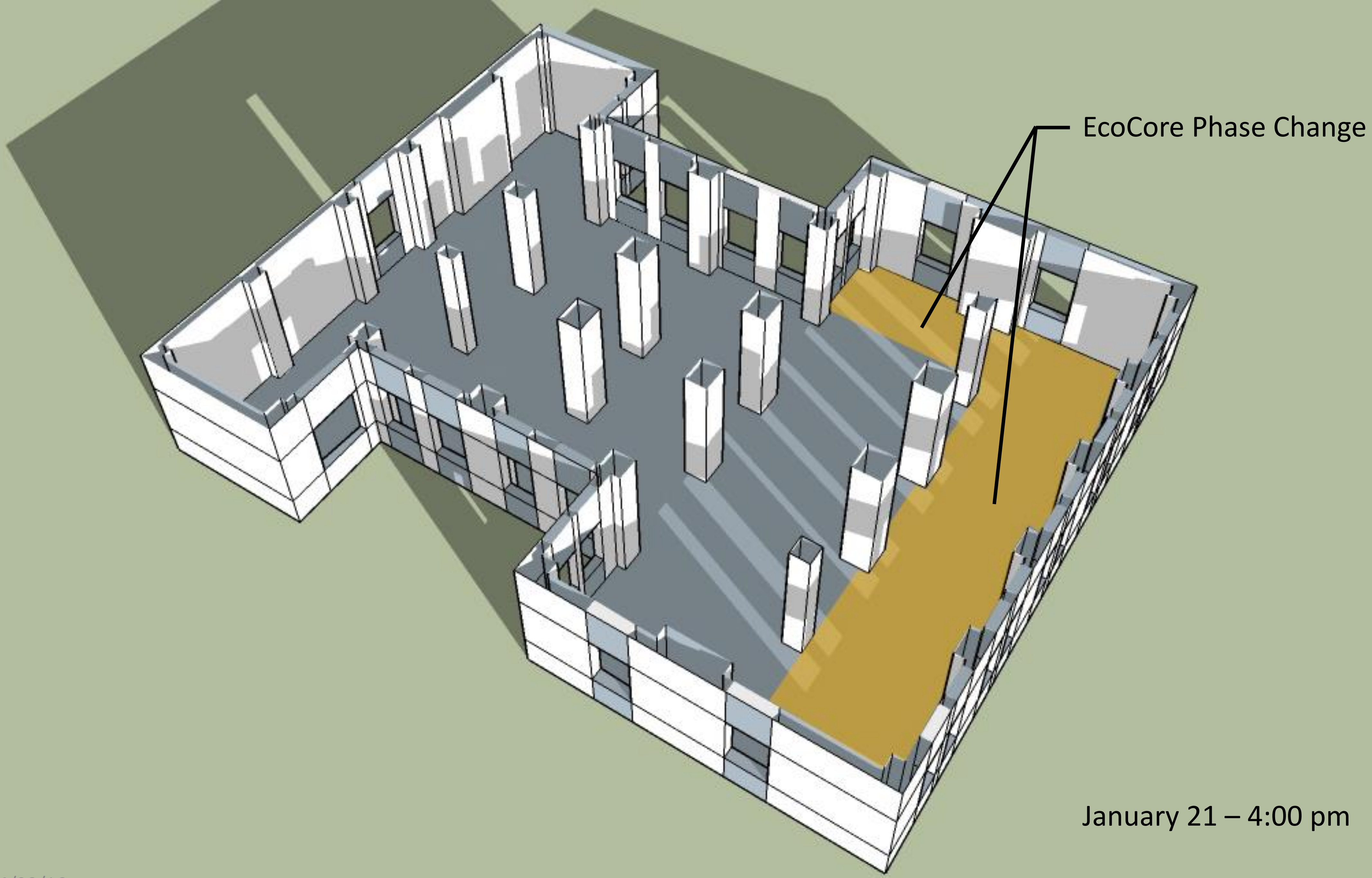

EcoCore Phase Change
January 21 – 12:00 Noon

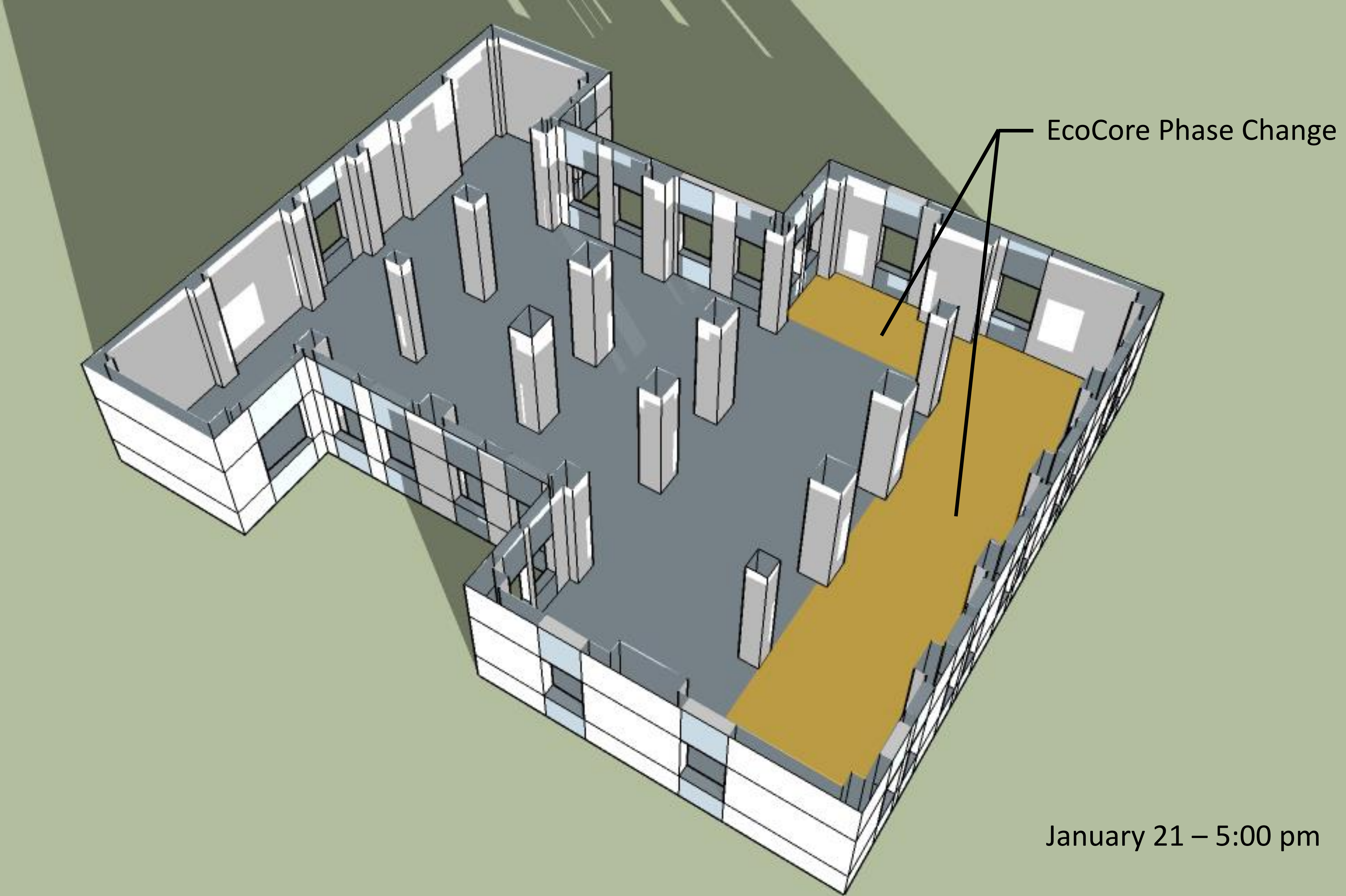

EcoCore Phase Change
January 21 – 1:00 pm



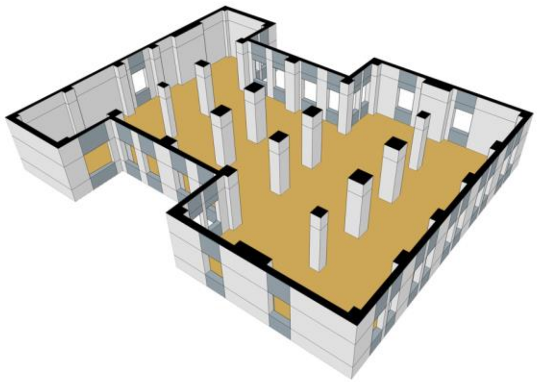
January 21 – 2:00 pm

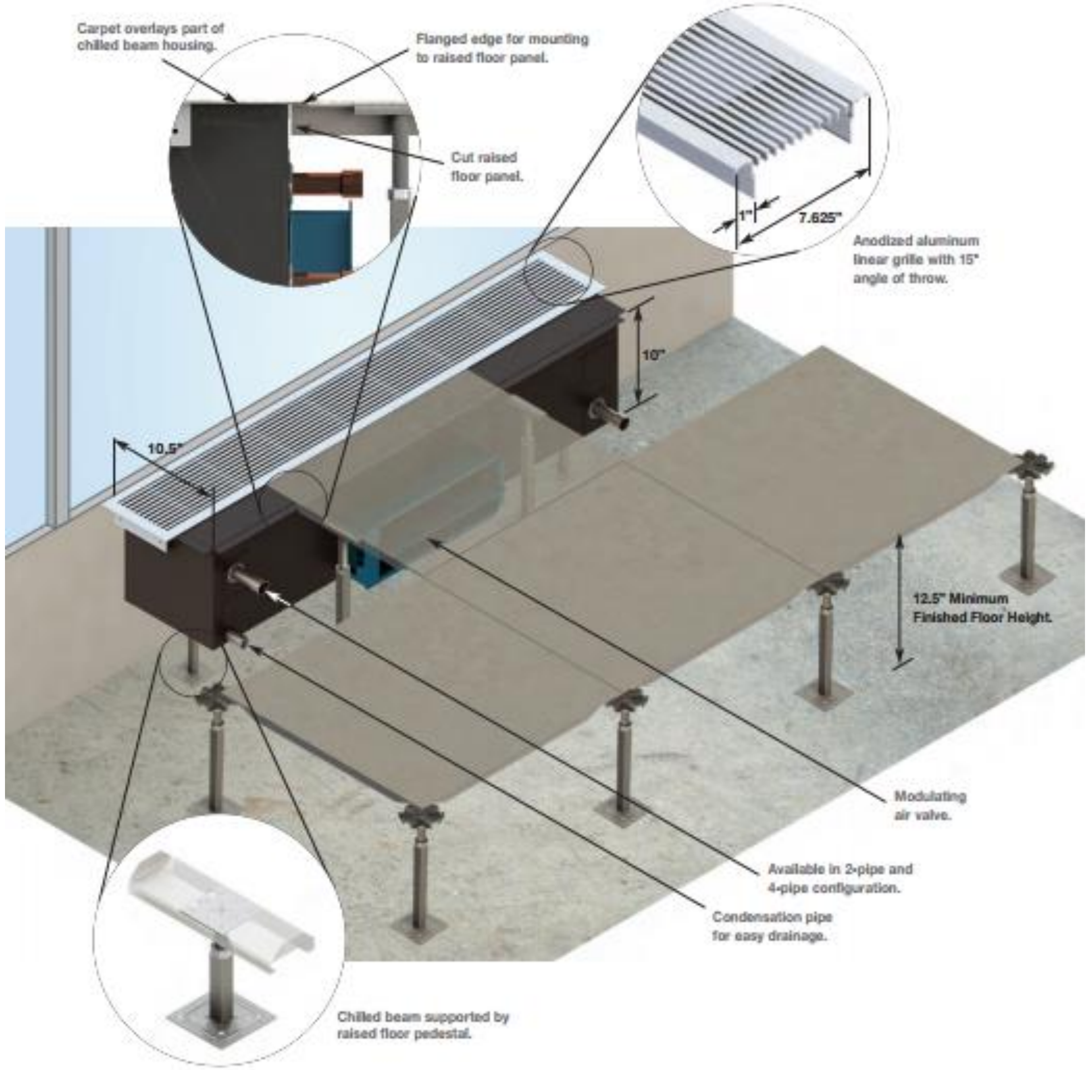

EcoCore Phase Change
January 21 – 3:00 pm


EcoCore Phase Change
January 21 – 4:00 pm


EcoCore Phase Change
January 21 – 5:00 pm

Floor Systems – Active Chilled Beams





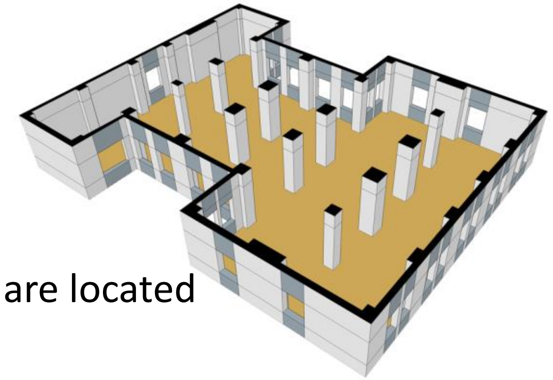
•Can be installed under continuous linear grilles along the perimeter or segmented only where needed.

•A reduced number of diffusers in the perimeter zone eliminates the need for equipment to be installed under floor panels.

•The elimination of the drop ceiling and the reduction in service distribution space for expanded daylighting and access to views.

Source: In-floor Active Chilled Beams. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

Floor Systems – Active Chilled Beams



The 2-Pipe model

A supply and return water connection are located on opposite ends of the chilled beam.

Hot and chilled water can be alternately passed through the beam

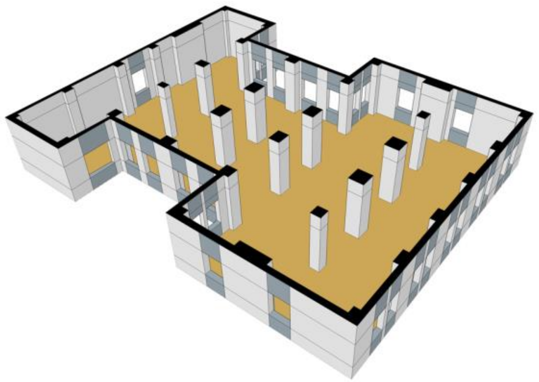
The 4-Pipe model

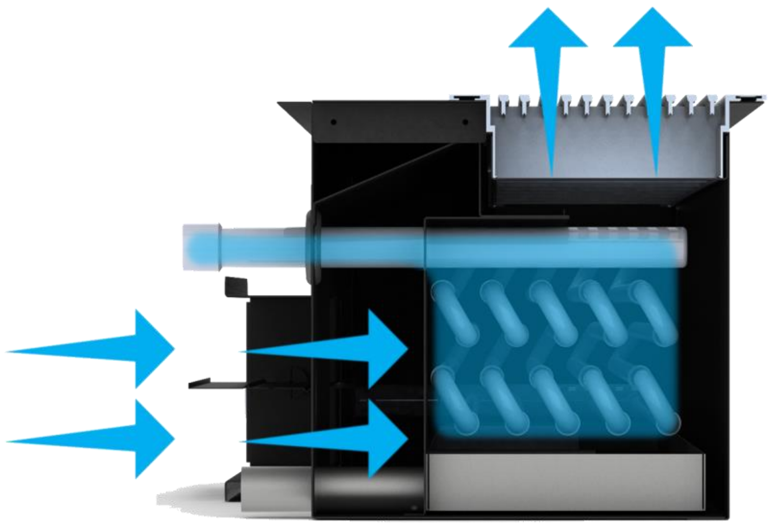
Two supply and return water connections are located on opposite ends of the chilled beam.

Hot and Chilled water can be simultaneously passed through the beams

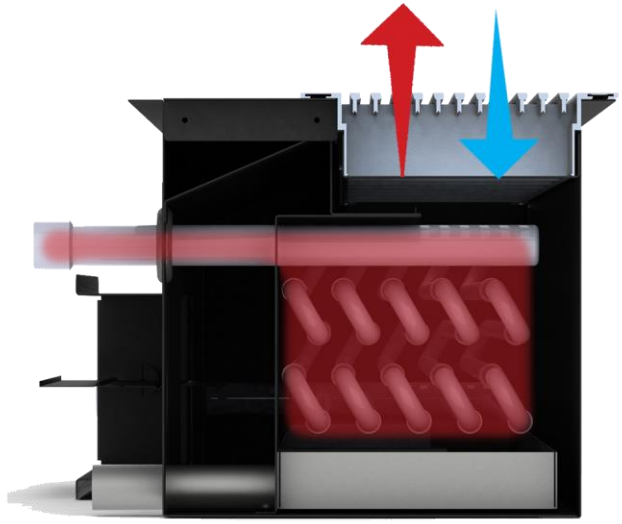
Source: In-floor Active Chilled Beams. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

Floor Systems - Active Chilled Beams





Chilled water flows through the coil and once the set point is reached, the system returns to suspend mode, closing the air and water valves

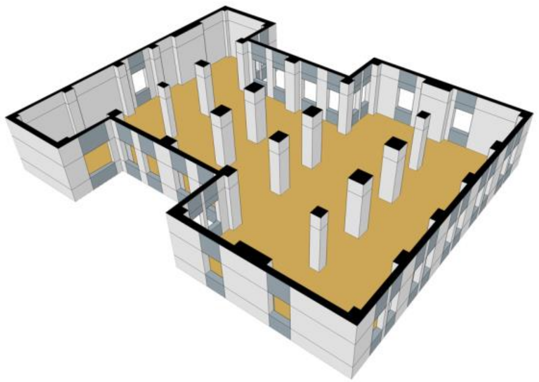


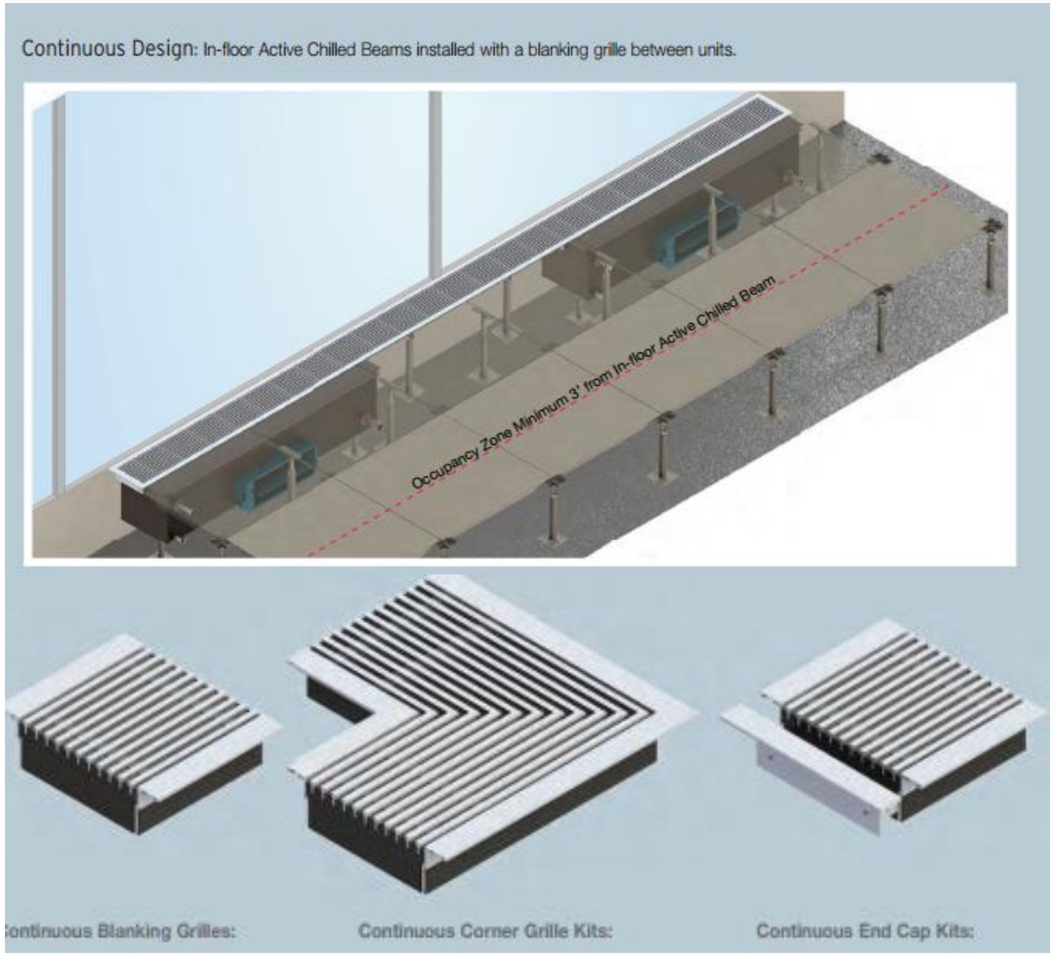
Hot water flows through the coil, air falls into the chilled beam where it is heated and convects out into the space

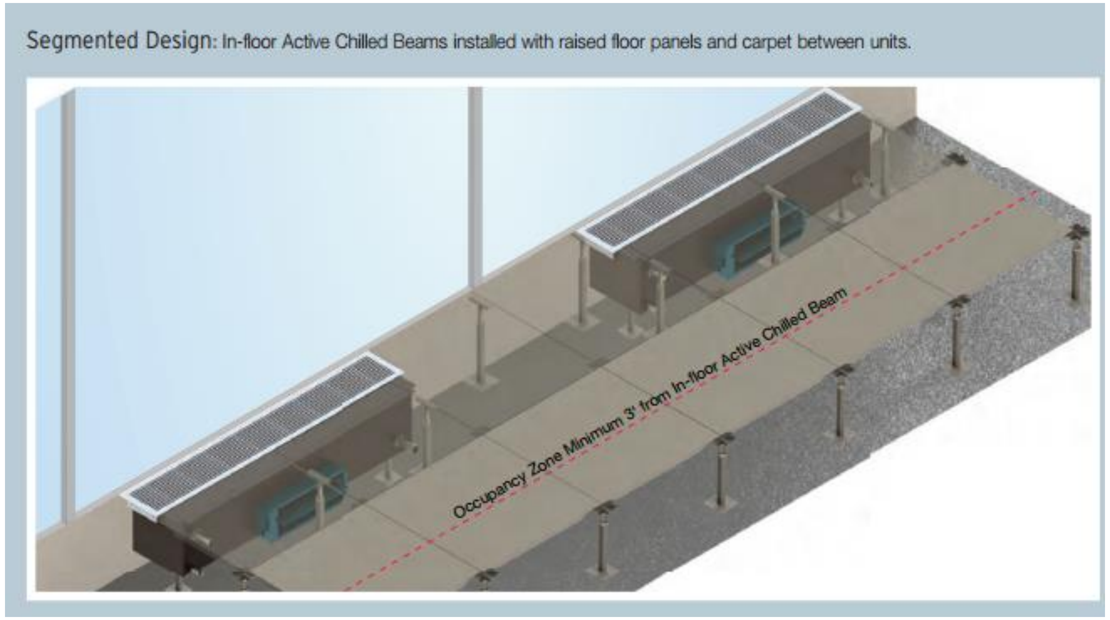
Source: In-floor Active Chilled Beams. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

Floor Systems – Active Chilled Beams

Grille Profile



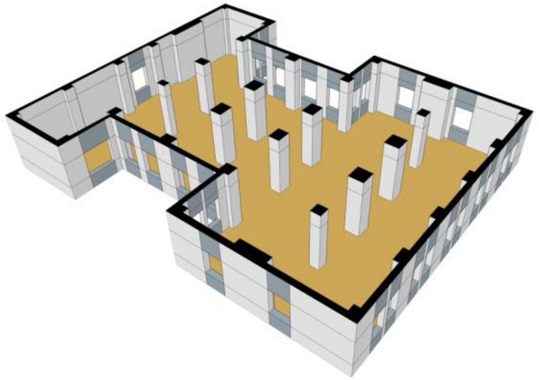




Source: In-floor Active Chilled Beams. Retrieved from *http://tateinc.com/commercial/underfloor-air-distribution/ecocore-phase-change-technology-access-floors*

Floor Systems - Active Chilled Beams

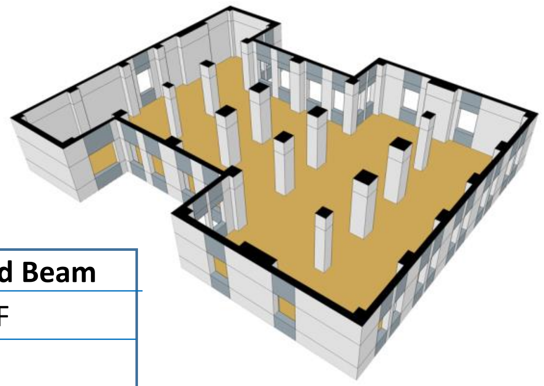
In-floor System Advantages



- There is little concern of damage from leaking water lines and latent loads producing condensate unlike ceiling based.
- Require little to no ductwork as it utilizes the benefits of the raised floor.
- Improved heating capacity, since it is designed to be directly under the perimeter of the building.

Floor Systems – Active Chilled Beams

In-floor System Energy Reduction

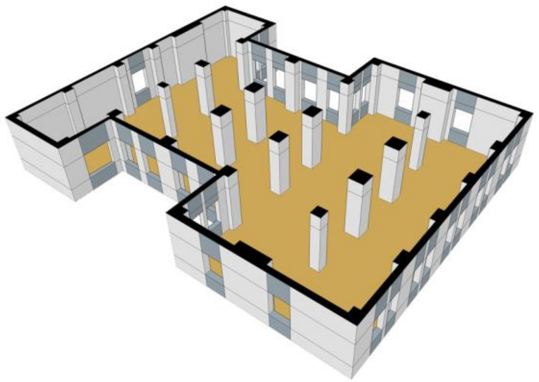


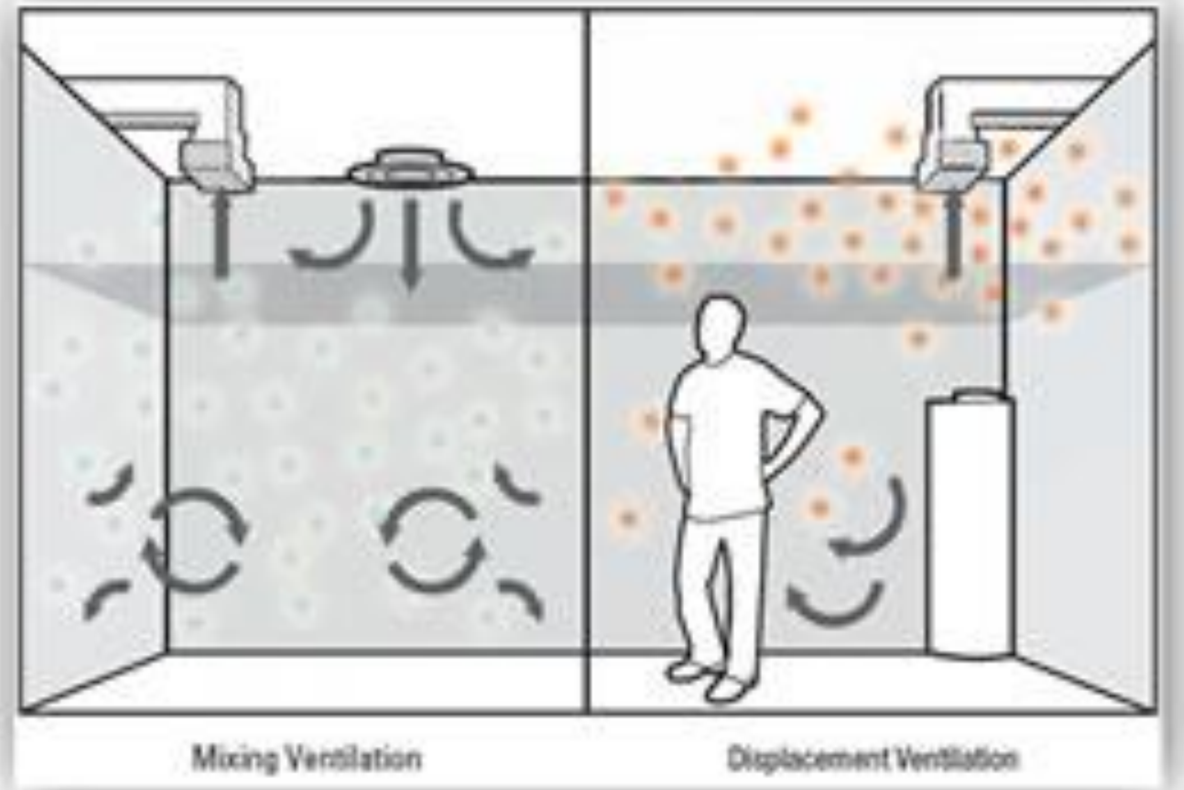
Typical Open Office Building Parameters		
-	Building length (ft)	78
-	Building width (ft)	60
-	Total Floorplate Area (ft2)	3842
A_p	12' Perimeter Area (ft2)	3312
L_p	Total Perimeter Length (ft)	276
T_{rm}	Room Condition	72F
C_e	Chilled Water kWhr/Ton	0.55
F_e	Fan kWhr/cfm	0.0003
h_s	Skin Load (btu/hr-lf)	150

		Typical FPTD	Chilled Beam
Perimeter Air			
T_{air}	Room Supply Air Temp (°F)	66F	55F
	Skin Load (btu/hr) (h_s x L_p)	108000	
	People Sensible Load (btu/hr) *(1.275 btu/hr-ft² x A)*	67187	
	Equipment Load (btu/hr) *(3 btu/hr-ft² x A)*	366474	
H_p	**Total Load (Btu/hr)**	541661	
Q_p	**Primary Air (CFM)** *(Hp / [1.08 x (T_{rm}-T_{air})])*	30156	16291
Perimeter Energy			
	Chilled Water kWhr *((H_p x C_e) / 12,000 Btu/hr)*		6.5
	FPTD Fan Energy kWhr *(F_e x Q_p)*	6.6	
E_p	**Total Perimeter kWhr**	6.6	6.5
Interior Air			
Q_i	**Total Interior Primary Air (CFM)** *(Given)*	11305	
Air Handler			
Q_t	**AHU Volume (CFM)** *(Q_p + Q_i)*	41461	27596
E_{ahu}	**AHU Fan kWhr** *(F_e x Q_t)*	10	5.7
Energy Analysis			
	Total kWhr *(E_p + E_{ahu})*	16.6	12.2
	Primary AHU CFM Reduction	43%	
	Floor Plate HVAC Energy Reduction	26%	

Note: Although perimeter supply air volume has been reduced by the lower supply air temperature, th
ventilation air provided to the perimeter zone. The Indoor Active Chilled Beam's supply air volume o

Floor Systems – Displacement Ventilation





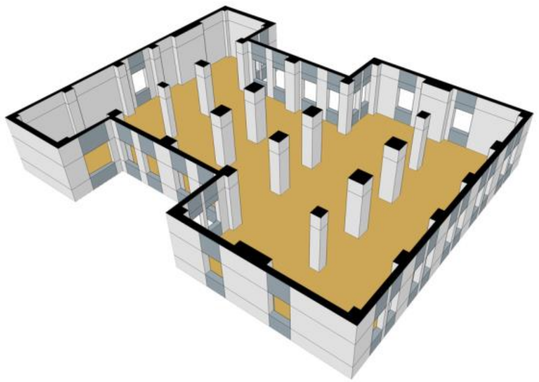
DV systems deliver cool air into the conditioned space at or near the floor level and return air at the ceiling level.

By utilizing the natural buoyancy of warm air and the thermal plumes generated by heat sources, cooler air is delivered from lower elevations.

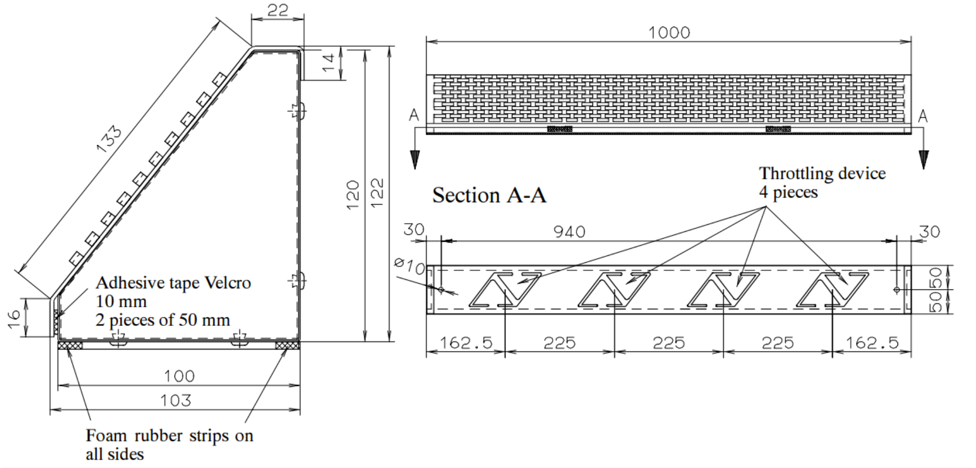
While similar, UFAD tends to encourage more mixing within the occupied zone.

The major practical differences are that in UFAD, air is supplied at a higher velocity through smaller-size supply outlets than in DV, and the supply outlets are usually controlled by the occupants

Floor Systems – LTG Displacement Air Diffuser



AIR TECH SYSTEMS



This product has been specially designed to be installed in raised floors.

The supply air is introduced into the room at low velocity through a perforated panel.

The air is spread evenly as a result of its perforated surface

It feeds fresh air while removing thermal or pollution loads from occupied spaces in a precise and comfortable manner.

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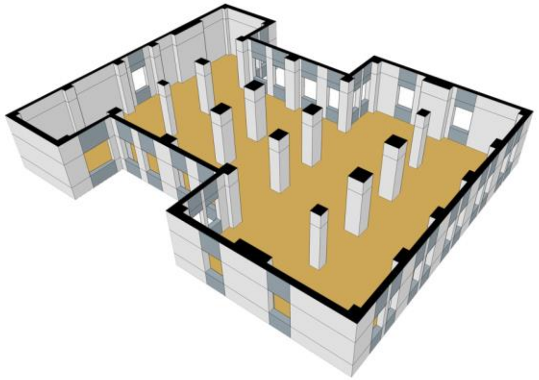
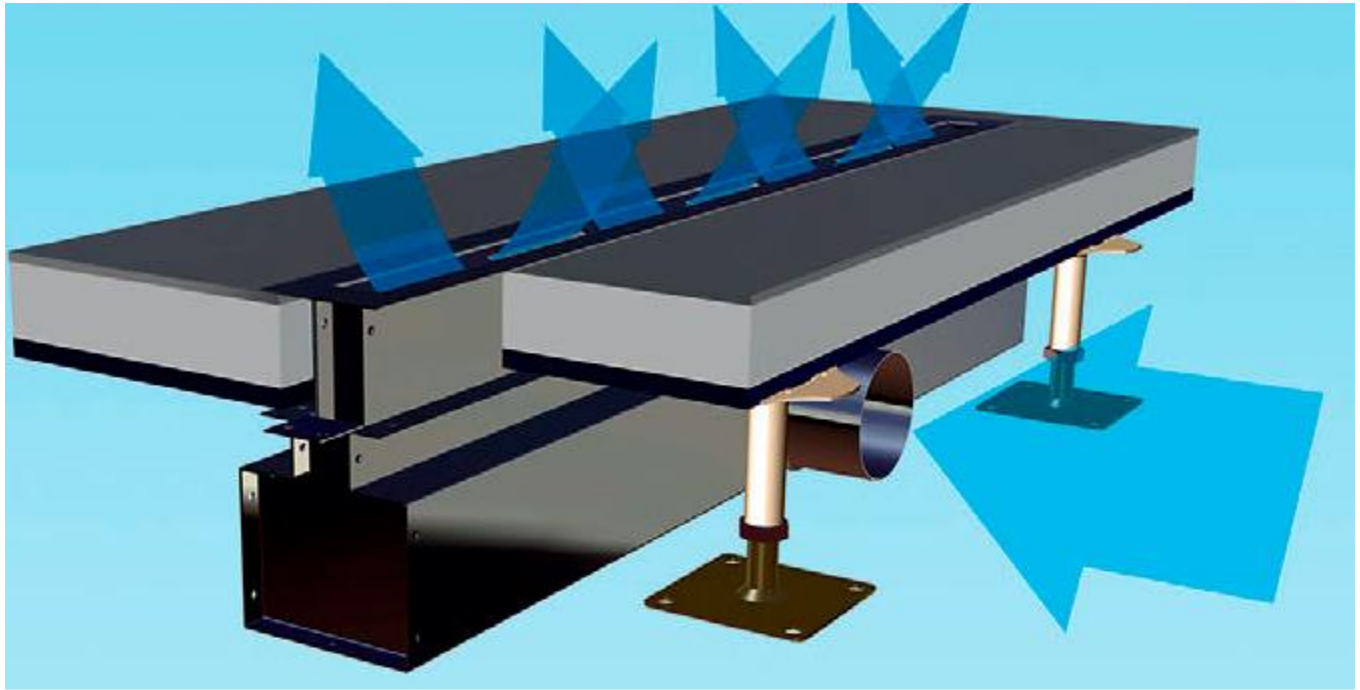
Source: LTG Aktiengesellschaft Floor Level air diffuser Type BLQ. Retrieved from *http://www.mapuk.com/downloads/BLQ_Literature.pdf*

Floor Systems – LTG Displacement Air

Displacement Air Diffuser





In the zone close to the diffuser,

A turbulent mixed airflow ensures rapid reduction of air speed and quick heating of the air jets.

Low--turbulence displacement air flow is then formed within about one meter from the diffuser that directs the supply air into the room along the floor where it rises over load areas (occupants, appliances)

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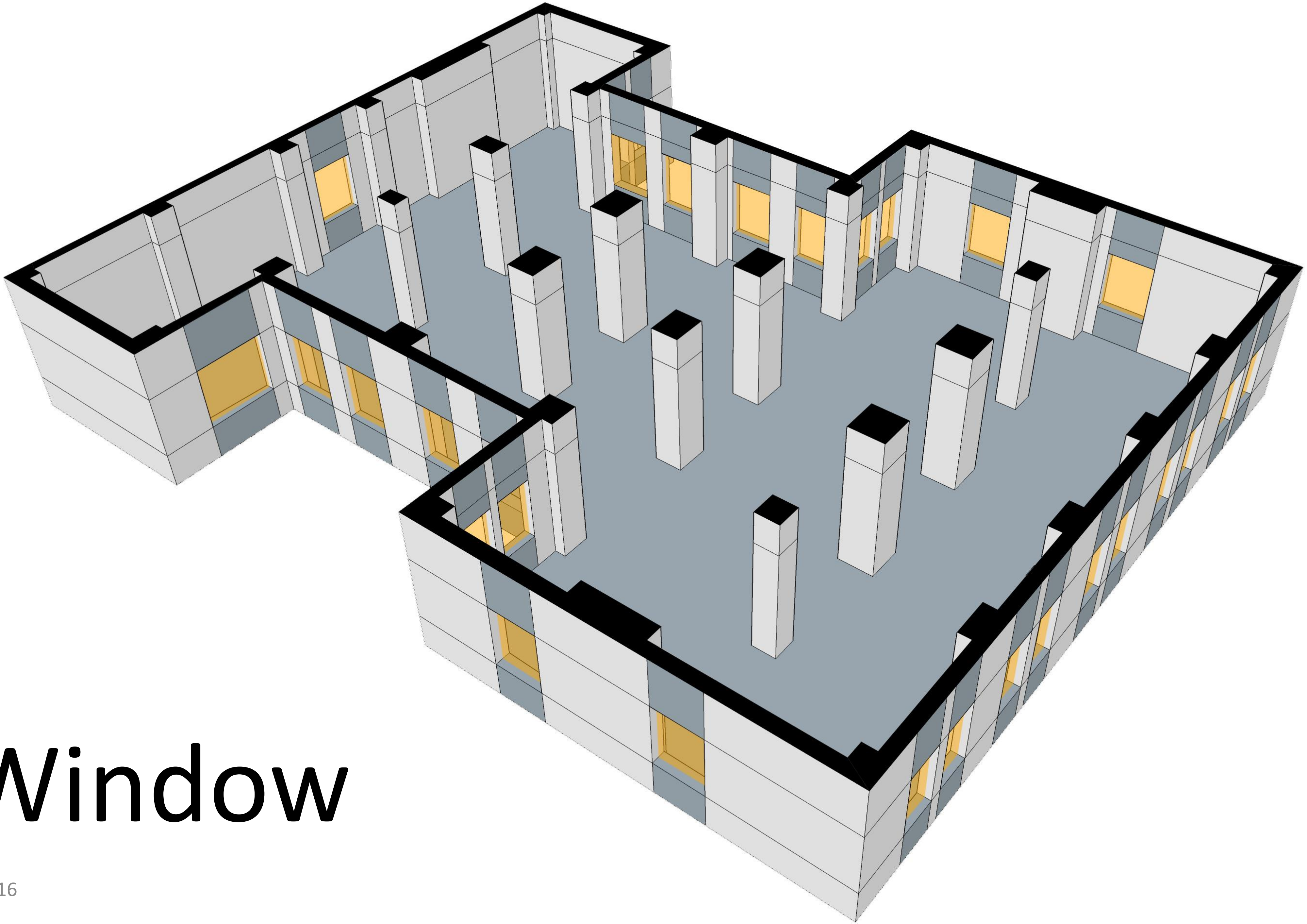
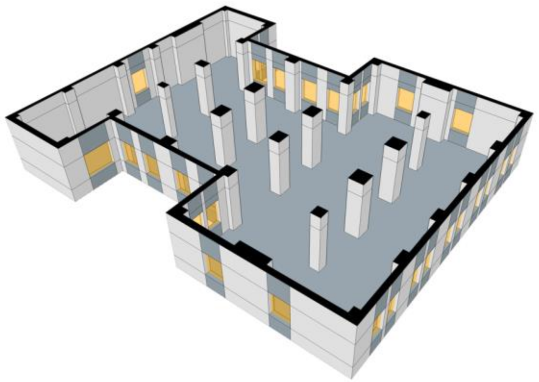
Source: LTG Aktiengesellschaft Floor Level air diffuser Type BLQ. Retrieved from *http://www.mapuk.com/downloads/BLQ_Literature.pdf*



Window

Window Systems – Active Skin

Triple Layer Control



Bullitt Center in Seattle, WA

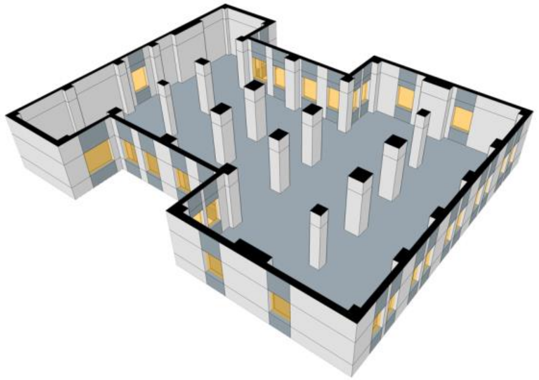
Windows designed by Shuco in Germany, manufactured in Seattle.

Exterior blinds by Warema. Self-supporting and controlled by photo-sensors.

Bullitt Center. (2016). *Bullitt Center*. Retrieved February 14, 2016, from Building: http://www.bullittcenter.org/building/

Window Systems – Active Skin

Layer 1 – Exterior Shading



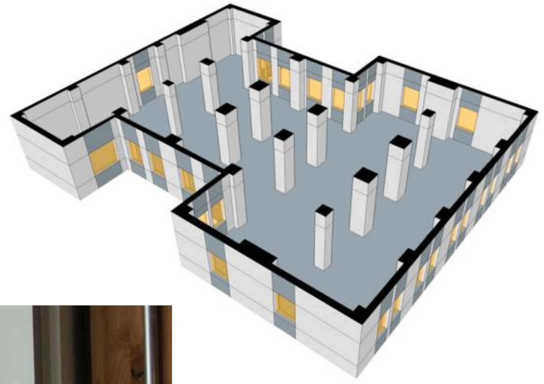
Control ventilation, daylight, view, and glare independently. Semi-autonomous through photo sensors and ability to control remotely.

Self-supporting blinds do not require intensive modification of existing facades.

Bullitt Center. (2016). *Bullitt Center*. Retrieved February 14, 2016, from Building: http://www.bullittcenter.org/building/

Window Systems – Active Skin

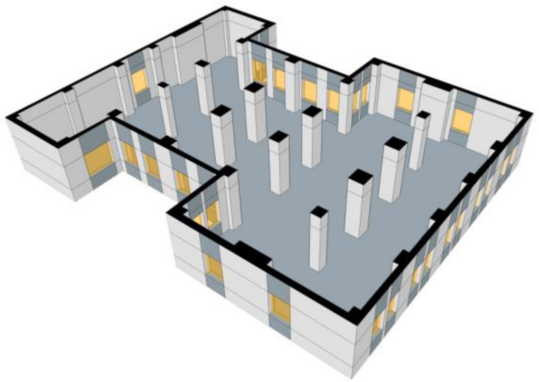
Layer 2 – Operable Windows



Bullitt Center. (2016). *Bullitt Center*. Retrieved February 14, 2016, from Building: http://www.bullittcenter.org/building/

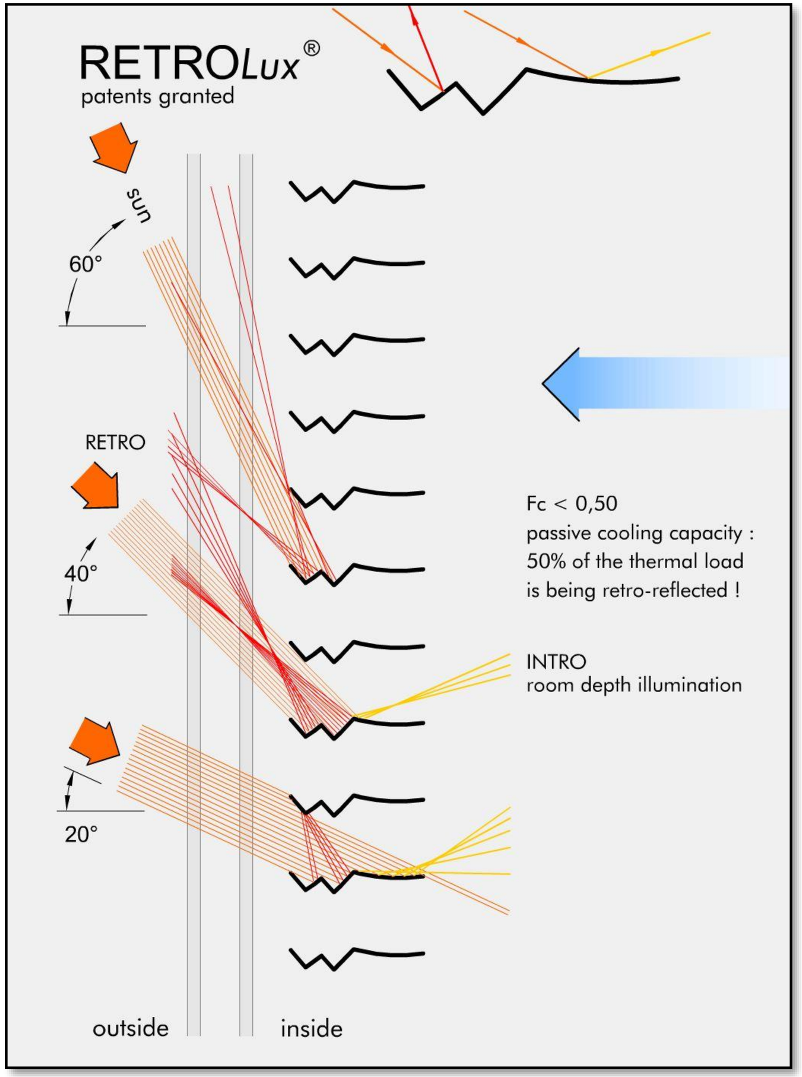
Window Systems – Active Skin

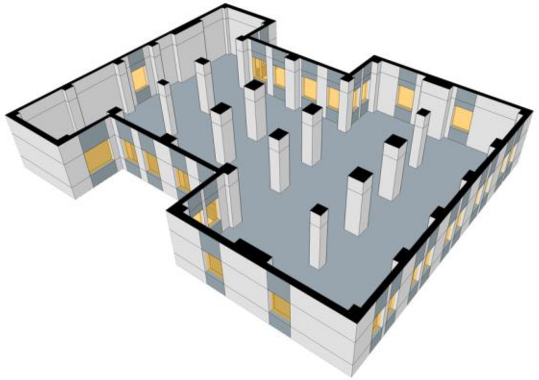
Layer 3 – Internal Shading



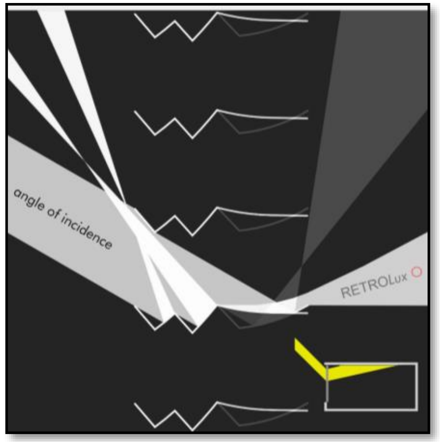
Bullitt Center. (2016). *Bullitt Center*. Retrieved February 14, 2016, from Building: http://www.bullittcenter.org/building/

Window Systems – RetroSolar





- The ‘W’ shaped solar reflector of Retrosolar blind is designed in such a way that it reflect the incident solar radiation back by 70-90%
- The extension on the interior serves as the light shelf which invites the rays during winter time when the sun is low.
- 20’ light extension into building interior
- 32% light energy saved



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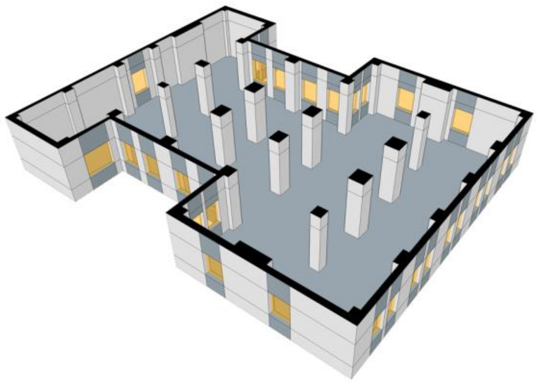
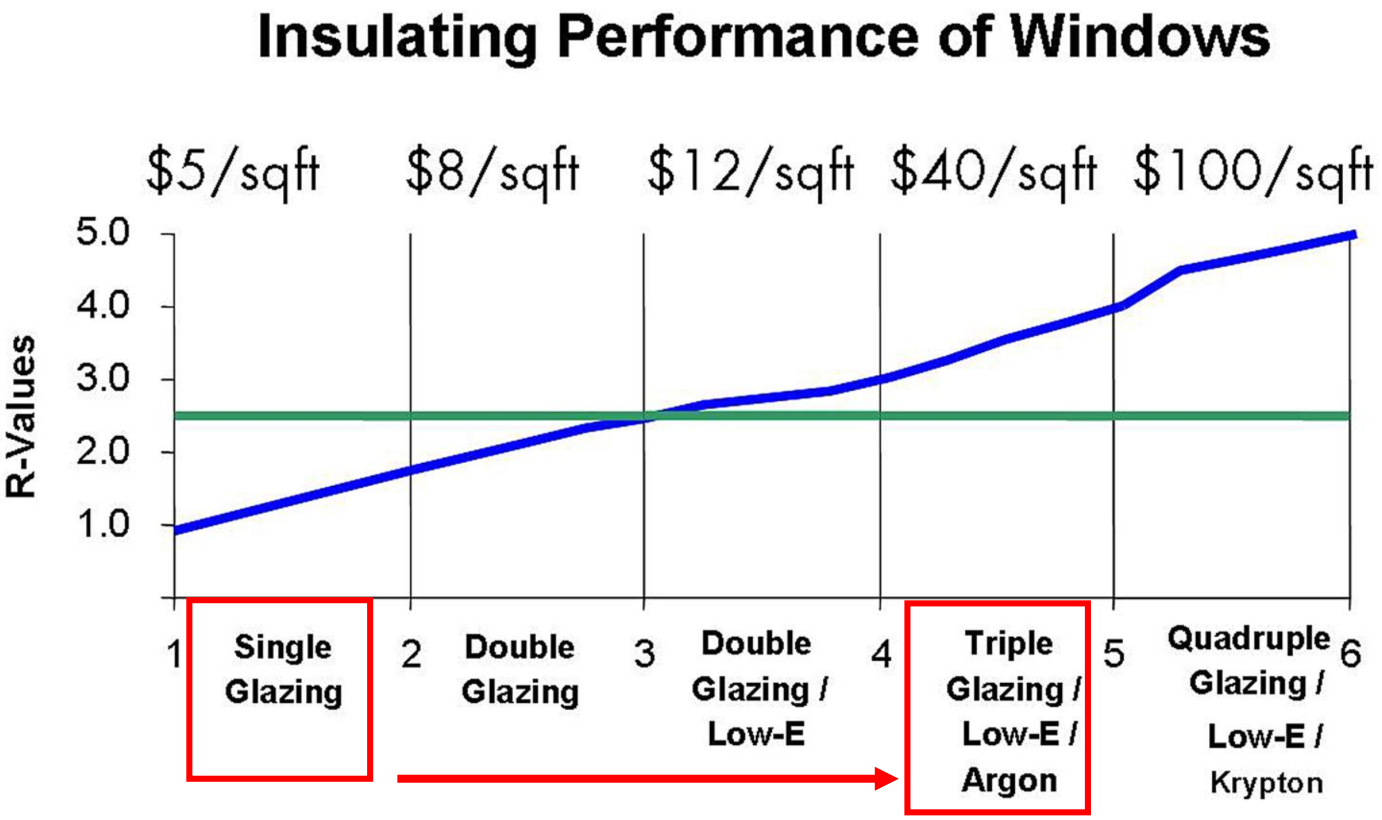
Source: RetroSolar. Retrieved from *http://www.retrosolar.de/gb/company_gb.html*

Window Systems – Triple Glazing





https://soleradaylighting.files.wordpress.com/2010/06/non_linear_cost2.jpg

Heat Loss Calculation

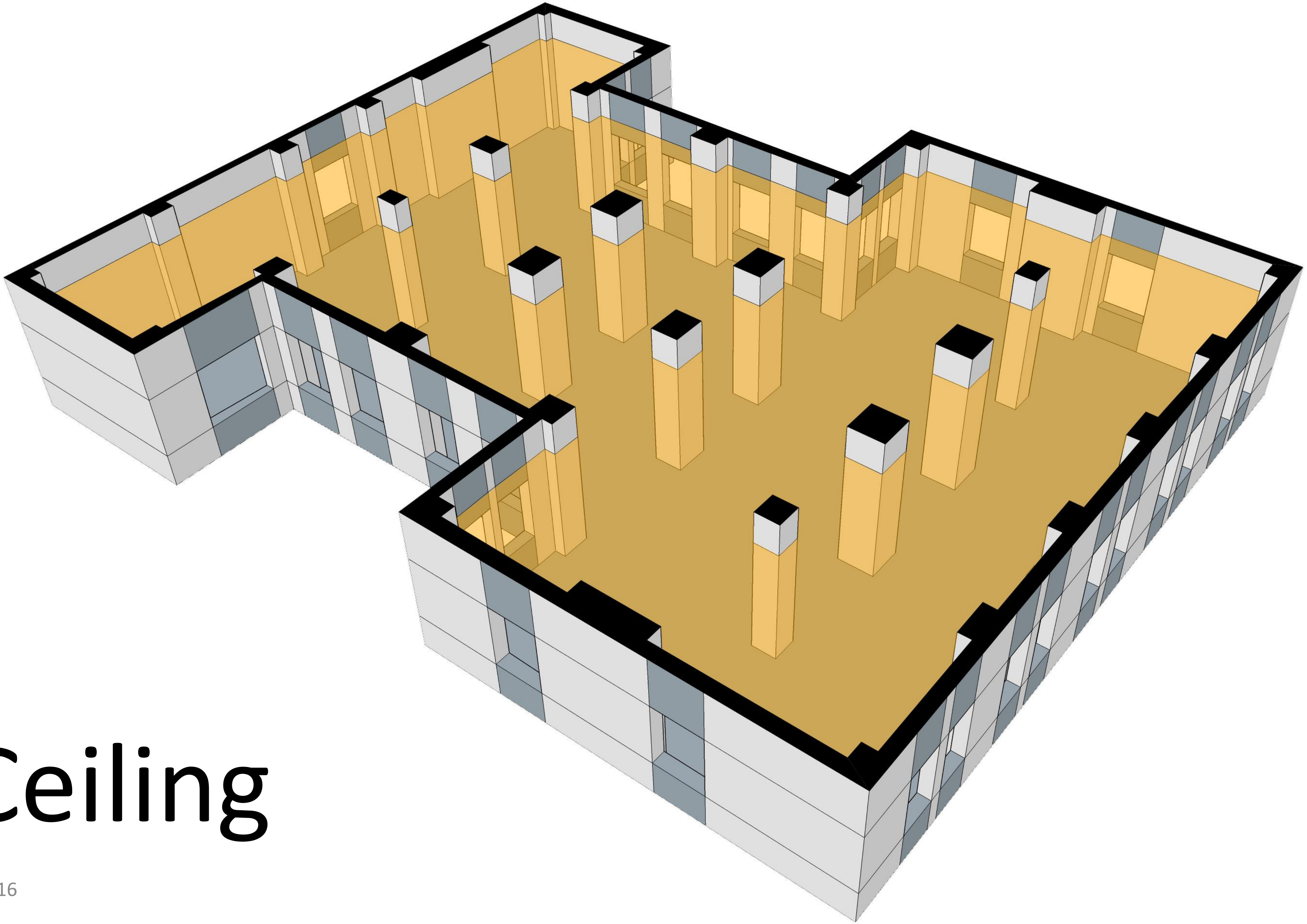
Current Windows

uA▲T = 1 X 614 X 60F
= 358 kbtu/yr

After retrofit:

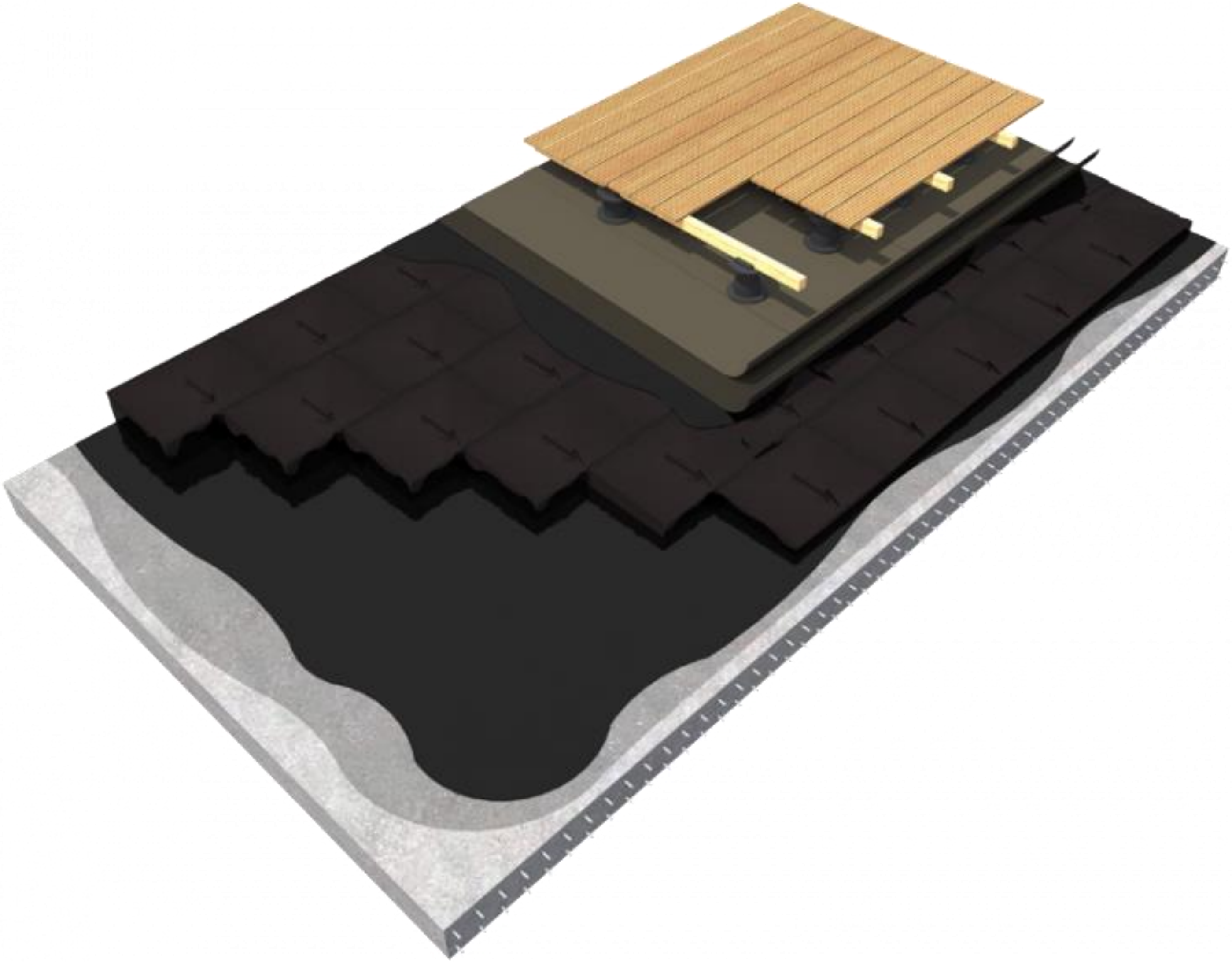
uA▲T = 0.25 X 614 X 60F
= 92 kbtu/yr

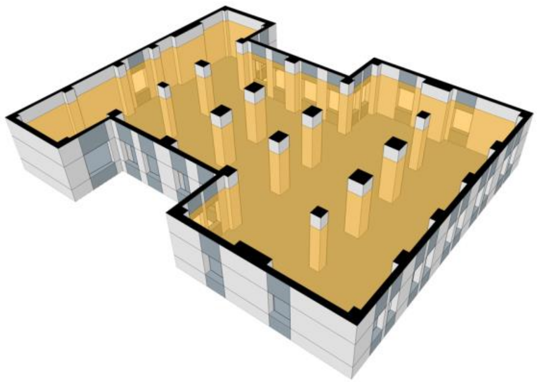
Heat Loss through the windows
: **74% Reduction**



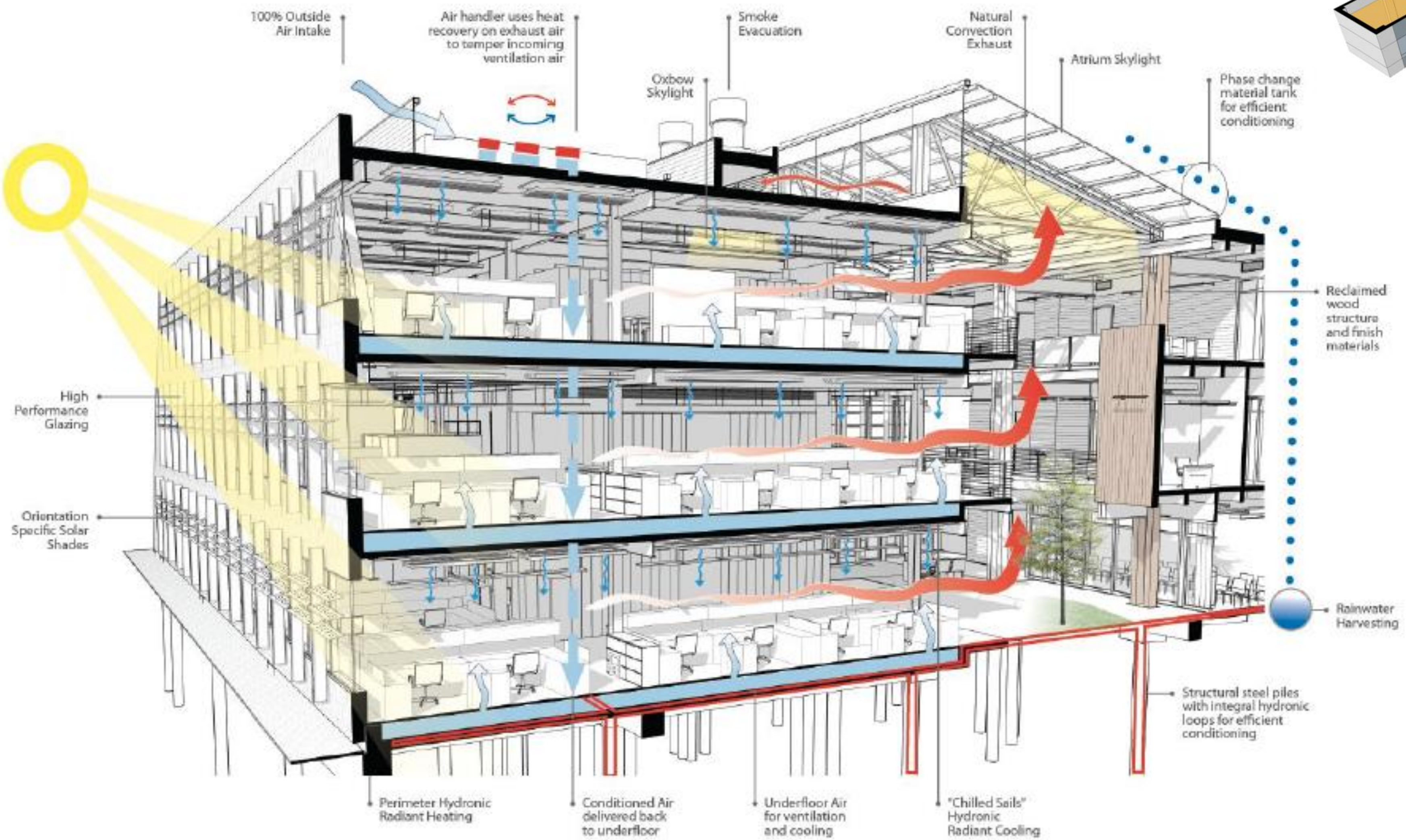
Ceiling

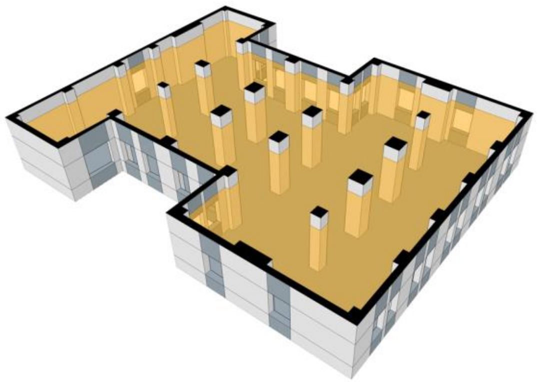
Ceiling Systems – Foamglas®





Ceiling Systems – Passive Chilled Sail

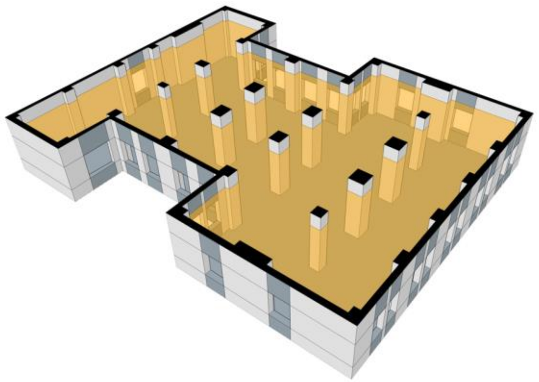


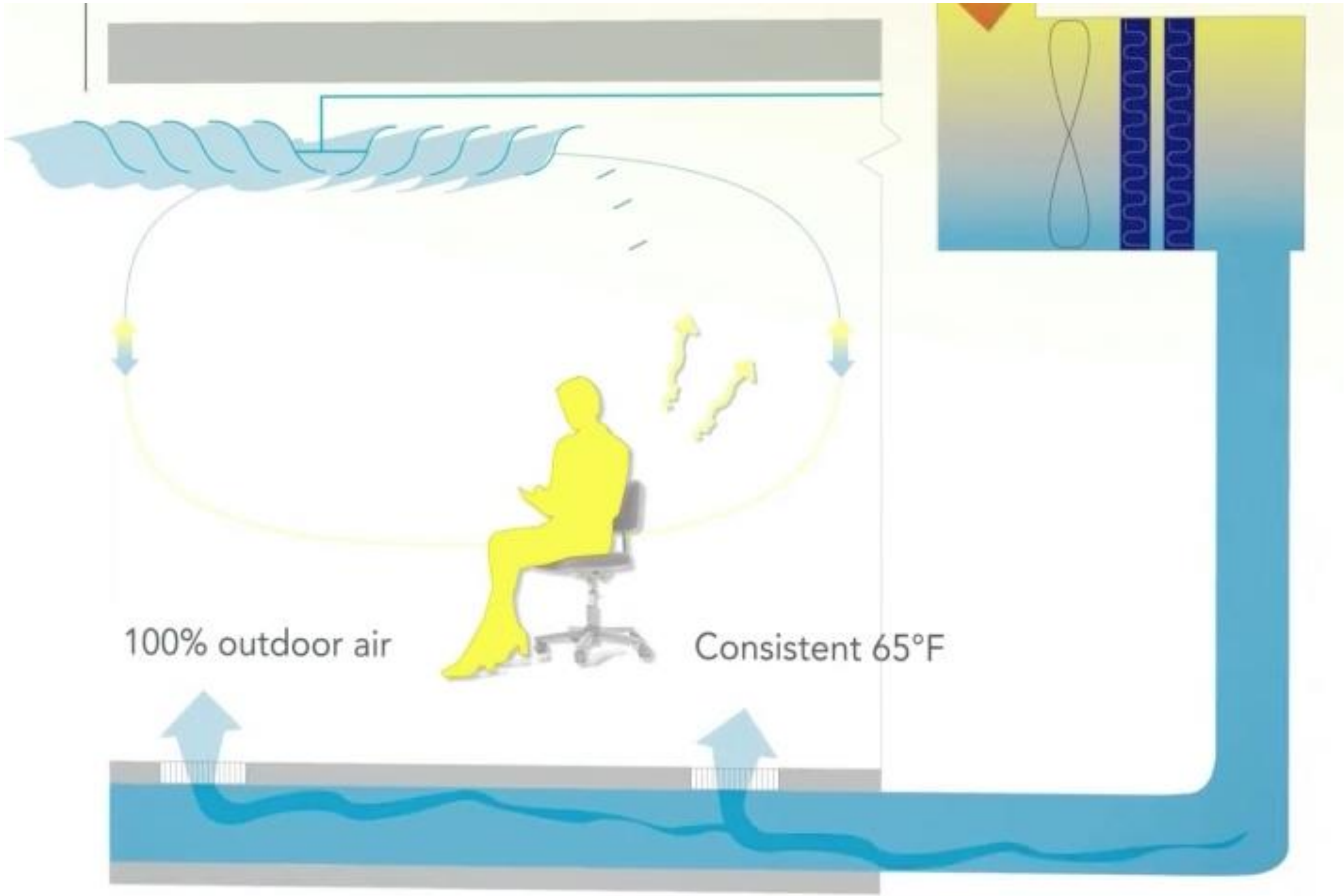


National Institute of Building Sciences. (2016). *Federal Center South Bluilding 1202*. Retrieved February 12, 2016, from Whole Building Design Guide: https://www.wbdg.org/references/cs_fcsb1202.php

Ceiling Systems – Passive Chilled Sail

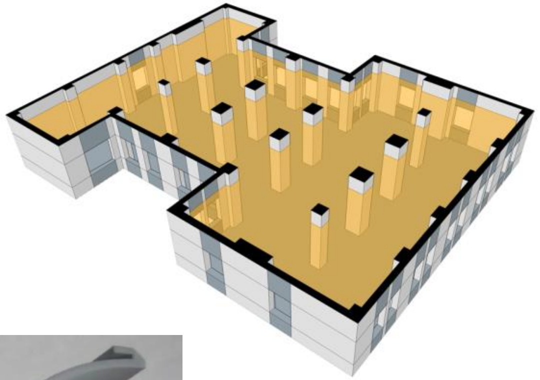
Human Benefit – Comfort and Health





National Institute of Building Sciences. (2016). *Federal Center South Bluilding 1202*. Retrieved February 12, 2016, from Whole Building Design Guide: https://www.wbdg.org/references/cs_fcsb1202.php

Ceiling Systems – Passive Chilled Sail

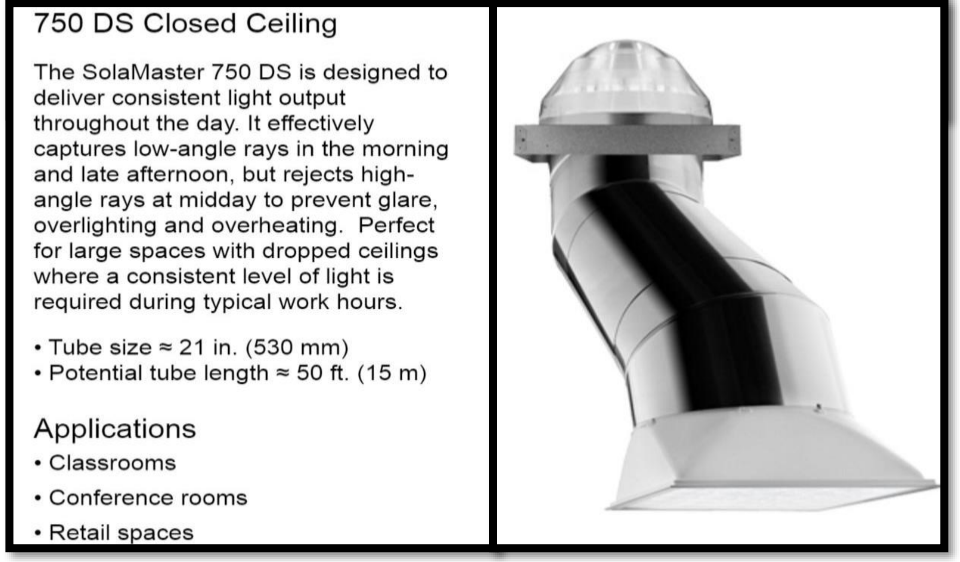


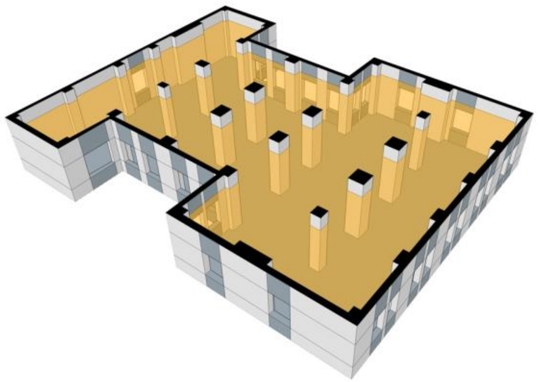
Human Benefit – Comfort and Health

- Chilled Sails are designed to provide radiant and convective cooling and heating.
- Silent compared to air systems
- Reduces spread of illness and cross-contamination
- Duct free (no installation or cleaning), reduced maintenance cost.
- Low-profile, easy to install, easy to disguise.

National Institute of Building Sciences. (2016). *Federal Center South Bluilding 1202*. Retrieved February 12, 2016, from Whole Building Design Guide: https://www.wbdg.org/references/cs_fcsb1202.php

Ceiling Systems – SolaTube



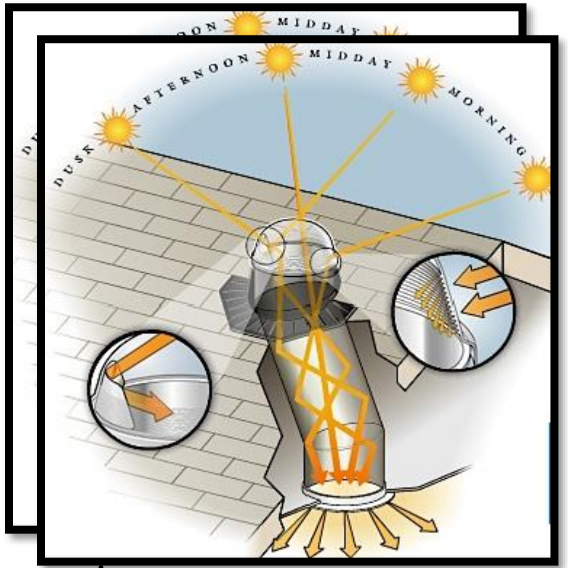


High-performance tubular daylighting devices.

Bring daylight into deeper spaces

Sometimes called “tubular skylights,” “light tubes,” “sun pipes,” and even “light tunnels”.

It can be an interesting aesthetic element In the form of a coffered ceiling



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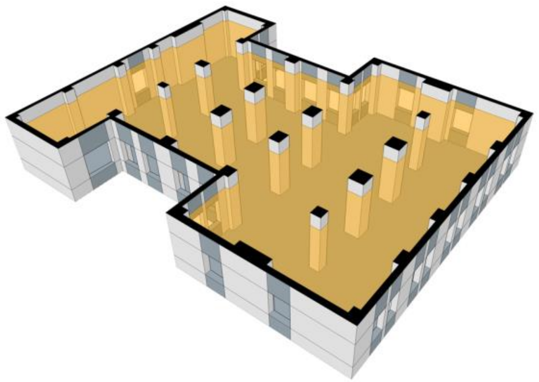
Source : Solatube. Retrieved from *http://thingelstad.com/wp-content/thingelstad/uploads/2007/05/solatube1.jpg*
Solatube. Retrieved from *http://international.solatube.com/mr/commercial/solamaster#models*

Ceiling Systems – SolaTube

Advanced Version – SolaTube Smart LED Primary System



As light levels begin to dim, its "smart" sensors activate the LED lighting.

CAPTURE

Raybender® 3000 Technology

A patented daylight-capturing dome lens that:

- Redirects low-angle sunlight for maximum light capture
- Rejects overpowering summer midday sunlight
- Provides consistent daylighting throughout the day

LightTracker™ Reflector

An innovative in-dome reflector that:

- Redirects low-angle winter sunlight for maximum light capture
- Increases light input for greater light output
- Delivers unsurpassed year-round performance

TRANSFER

Spectralight® Infinity Tubing

Tubing made of the world's most reflective material that:

- Delivers 99.7% * specular reflectivity for maximum sunlight transfer
- Provides the purest color rendition possible so colors are truer, brighter
- Allows for run lengths over 20 feet to deliver sunlight to lower floors

DELIVER

SunSense Technology

A patented control center that:

- Continually assesses light levels and determines when supplemental light is needed
- Automatically triggers LEDs to provide optimal light output
- Seamlessly transitions from waning daylight to radiant LED light

Upto 94% Lighting Energy Savings

Smart LED Primary Unit

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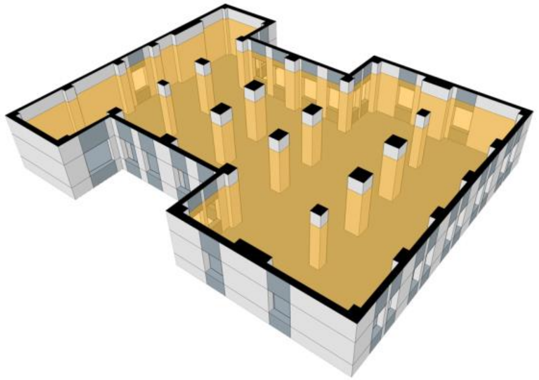
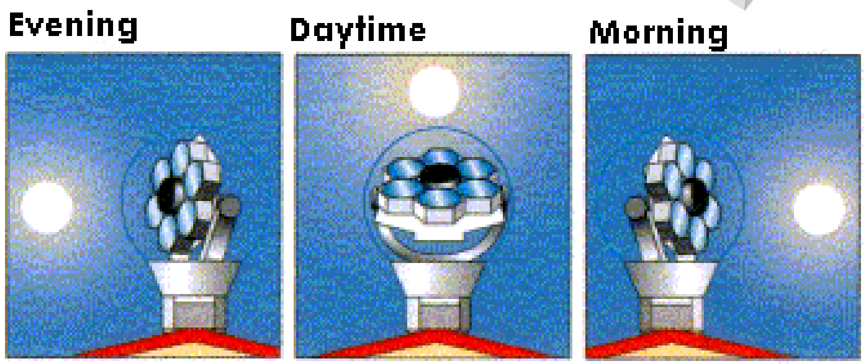
Ceiling Systems – Himawari Solar Lighting

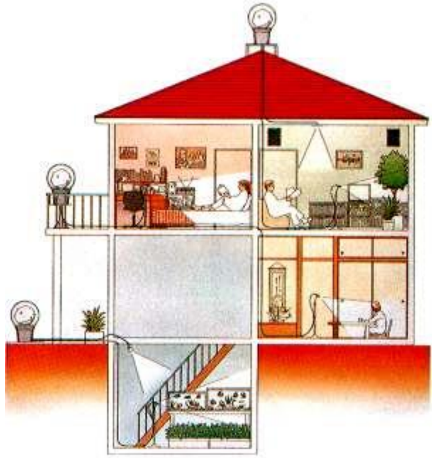


Himawari transmits sunlight through optical fiber to wherever it's needed, eliminating almost all ultraviolet and some infrared rays.

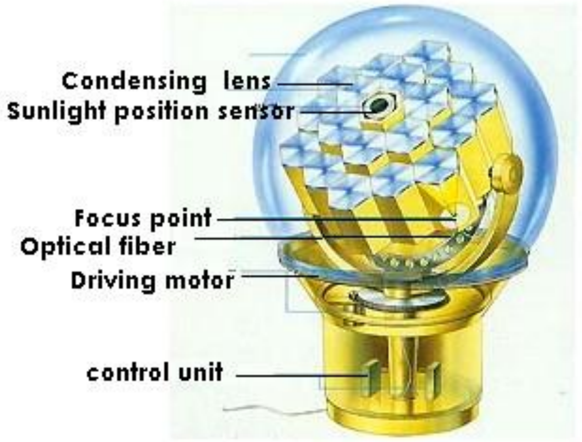
Himawari supplies value-added sunlight to buildings in spots where daylight does not reach through windows.



http://www.himawari-net.co.jp/e_page-index01.html



Type	Number of lenses	Lens size(mm)	Light receiving area(cm2)	Dome diameter (mm)	Height (mm)	Weight (kg)	Number of cables	Total luminous flux(lm)	Electric power supply	Power consumption
XD-100S /36AS	36	95	2,552	1,000	1,475	88	6	11,520	AC85V～264V	5W
XD-50S /12AS	12	95	851	520	810	14	2	3,840	AC85V～264V	2W



spatial thermal air quality acoustical visual building integrity

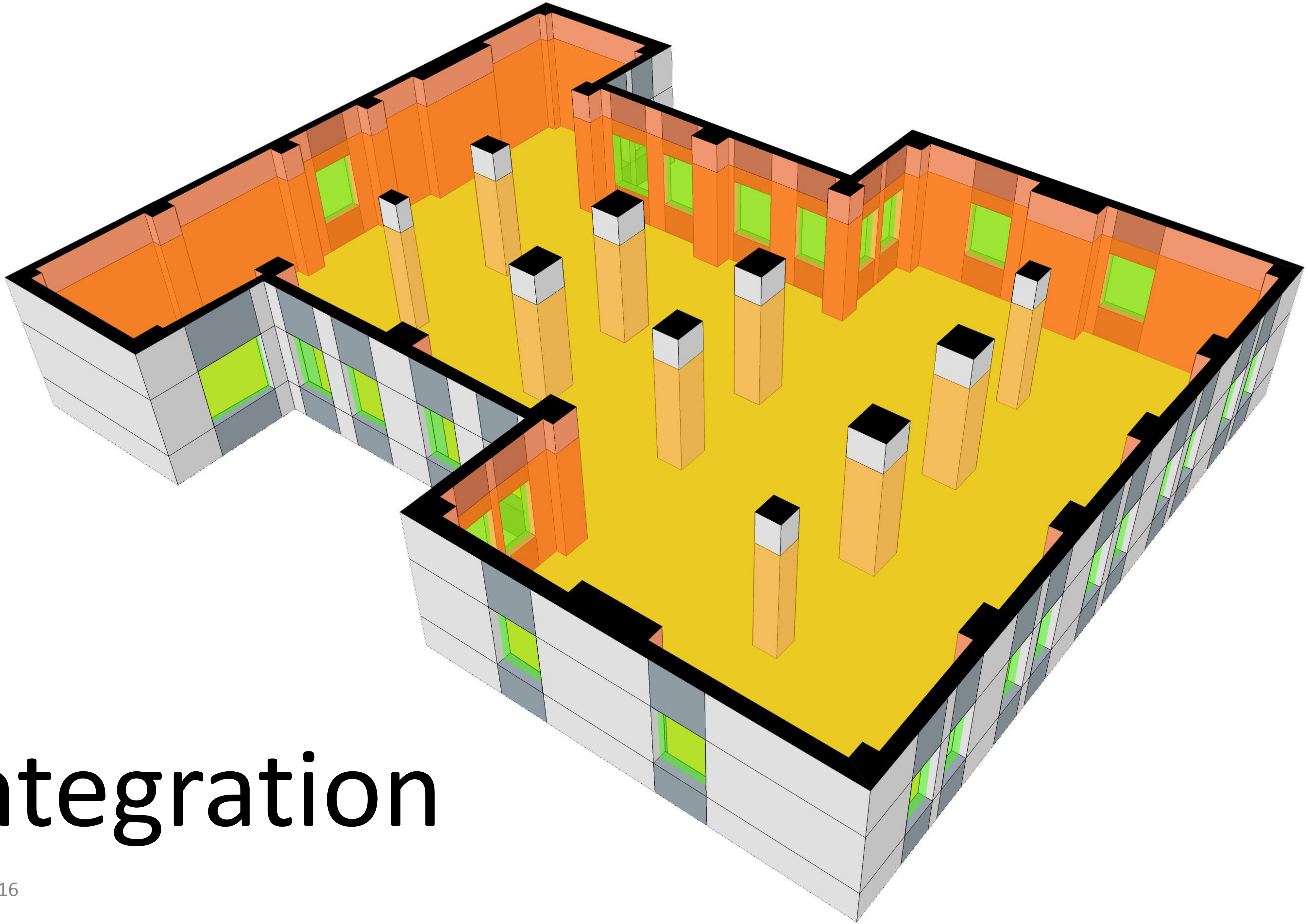
Source: Himawari Solar Lighting System. Retrieved *from http://www.himawari-net.co.jp/e_page04.htm*

Building Investment Decision Support for Six Energy Efficient Lighting Retrofits

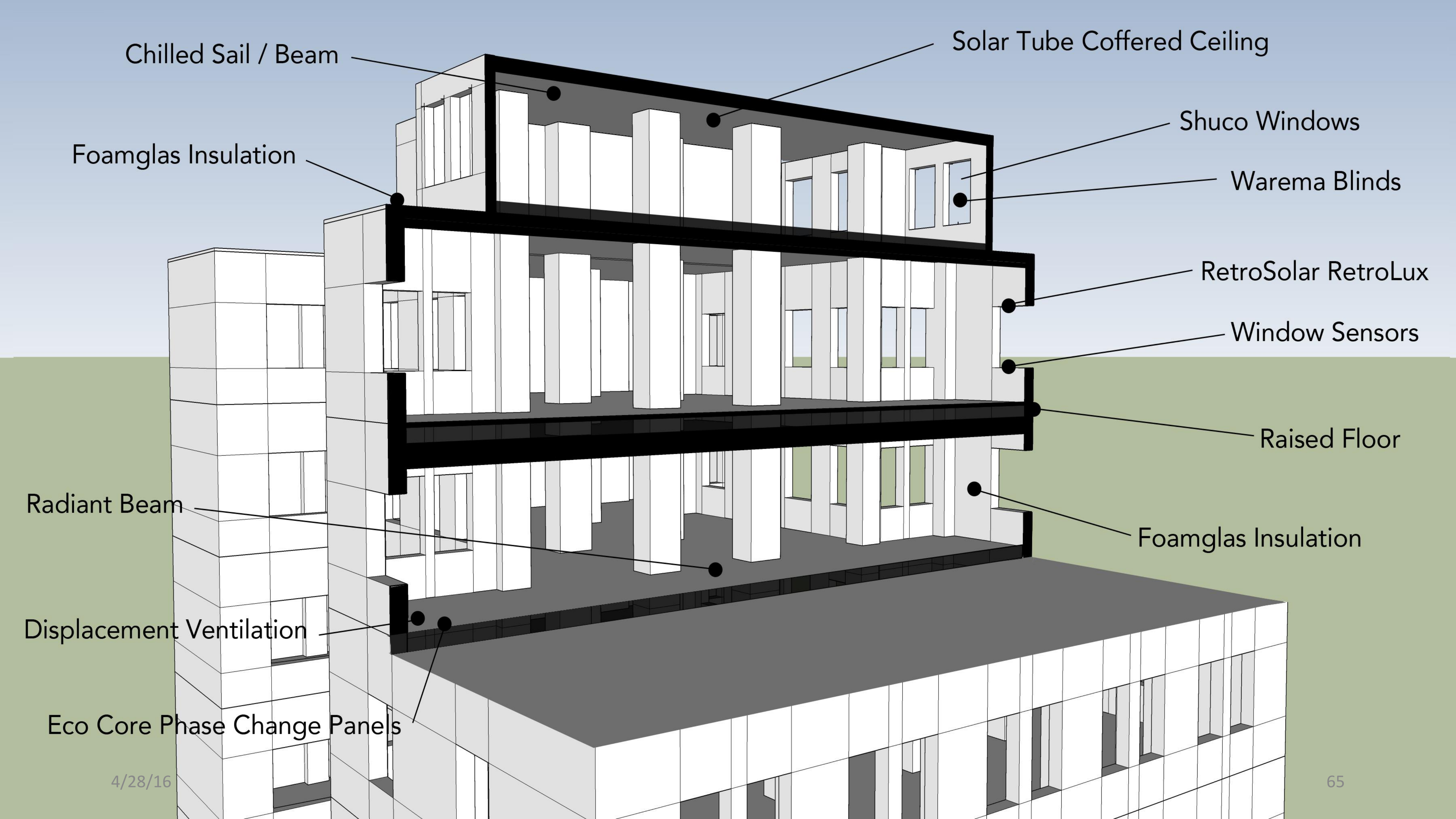
Recommendations for Triple Bottom Line Savings

Recommendation		Light Energy Saved
1 **Install occupancy/vacancy sensors for closed spaces.** Savings: Economic ROI = 45% Environmental ROI = 59%		13%
2 **Install daylight harvesting for perimeter lights.** Savings: Economic ROI = 21% Environmental ROI = 28% Equity = 385%		30%
3 **Lower task-Ambient light levels and add task lights.** Savings: Economic ROI = 37% Environmental ROI = 45% Equity = 146%		40%
4 **Use blinds effectively for daylight, shade and glare control as well as for heat exchange control at night.** Savings: Economic ROI = 17% Environmental ROI = 22% Equity = 202%		32%
5 **Install individually addressable high performance fixtures with automation system.** Savings: Economic ROI = 15% Environmental ROI = 19% Equity = 238%		65%
6 **Install “vertically integrated” LED light fixtures (lamp, ballast, and fixture) plus add-ons for dimming and IP controlling.** Savings: Economic ROI = 18% Environmental ROI = 22% Equity = 289%		85%

Source : Loftness, V., Cochran, E., & Srivastava, R. (February 2013). *Building Investment Decision Support for Energy Efficient Lighting Retrofits* (Rep.). Pittsburgh, PA: Center for Building Performance and Diagnostics, Carnegie Mellon University



Integration


Chilled Sail / Beam
Solar Tube Coffered Ceiling
Shuco Windows
Foamglas Insulation
Warema Blinds
RetroSolar RetroLux
Window Sensors
Raised Floor
Radiant Beam
Foamglas Insulation
Displacement Ventilation
Eco Core Phase Change Panels

Systems Integration – Total Performance

Spatial

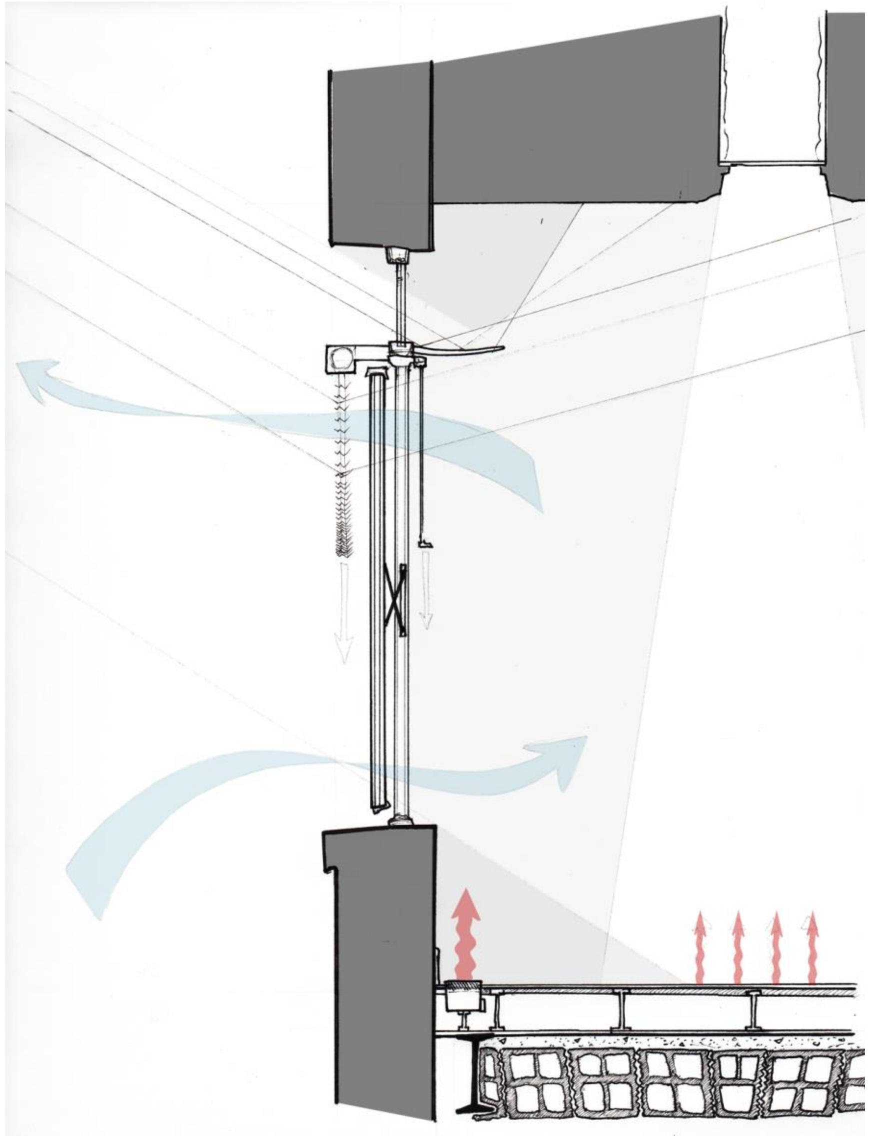
- No plenum, increased floor-to-ceiling height
- Sub-floor conduit, raceways, and HVAC management

Thermal

- + R-7 to exterior assemblies
- 41% reduction in heat loss through walls
- 74% reduction in heat loss through windows
- Reduced solar heat gain through windows
- Passive heat and load balancing through phase change

Air Quality

- Non-toxic, zero off-gassing insulation
- Natural Ventilation
- Healthier breathing air through displacement ventilation



Systems Integration – Total Performance

Acoustical

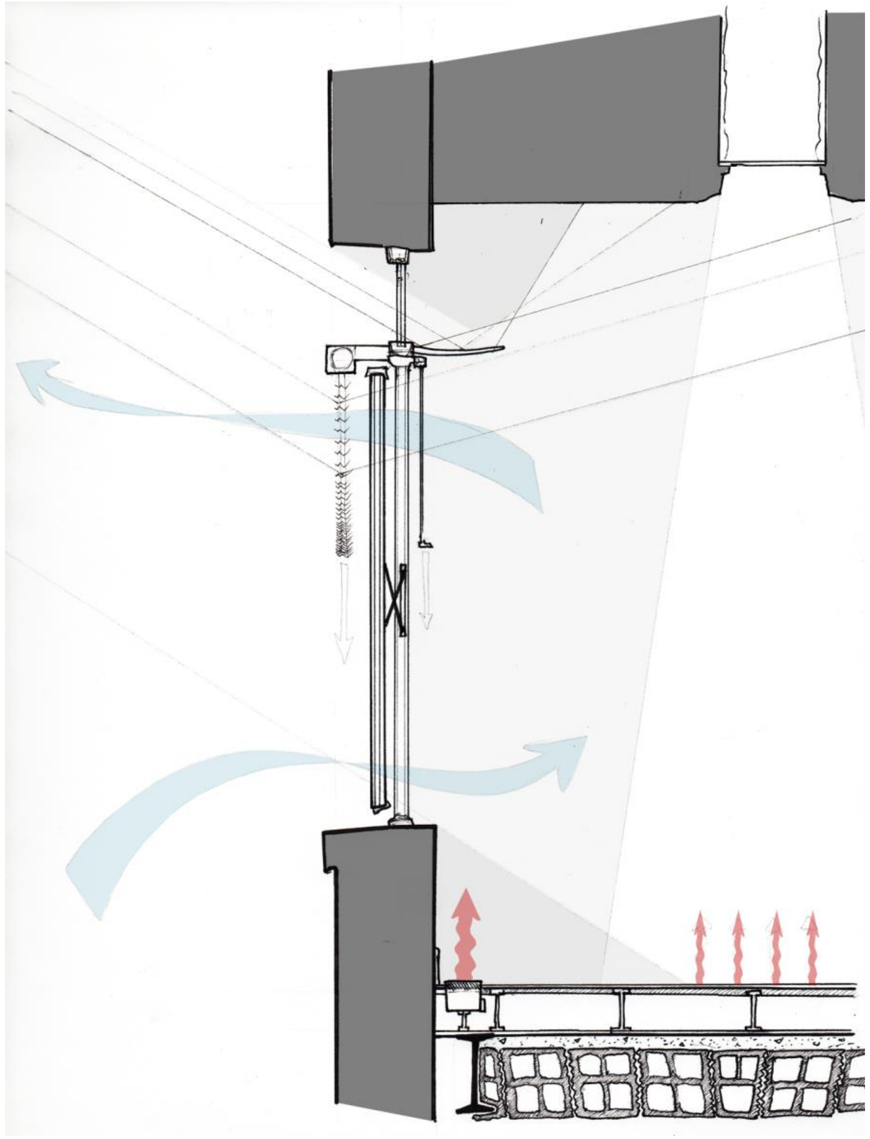
- 100% reduction in HVAC fan or duct noise
- Increased sound attenuation from insulation

Visual

- 20’ extended daylighting at perimeter
- Reduced glare and glare control
- 32% lighting energy saved with RetroSolar blinds
- Preservation of views
- Coffered ceiling becomes light source

Building Integrity

- Foamglas is water/vapor impermeable
- Twice the compressive strength of rigid insulation
- Accessible, repairable, reconfigurable sub-floor



Comments / Questions?

Krupa Patel - Radhna Saxena - Andrew Petralia