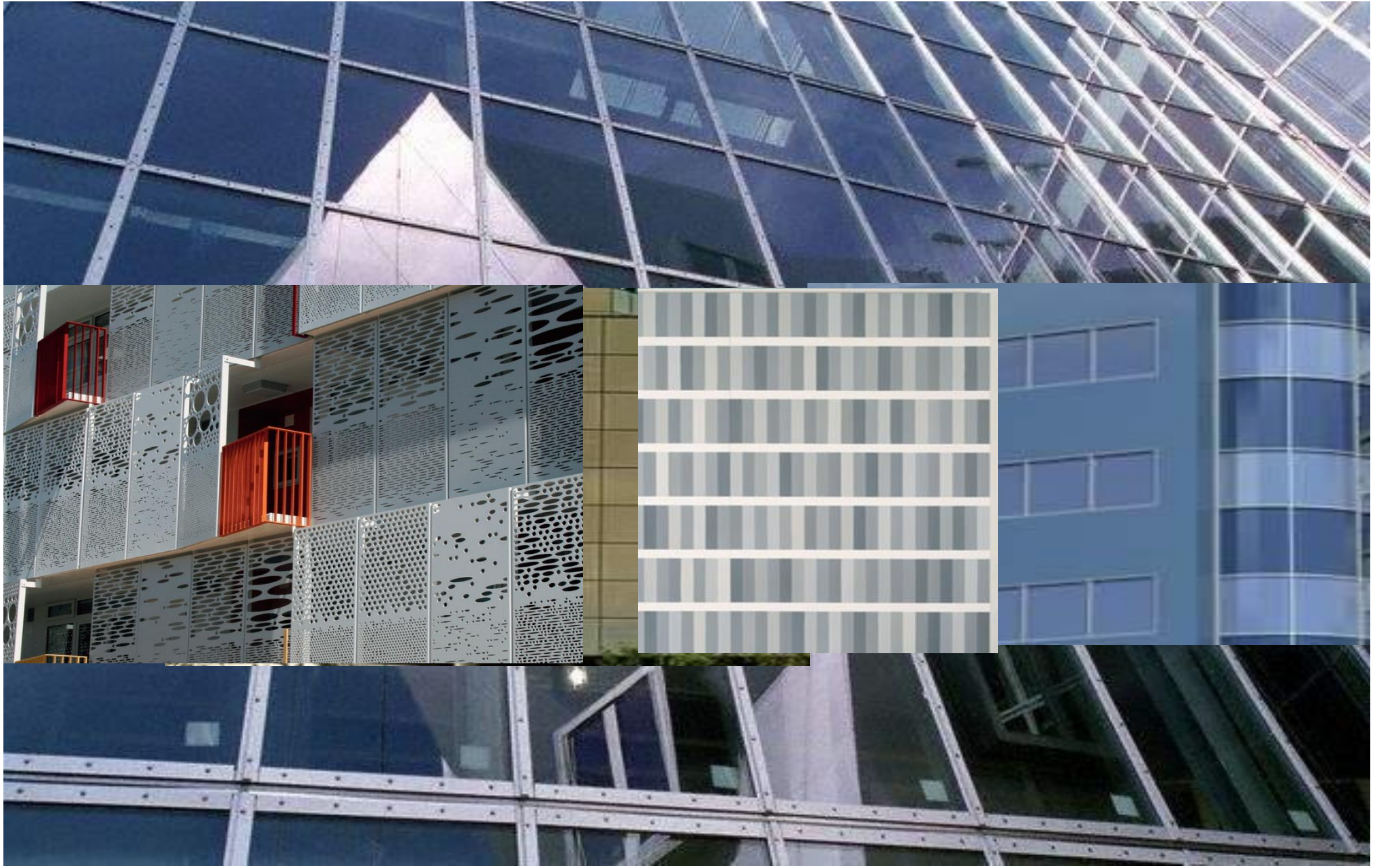
The CMU Intelligent Workplace CBPD Zoelly BCJ

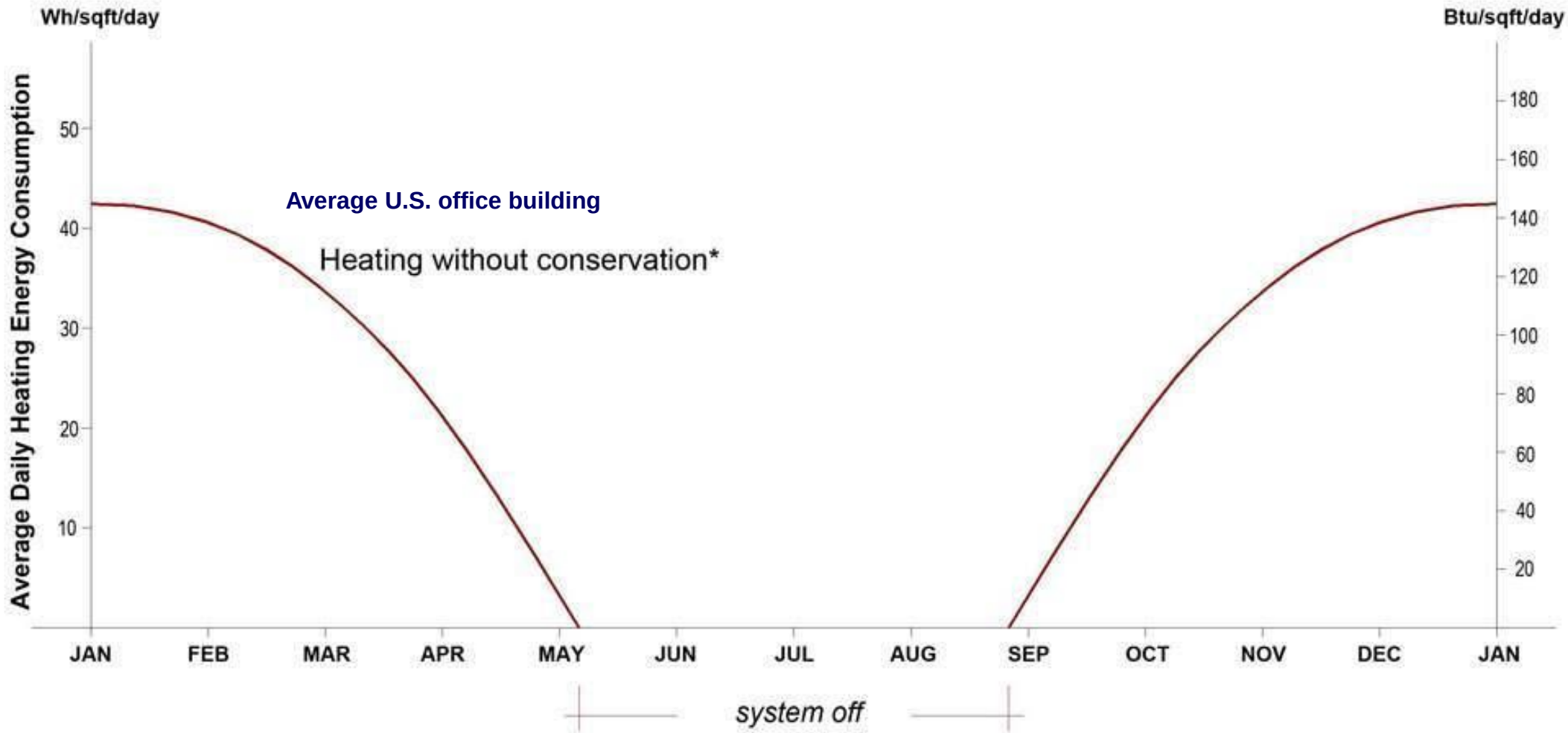
Environmental Surfing
for Health, Productivity and a Resilient Future

Vivian Loftness, FAIA



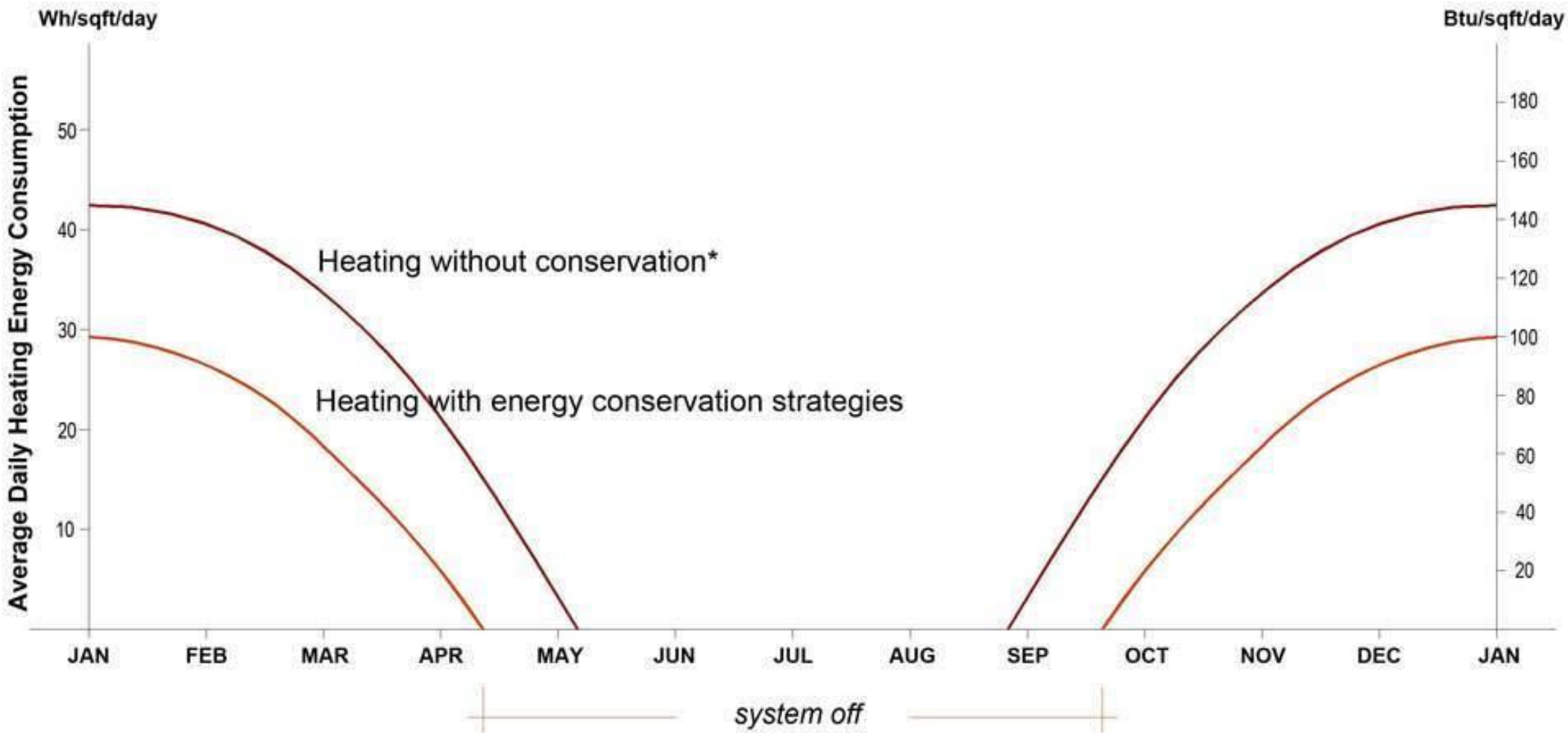
climate indifferent, sealed, and static facades are non sustainable

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



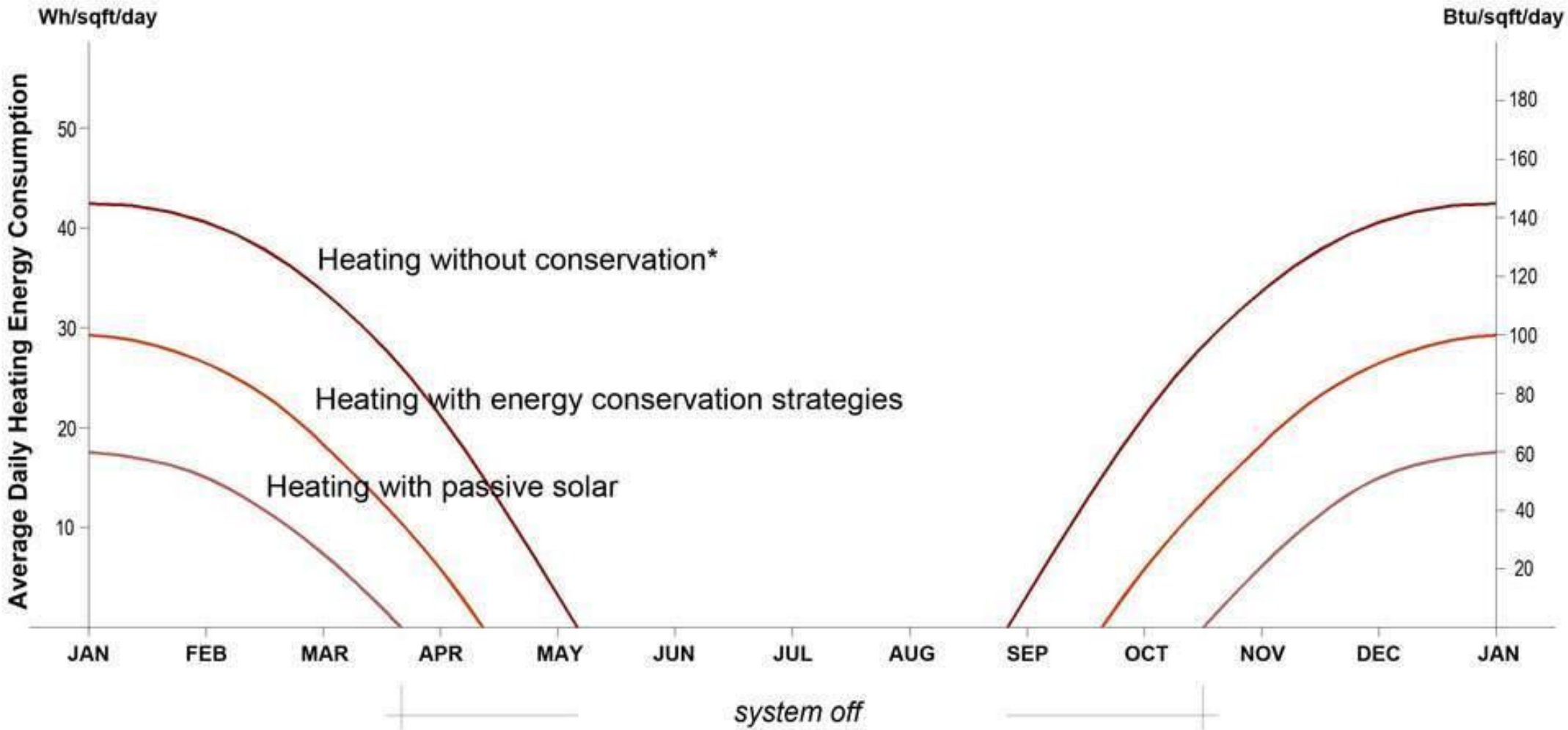
* Total annual heating energy consumption refers to EIA-CBECS 1995 &1999

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



* Total annual heating energy consumption refers to EIA-CBECS 1995 &1999

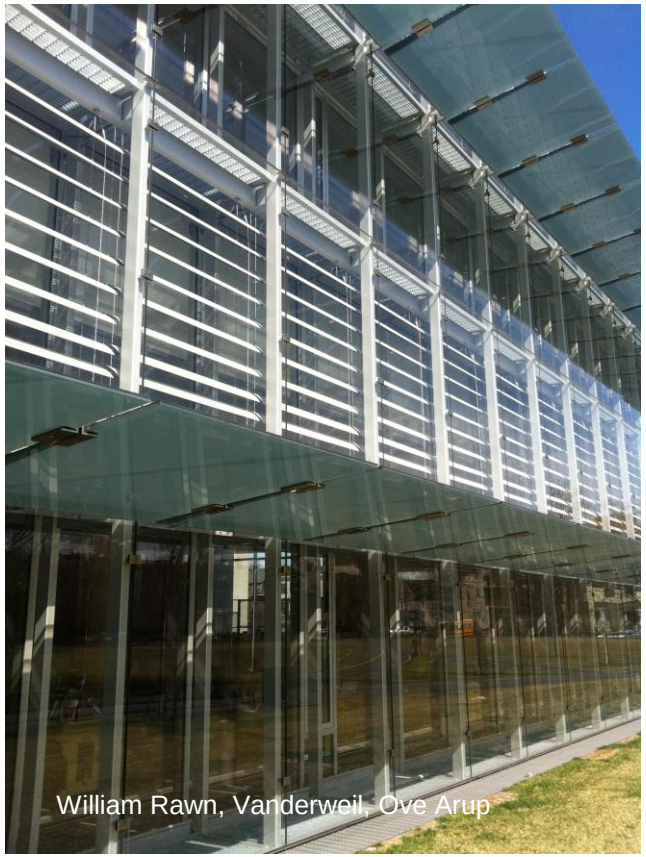
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



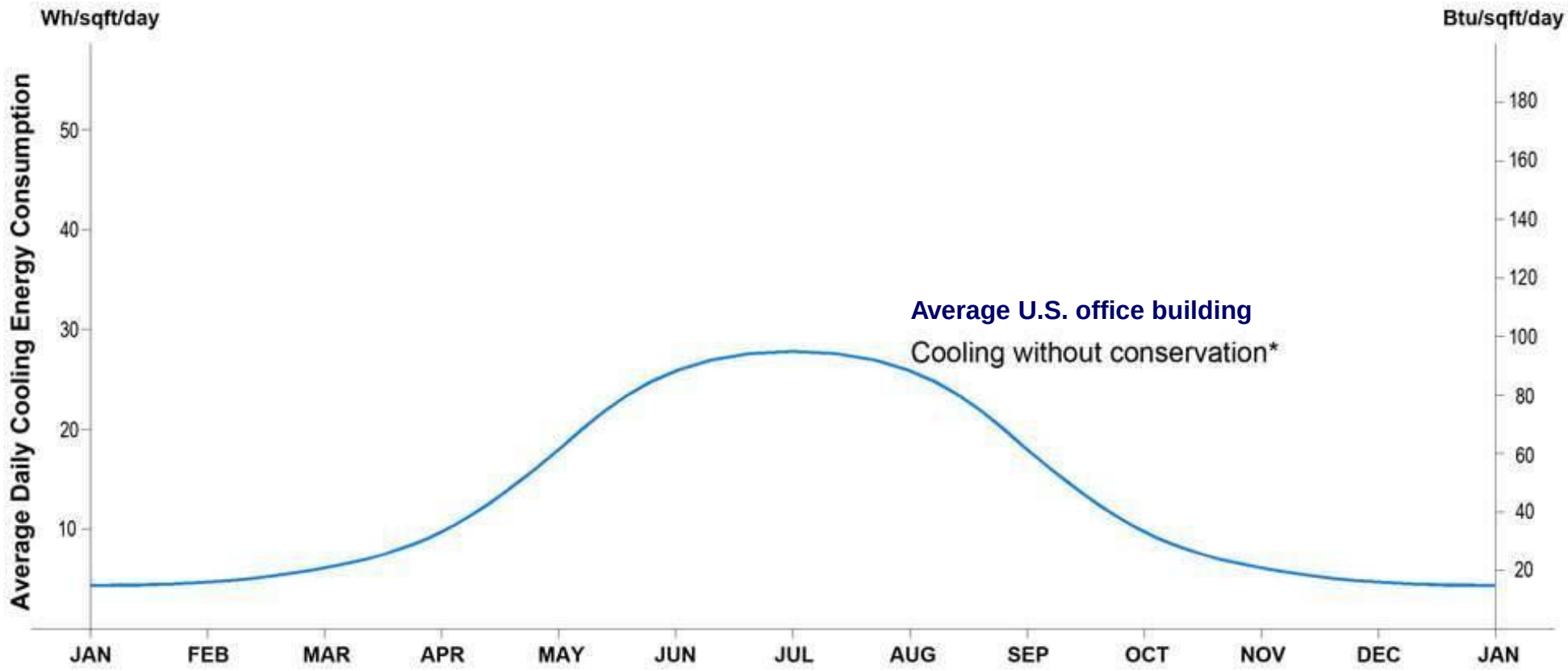
* Total annual heating energy consumption refers to EIA-CBECS 1995 &1999

Passive solar

embrace

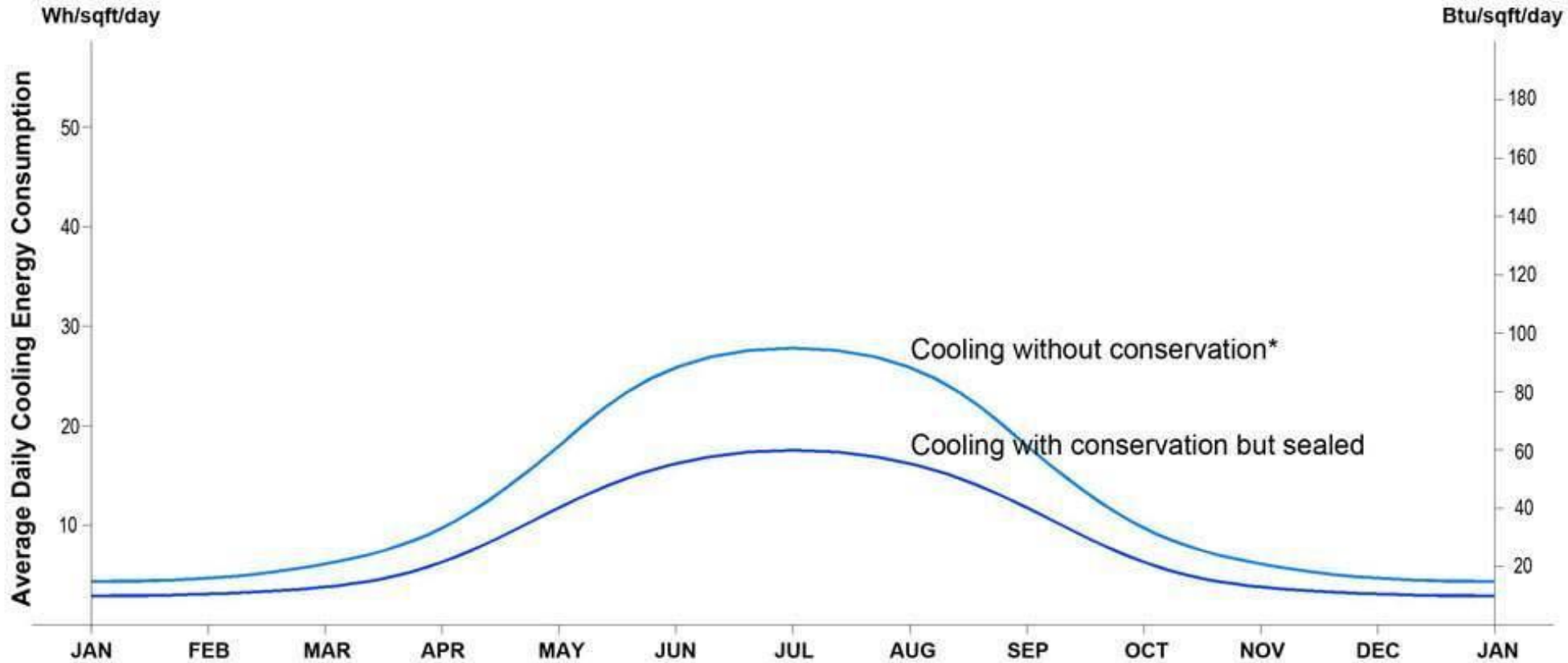


Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



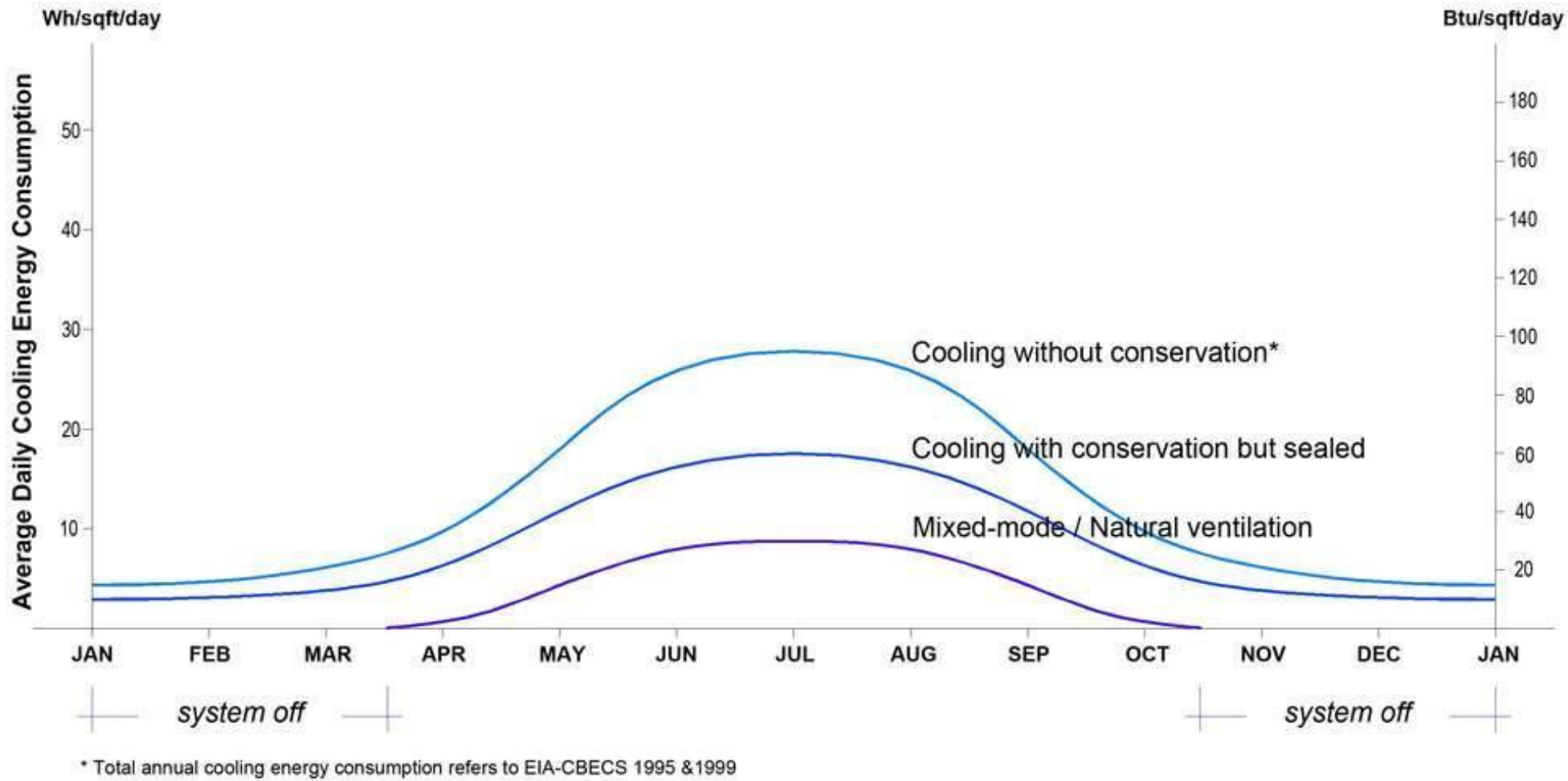
* Total annual cooling energy consumption refers to EIA-CBECS 1995 &1999

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



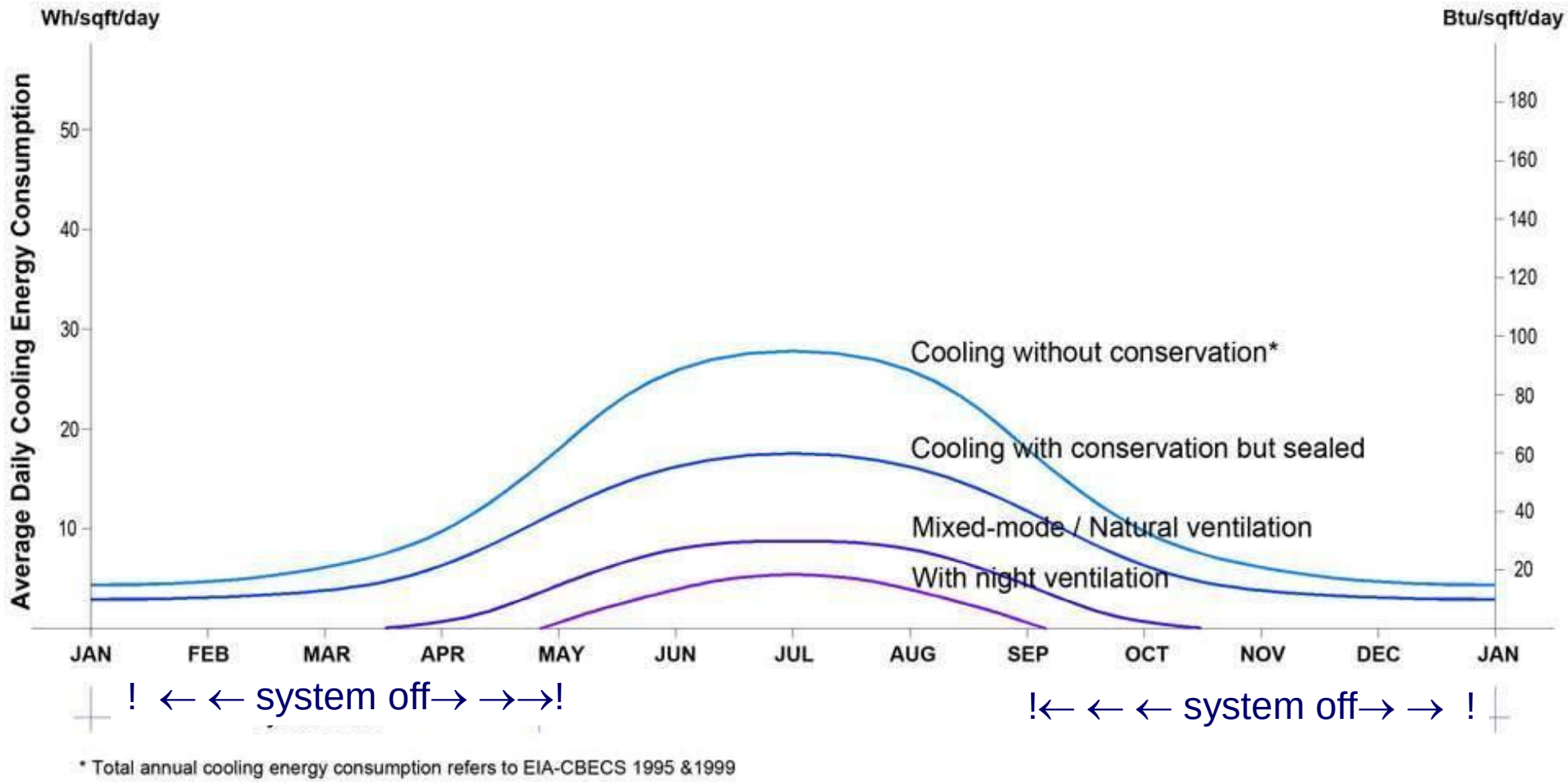
* Total annual cooling energy consumption refers to EIA-CBECS 1995 &1999

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University

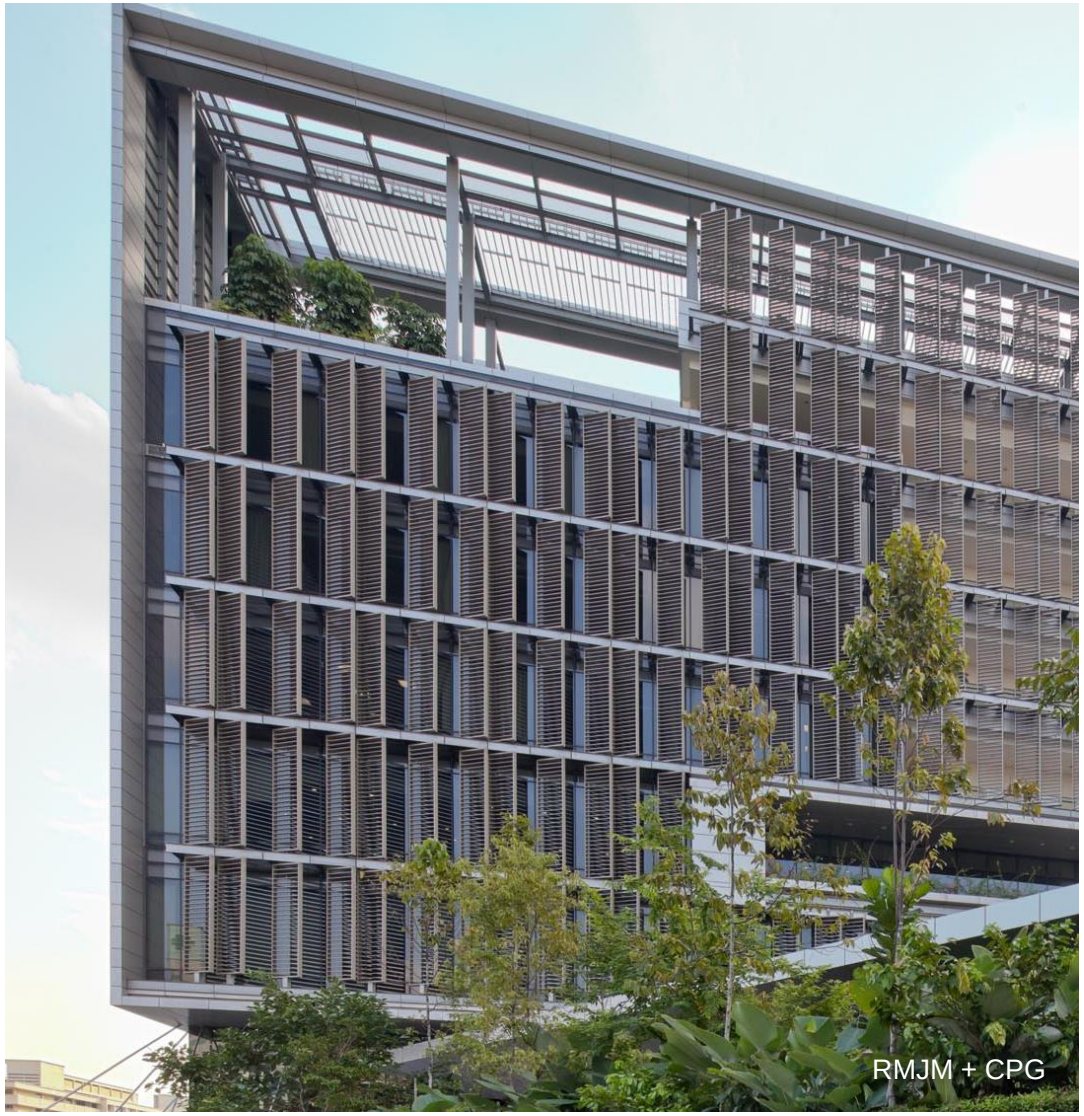


* Total annual cooling energy consumption refers to EIA-CBECS 1995 &1999

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



* Total annual cooling energy consumption refers to EIA-CBECS 1995 &1999

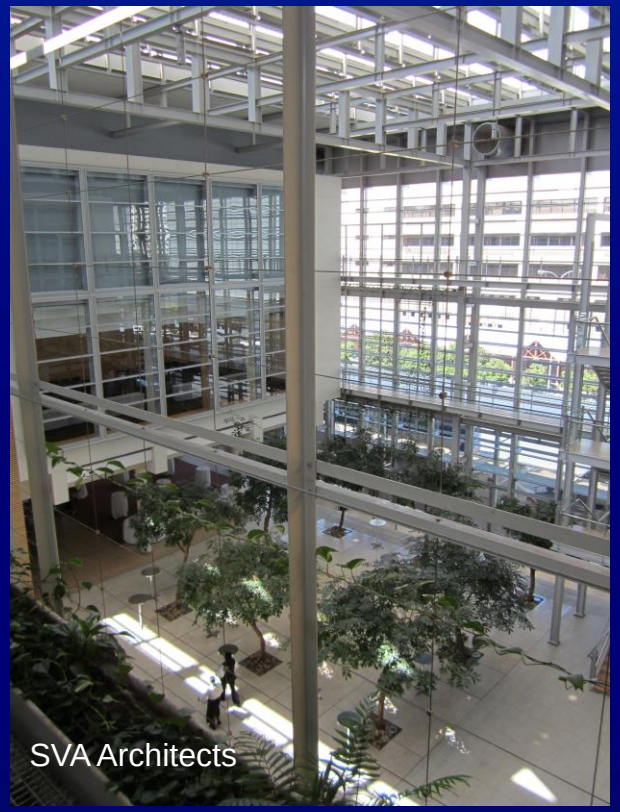


Shade

Lake Flato

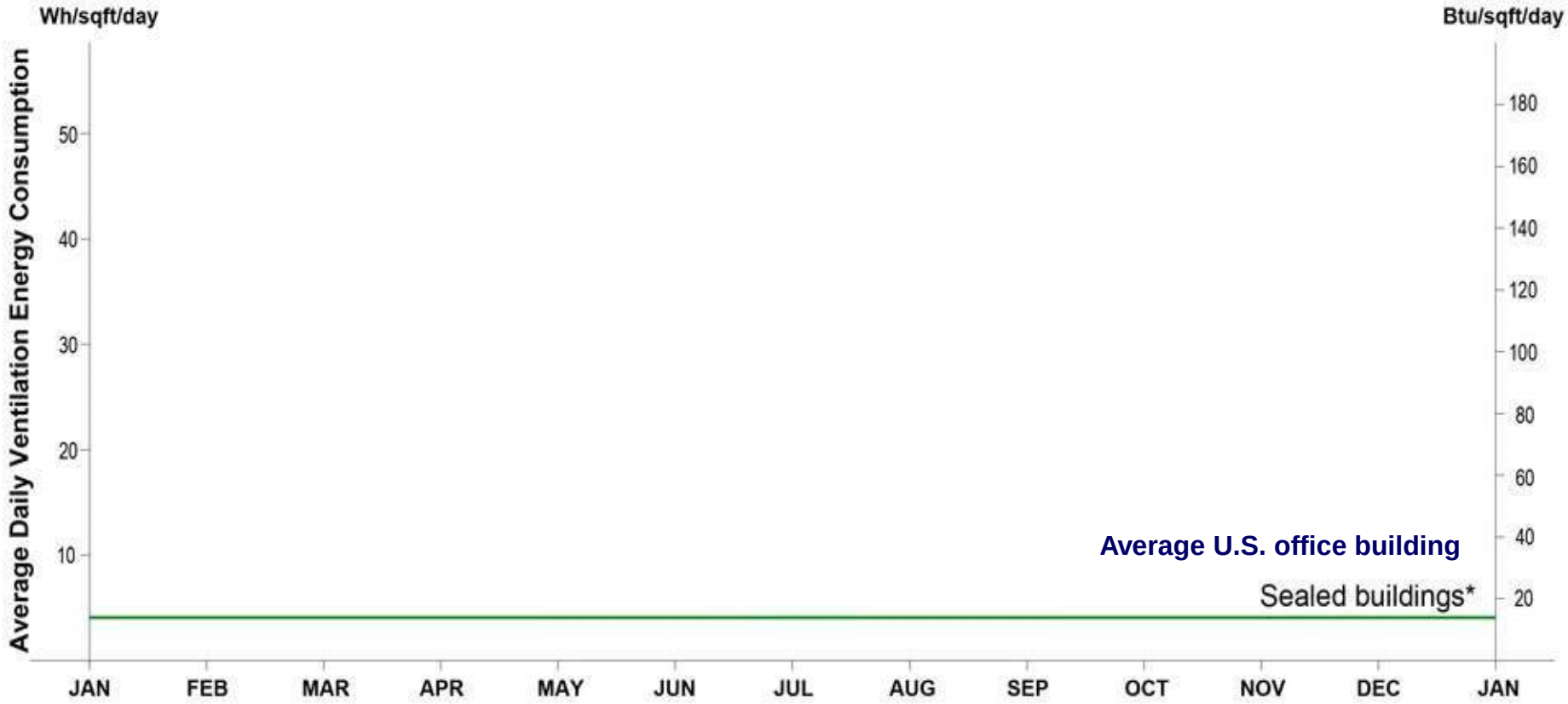
Shading, Ventilation & Night Cooling

Sustainable buildings embrace the outdoors



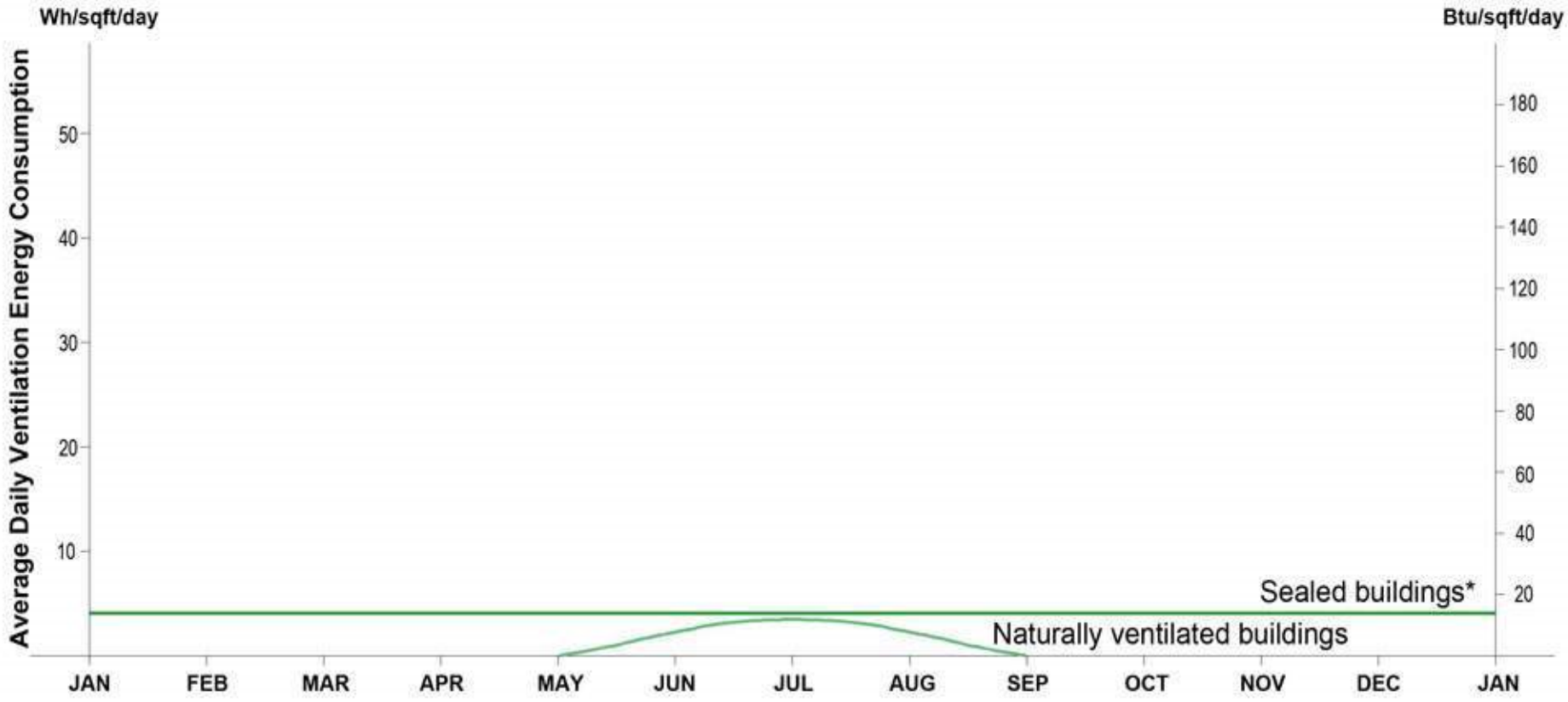
Resilient Convention Centers – 50% outdoor spaces

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



* Total annual ventilation energy consumption refers to EIA-CBECS 1995 &1999

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



!← ← system off→ →→!

!← ← ← system off→ →!

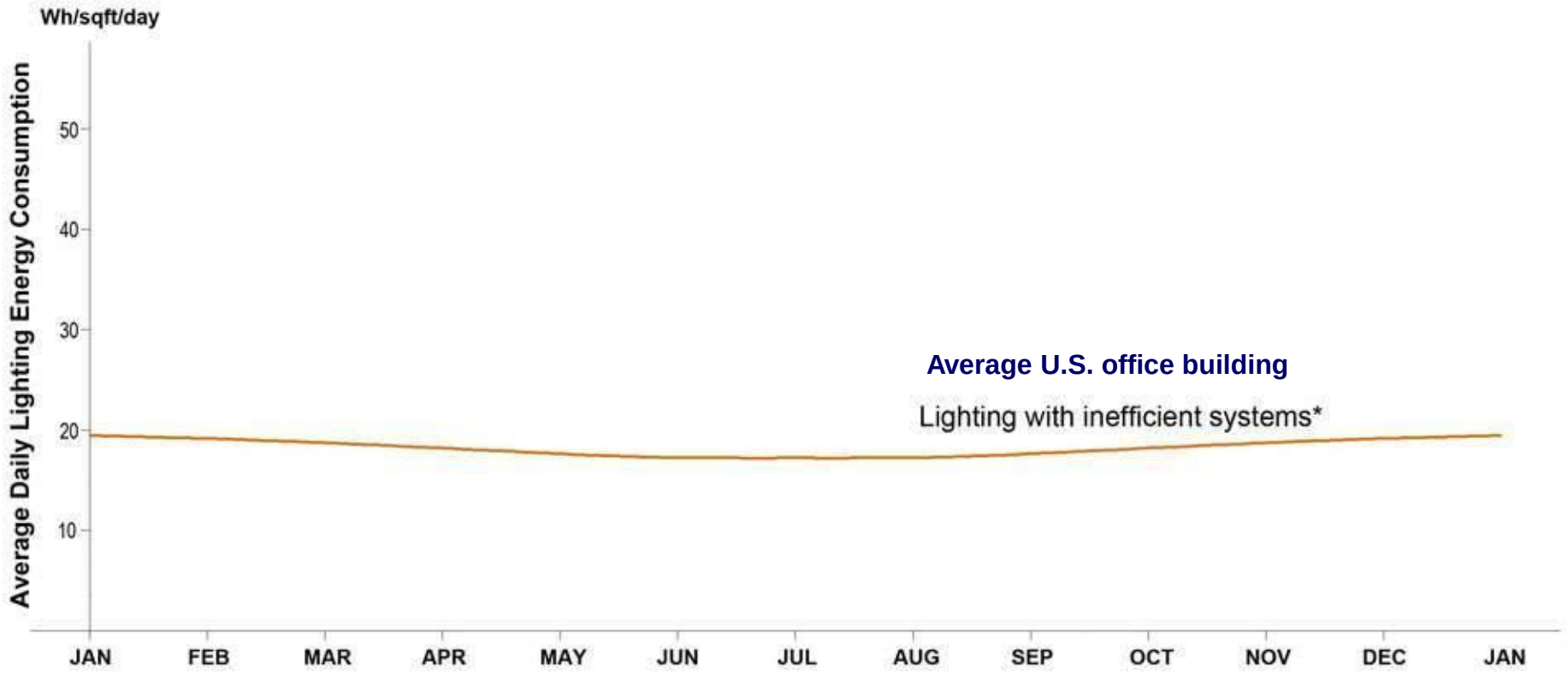
* Total annual ventilation energy consumption refers to EIA-CBECS 1995 &1999

Natural Ventilation
can displace
50 - 70% of today's ventilation

Resilient Schools _ Natural Ventilation and Natural Cooling

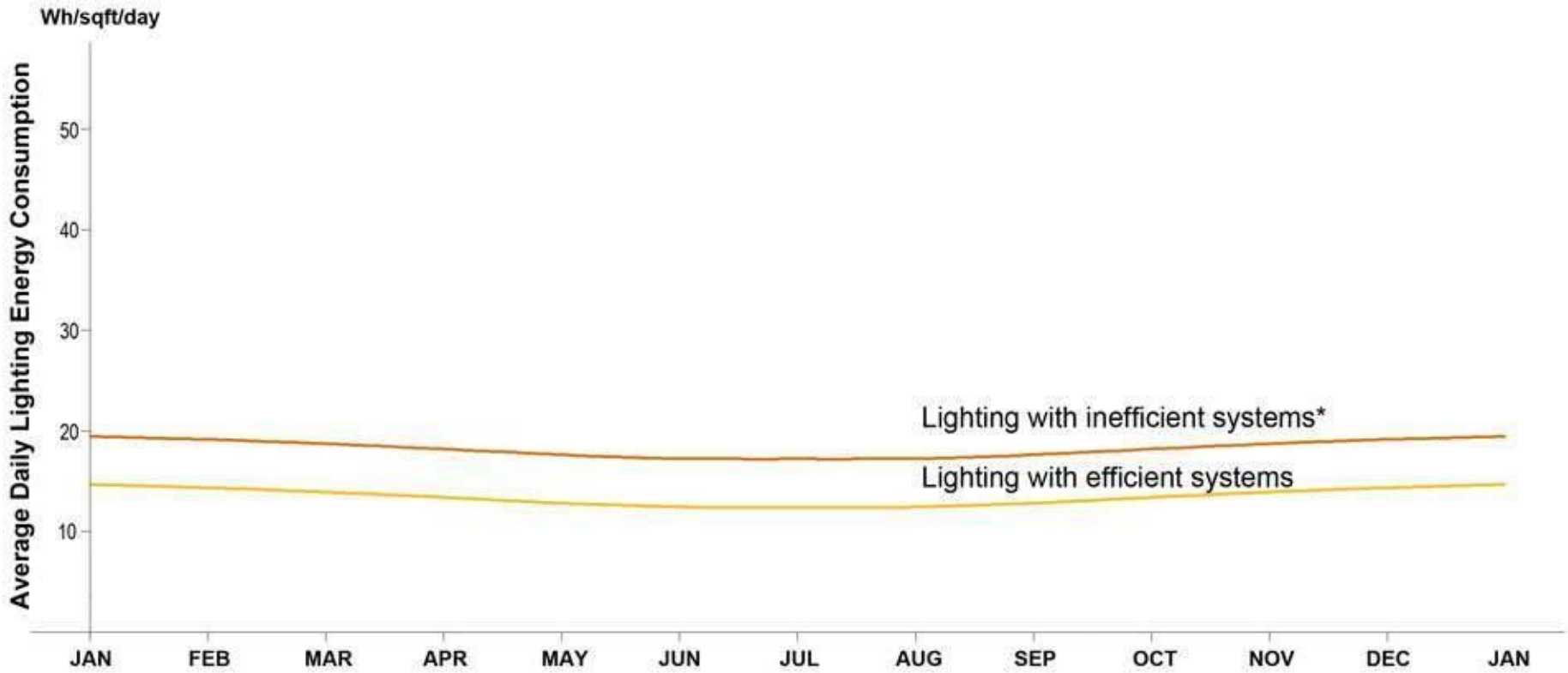
embrace

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



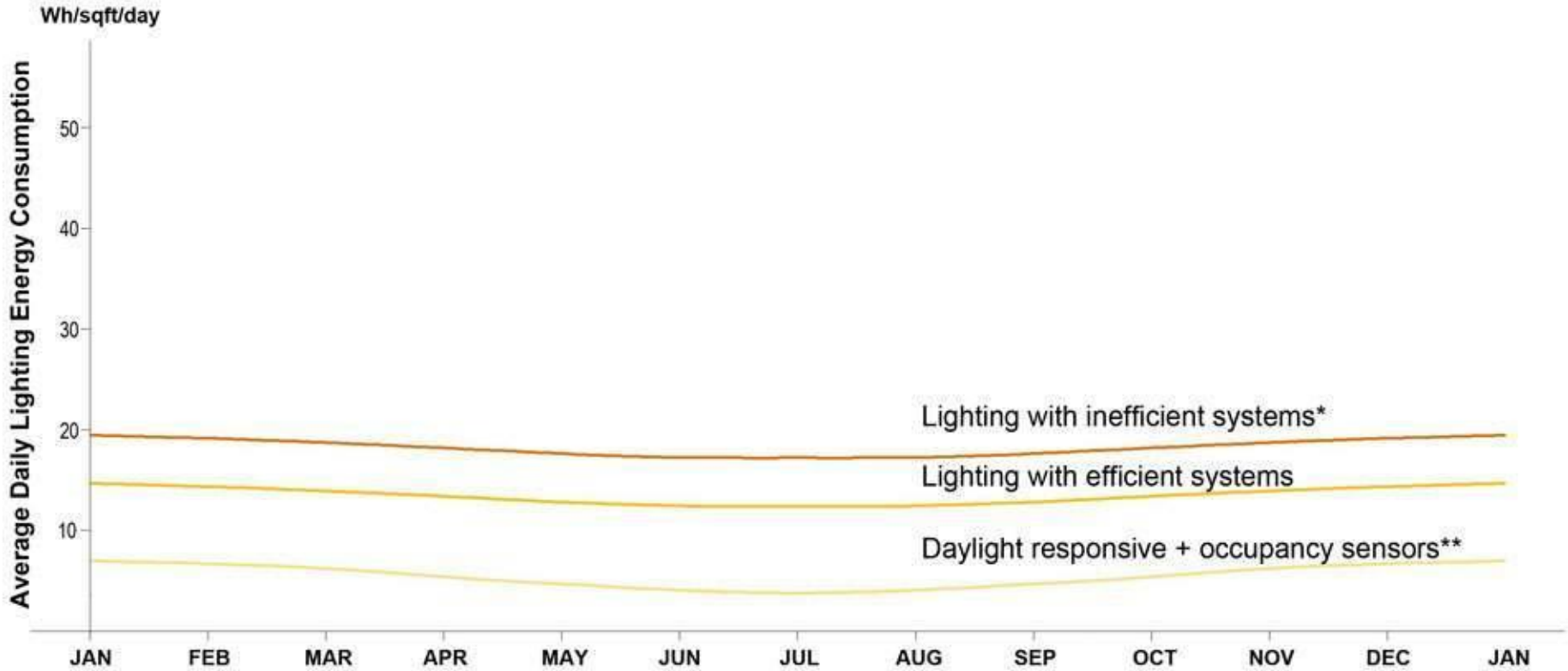
* Total annual lighting energy consumption refers to EIA-CBECS 1995 &1999

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



* Total annual lighting energy consumption refers to EIA-CBECS 1995 &1999

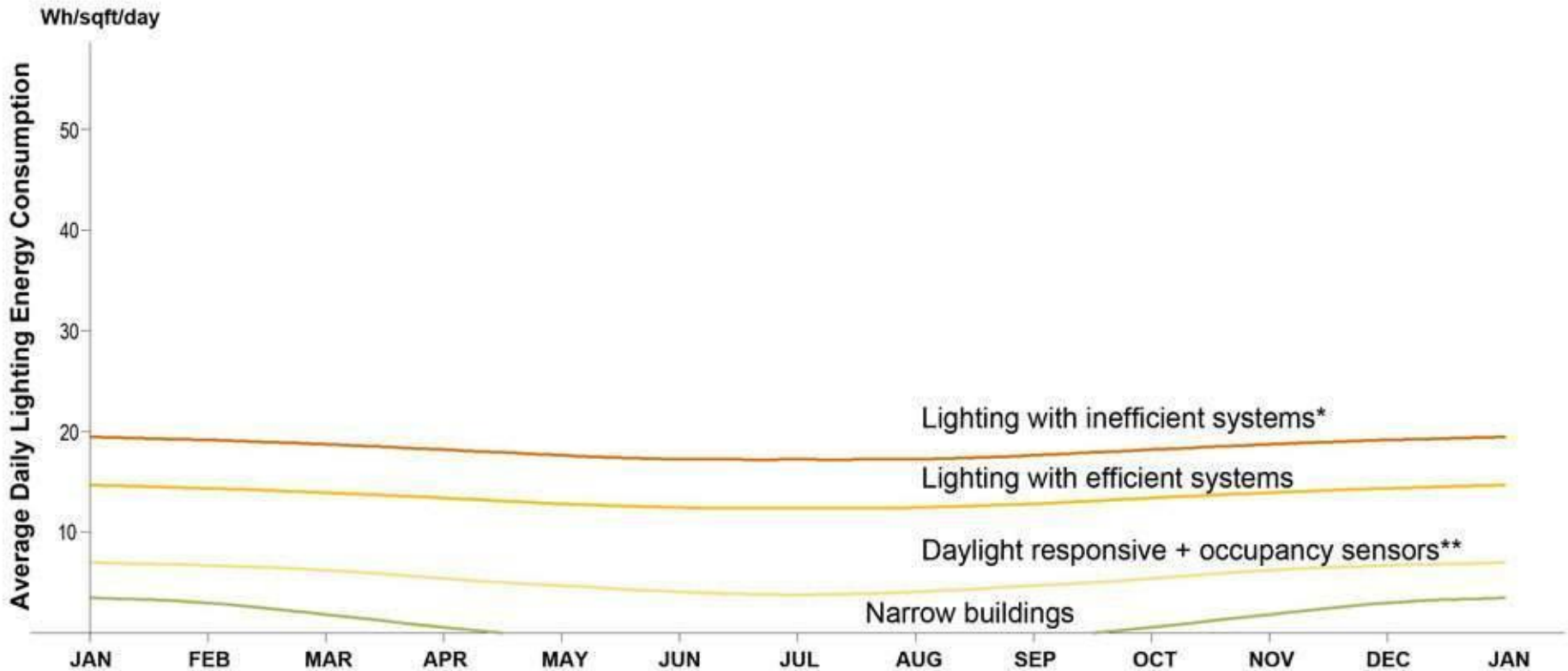
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



* Total annual lighting energy consumption refers to EIA-CBECS 1995 &1999

** Monthly lighting energy profile refers to McDougall, T., Nordmeyer, K. & Klaassen, C. J. (2006). Low-Energy building case study: IAMU office and training headquarters. ASHRAE Transactions, Vol.12, pp312-320

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



! ← ←← ←← system off →→ →→!

* Total annual lighting energy consumption refers to EIA-CBECS 1995 &1999

** Monthly lighting energy profile refers to McDougall, T., Nordmeyer, K. & Klaassen, C. J. (2006). Low-Energy building case study: IAMU office and training headquarters. ASHRAE Transactions, Vol.12, pp312-320

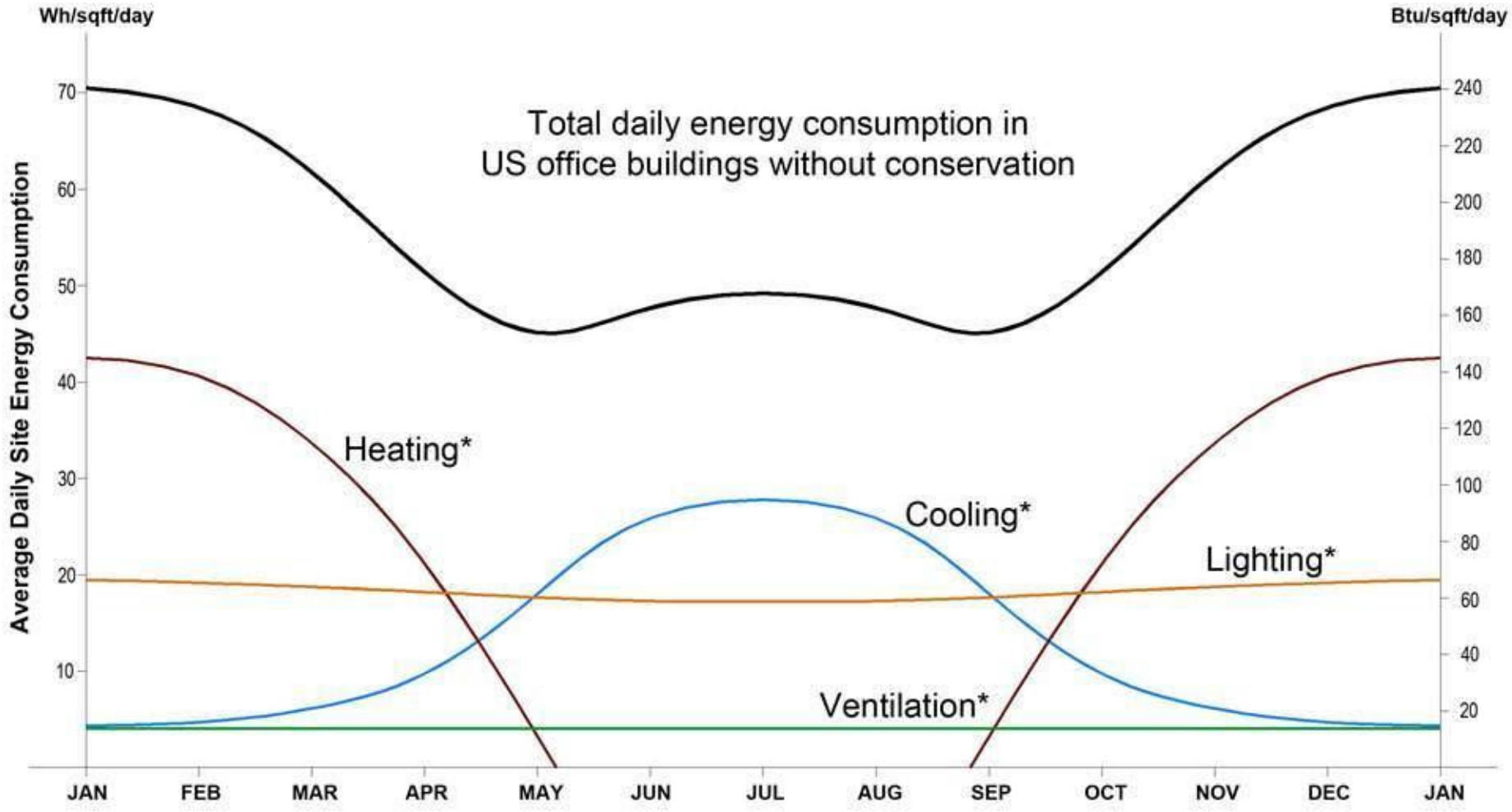

Daylight can displace 75% of today’s lighting

Sustainable buildings
*daylight **all** spaces*

Pelli Clarke Pelli

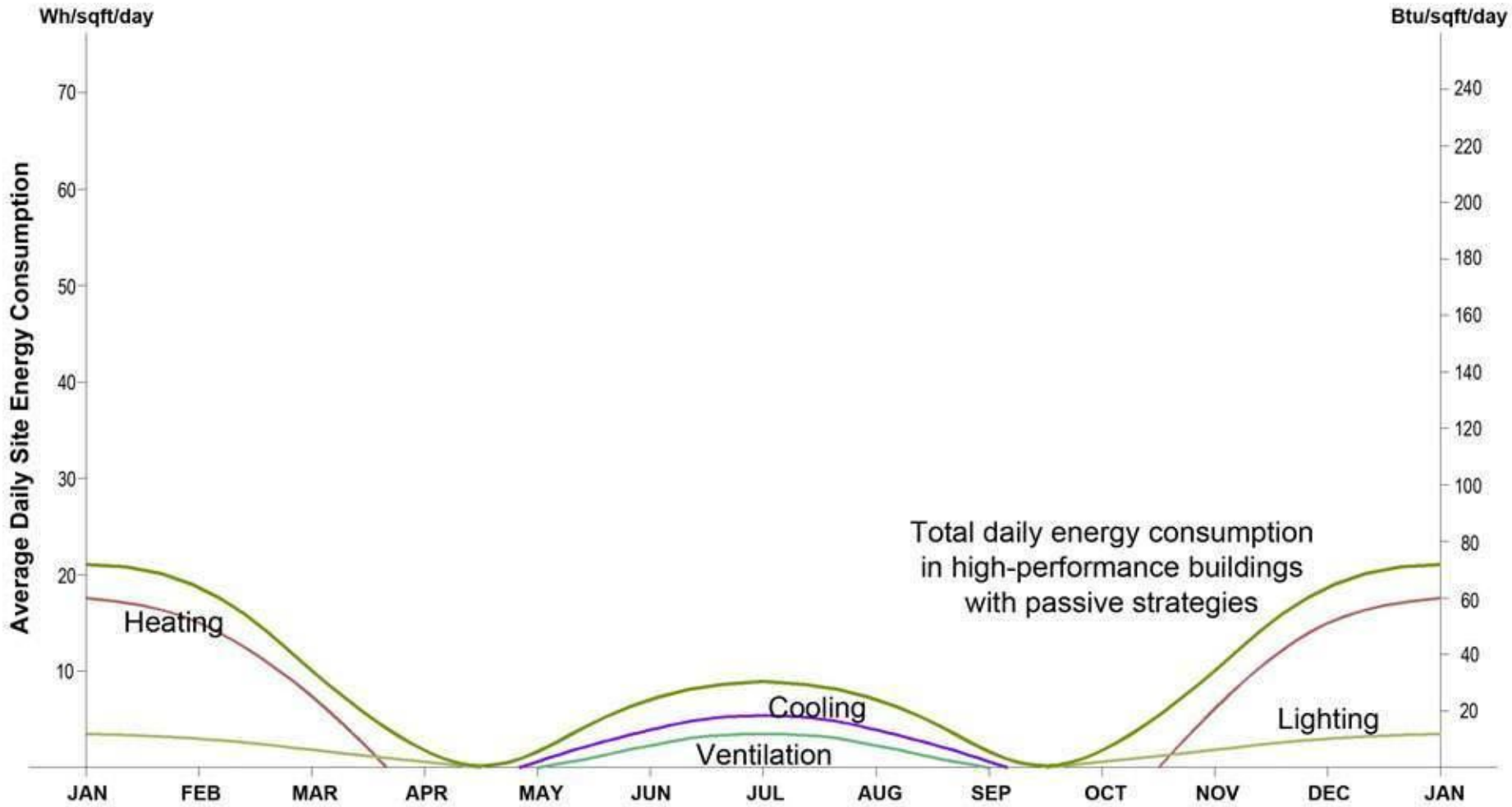

E28
Paul Andreu

Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University

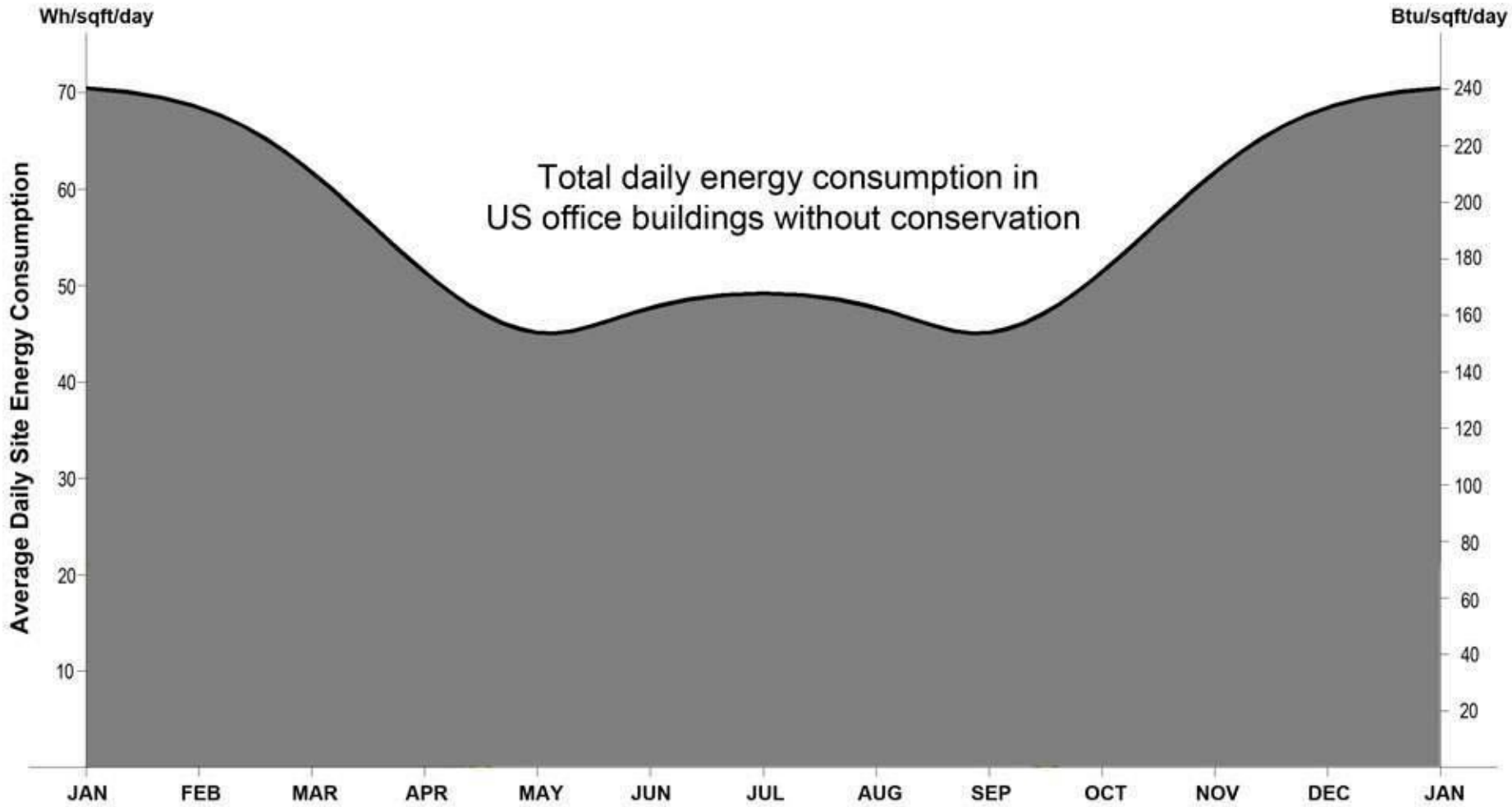


* Total annual heating, cooling, ventilation and lighting energy consumption refers to EIA-CBECS 1995 &1999

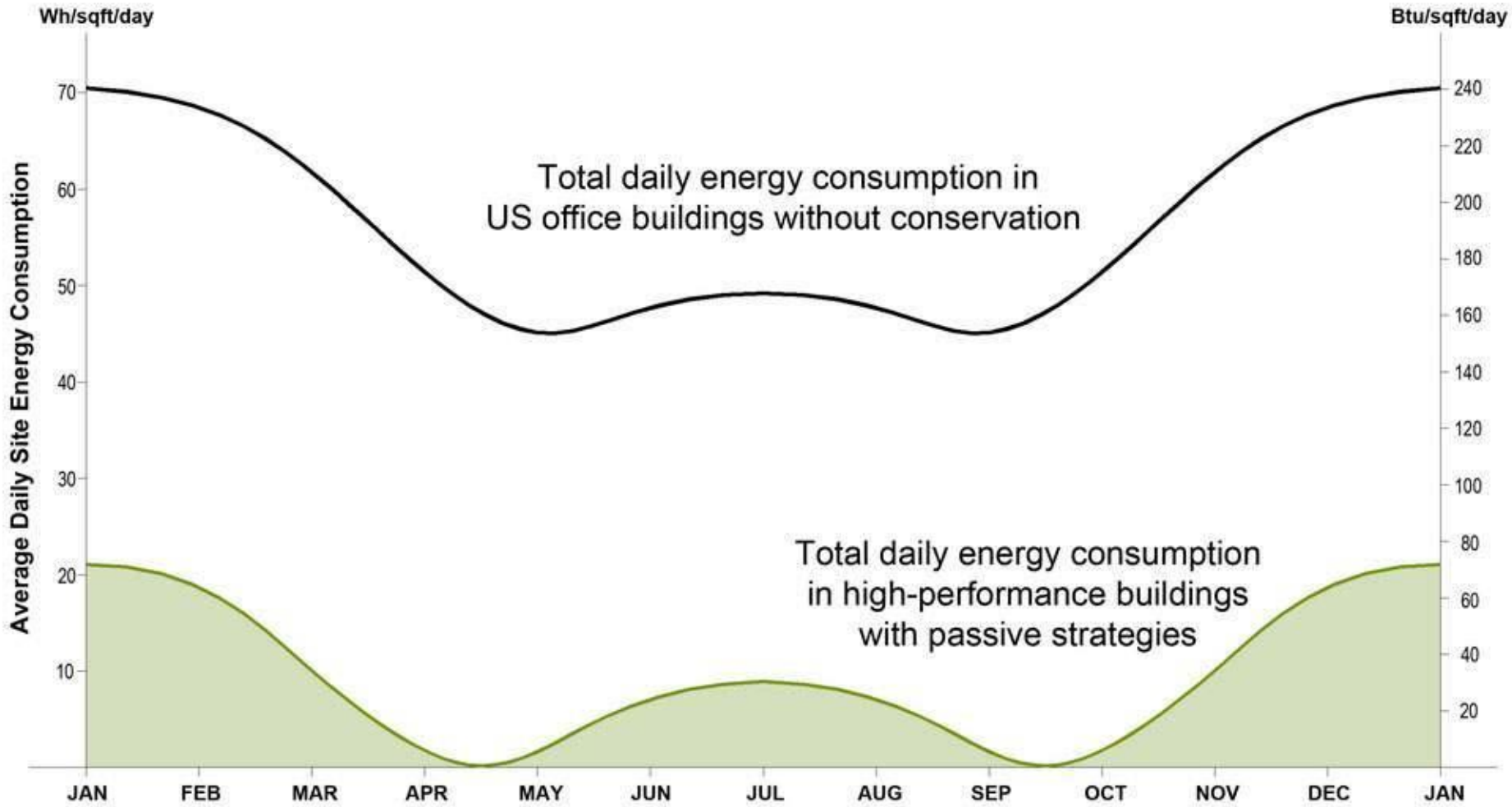
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University

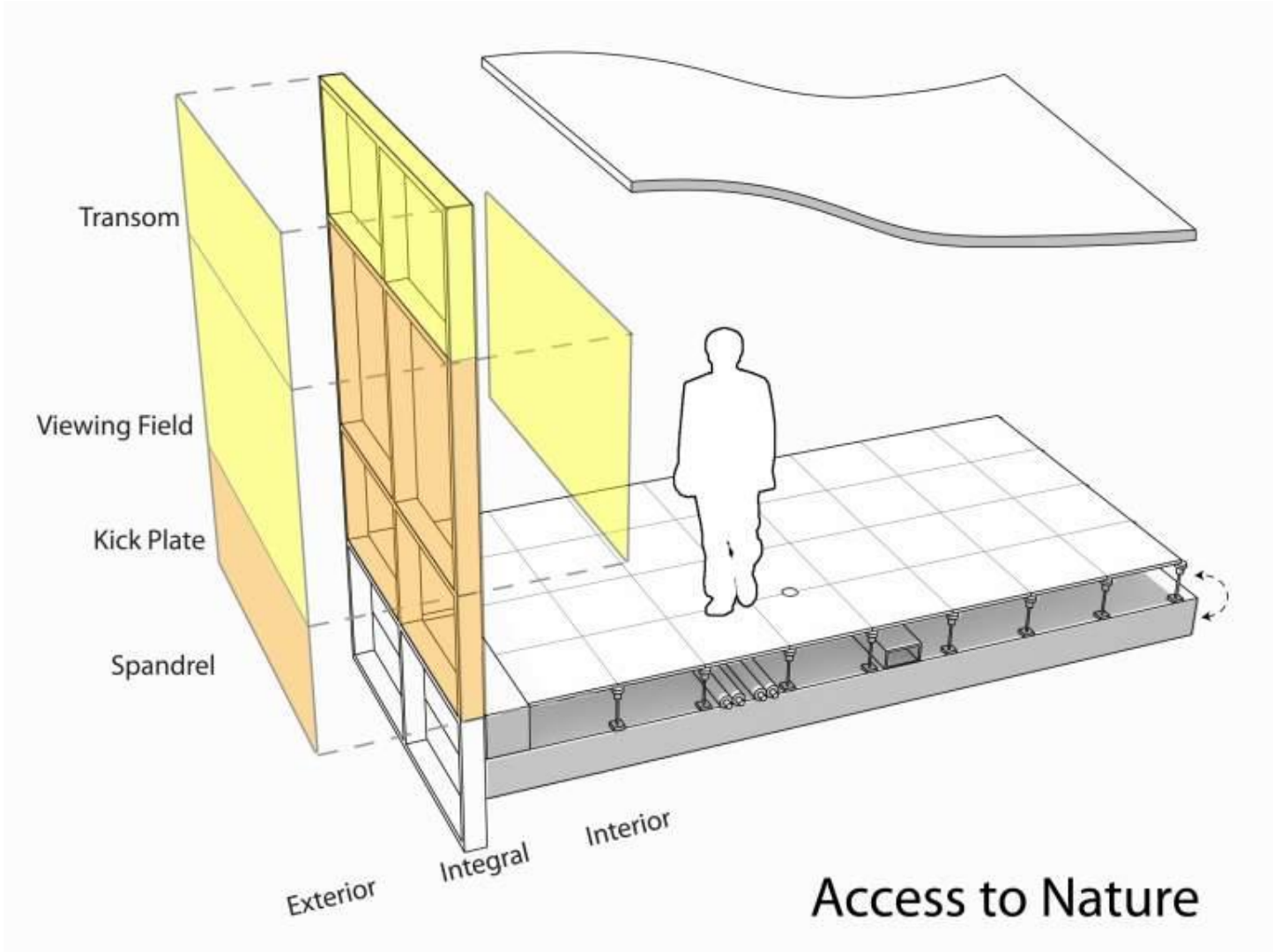


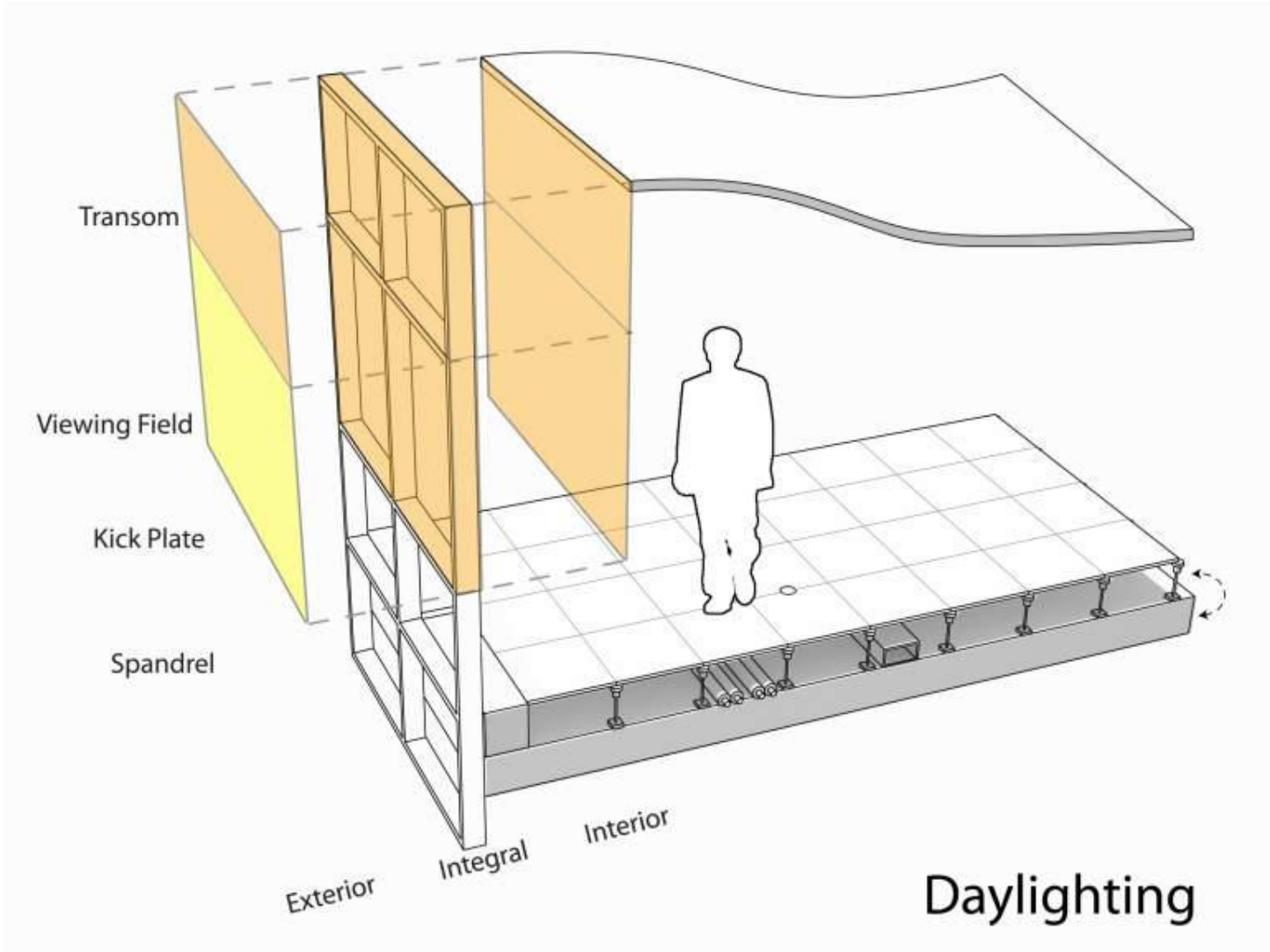
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University

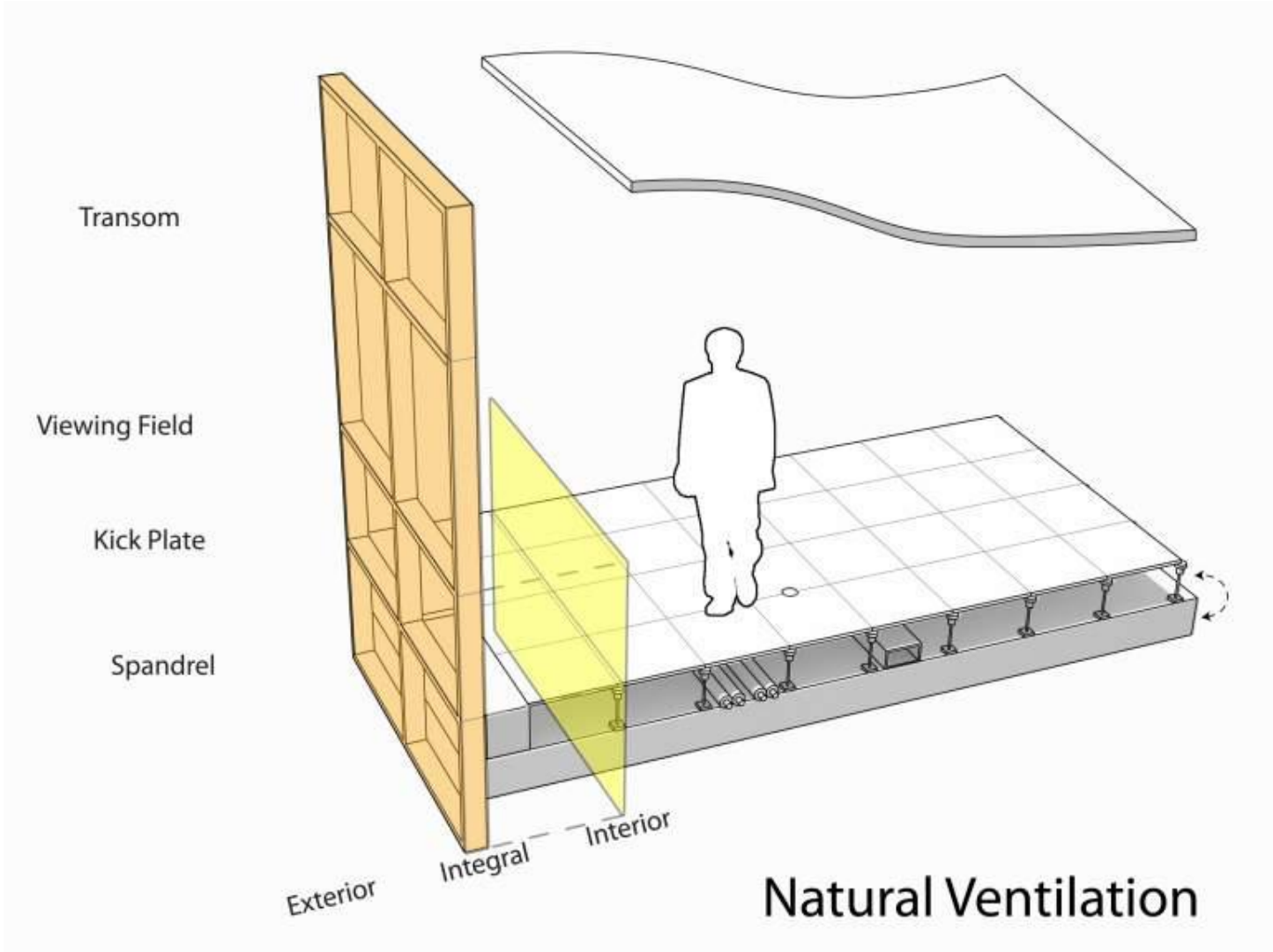


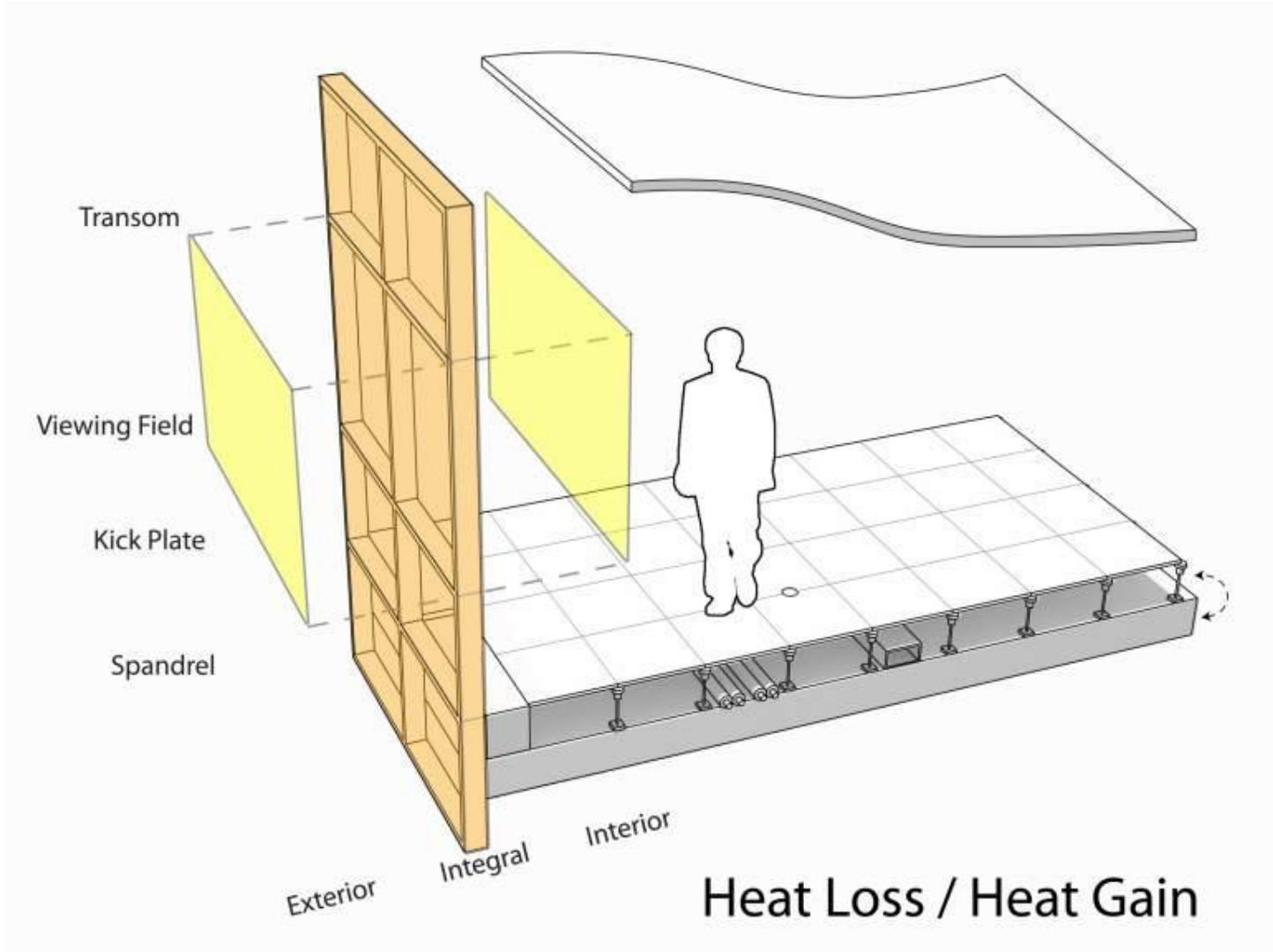
	INTERIOR	INTEGRAL	EXTERIOR
TRANSOM	A1	A2	A3
VIEWING FIELD	B1	B2	B3
BRUSTUNG	C1	C2	C3
SPANDREL	D1	D2	D3

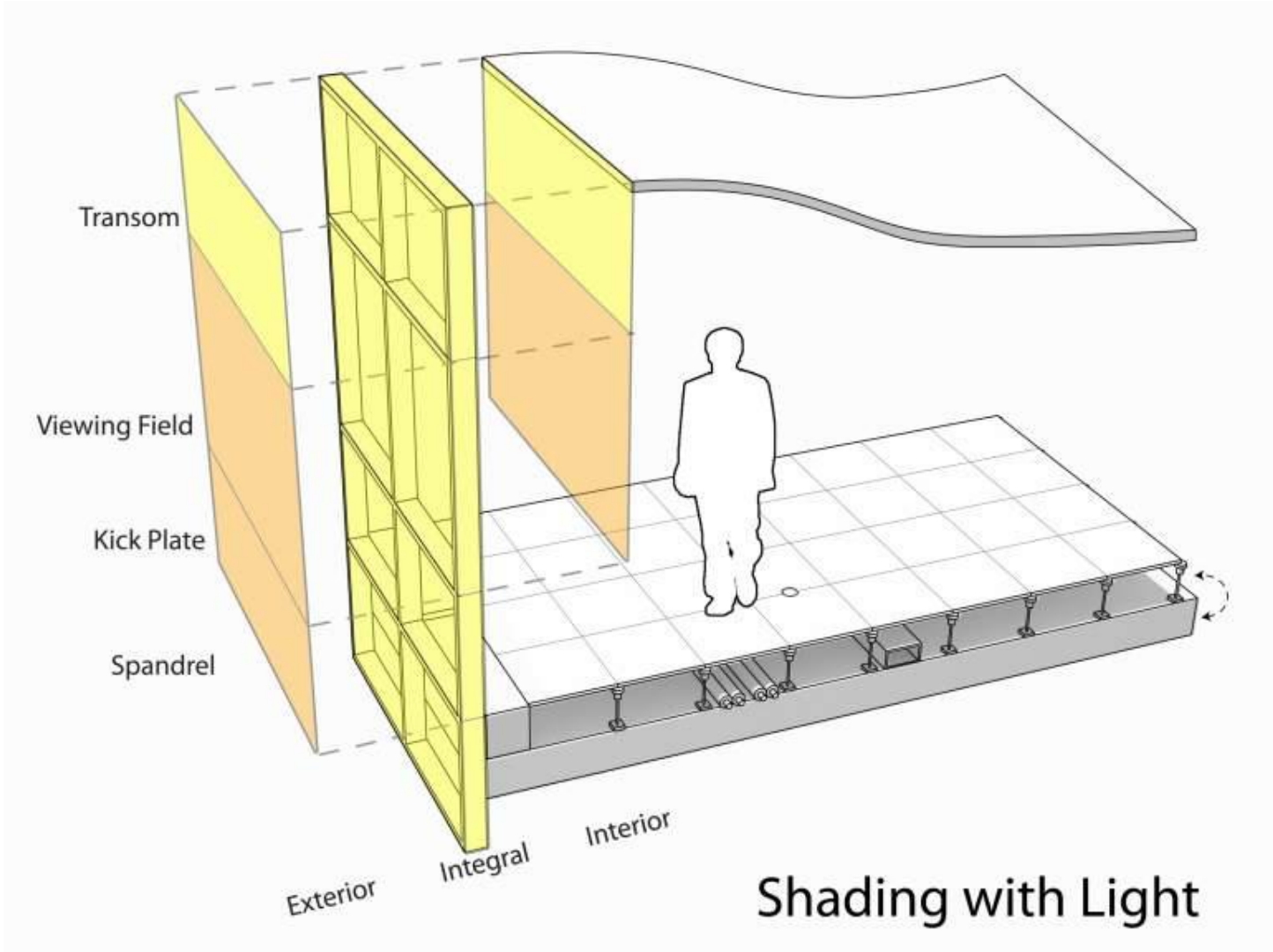
Sustainable Enclosures

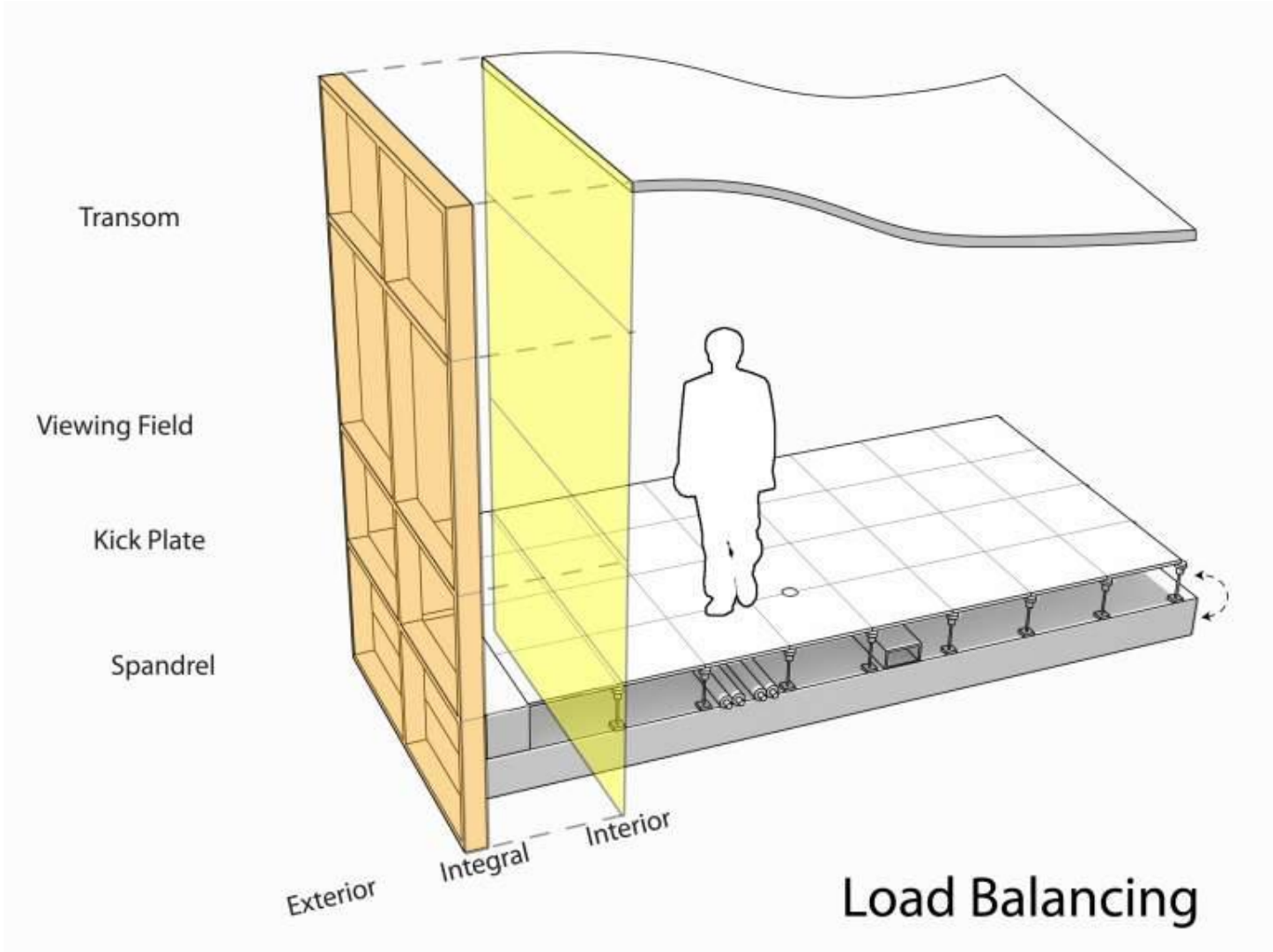

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Access to Nature

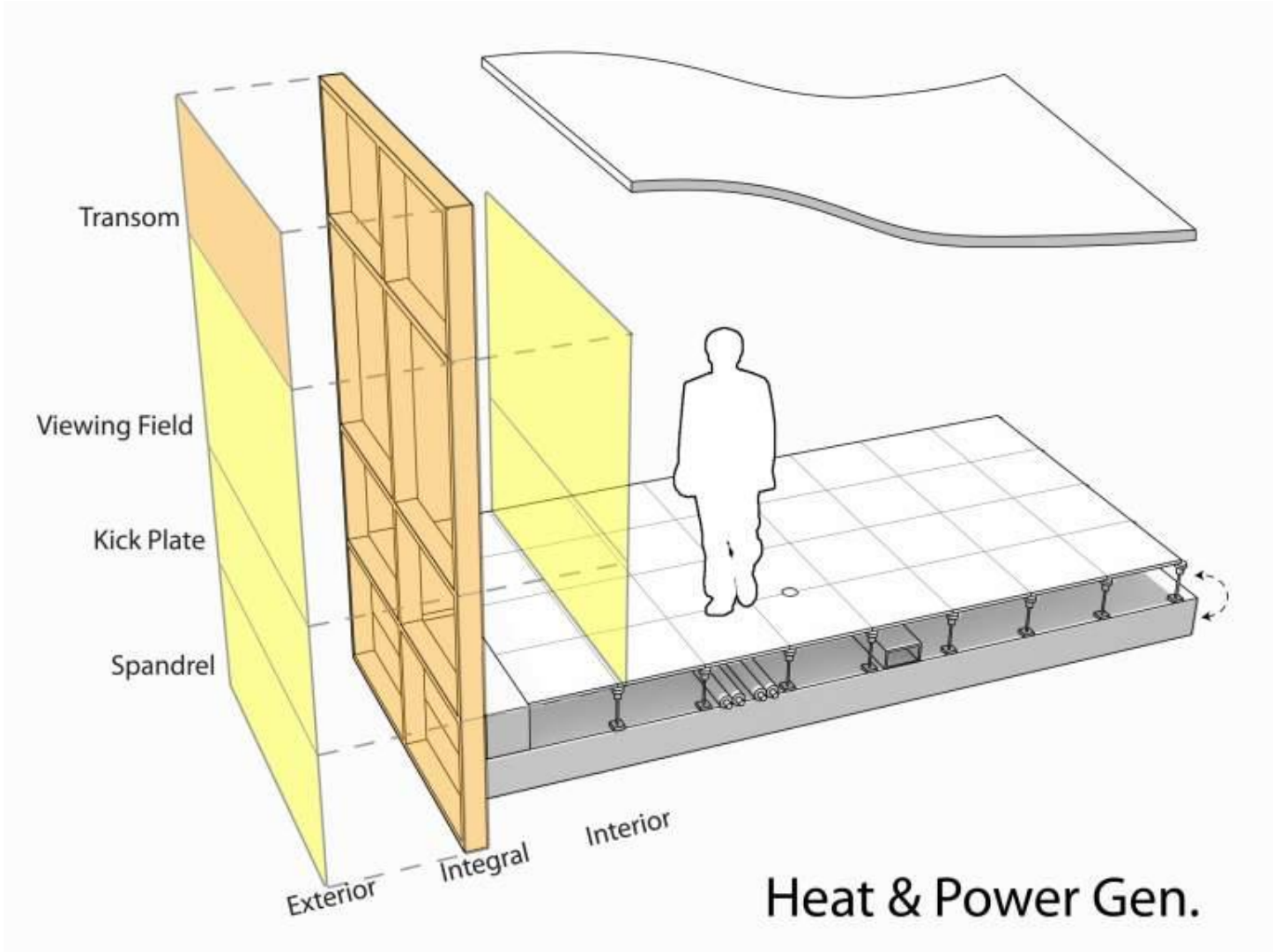

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Daylighting

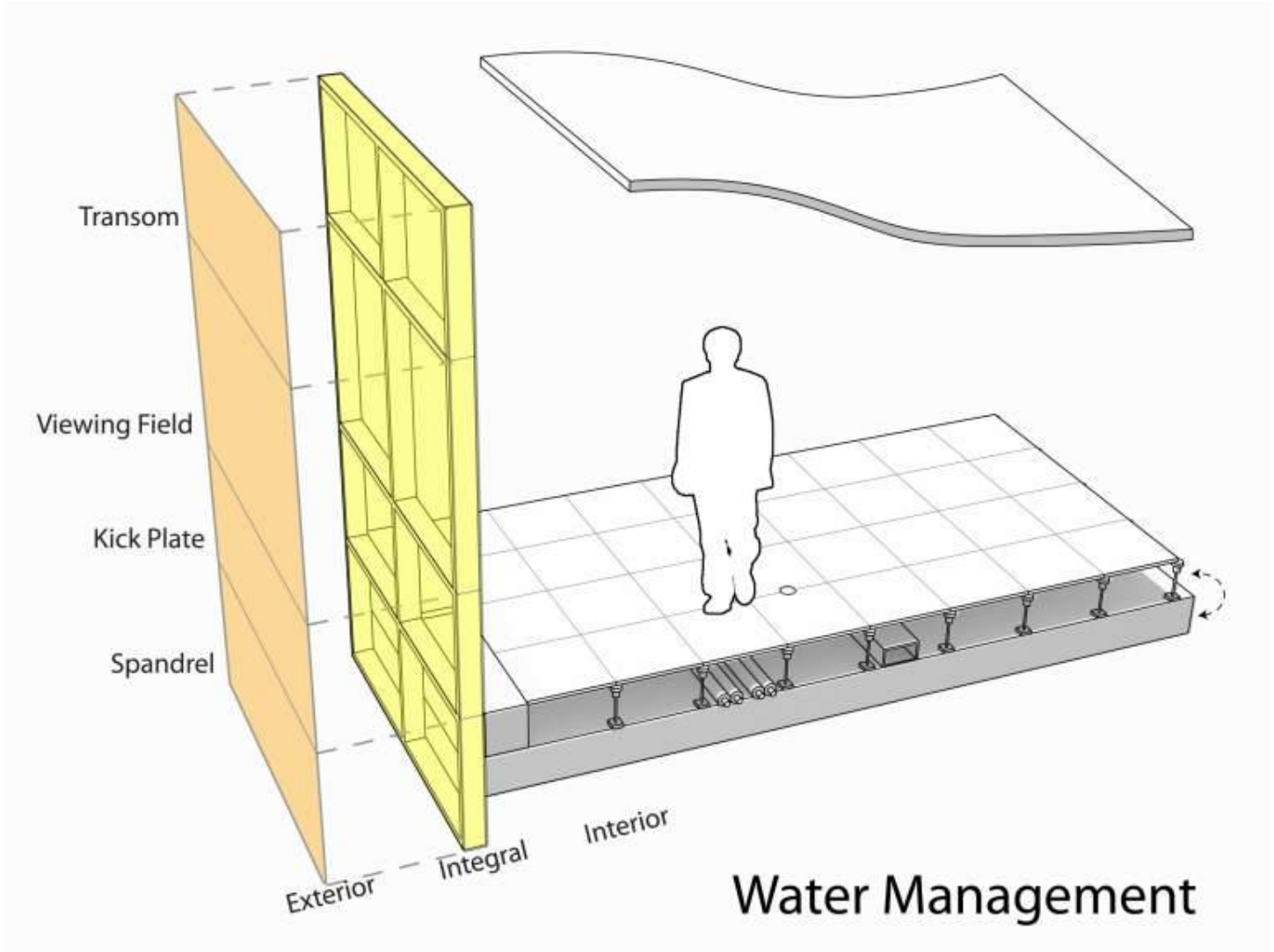

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Natural Ventilation

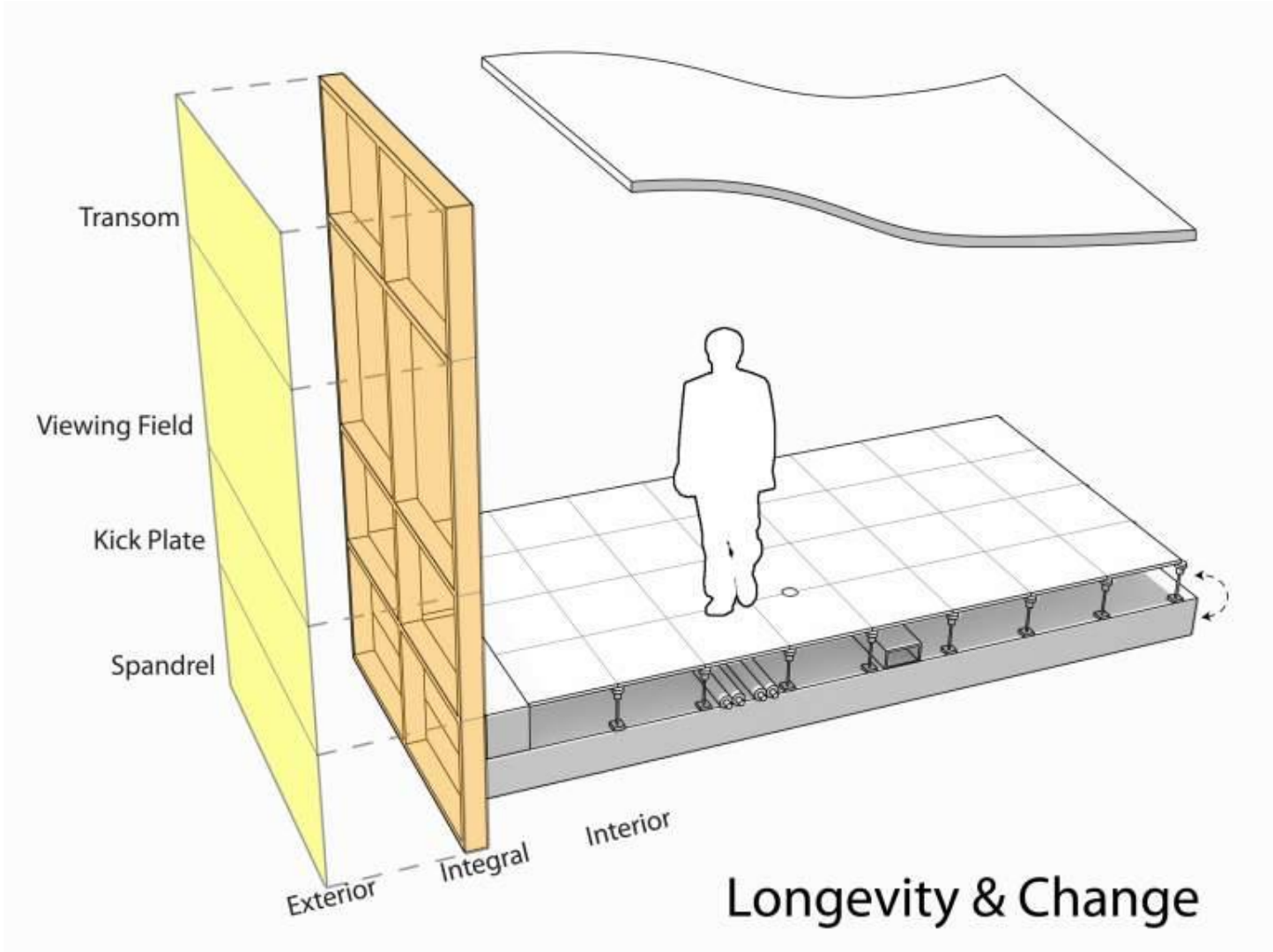

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Heat Loss / Heat Gain

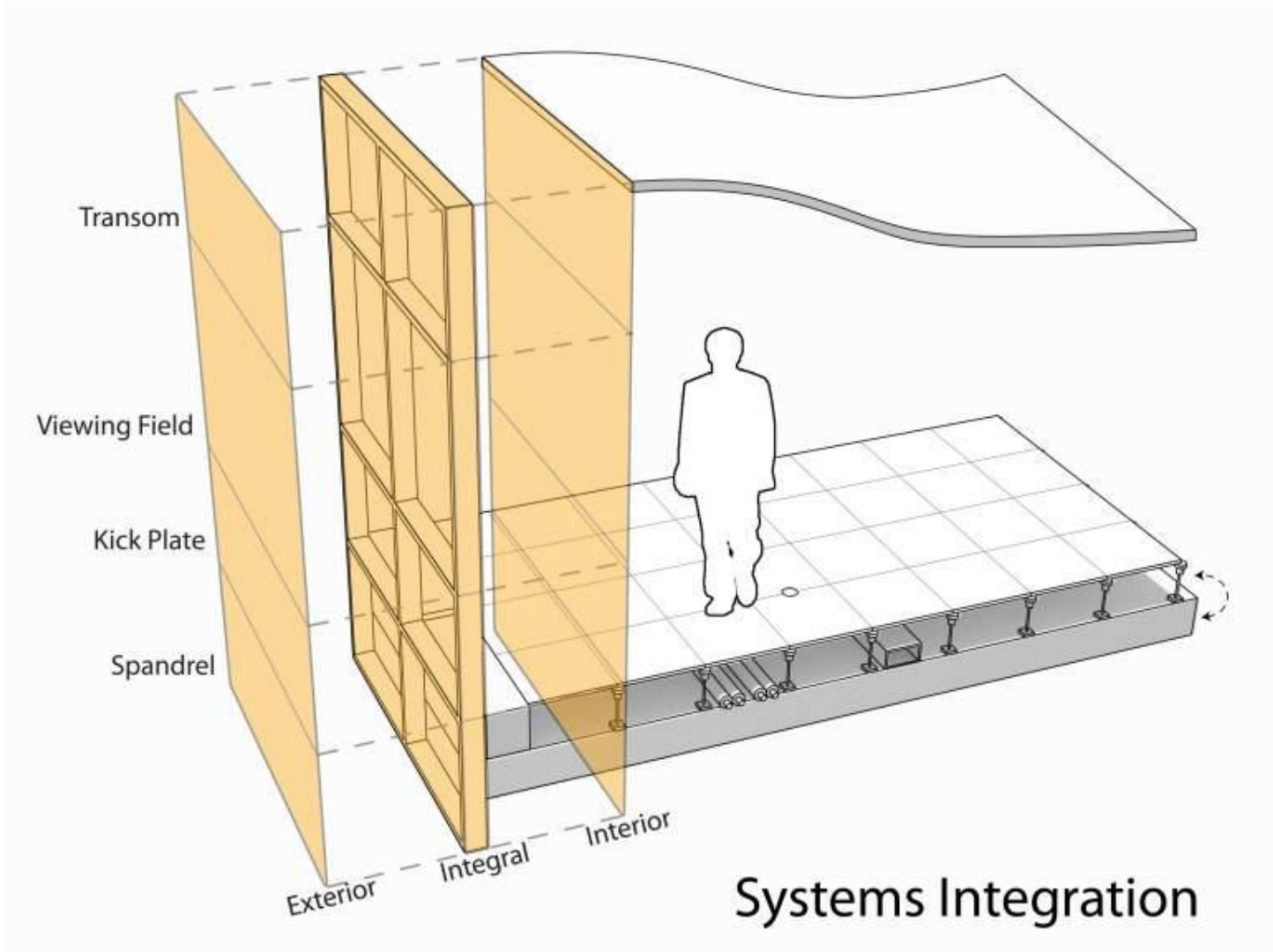

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Shading with Light


Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Load Balancing

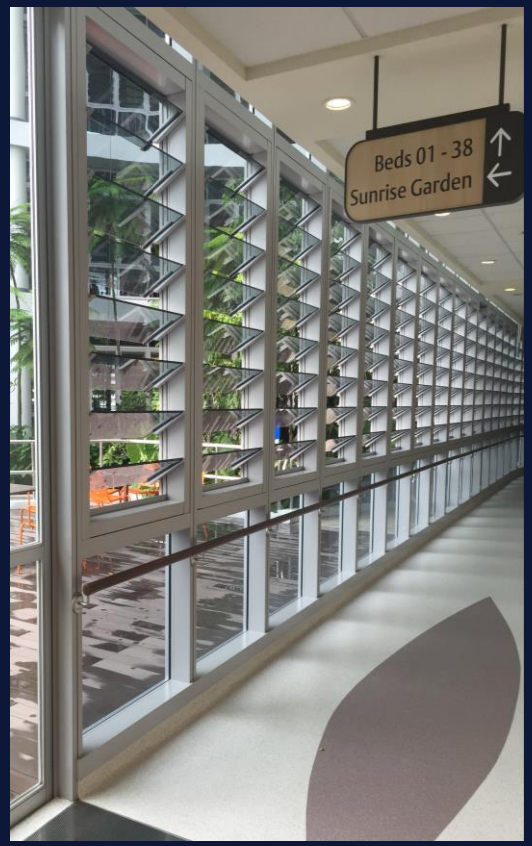

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Heat & Power Gen.

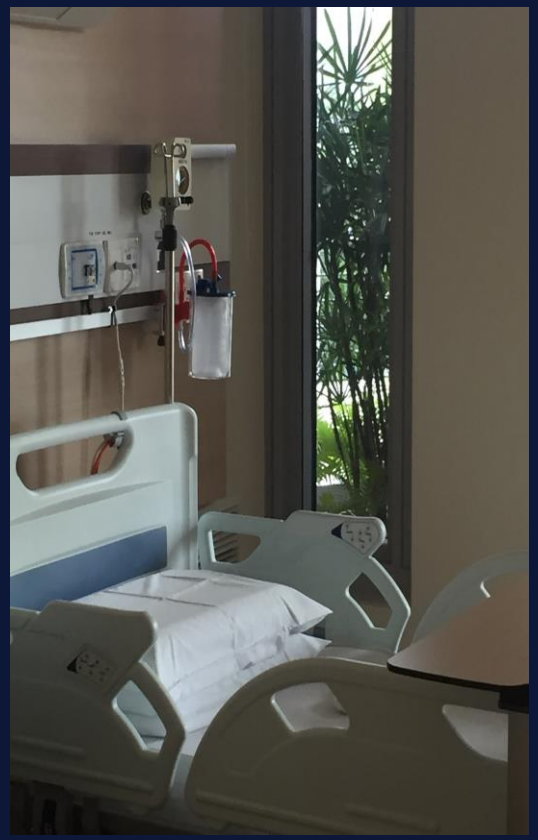

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Water Management


Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Longevity & Change

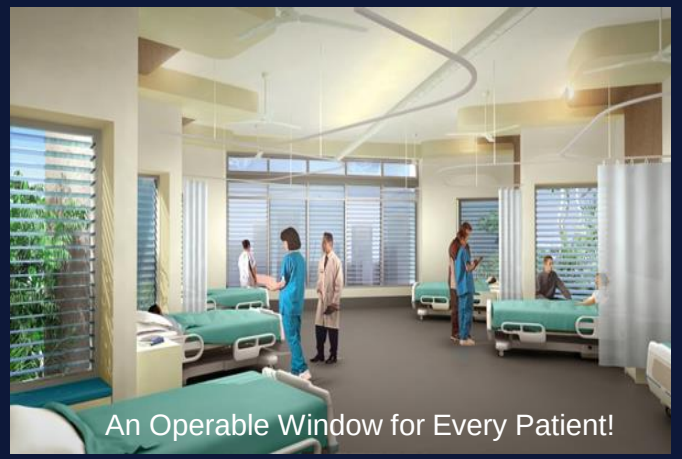

Transom
Viewing Field
Kick Plate
Spandrel
Exterior
Integral
Interior
Systems Integration

Ng Teng Fong General Hospital





CPG A+E
Studio 505 & HOK
Vipac Acoustics



An Operable Window for Every Patient!

How do we Pay for This?

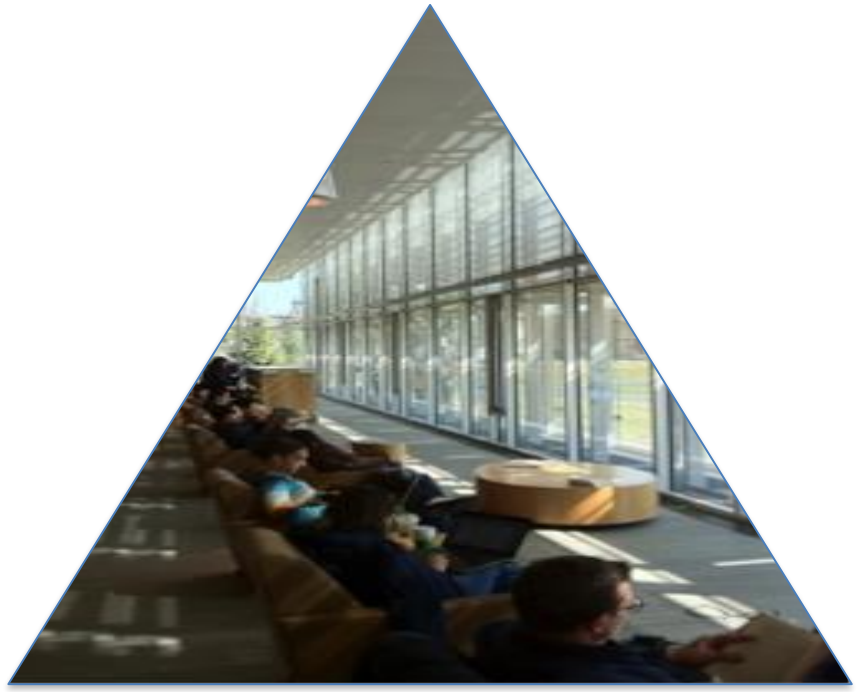
Emerging Biophilic Research

Views of Nature & Community
Daylight Variability
Solar Heat
Thermal Variability – Alliesthesia
Natural Ventilation
Access to Nature – Active Design
Dynamics of Time and Place

Triple Bottom Line of
daylight and natural ventilation as a dominant source

Profit
Lighting Energy Savings
Heating Energy Savings
Cooling Energy Savings
Real estate value

People
Respiratory Health
Visual System Health
Alertness/Sleep Cycles
Employee Productivity
Student Performance
Motivation
Community Engagement
Community Safety



Planet
Power Plant CO2, SOX/NOX/PM
Urban Heat Island Mitigation
Glass Sustainability
HP Window Reusability

TBL Calculations: Invest in Light Redirection Louvers/Blinds

Use light shelves or inverted blinds/louvers for daylighting, shading and views.

Light Redirection Louvers/Blinds: 1st Bottom Line – Financial Capital

The baseline assumes a 50,000 sf building with 6.8 kWh/sf annual lighting energy use at $0.10/kWh.

Costs to Install Light Redirection Louvers

	Per sq ft	Per employee
First Cost Investment *(60% window wall ratio, 33% floor area)*	$20	$400
Total Investment for 50,000 sq ft building	**$66,780**	

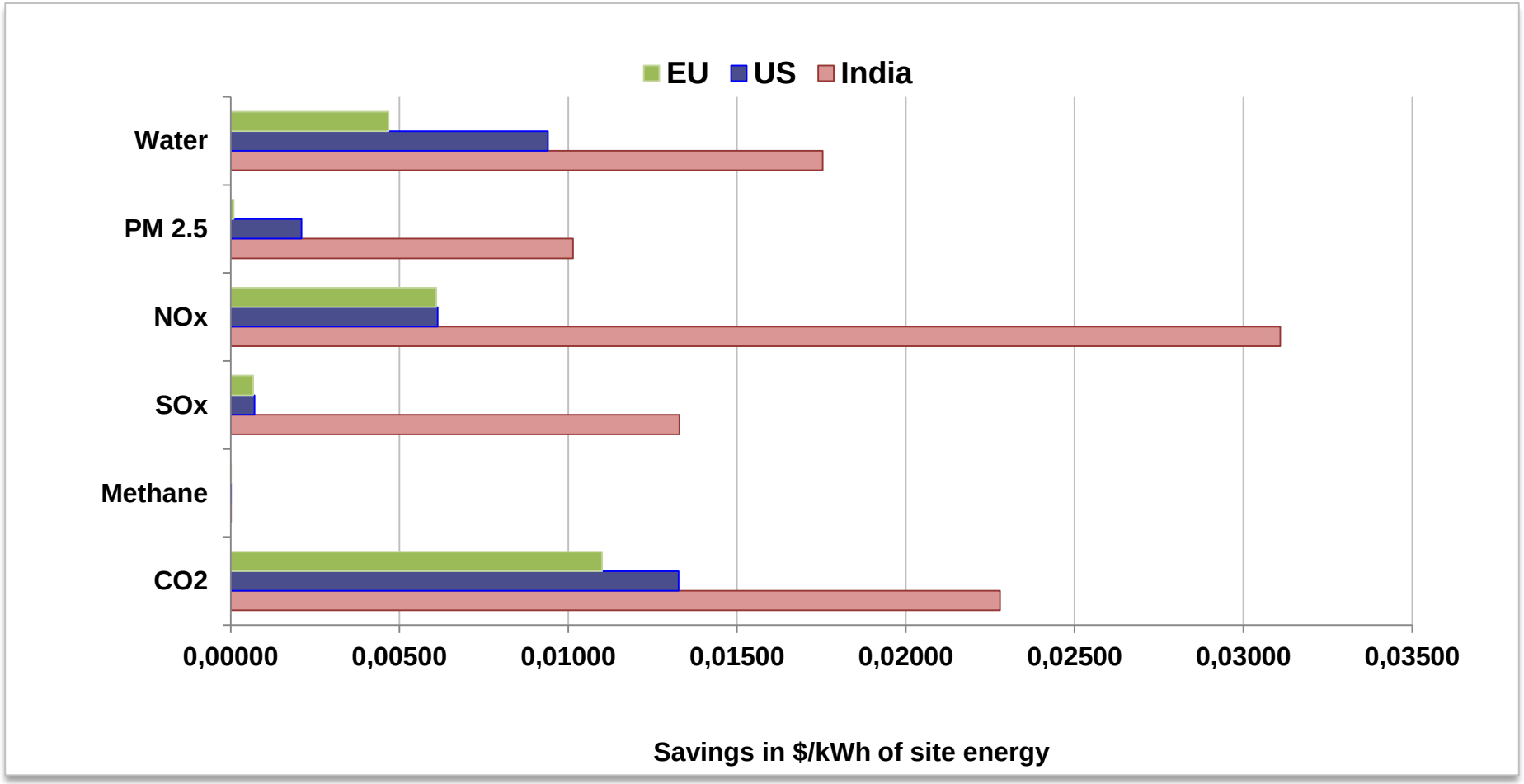
1 Financial Capital Benefits of Light Redirection Louvers

	Per sq ft	Per employee
Annual lighting energy savings (35%)[1]	$0.23	$46
Cumulative ROI (Financial)	**12%**	
Payback Period	**8.5 years**	
15 year Net Present Value *(10% discount rate)*	**$60,000**	

1. De Carli, and De Giuli, (2009): Optimization Of Daylight In Buildings To Save Energy And To Improve Visual Comfort; Analysis In Different Latitudes: Eleventh International IBPSA Conference;

2nd bottom line – Natural Capital in a kWh saved

Developing a data set for environmental cost-benefits of electricity use in three economies, given that economy's fuel mix and efficiency, but US value per pollutant reduction.



28 reference sources, thesis in progress "Integrating Financial, Natural and Human Capital for High Performance Investments in the Built Environment", **Srivastava 2017.**

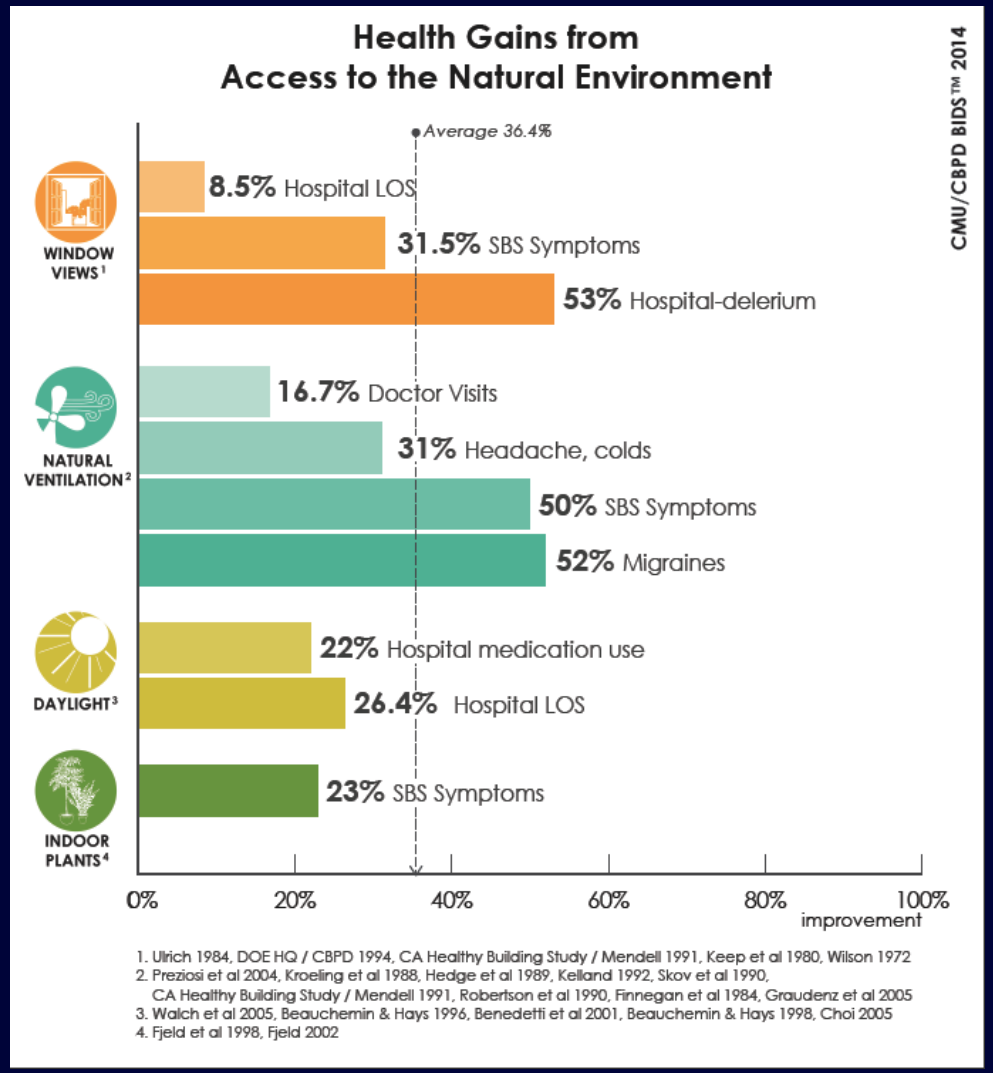
Light Redirection Louvers/ Blinds: 2nd Bottom Line – Natural Capital US

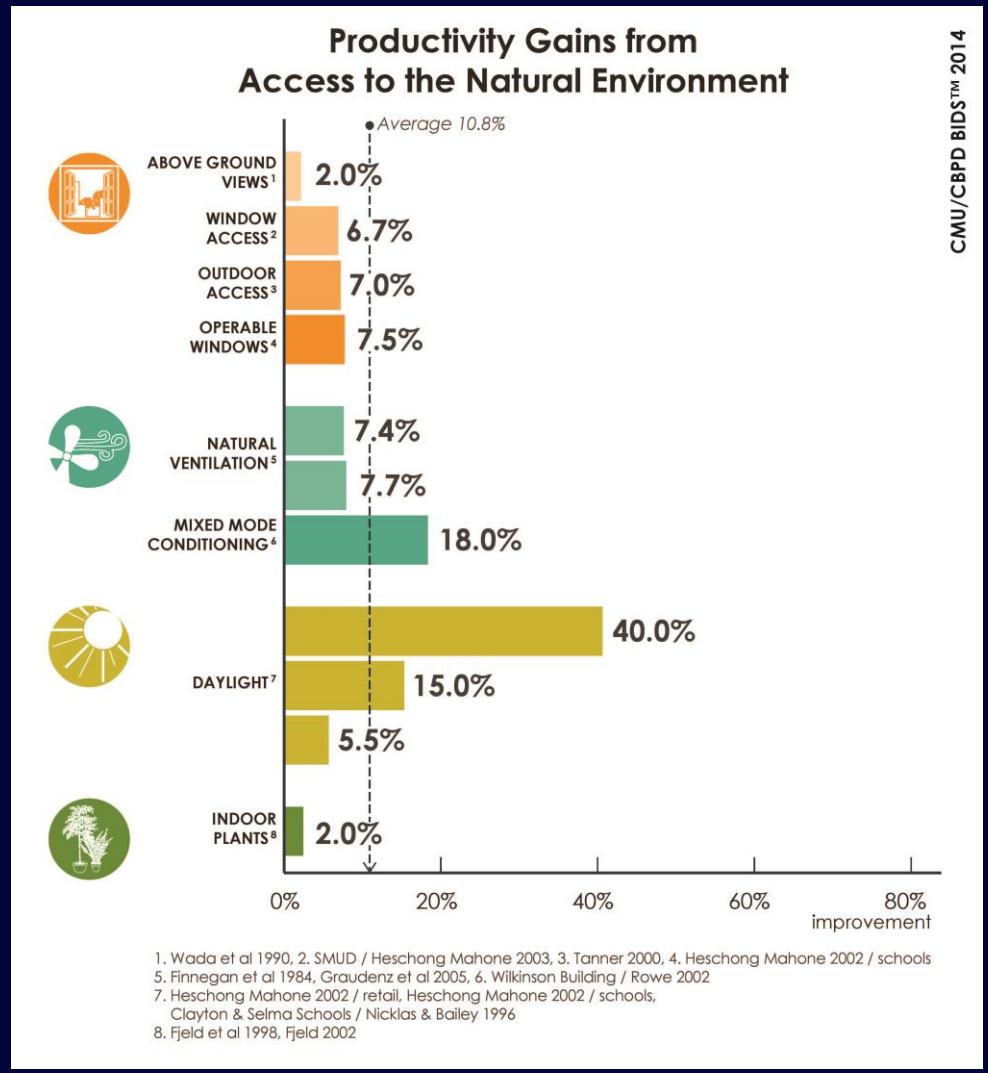
Carbon trading or corporate sustainability declarations increase ROIs
for redirection louvers from 12% to 16% and shorten payback from 8.5 years to 6.5

2 Financial + Natural Capital Benefits of Light Redirection Louvers

	Per sq ft	Per employee
Environmental benefits from energy savings of:	1.30 kWh	475 kWh
Air pollution emissions (SO_X, NO_X)	$0.02	$4.30
CO_2 reductions	$0.03	$6.30
Water savings	$0.02	$4.50
Annual 2nd bottom line savings	$0.07	$15.00
Cumulative ROI (Financial + Natural)	**16%**	
Payback Period	**6.5 years**	
15 year Net Present Value *(10% discount rate)*	**$79,500**	

Ghodke, Kumar, Singh and Khandelwal (2012) Estimation of Green House Gas Emission from Indian Coal Based Thermal Power Plant. IOSR Journal of Engineering, vol 2(4) 591-597
Mittal, Sharma and Singh (2012) Estimates of Emissions from Coal Fired Thermal Power Plants in India
EPA. 2010. Social Cost of Carbon for Regulatory Impact Analysis;Goodkind A.L. and Polasky S. 2013. Health and Environmental Costs of Electricity Generation in Minnesota.
Levy J. (1999) "Environmental Health Effects of Energy Use: A Damage Function Approach.





Environmental surfing for sun, light, air & natural cooling,
contributes measurably to human health and productivity.

Seated Views = Individual productivity

SMUD Call Center /Heschong Mahone Group 2003

7% faster Average Handling Time (AHT) for employees with seated access to views

ROI: 299%

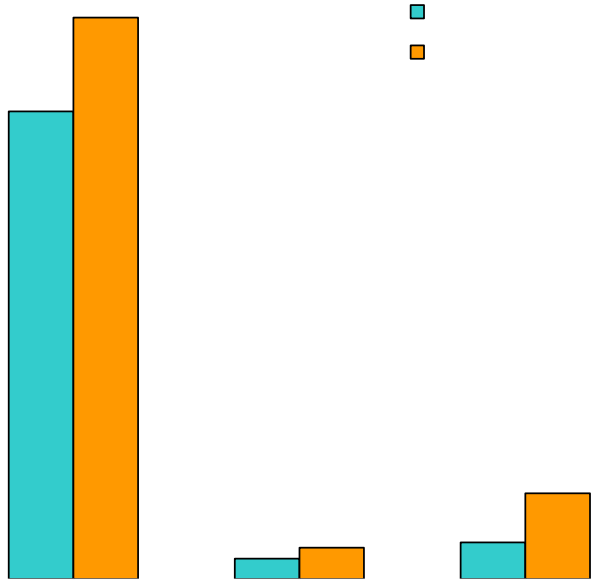
Natural Ventilation = Health + Individual Productivity

Preziosi et al 2004

57.1%
reduction in sickness absence, a 16.7%
reduction in medical services

with natural

ventilation



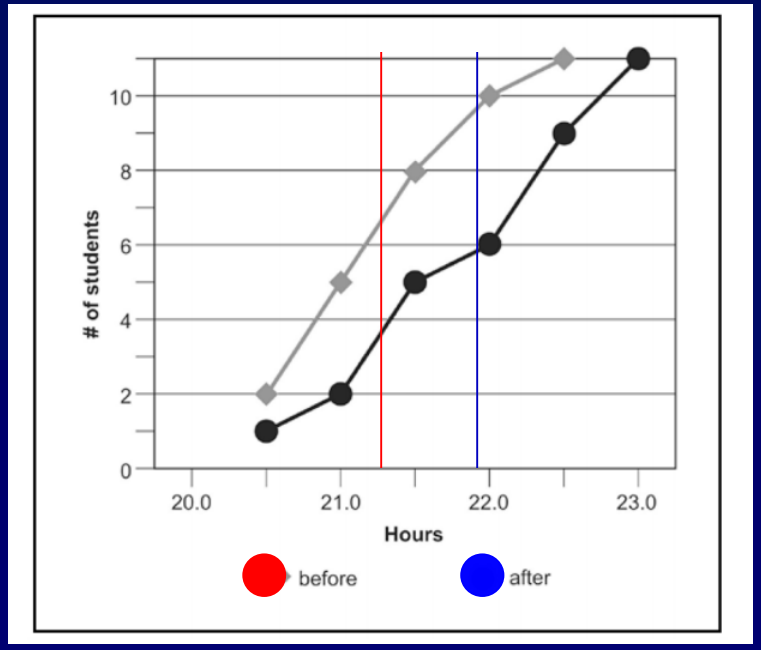
ROI: 27%

Daylight = Sleep Cycles (and Performance)

North Carolina School/ Figueiro and Rea 2012

In a 2010 study of sleep cycles of 8th grade students in the Smith Middle School in Chapel Hill, Figuero and Rea identify that student exposure to short-wavelength morning light significantly regulates their circadian clock and improves sleep times by as much as 30 minutes.

Wolfson and Carskadon (1998) identified that poor performing students obtained about 25 minutes less sleep per night and went to bed on average 40 minutes later on school nights than those who were good performers.



Dim Light Melatonin Onset DLMO
(after – no morning light)

Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students
Mariana G. Figueiro and Mark S. Rea Neuro Endocrinol Lett . 2010 ; 31(1): 92–96..

Light Redirection Louvers/ Blinds 3rd Bottom Line – Human Capital

The baseline assumes 250 employees with an average salary of $45,000 and 256 workdays per year. In a baseline organization, a 15% reduction in absenteeism[1] and 3% productivity[2] increase in office tasks results in a less than1 year payback if purchasing light redirection louvers that support glare control and shade while maintaining seated views.

3 Financial + Natural + Human Capital Benefits of Light Redirection Louvers

	Per sq ft	Per employee
Absenteeism Savings (15% of 1.7%)[1]	$0.58	$115
Productivity increase (3% of 10%)[2]	$2.25	$450
Cumulative ROI (Economic + Environment + Equity)	**158%**	
Payback Period	**Less than 1 year**	
15 year Net Present Value (10% discount rate)	**$195,000**	

1. Thayer, Burke Miller (1995) Daylighting & Productivity at Lockheed. Solar Today, Vol.9, 1995.
Romm, Joseph I. and Browning, William D. Greening the Building and the Bottom Line, http://www.rmi.org/images/other/GDS-GBBL.pdf
2. Osterhaus, W. and Bailey, I. (1992): Large Area Glare Sources and Their Effect on Discomfort and Visual Performance at Computer Workstations: 1992 IEEE Industry Applications Society Annual Meeting; Houston, TX: LBL-35037.

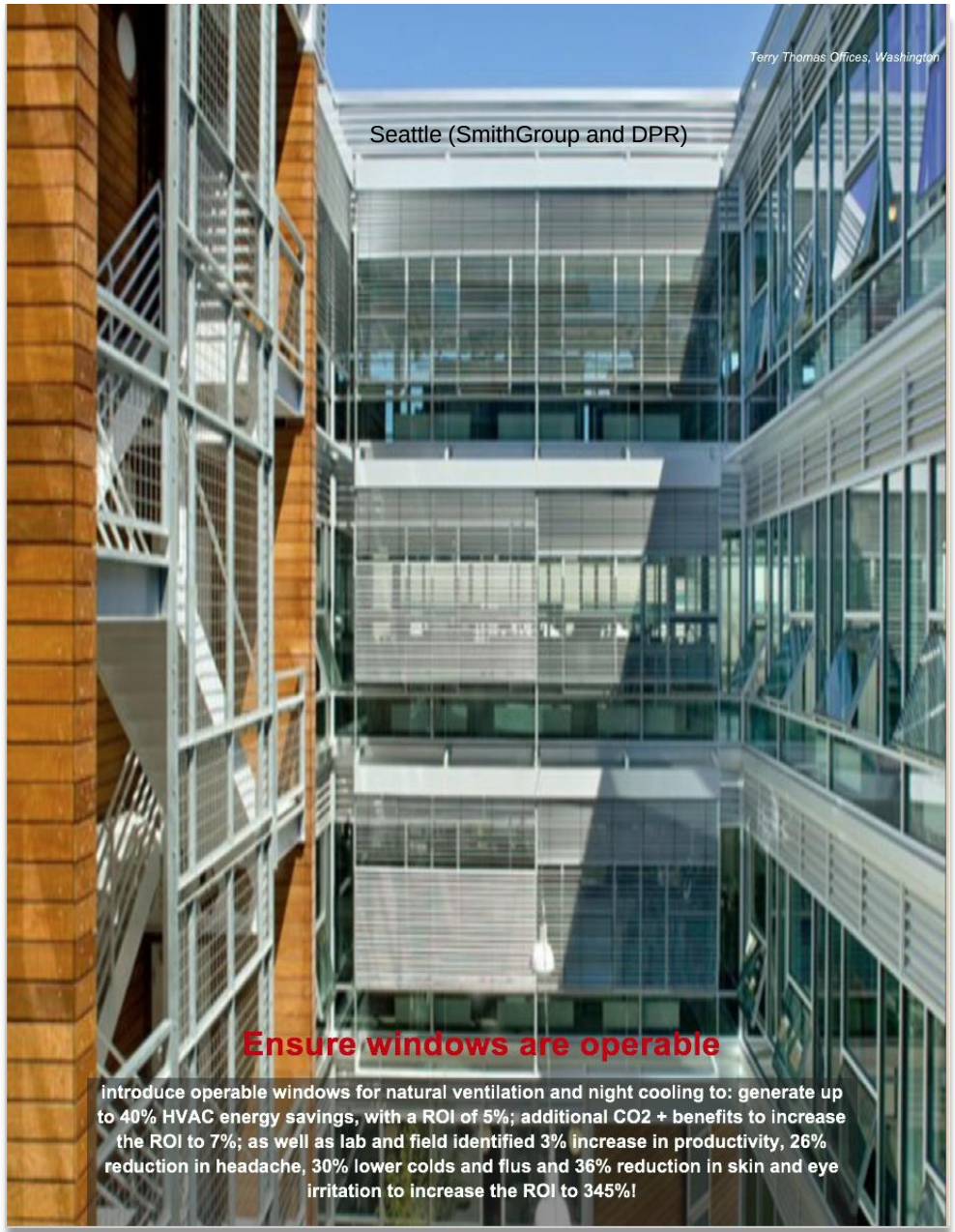


Table 19: Triple bottom line calculations for introducing operable windows for natural ventilation and night cooling

Costs of buying operable windows for natural ventilation and night cooling

	Per sq. ft.	Per employee
First cost for the investment	$15	$360
Initial Investment costs for a 100,000 sq. ft. building *(for 1/3 baseline building perimeter area)*	**$120,000**	

1st Financial Capital savings

	Per sq. ft.	Per employee
HVAC Energy Savings (40%)	$0.09	$19
Annual 1st bottom line savings	**+$0.09**	**+$19**
ROI (Financial)	**5%**	
Payback Period	**19 years**	
Cumulative 15-year Net Present Value	**$ 73,000**	

2. Financial + Environmental Capital savings

	Per sq. ft.	Per employee
Environmental benefits from energy savings of:	0.96 kWh	192 kWh
Air pollution emissions (SO_x, NO_x, PM, CH4)	$0.02	$3
CO_2 reductions	$0.01	$2
Water savings	$0.004	$0.8
Annual 2nd bottom line savings	**+$0.03**	**+$5.8**
Cumulative ROI (Financial + Environmental)	**7%**	
Payback Period	**14 years**	
Cumulative 15-year Net Present Value	**$94,950**	

3. Financial + Environmental + Human Capital savings

	Per sq. ft.	Per employee
Headache reduction (26% * $73)	$0.10	$19
Cold & flu reduction (30% * $68)	$0.10	$20
Skin & eye irritation reduction (41% * $86)	$0.15	$31
Asthma & allergies reduction (20% * $105)	$0.10	$20
Productivity increase (3%)	$5.62	$1,125
Annual 3rd bottom line savings	**+$6.21**	**+$1241**
ROI (Financial + Environment+ Human)	**345%**	
Payback Period	**2 months**	
Cumulative 15-year Net Present Value	**$ 805,700**	

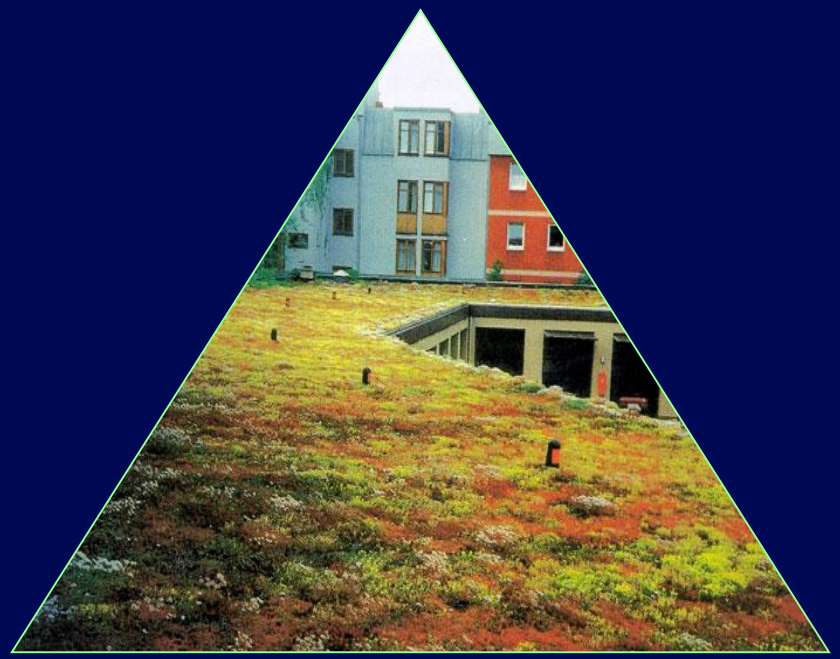
83

Triple Bottom Line

Profit

Economy

Financial Capital



People

Equity

Human Capital

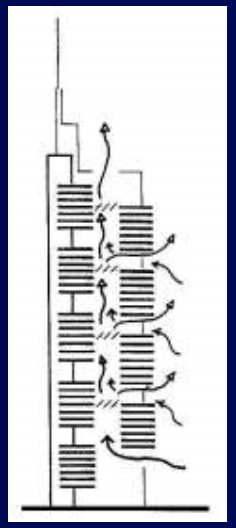
Planet

Environment

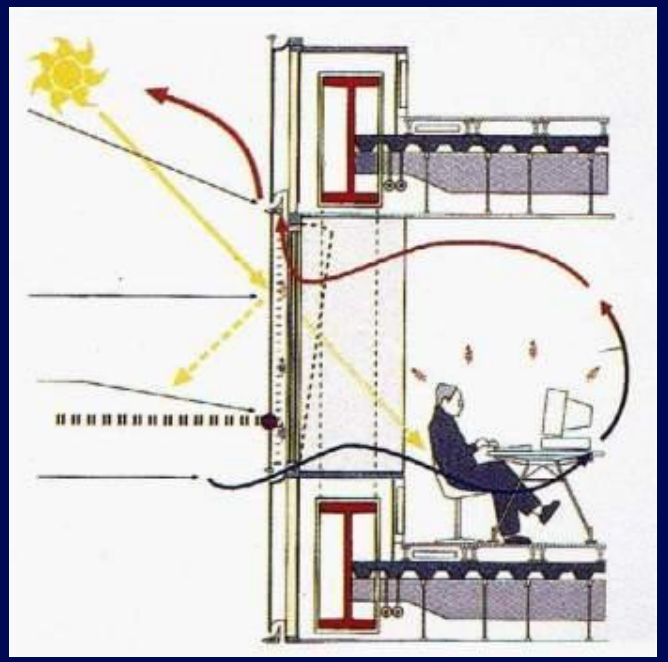
Natural Capital

Vivian Loftness, FAIA Center for Building Performance & Diagnostics Carnegie Mellon University

Commerzbank Frankfurt Foster & Arup



Even high rise offices can be naturally ventilated



GHD Theater - Daylit & Naturally Ventilated Theater, University of Queensland Australia (Richard Kirk, Hassell Eng)

Bullitt Center Daylit & Naturally Ventilated Offices Seattle (Miller Hull, PAE Eng)

Mixed Mode: Daylight & Electric Light

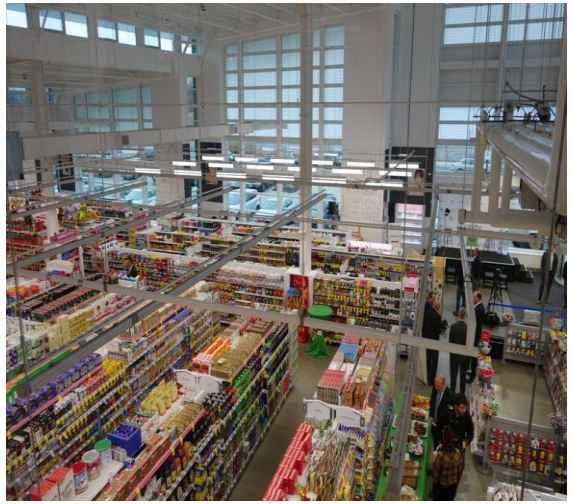
H.E.B. Retail in Texas (Lake Flato and Arup)
Natural Cooling + A.C. (Side by Side & Change

Terry Thomas Offices in Seattle (SmithGroup and DPR)
Natural Cooling only with demand controlled ventilation

Mixed Mode: Natural Cooling & Mechanical

The Leala Hotel in Kovalam India (Charles Correa)
Natural Ventilation + A.C. (Side by Side or Zoned)

Walgrens Retail in Illinois (Camburus, GI En
Natural Ventilation + A.C. (Changeover)



Mixed Mode: Natural Ventilation & Mechanical

The sixth floor "Garden in the Sky" is used frequently for formal and informal meetings and events.

Institute of Building Research Offices in Shenzhen, China (Ye Qing)
Natural Cooling + A.C. (Changeover)

Ng Teng Fong Hospital Singapore (Studio 505, HOK, CPG) Natural Cooling in 70% patient rooms with garden

Mixed Mode: Outdoor & Indoor Work/Learn/Play/Heal

Sustainable Workplaces for Human Health and Produ

Vivian Loftness, FAIA