Sustainable Design for Health & Productivity

South Africa Green Building Council
November 2008

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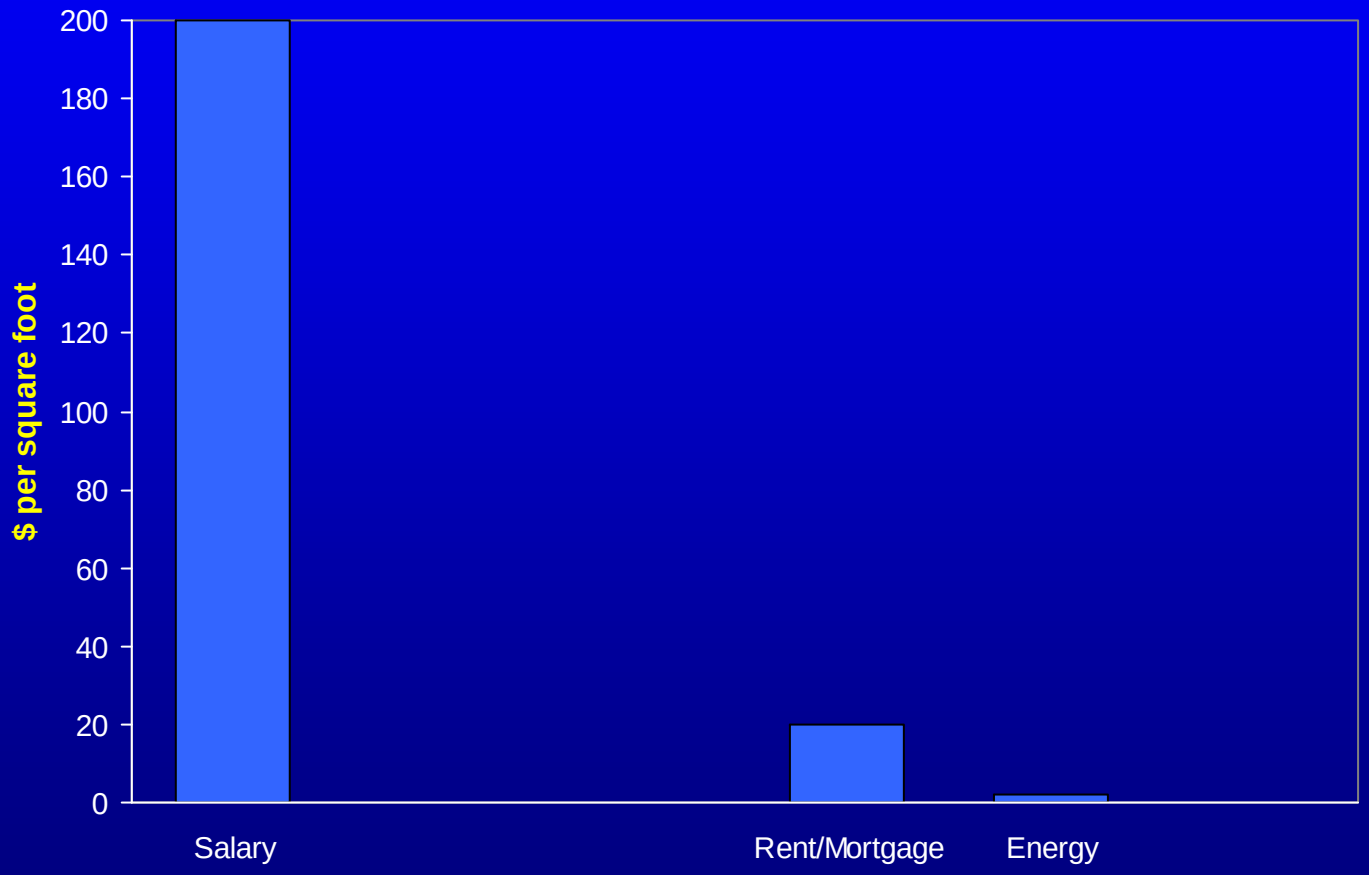
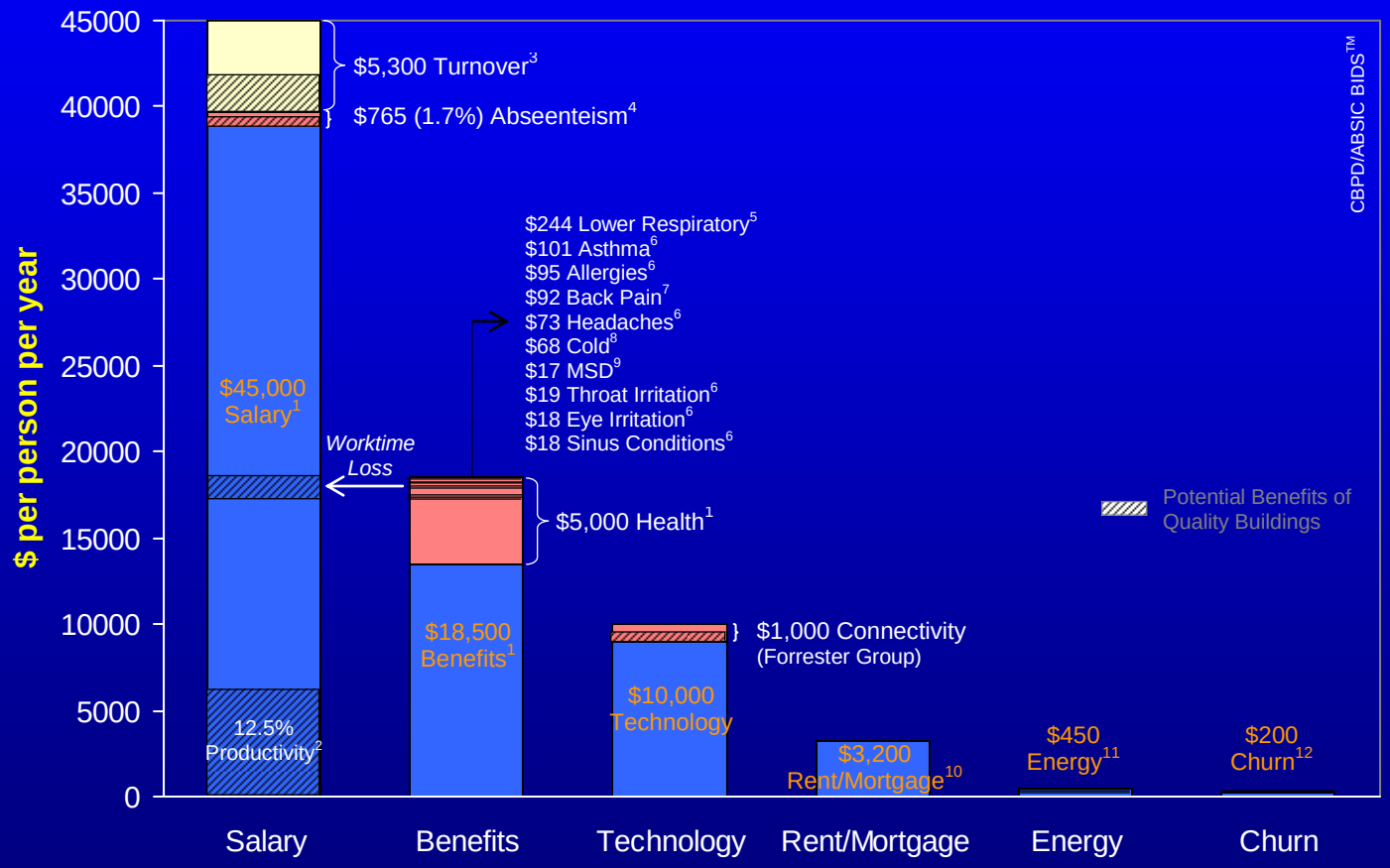
USGBC Board Member, LEED AP
AIA Communities by Design Board Member

Center for Building Performance & Diagnostics
With the Advanced Building Systems Integration Consortium

Potential Cost-Benefits for Building Quality Differences - BIDS™



Potential Cost-Benefits for Building Quality Differences - BIDS™



The True Cost of Least-cost Buildings

First Cost

Operations/ Energy

Individual Productivity

Organizational Productivity

Health

Attraction/ Retention

Organizational Churn

Technological Churn

Tax/ Litigation/ Insurance

Salvage/ Waste

The True Cost of Least-cost Buildings: Annual Energy

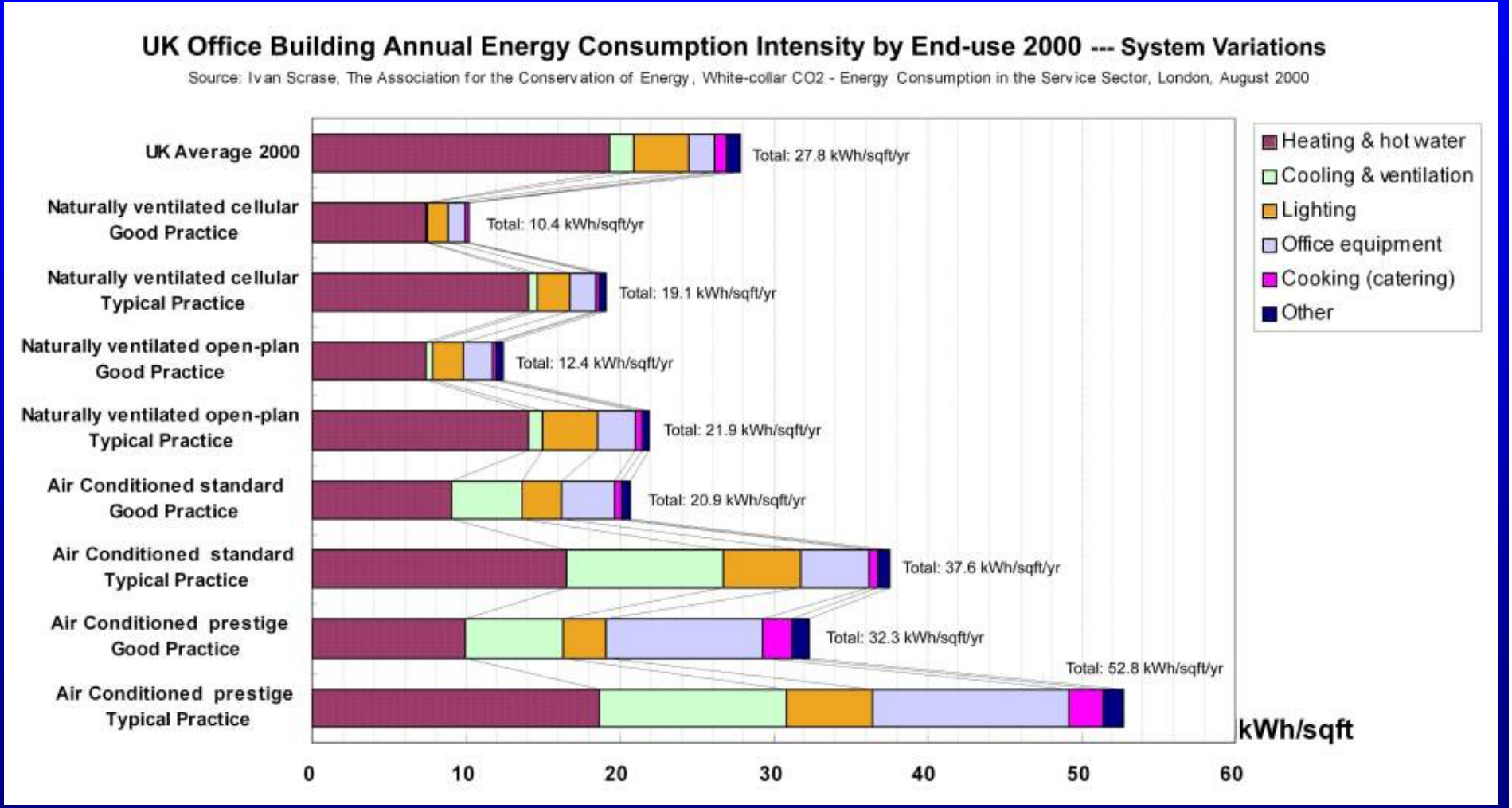
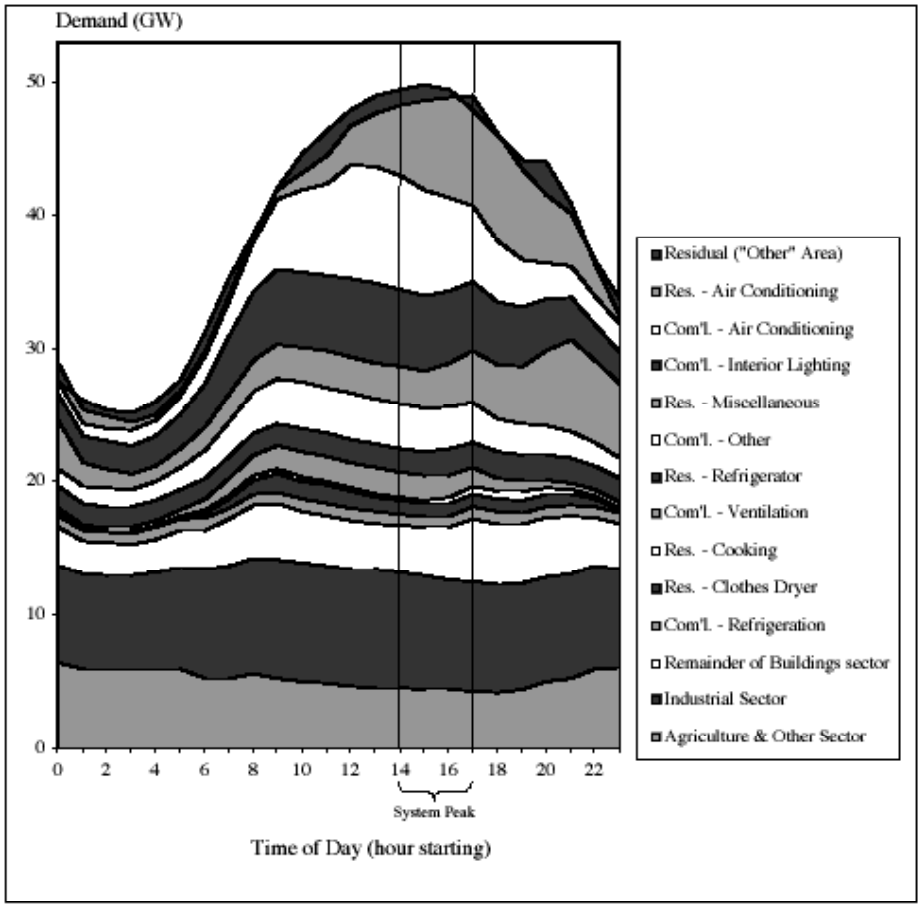


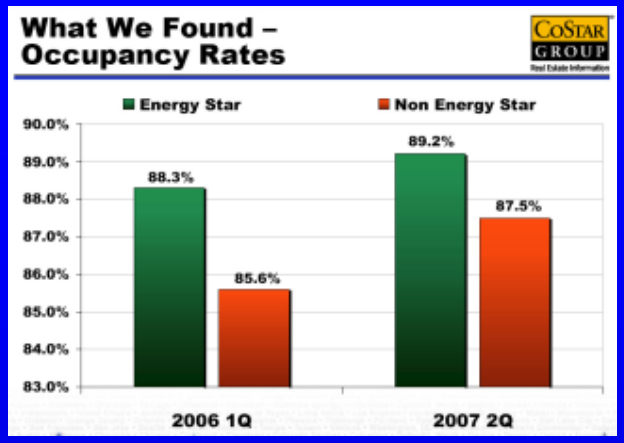
Figure 1: California 1999 Summer Peak-day End-use Load (GW): 10 largest coincident building-sector end-uses and non-building sectors

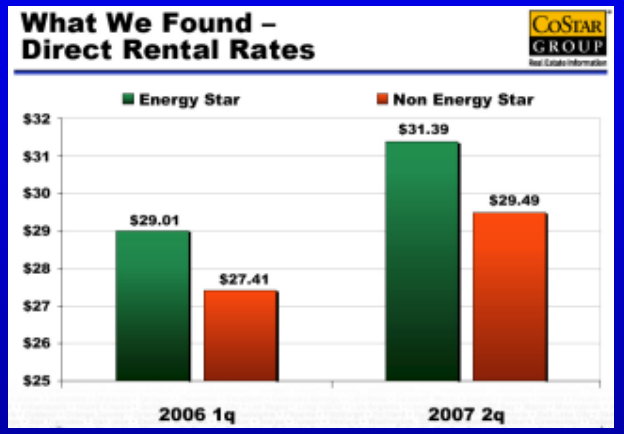


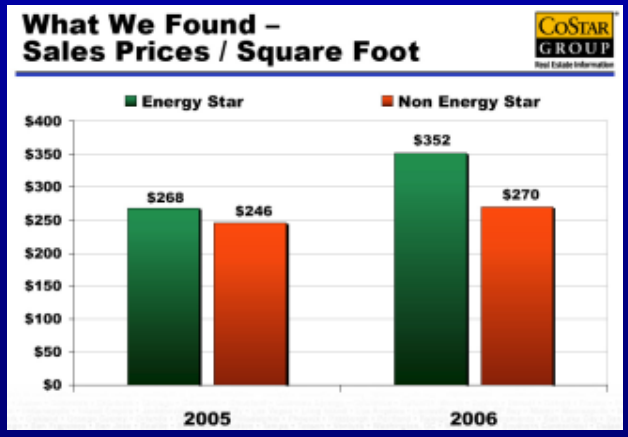
The True Cost of Least-cost Buildings: Peak Energy

increasing peak power demands in buildings are challenging electricity reliability; purchases in inefficient stand-by power are siphoning off energy efficiency investments.

The True Cost of Least-cost Buildings:
Vacancy





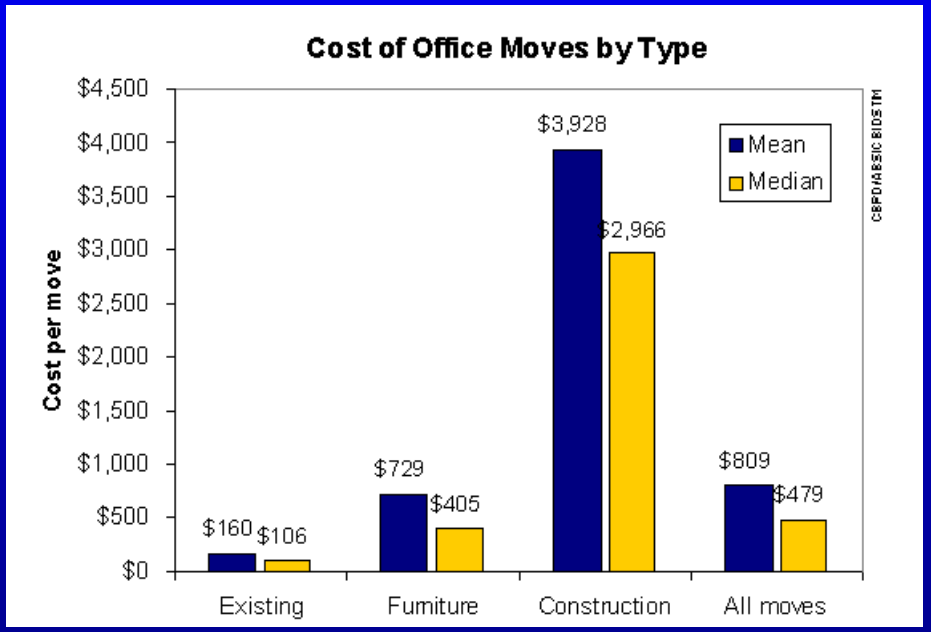


True Cost of Least-cost Buildings:
Churn Rate and Cost

Churn Rate

Facility Use	Churn Rate
Headquarters	45%
Other offices	47%
Multi-use	32%
Research	34%
Factory/Plant	25%
Education/Training	11%
Call Center	47%
Average	41%

Churn Cost



International Facility Management Association (IFMA) (2002) Research Report 23: Project Management Benchmarks

Average Churn Cost is $200 per employee annually
based on a 41% average churn rate at $479 per move

True Cost of Least-cost Buildings: Absenteeism

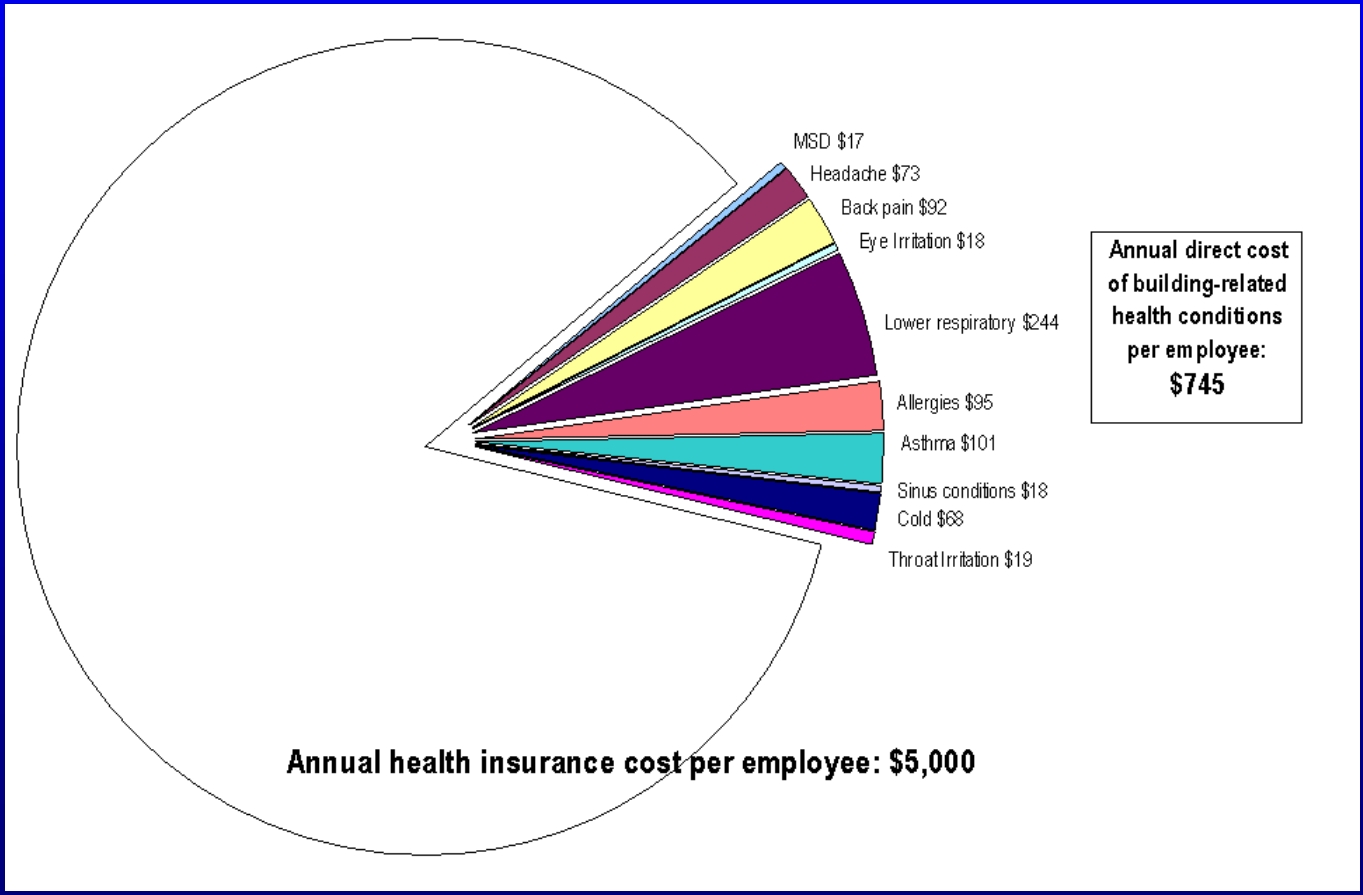
Baseline Employee Salary and Benefits

	Annual absenteeism rate	Equivalent hours lost work	Annual cost to employer
Private sector employees	**1.7%**	35	$ 765
Public sector employees	**2.2%**	42	$ 1,100

Bureau of Labor Statistics, U.S. Department of Labor (2003)

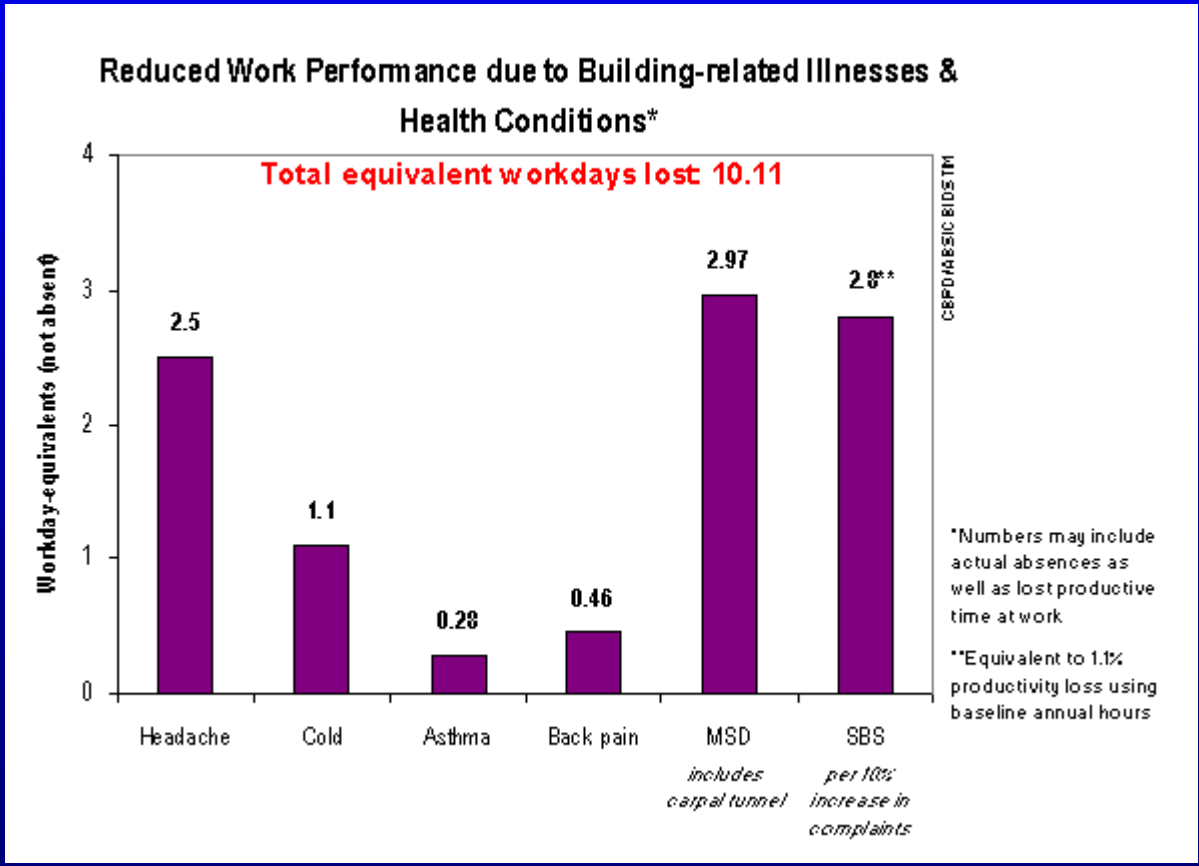
True Cost of Least-cost Buildings:
Direct Costs of Building-related Illnesses and Health Conditions

Treatment for illnesses and health conditions that are influenced by the indoor environment ,costs employers at least $750 per employee annually, accounting for approximately 14% of all annual health insurance expenditures.



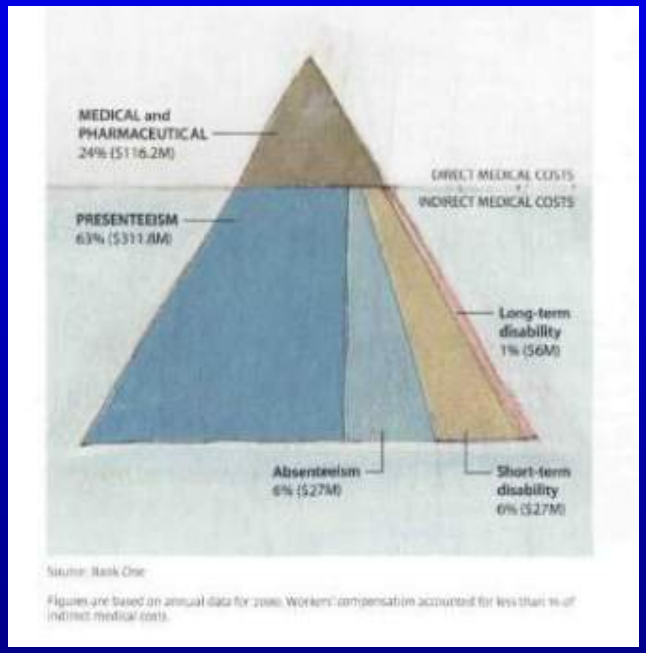
True Cost of Least-cost Buildings:
Health-related Productivity Costs

Productivity loss may result from absence from work, but is more often due to reduced effectiveness on the job. In total, productivity losses from building-related health problems are equivalent to more than 10 days per employee per year.



Presenteeism - at work but out of it

Paul Hemp HBR Oct. 2004



Condition	Prevalence	Average productivity loss	Aggregate annual loss
Migraine	12.0%	4.9%	$434,385
Arthritis	19.7	5.9	865,530
Chronic lower-back pain (without leg pain)	21.3	5.5	858,825
Allergies or sinus trouble	59.8	4.1	1,809,945
Asthma	6.8	5.2	259,740
GERD (acid reflux disease)	15.2	5.2	582,660
Dermatitis or other skin condition	16.1	5.2	610,740
Flu in the past two weeks	17.5	4.7	607,005
Depression	13.9	7.6	786,600

Source: Debra Lerner, William H. Rogers, and Hong Chang, at Tufts–New England Medical Center

True Cost of Least-cost Buildings:
Attraction/Retention Cost and Turnover Rate

Average Attraction/Retention Cost is $5,300 per employee annually based on $25,875 turnover cost at a rate of 20%.

Turnover Rate

	Average Turnover Rate
Private professional	20.3%
Government	6.8%

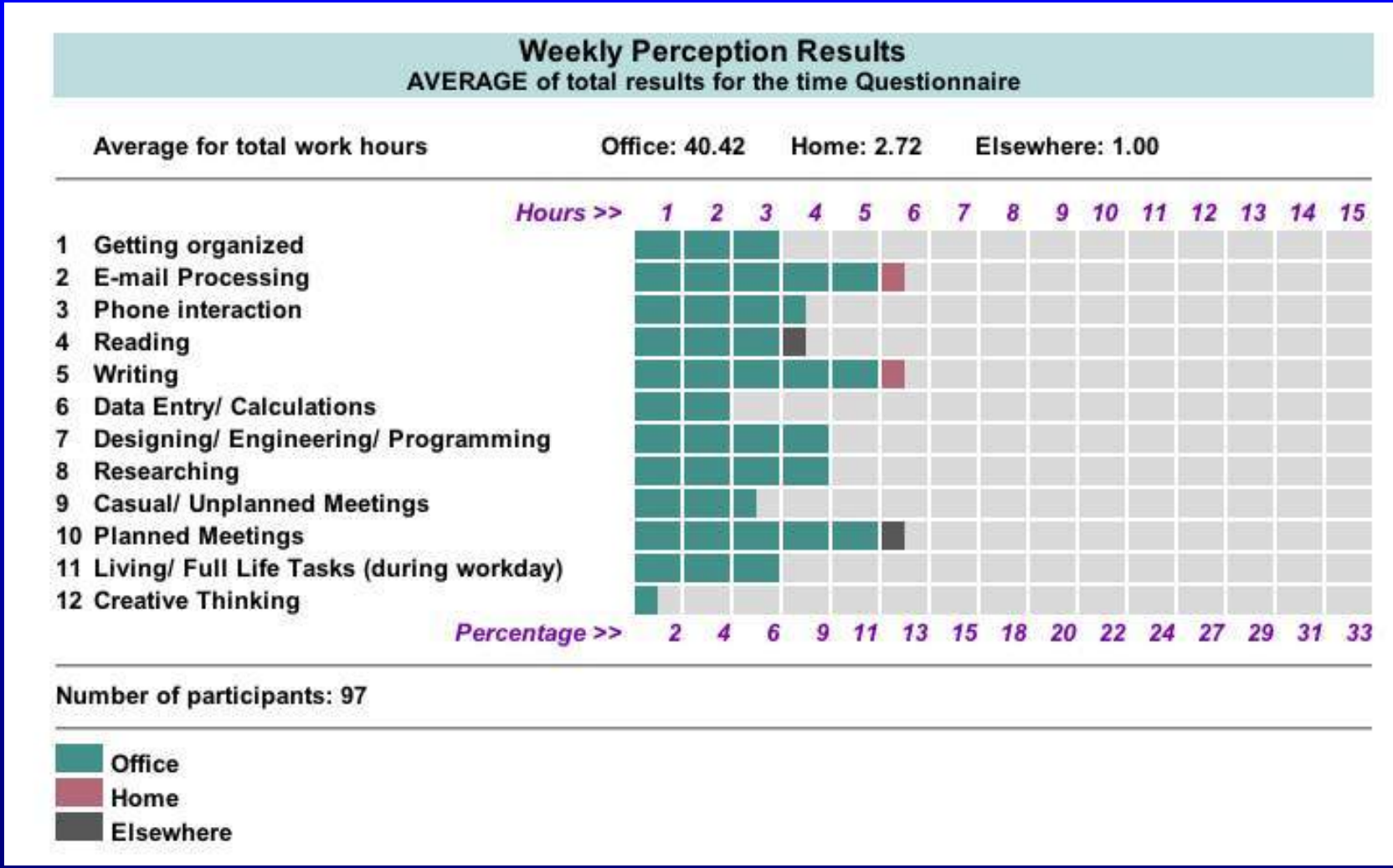
Turnover Cost

Cost of Turnover for one position		
Termination	$ 1000	
Replacement	$ 9,000	
Productivity	$15,875	(3 months baseline salary and benefits)
Total	**$25,875**	

Fitz-Enz, Jac (2000) The ROI of Human Capital: Measuring the Economic Value of Employee Performance. New York: American Management Association, 2000.
Bureau of Labor Statistics, U.S. Department of Labor (2003) Job Openings and Labor Turnover Survey (JOLTS)

Measuring Productivity?

Dependent on Tasks and Time Spent



What building attributes matter the most?

Air

Light

Thermal Control

Privacy and Interaction

Ergonomics

Material Quality

Access to Nature

Land use and mobility

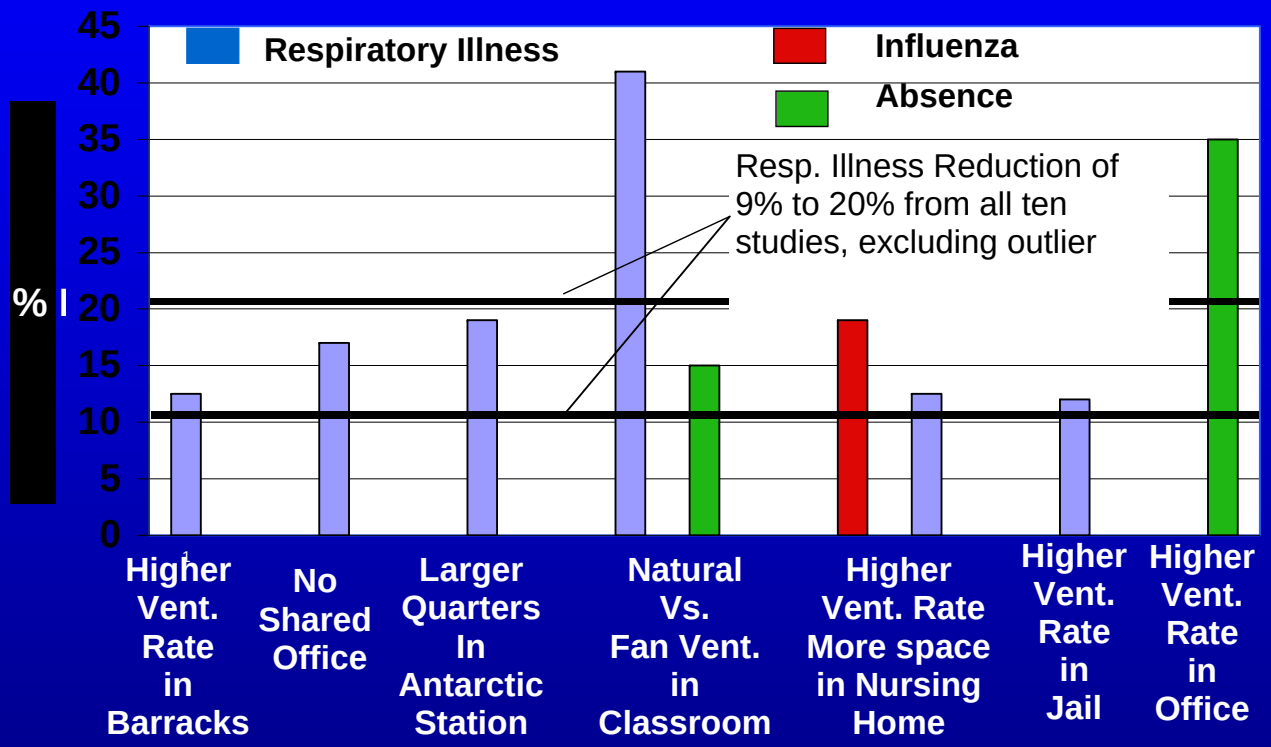
Wine Creek Residence, Siegel & Strain, CA

Healthy, Sustainable Air

Maximize natural ventilation with mixed-mode HVAC
Separate ventilation air from thermal conditioning
Provide task air for individual control
Pollution source control
Improve the quality and quantity of outside air

The Health Potential of Buildings and Communities

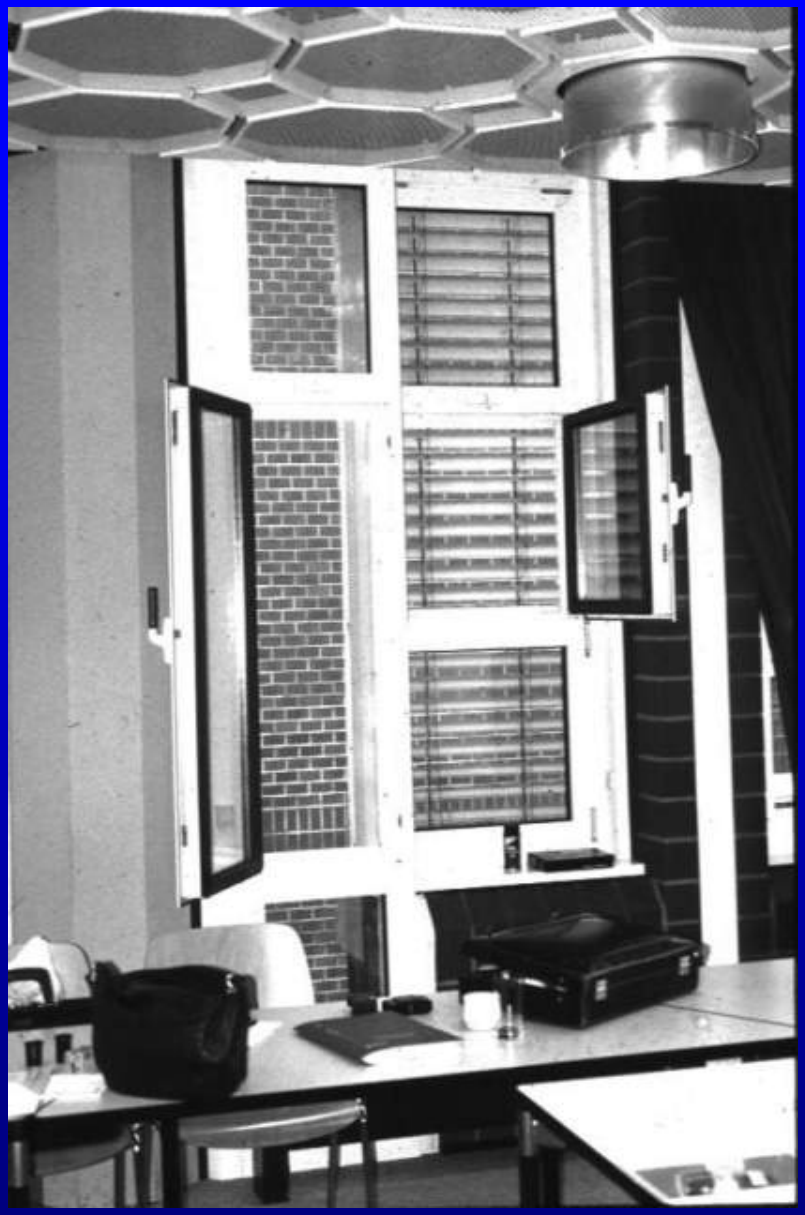
Sick Building Costs
Healthy Building Gains



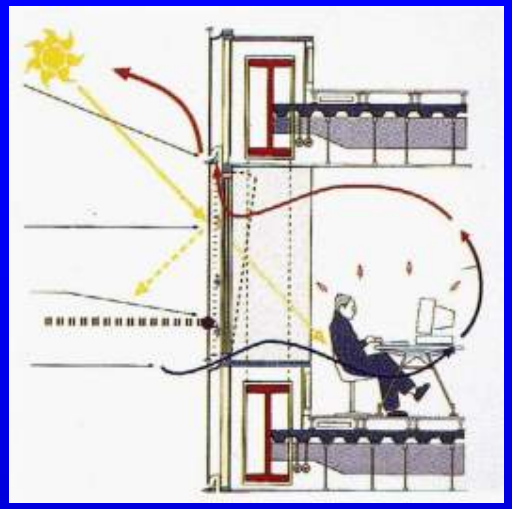
(Fisk/LBNL 2000)

Increased outdoor ventilation rates and natural ventilation significantly reduces respiratory illness, flus and absenteeism by 9-20%

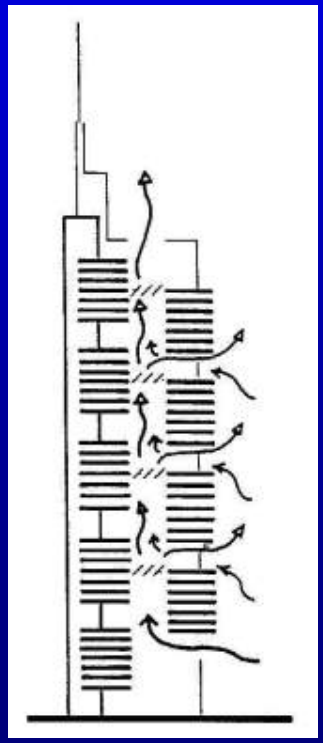
Access to operable windows reduces energy use, absenteeism, SBS symptoms, and improves productivity and test scores



Colonia Insurance



Even high rise offices can be naturally ventilated



	INTERIOR	INTEGRAL	EXTERIOR
TRANSOM ZONE A	A1	A2	A3
VIEWING FIELD ZONE B	B1	B2	B3
BRUESTUNG ZONE C	C1	C2	C3
SPANDREL ZONE D	D1	D2	D3

Sustainable Enclosures

Daylighting dominant
Natural ventilation dominant
Solar heat and glare control
Load balancing –
façade as circulatory system
Thermal mass/ flywheel effect

Solar heating, cooling, power
Sustainable materials
Modular, designed for change
Designed for disassembly
100% recycled content

Healthy, Sustainable Light

Maximize the use of Daylighting without glare
Select the highest quality lighting quality fixtures
Separate task and ambient light
Design Plug-and-play lighting and dynamic lighting zones

Shading alone passively reduces overheating, glare, and energy costs;

and can be combined with light redirection for effective daylighting

Sustainable, High Performance Lighting includes improvements in fixtures, ballasts, lamps, lenses; the separation of task and ambient lighting; with user responsive, innovative controls

Task light:
Split task-ambient lighting task light with articulated arm and relocatable on the desktop

Controls:
Individual control, continuous dimming to 0%, daylight dimming, occupancy sensors

Katzev 1992 | DeMarco and Lister 1987

Lighting Quality = Individual Productivity

In a 1992 controlled experiment, Katzev identifies a 26% improvement in reading comprehension in offices with direct/indirect luminaires, as compared to performance in offices with standard recessed troffers.

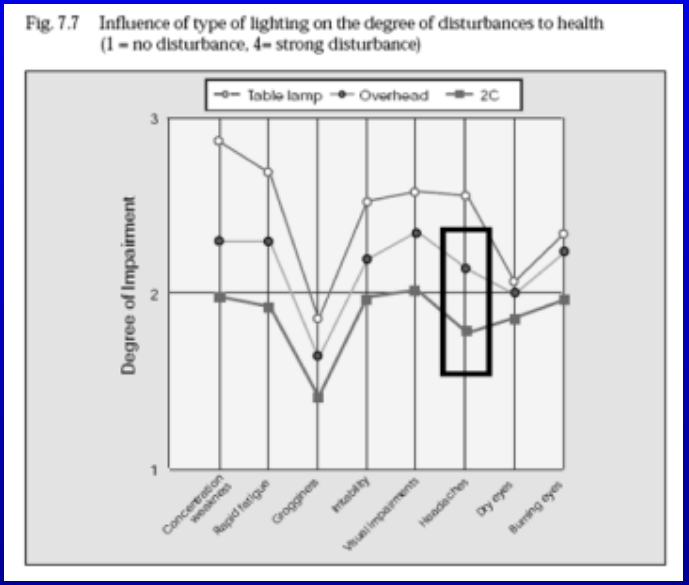
Katzev, R. (1992) The Impact of Energy-Efficient Office Lighting Strategies on Employee Satisfaction and Productivity. Environment and Behavior, 24:6, pp. 759-778.

DeMarco, T. and Lister, T. (1987) Peopleware: Productive Projects and Teams. Dorset House Publishing Co.

Lighting control = Individual productivity + Health

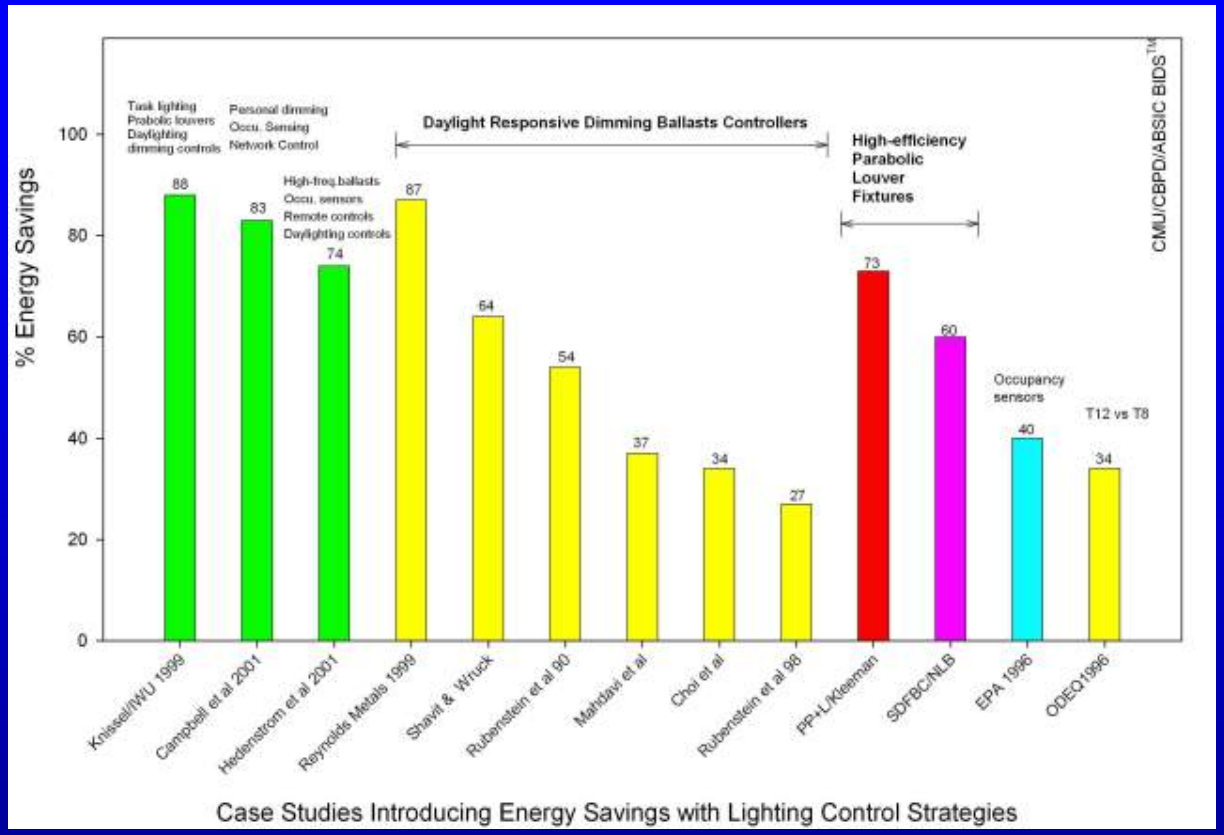
Cakir and Cakir 1998

In a 1998 multiple building study in Germany, Çakir and Çakir identify a 19% reduction in headaches for workers with separate task and ambient lighting, as compared to workers with ceiling-only combined task and ambient lighting.



First cost increase:	$314 /employee
Annual health savings:	$14 /employee
Annual productivity savings:	$87 /employee
ROI:	**32%**

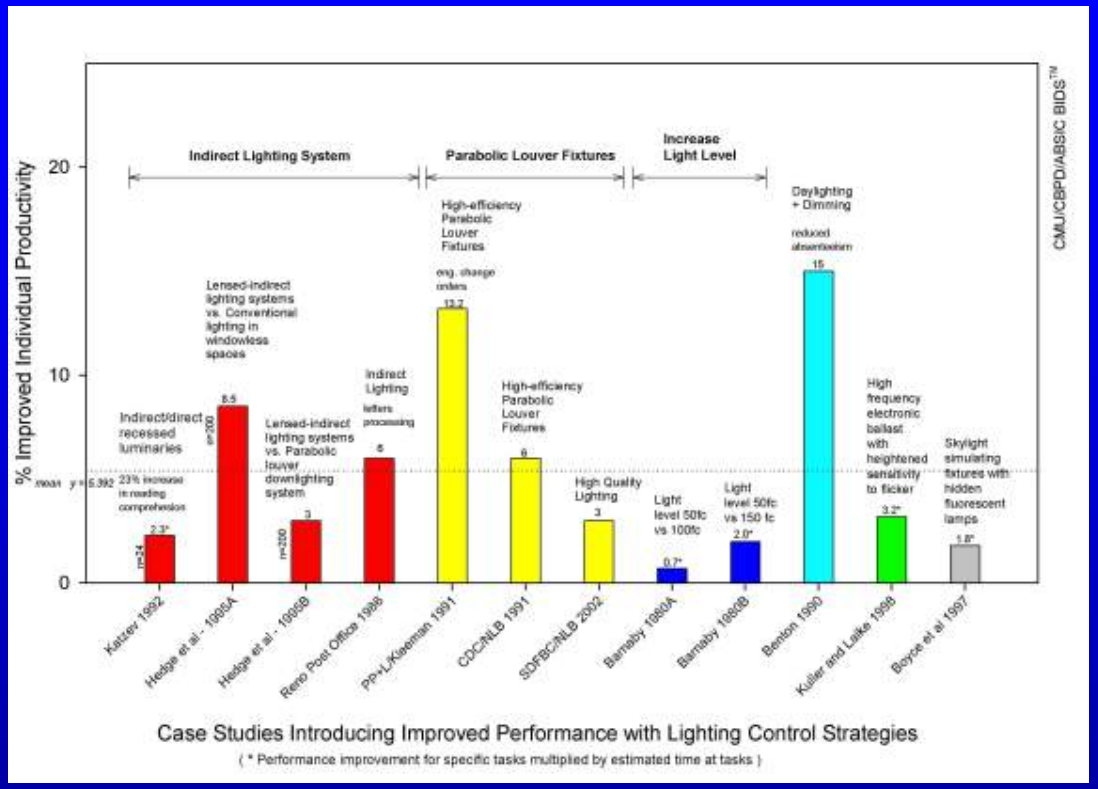
Lighting System Quality Reduces Energy Use



13 international case studies demonstrate that improved lighting design reduces annual energy loads by 27-88%.

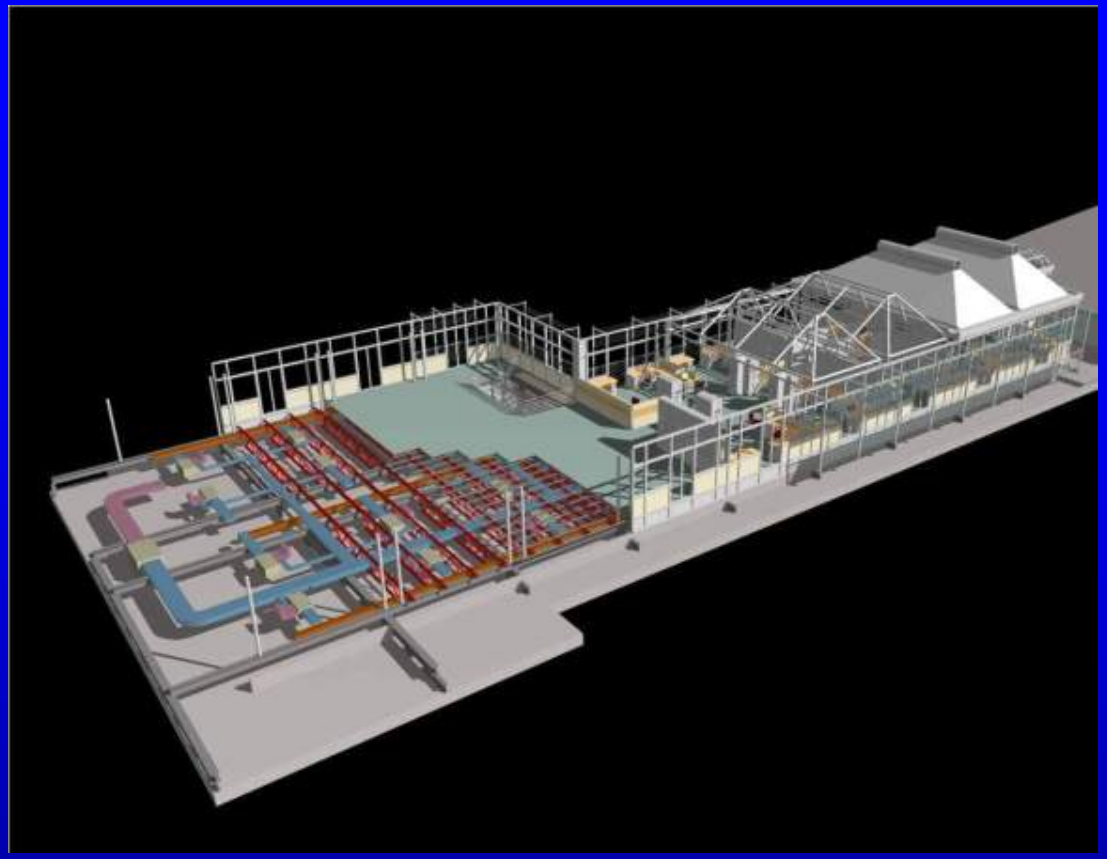
6 studies demonstrate 27-87% improved lighting design decisions
4 studies identify 40-88% energy savings through innovative control systems
3 studies illustrate 34-73% energy savings from higher quality fixtures

Lighting System Quality Increases Individual Productivity



12 international case studies demonstrate that improved lighting design increases individual productivity between 0.7-23%.

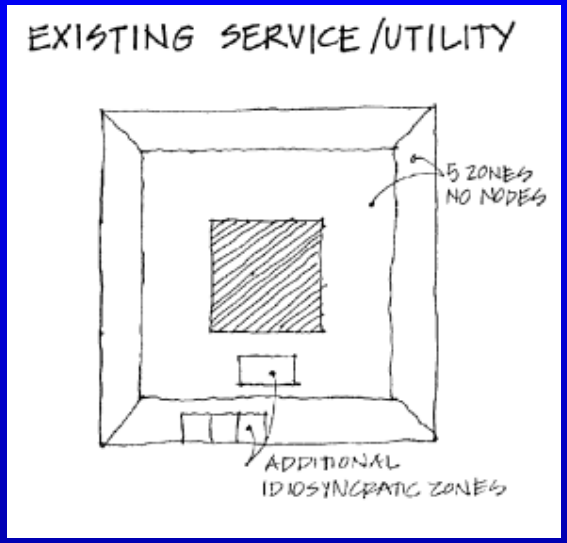
4 studies demonstrate 3-23% productivity gains with the introduction of indirect-direct lighting systems
4 studies demonstrate 3-13.2% productivity gains with the higher quality fixtures
4 studies demonstrate 0.7-2% productivity gains with higher daylighting levels & daylight simulating fixtures

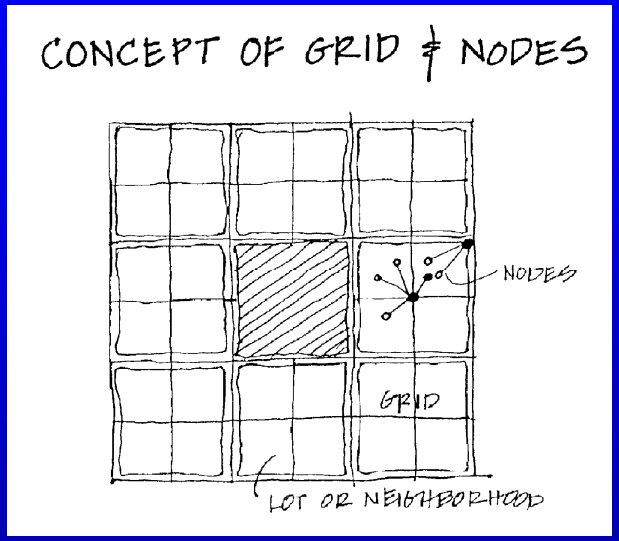


Healthy, Sustainable Thermal Control

Separate ventilation air from thermal conditioning
Install integrated, prototyped, robust HVAC systems
Provide individual thermal controls
Design for dynamic thermal zone sizes
Design for building load balancing and radiant comfort

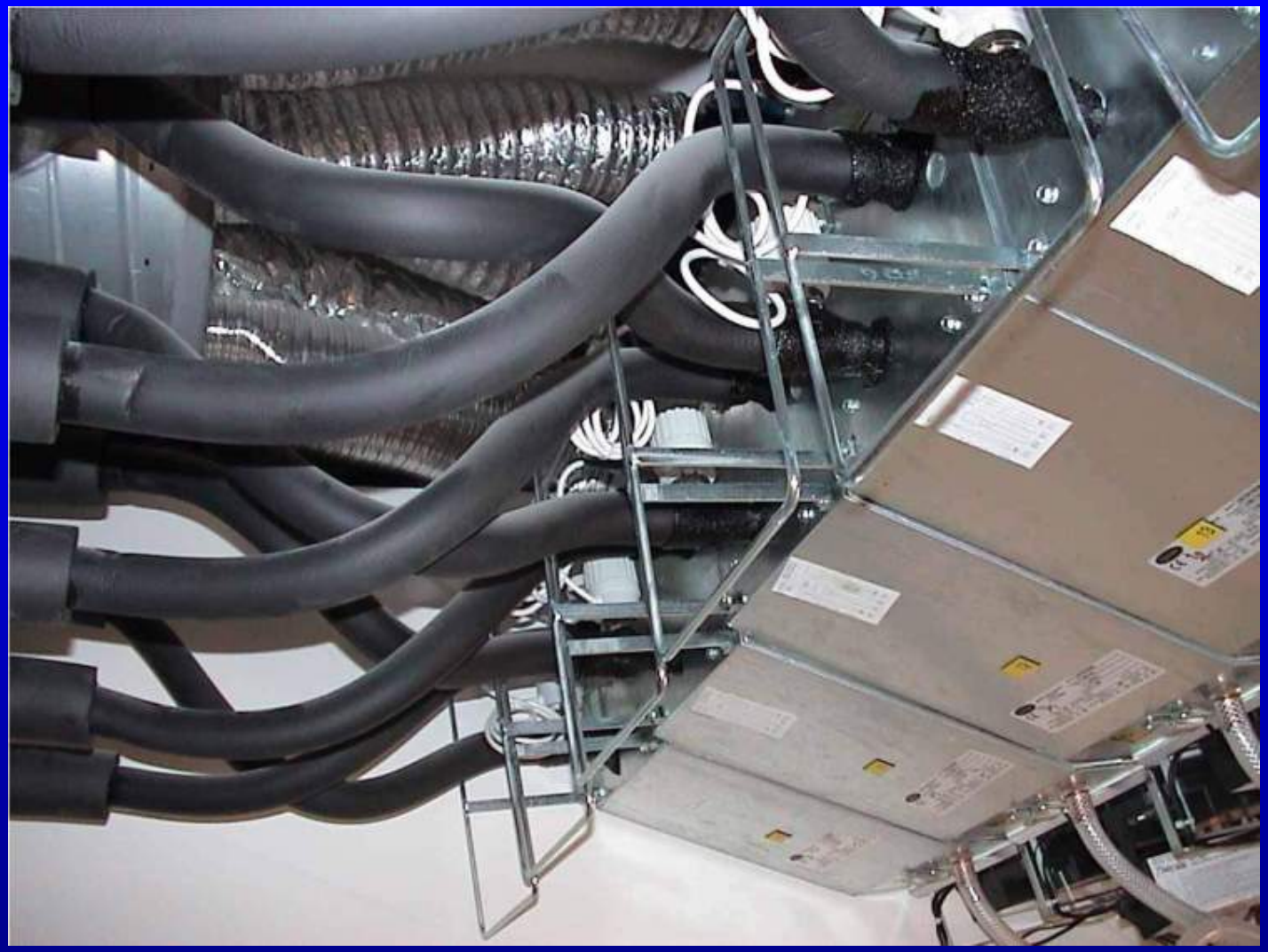
Sustainable design depends on the design of flexible, plug and play systems.





Flexible Grid - Flexible Density - Flexible Closure Building Infrastructure Systems

are a constellation of building subsystems that permit each individual to set the location and density of HVAC, lighting, telecommunications, and furniture, and the level of workspace enclosure (ABSIC/CMU).

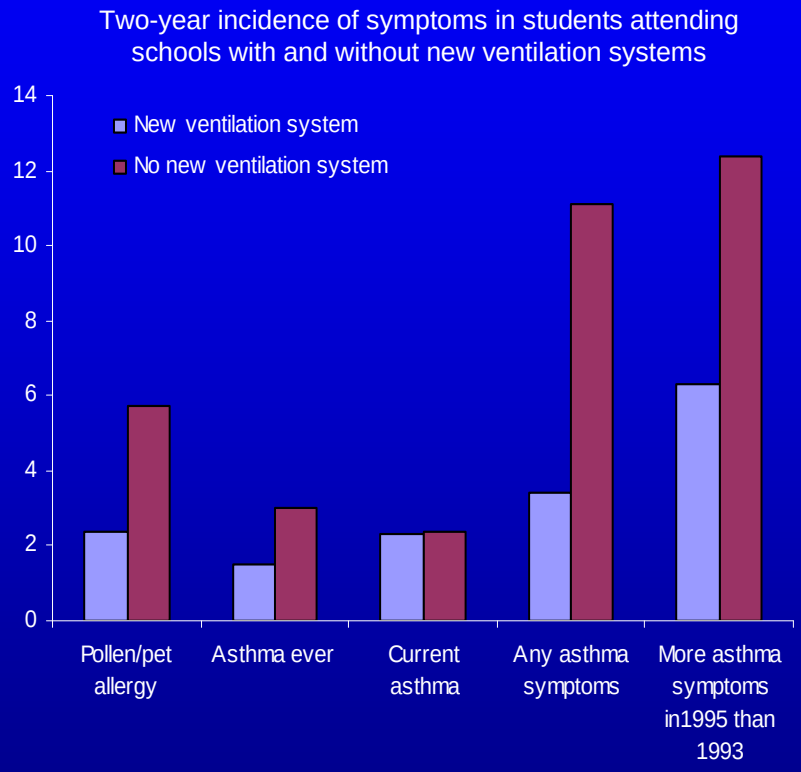


The best HVAC systems provide individual control, access for maintenance, and separate ventilation and thermal conditioning.

Floor-based ventilation + Increased outside air = Health

Smedje & Norback 2000 (School)

In a 2000 multiple building study of 39 schools in Sweden, Smedje and Norback identify a 69% reduction in the 2-year incidence of asthma among students in schools that received a new displacement ventilation system with increased fresh air supply rates, as compared to students in schools that did not receive a new ventilation system.



First cost increase:	$38 / student
Annual energy cost increase:	$2 / student
Annual health savings:	$36 / student
ROI:	**89%**

Reference: Smedje, G and Norback, D. (2000) New ventilation systems at select schools in Sweden—Effects on Asthma and Exposure. Archives of Environmental Health, 35(1), pp. 18-25.

Radiant Ceiling Panel System = Productivity + Energy Savings

Imanari et al 1999 (Office)

In a 1999 controlled field experiment and simulation study, Takehito et al identify a 23.8% improvement in measured work efficiency among women subjects and a simulated 10% HVAC energy savings in the Tokyo climate from providing cooling with a radiant ceiling panel system, as compared to a conventional air handling unit.

Results of work efficiency test with cooled ceiling and AHU

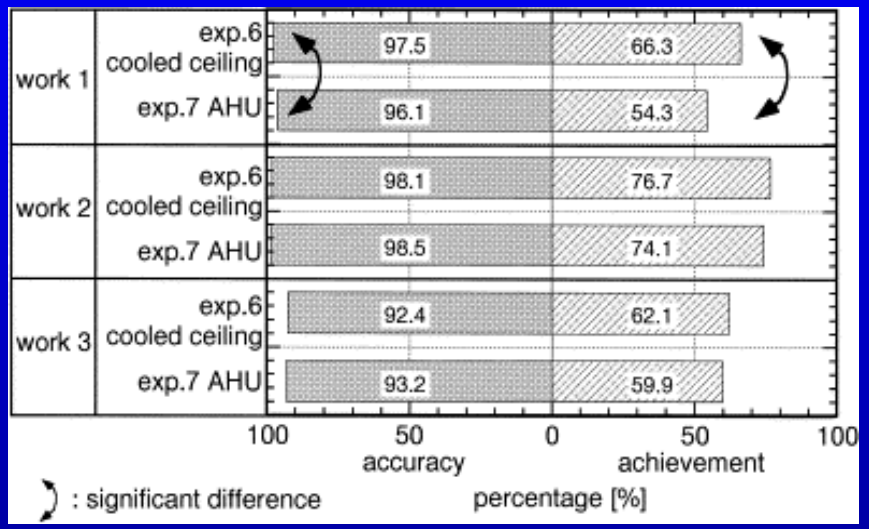
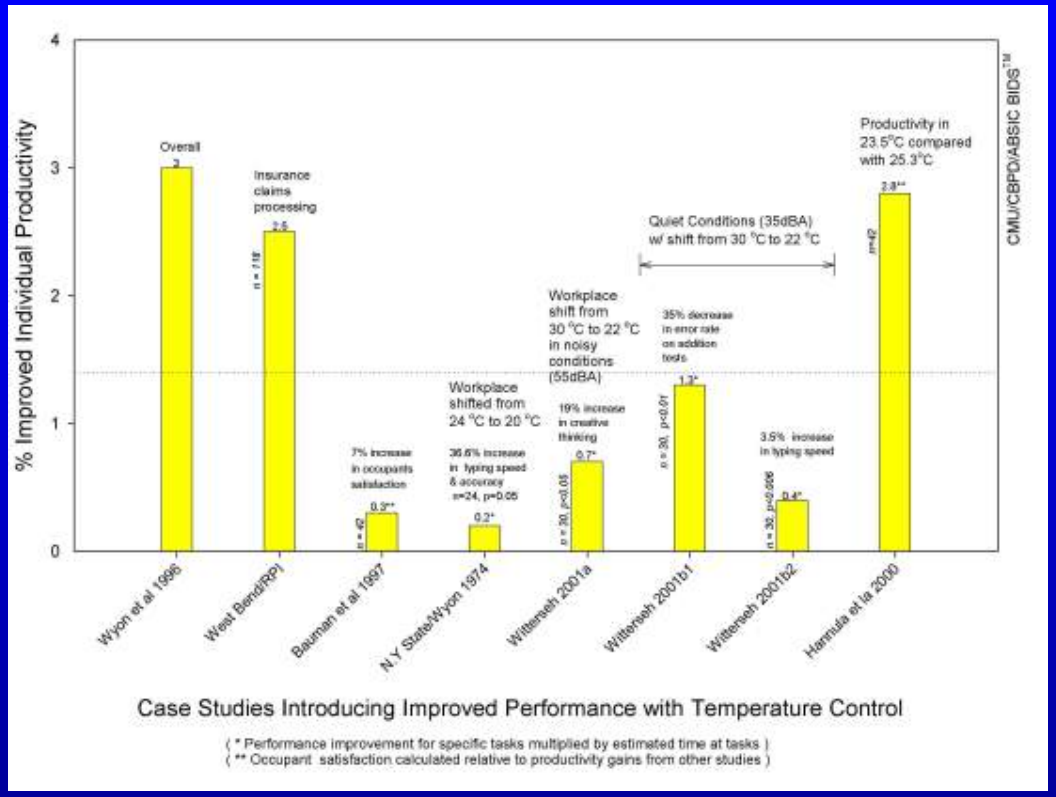


Chart: Imanari et al 1999

First cost increase:	$18 / employee
Annual health savings:	$18 / employee
Annual productivity savings:	$485 / employee
ROI:	**2,792%**

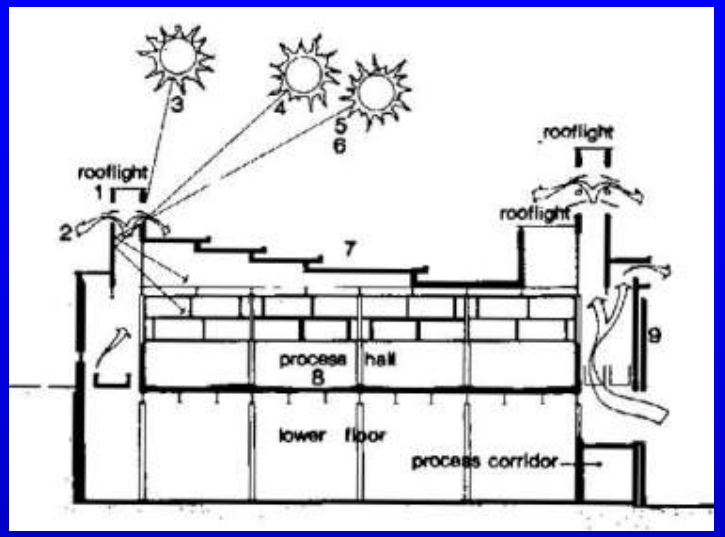
Reference: Imanari,T., T. Omori and K.Bogaki (1999) Thermal comfort and energy consumption of the radiant ceiling panel system. Comparison with the conventional all-air system. Energy and Buildings. Vol. 30, pp167-175.

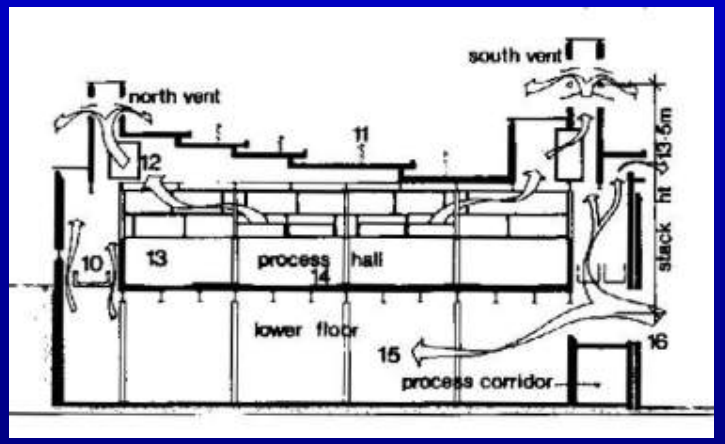
Temperature Control Increases Productivity and Reduces Energy Use



8 international case studies demonstrate that providing individual temperature control for each worker increases individual productivity by 0.2-3%.

Engineer load balancing and radiant temperatures



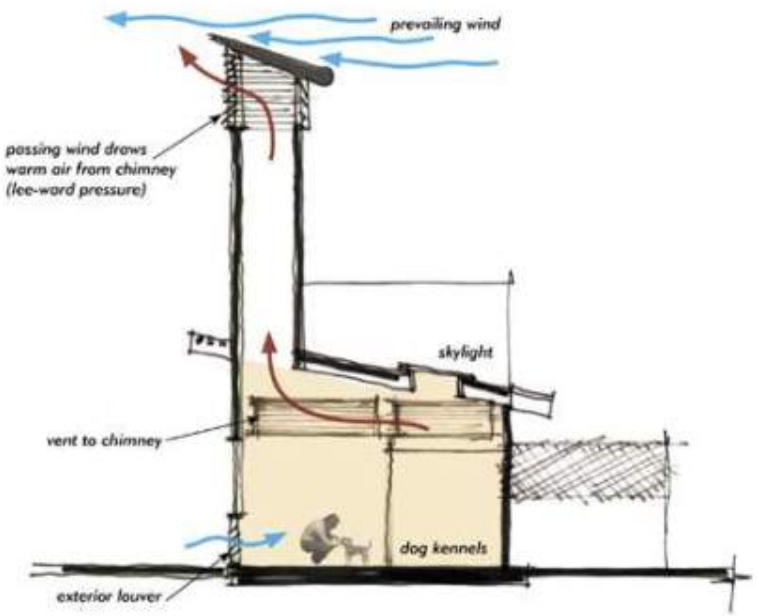


Advanced enclosure controls for night cooling of thermal mass without risk of condensation

Precedent Matters

Time lag, stack ventilation, evaporative cooling, and PV electricity = zero energy

Tate, Snyder, Kimsey Architects LV Animal Shelter COTE Top 10



HYBRID VENTILATION CONCEPT

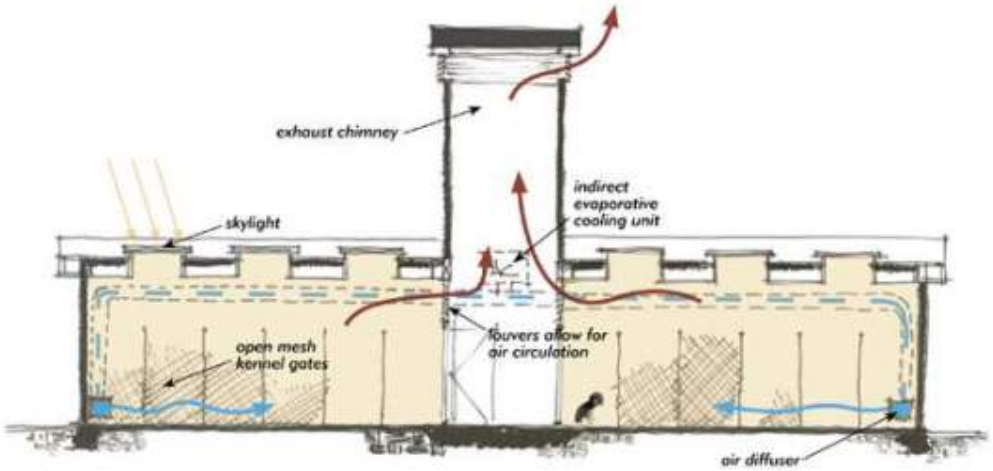
air is forced into the bungalow through an evaporative cooling unit that cools the interior environment. the cool air is delivered low into the room and passes through the dog kennels. as air warms rises and passes over the tops of the kennel walls, it collects in the high area of the roof. the hot air then vents into the base of the solar chimney which draws the air up and out the top. the draw in the solar chimney is accomplished by sloping the top of the chimney and taking advantage of the dominant southwesterly breeze across the site and by the sun heating up the southern face of the chimney.

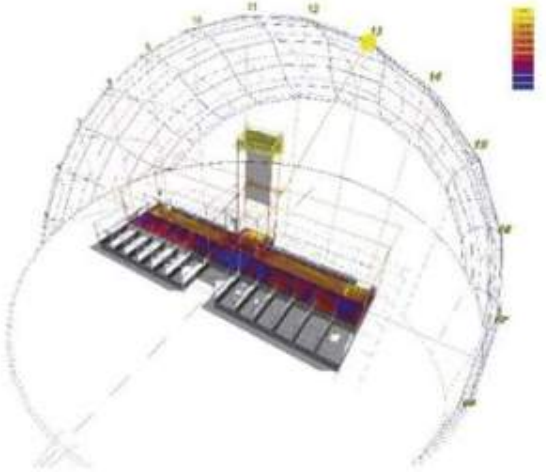
this passive/ displacement ventilation strategy also keeps air moving from human areas to dog areas to minimize unpleasant odors from the dog runs.

in moderate seasons operable exterior louvers will open automatically to allow fresh air to circulate through the building.

DAYLIGHTING

large shaded windows provide daylighting and an open sight into the bungalows. skylights provide a balanced light level through the bungalow while using a minimum of electric energy.





day-lighting study

Sustainable design depends on the use of materials and assemblies that ensure healthy environments

Mcdonough/Braungart

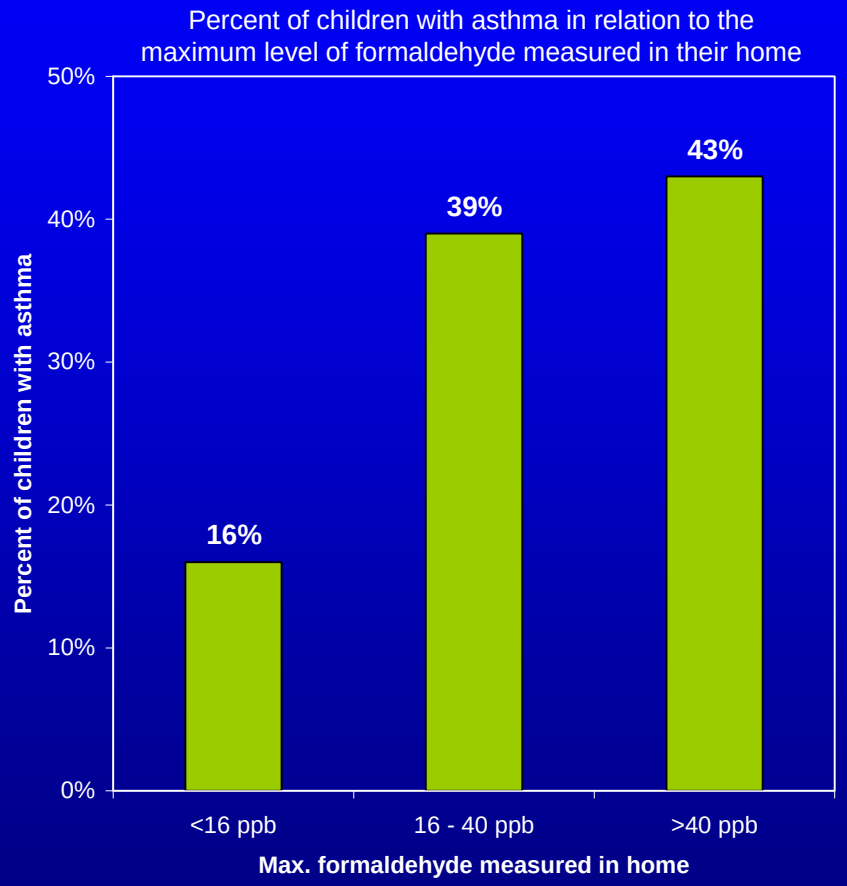
Material Selection is critical in relation to outgassing, toxicity in fires, radon, cancer causing fibers, and mold, impacting respiratory and digestive systems, eyes and skin.

Pollutant source control = Health + Individual productivity (hospital)

Garrett et al 1996

In a 1996 multiple building study of 80 homes Victoria, Australia, Garrett et al identify a 60% reduction in the prevalence of asthma and a 63% reduction in the prevalence of allergies among children whose homes contain formaldehyde-free composite wood products, as compared to those exposed to formaldehyde from furnishings and products in their home.

First cost increase:	$615 / household
Annual health savings:	$1,108 / household
ROI:	**180%**



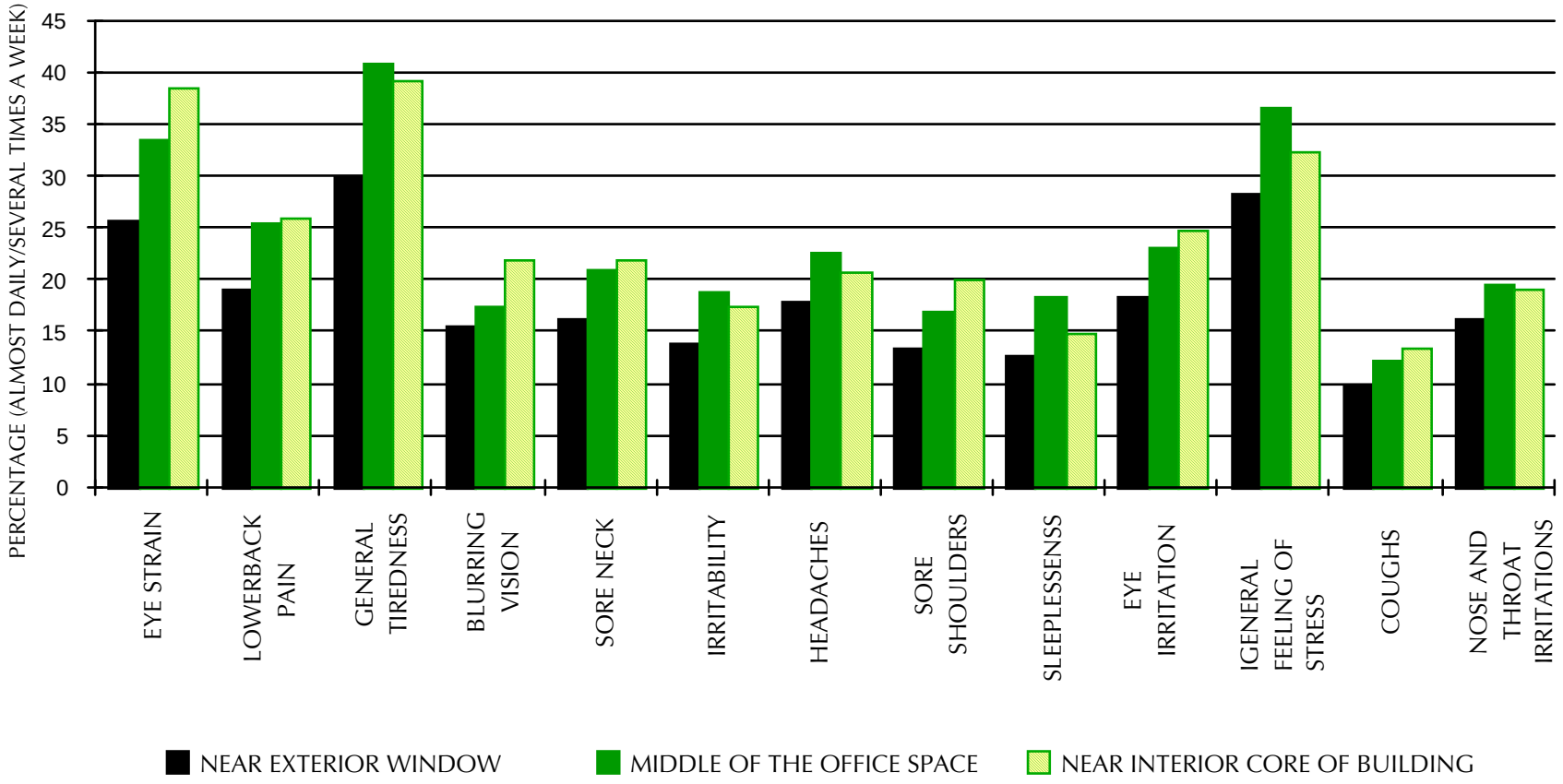
Garrett, MH, MA Hooper, and BM Hooper (1996) Low levels of formaldehyde in residential homes and a correlation with asthma and allergy in children. In Proceedings of Indoor Air 96, vol 1.

Healthy, Sustainable design depends on Access to the Natural Environment

Views
Daylight
Circadian Rhythm
Natural Ventilation
Connection to Outdoors
Biophilia

World Birding Center, Mission, Texas Lake Flato Achitects AIA Top 10

Comparison between Window Proximity and Health Complaints (Forrestal and Germantown)



Comparative studies of daylit offices and classrooms demonstrate 10-25% performance gains, 5-10% reductions in SBS symptoms, and over 30% energy savings

Ove Arup offices

Seated Views = Individual productivity

SMUD Call Center /Heschong Mahone Group, Inc. 2003

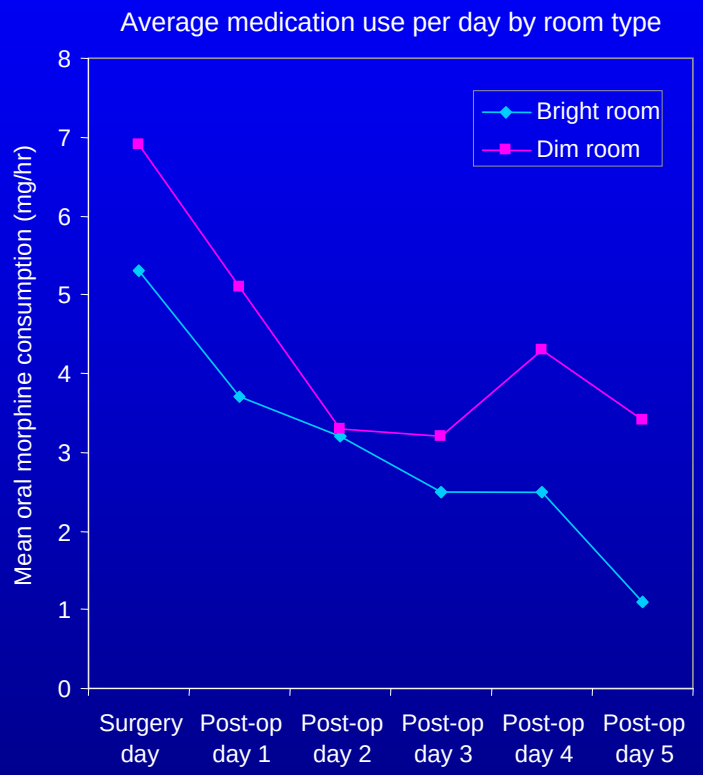
In a 2003 building case study of the Sacramento Municipal Utility District (SMUD) Call Center, Heschong et al identify a 6% to 7% faster Average Handling Time (AHT) for employees with seated access to views through larger windows with vegetation content from their cubicles, as compared to employees with no view of the outdoors.

First cost increase:	$1,000 /employee
Annual productivity savings:	$2,990 /employee
ROI:	**299%**

Sunlight = Health

Montefiore Hospital / Walch et al 2005

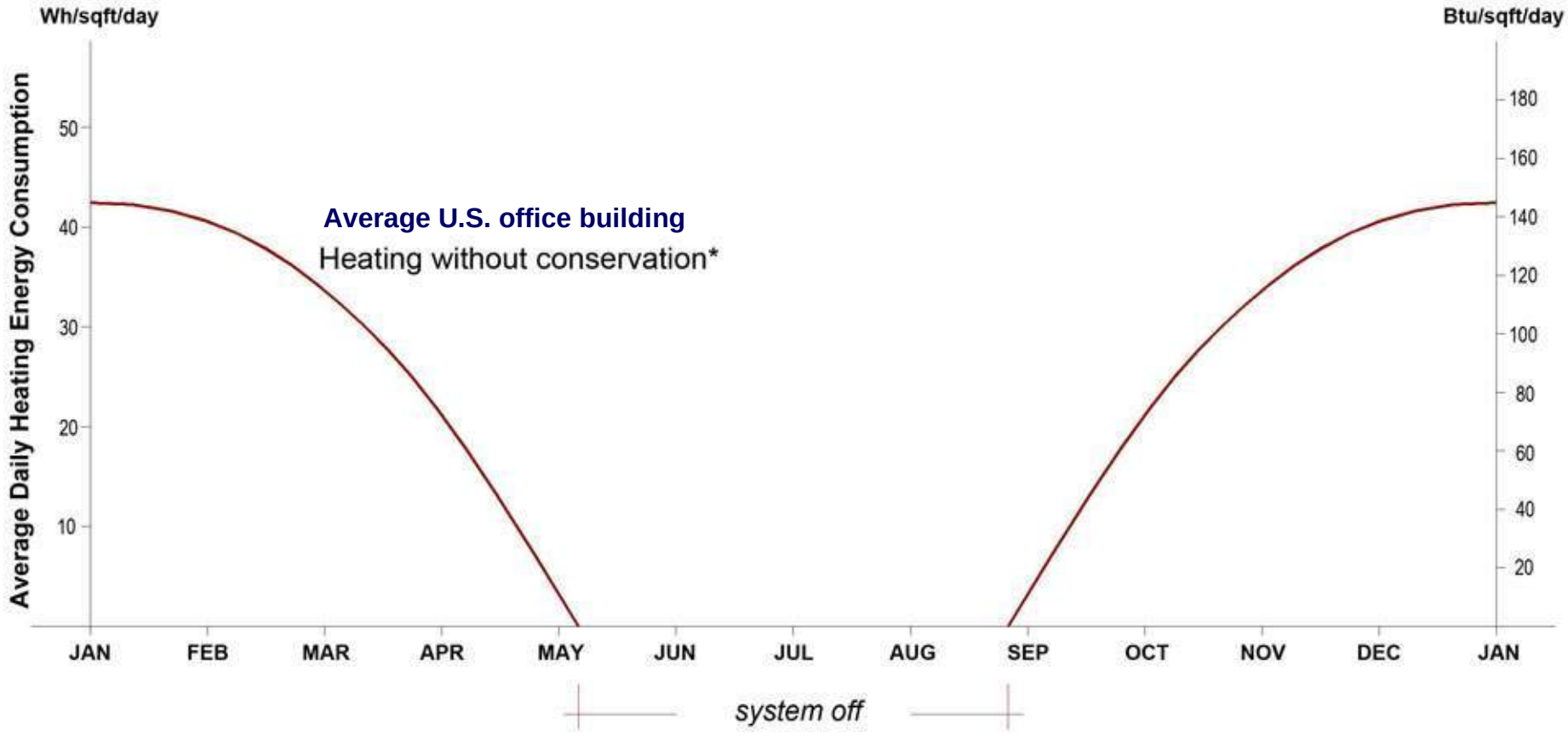
In a 2005 study of pain medication use among 89 patients undergoing elective cervical and lumbar spinal surgery at Montefiore Hospital in Pittsburgh, PA, Walch et al identify a 22% reduction in analgesic medication use among patients in bright rooms who were exposed to more natural sunlight after surgery, as compared to patients located in dim rooms after surgery.



First cost increase:	$1,000 / bed
Annual health savings:	$28 / bed
ROI:	**3%**

CMU Architecture Graduate: Walch, Jeffrey et al (2005) The effect of sunlight on postoperative analgesic medication use: a prospective study of patients undergoing spinal surgery. Journal of Psychosomatic Medicine, 67, pp. 156-163.

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



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

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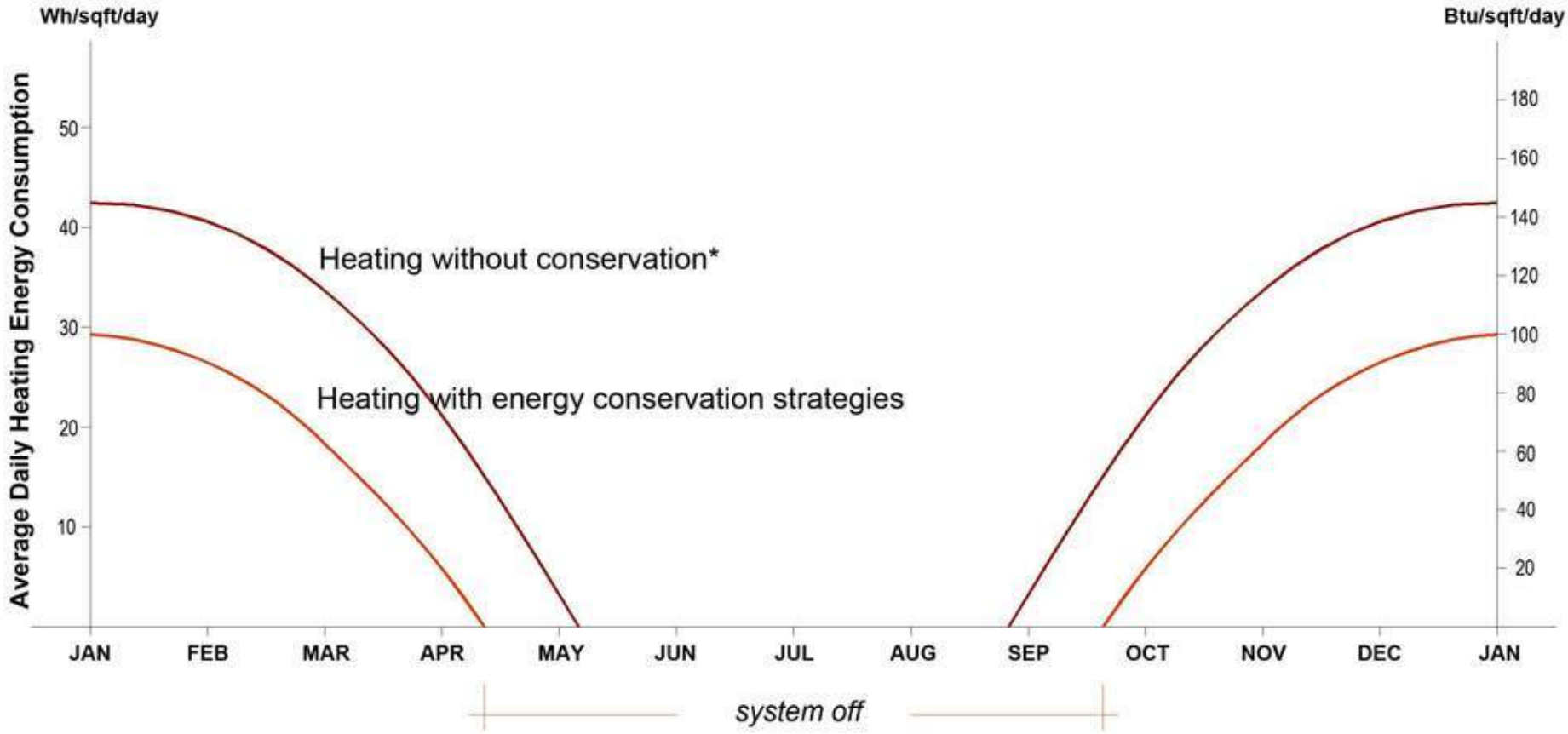

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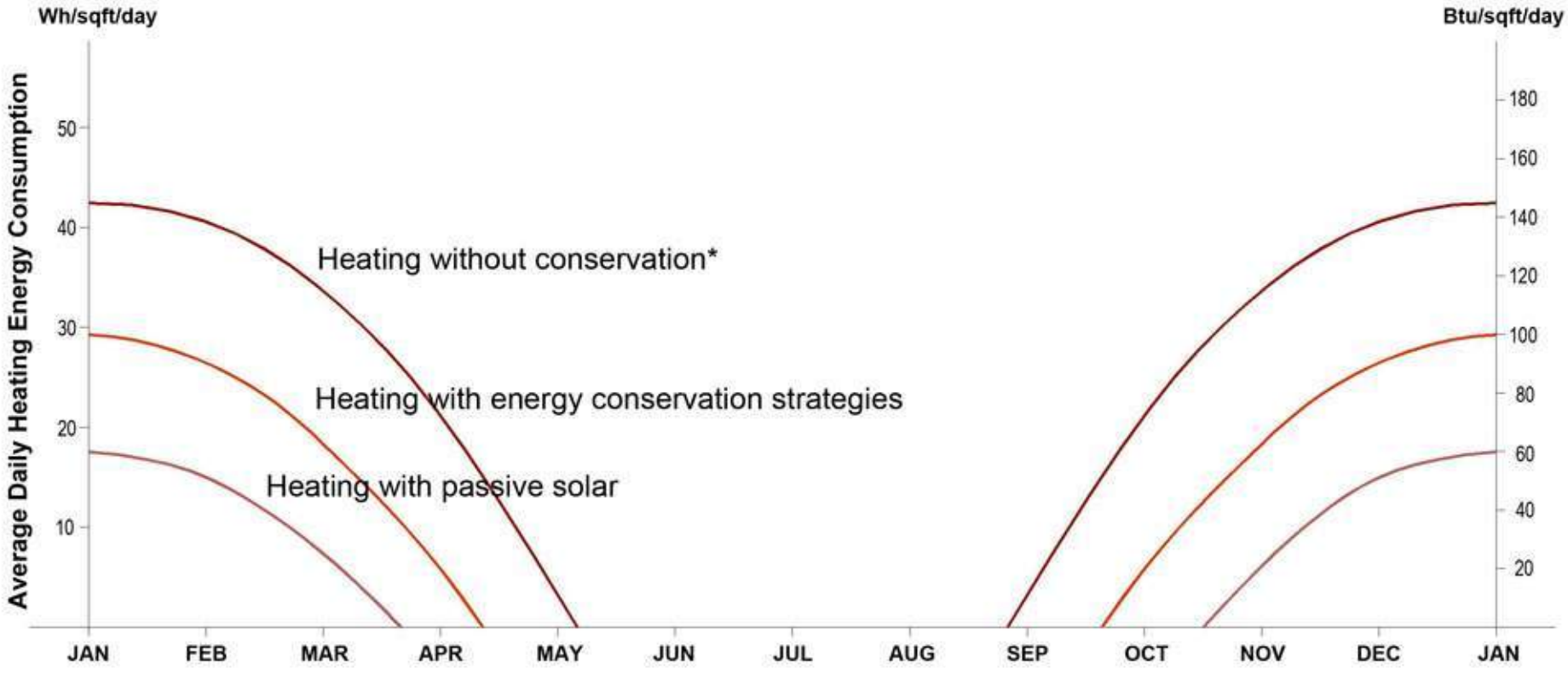

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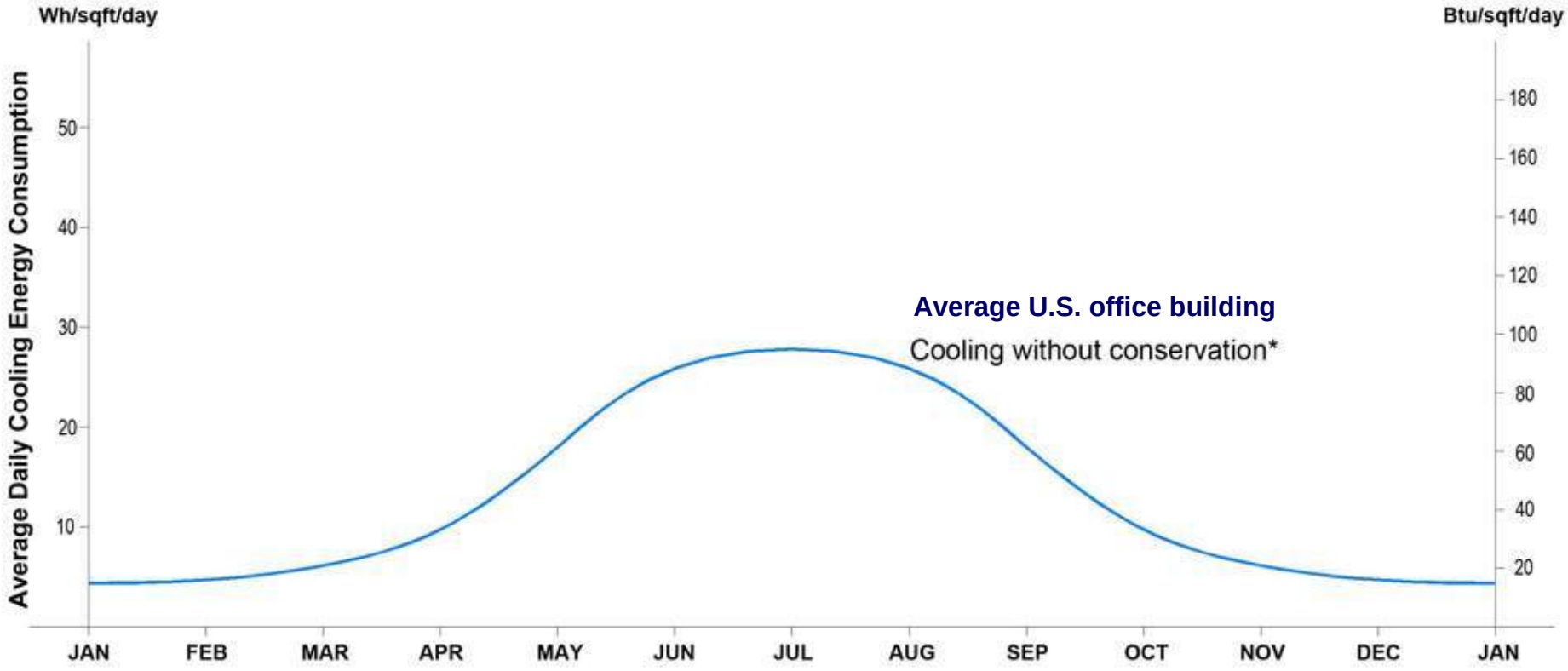

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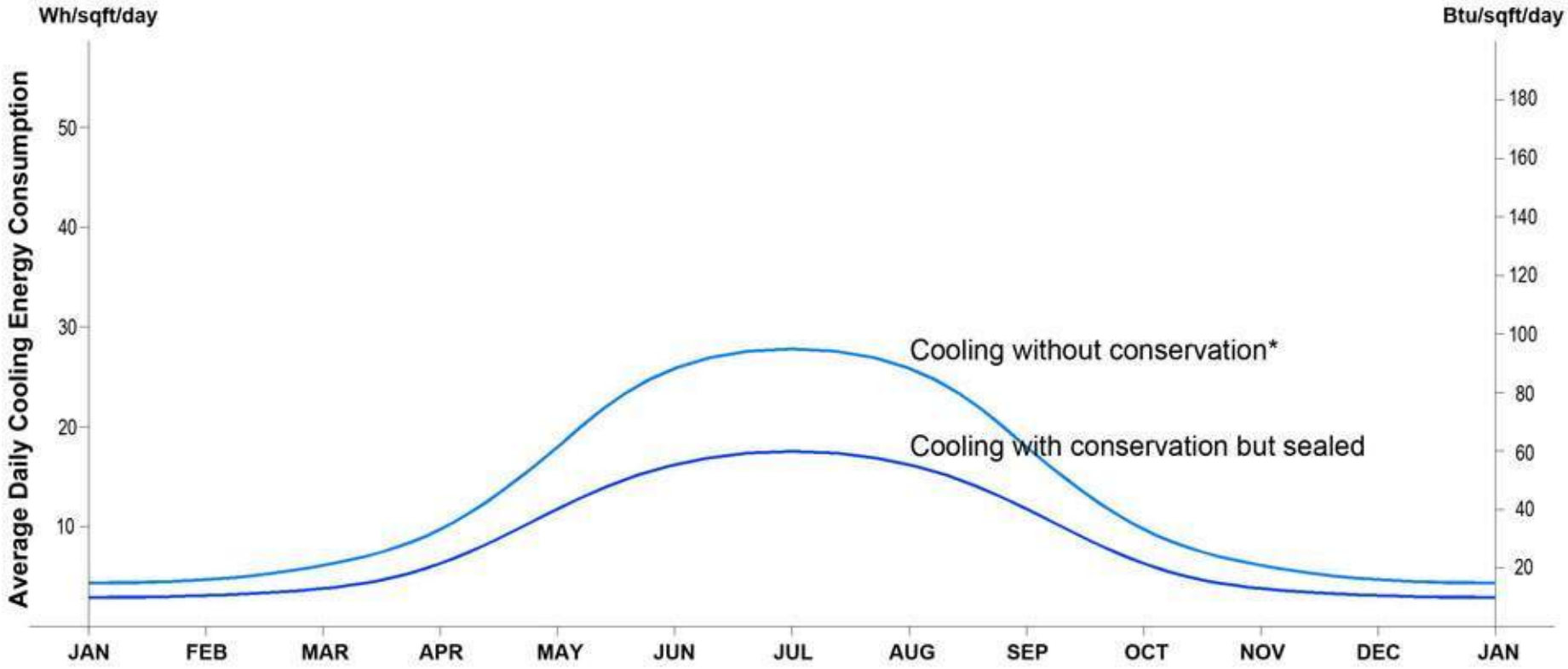

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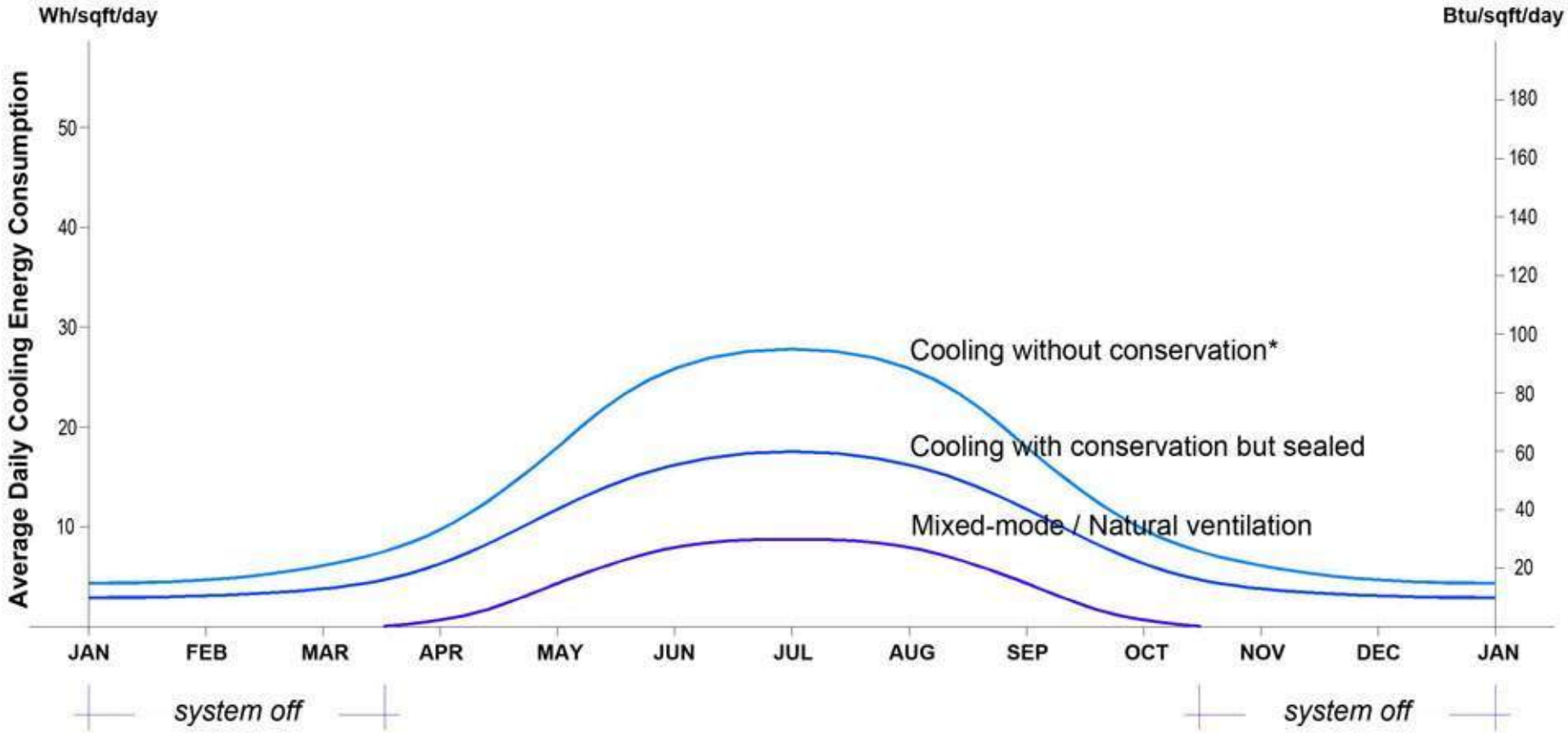

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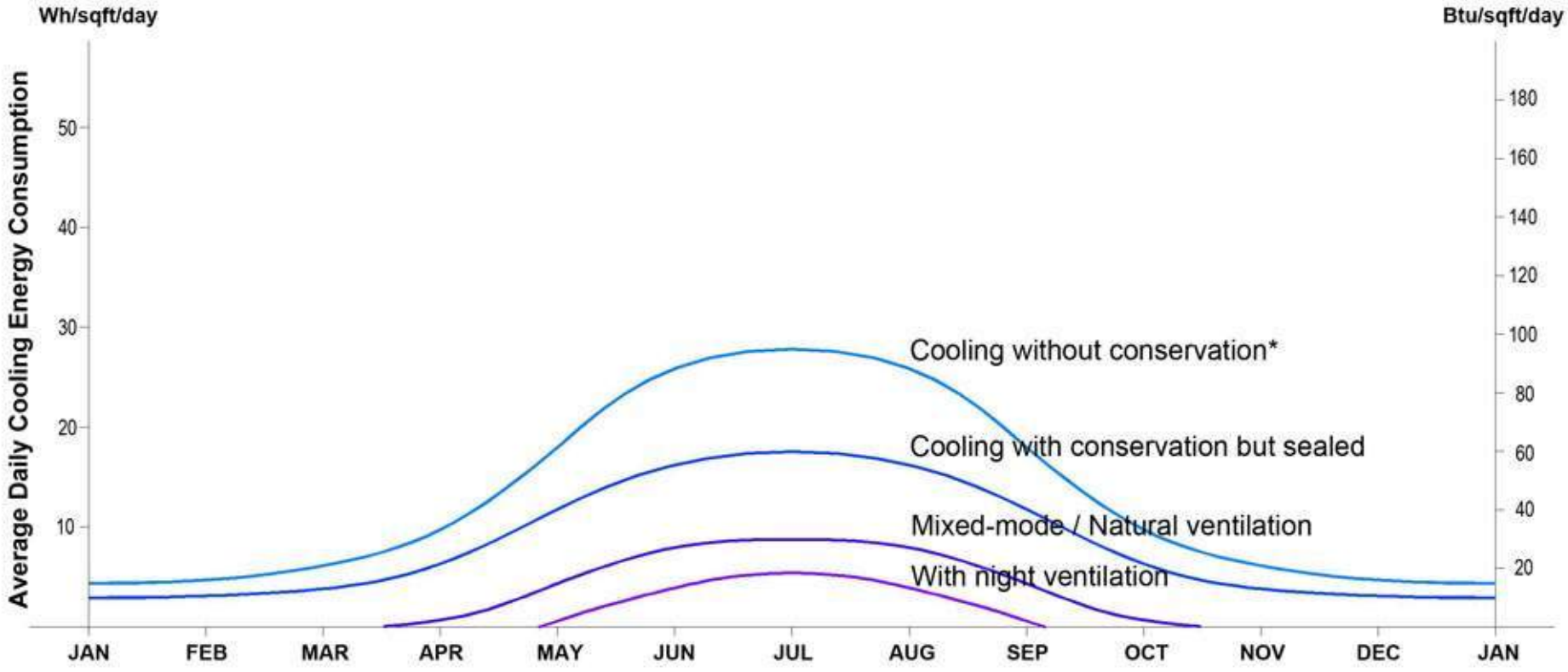

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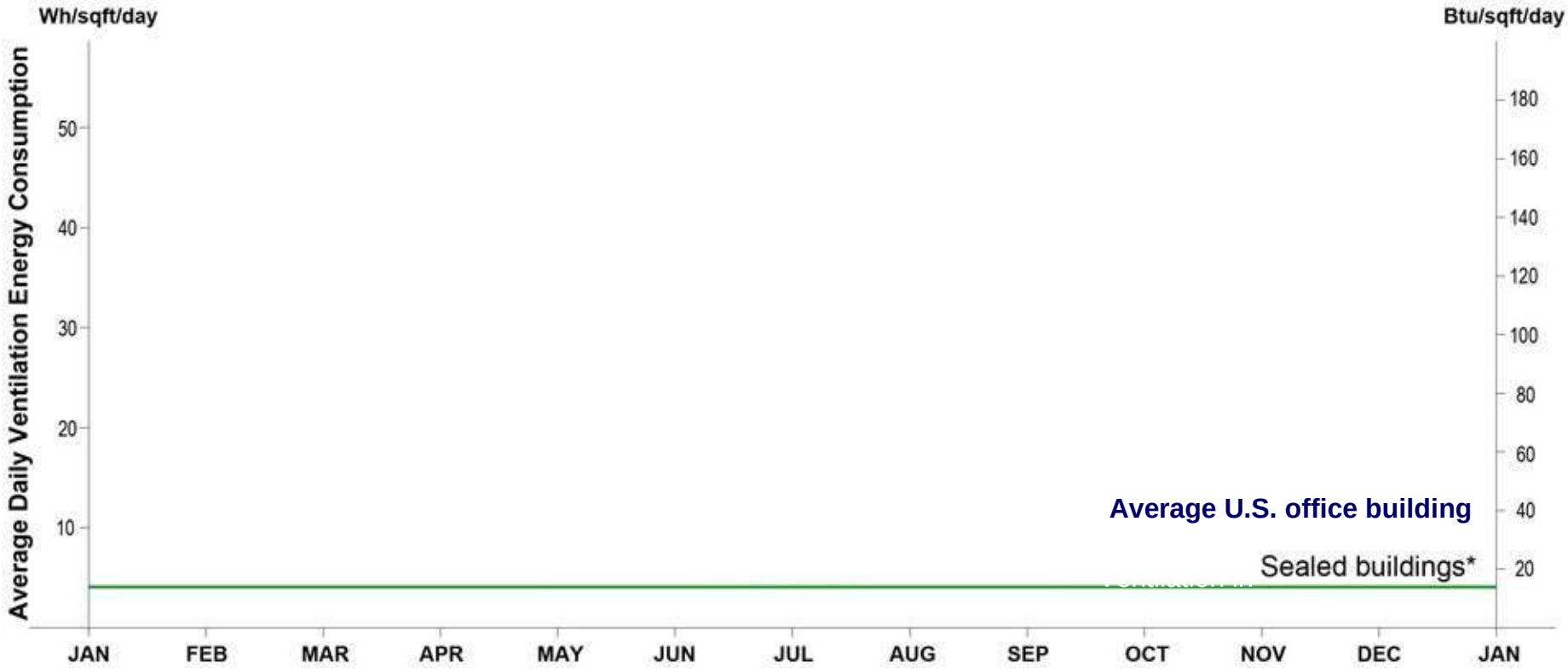

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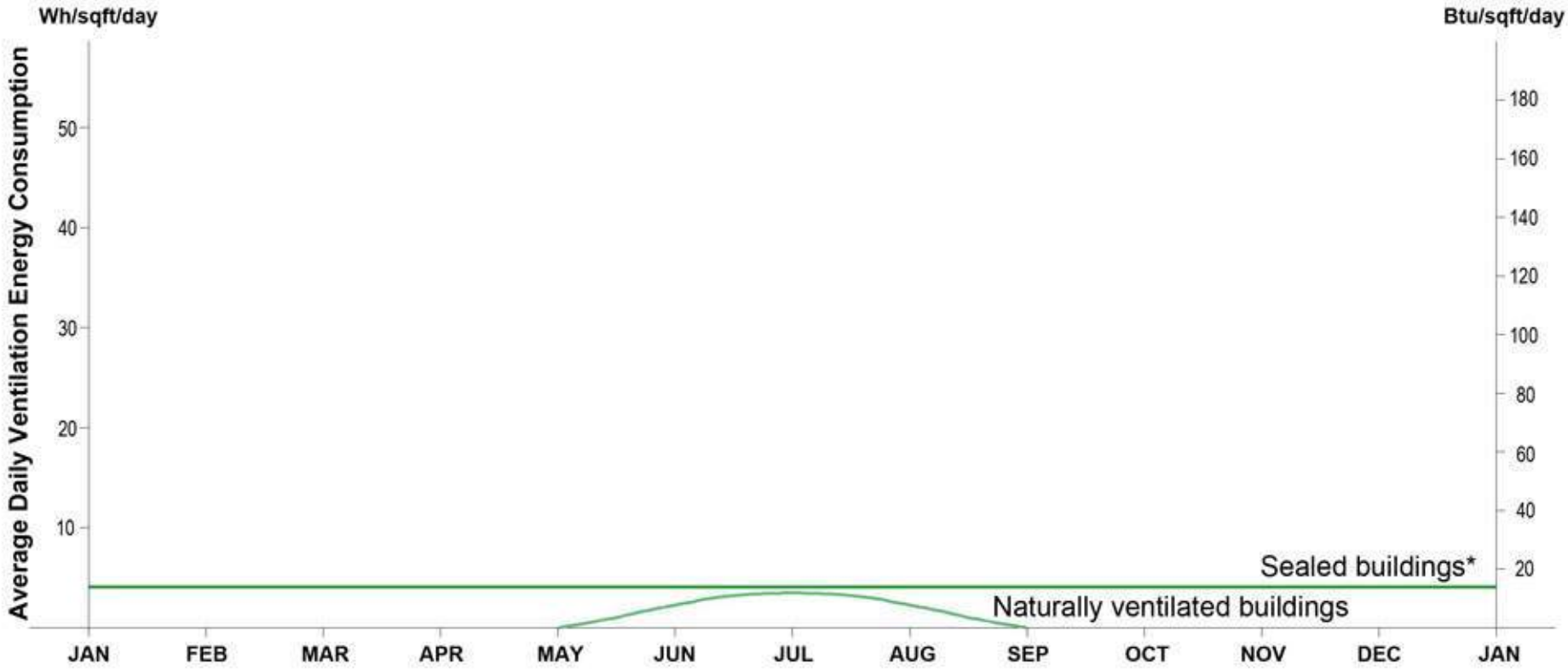

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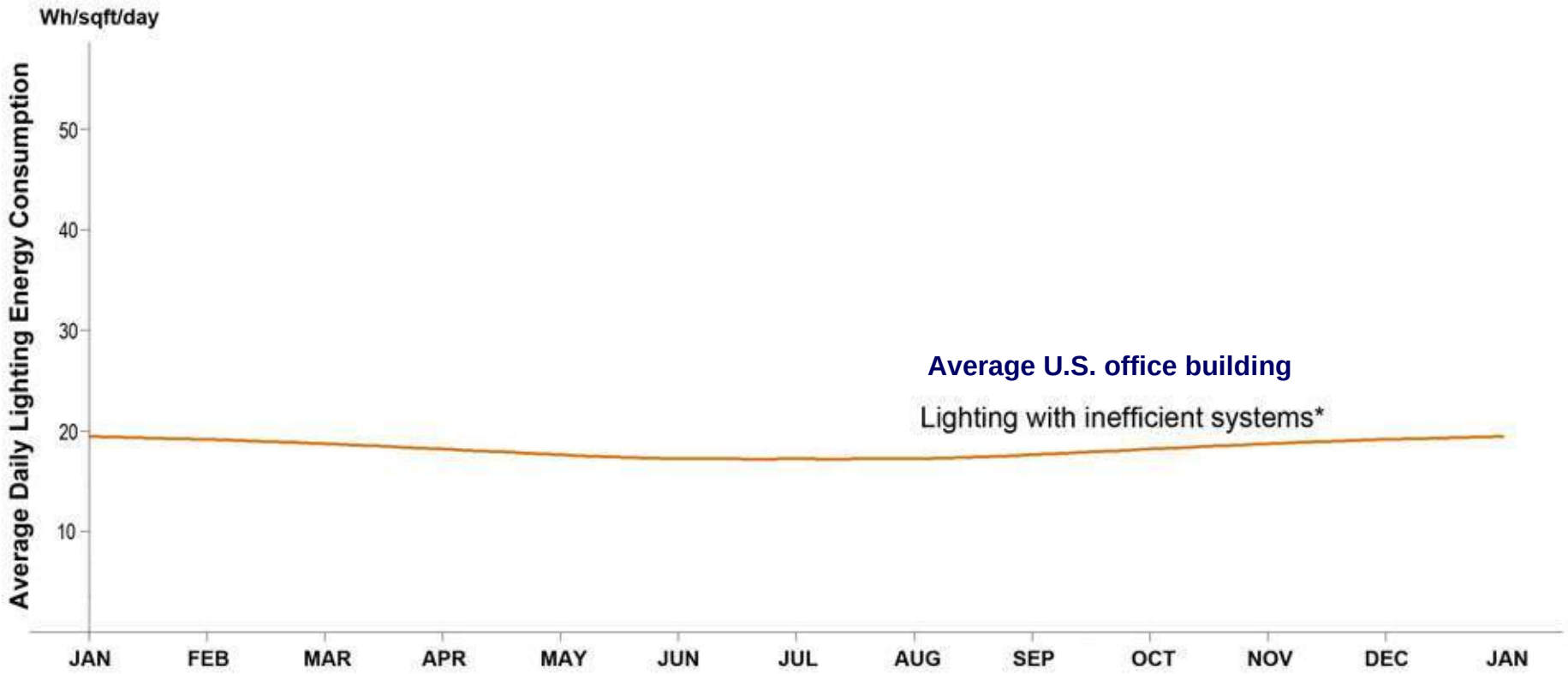

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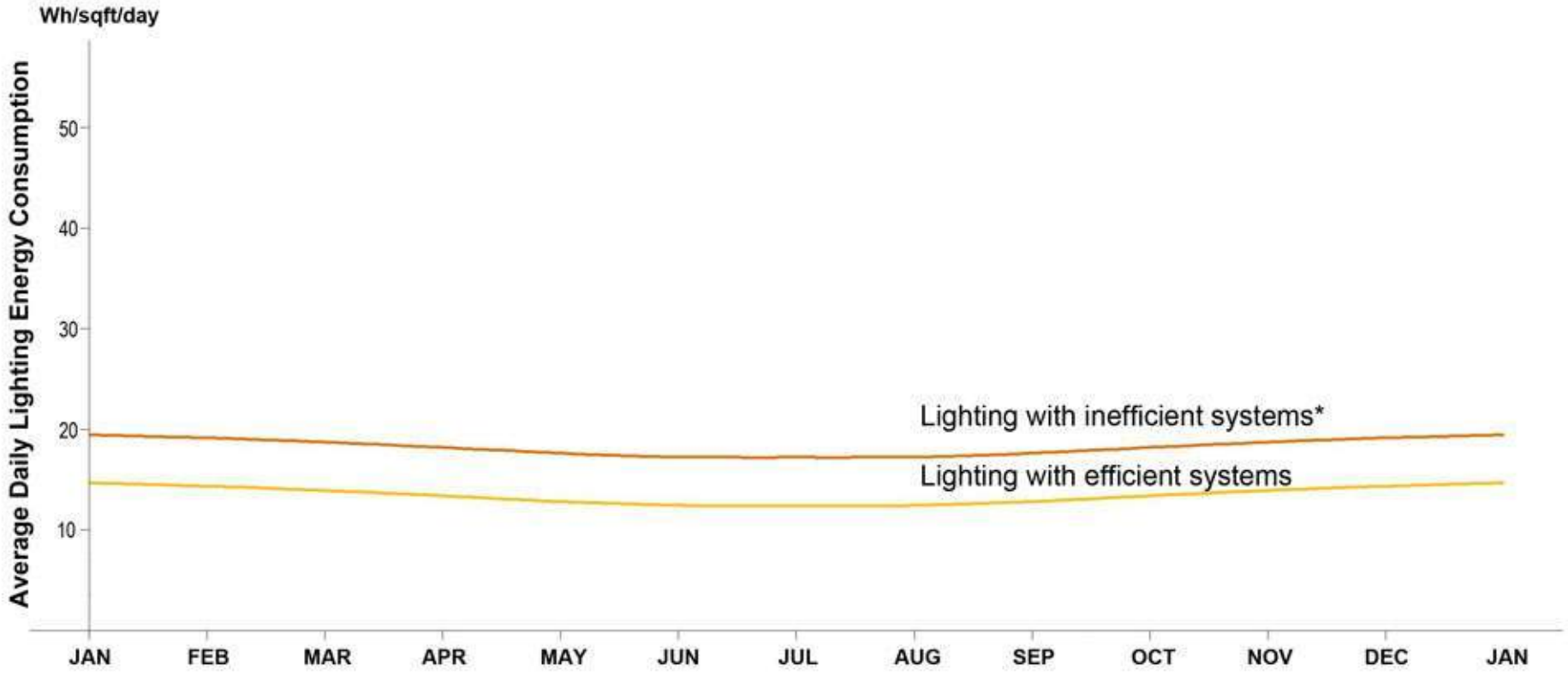

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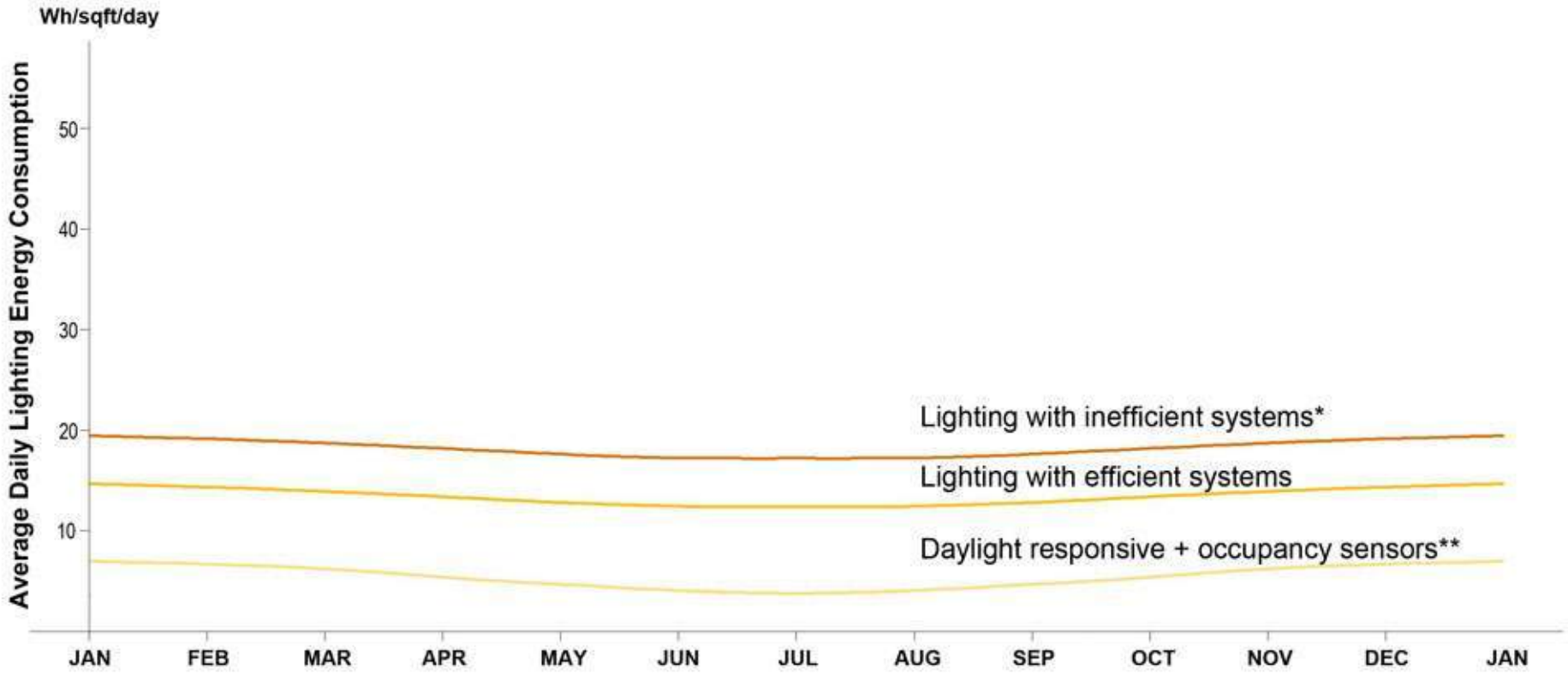

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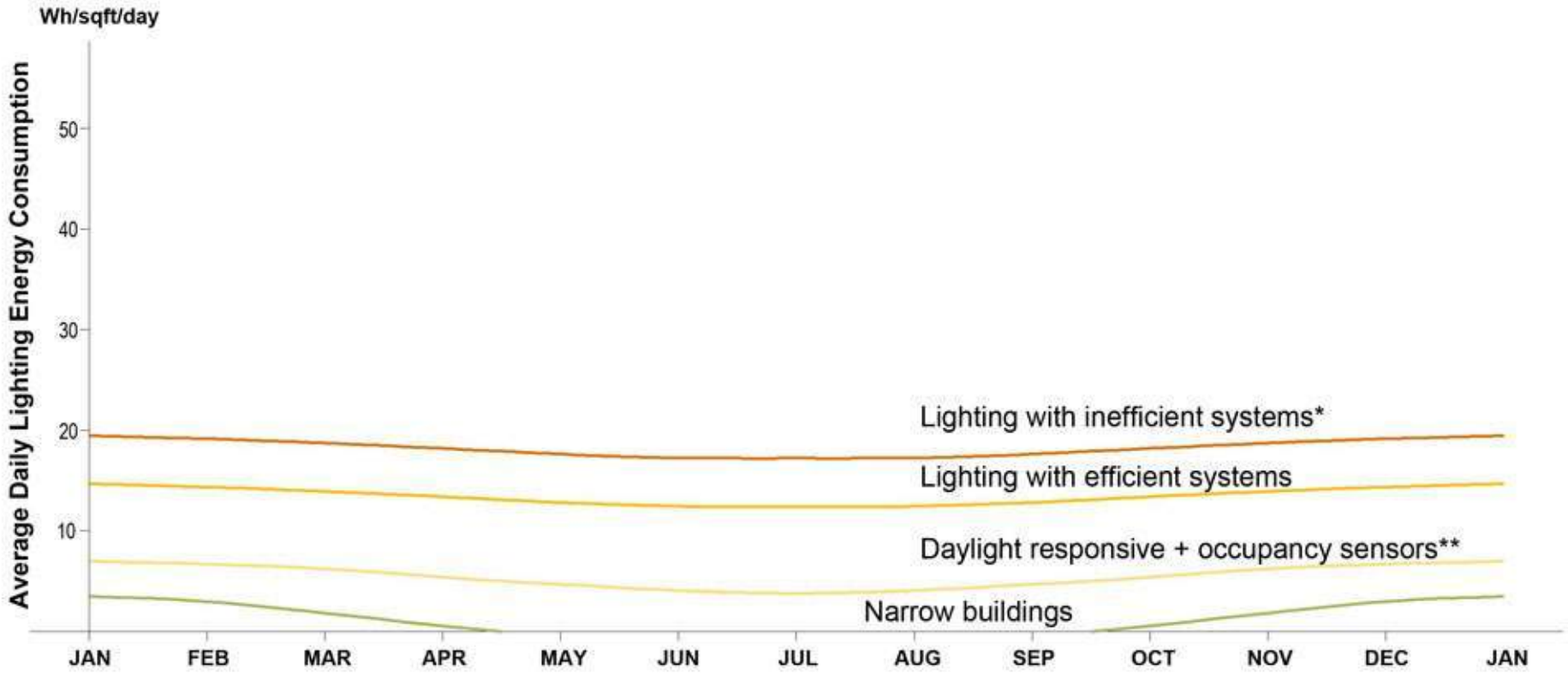

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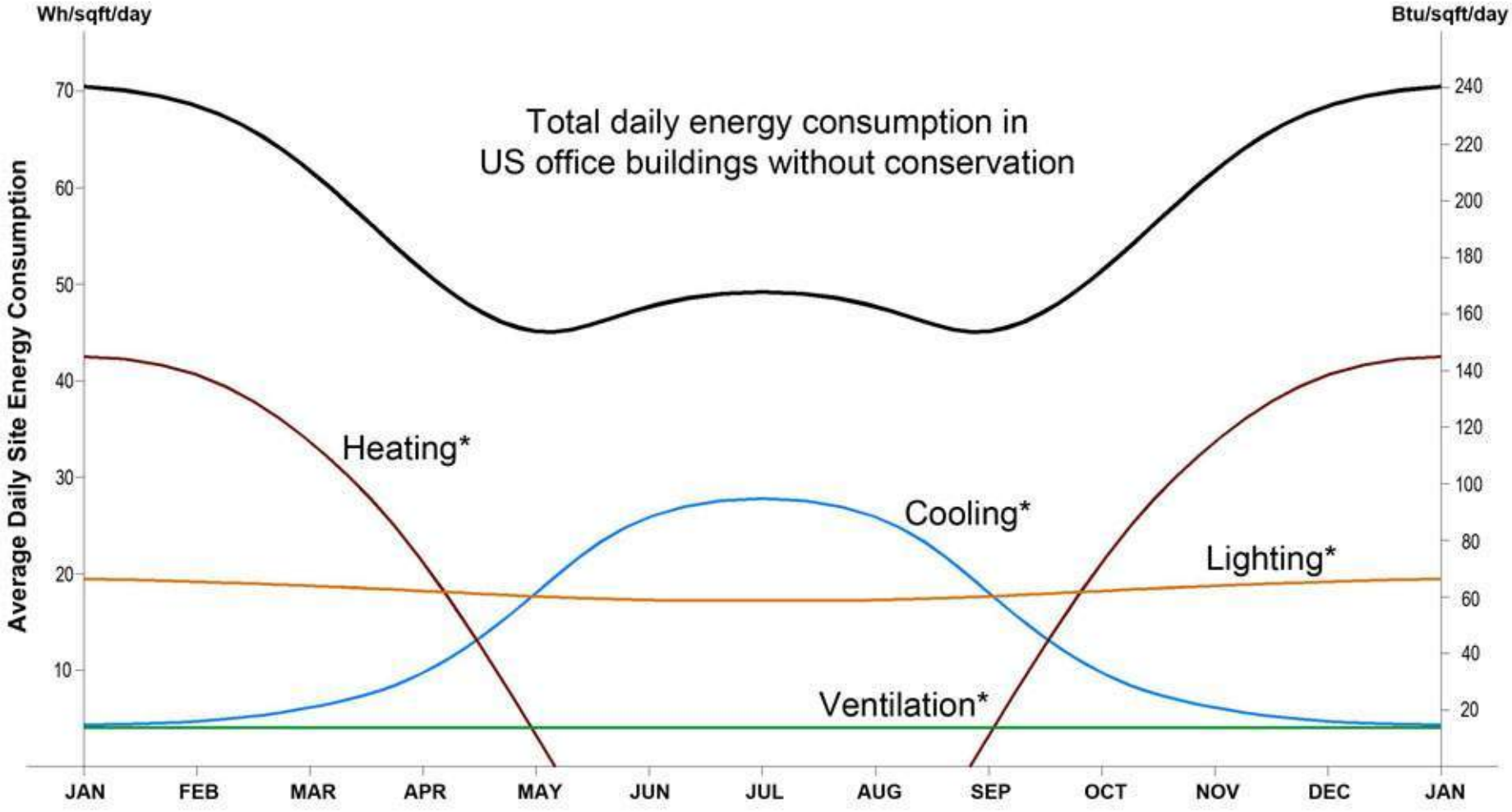
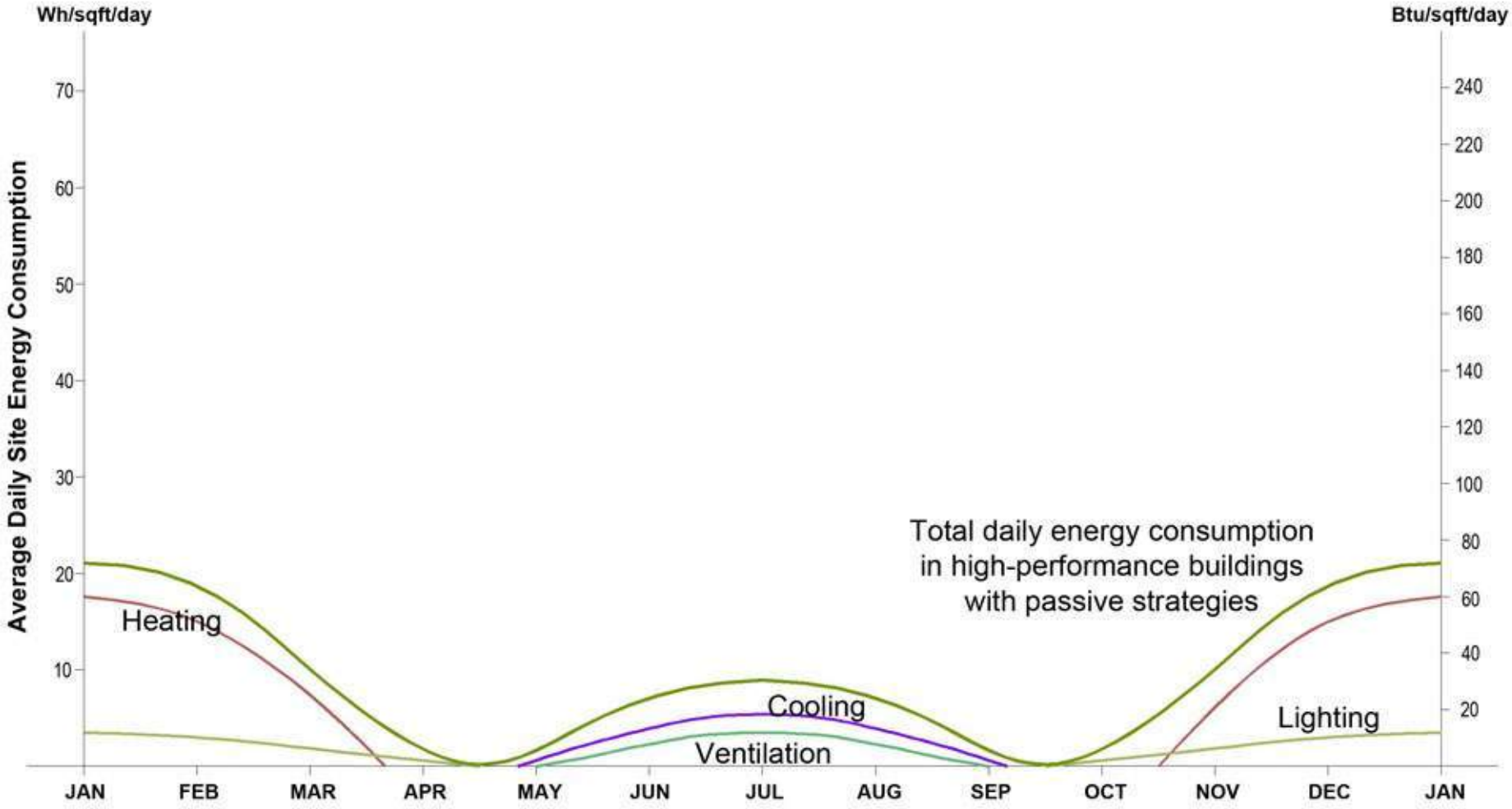


* Total annual heating, cooling, ventilation and lighting energy consumption refers to EIA-CBECS 1995 &1999



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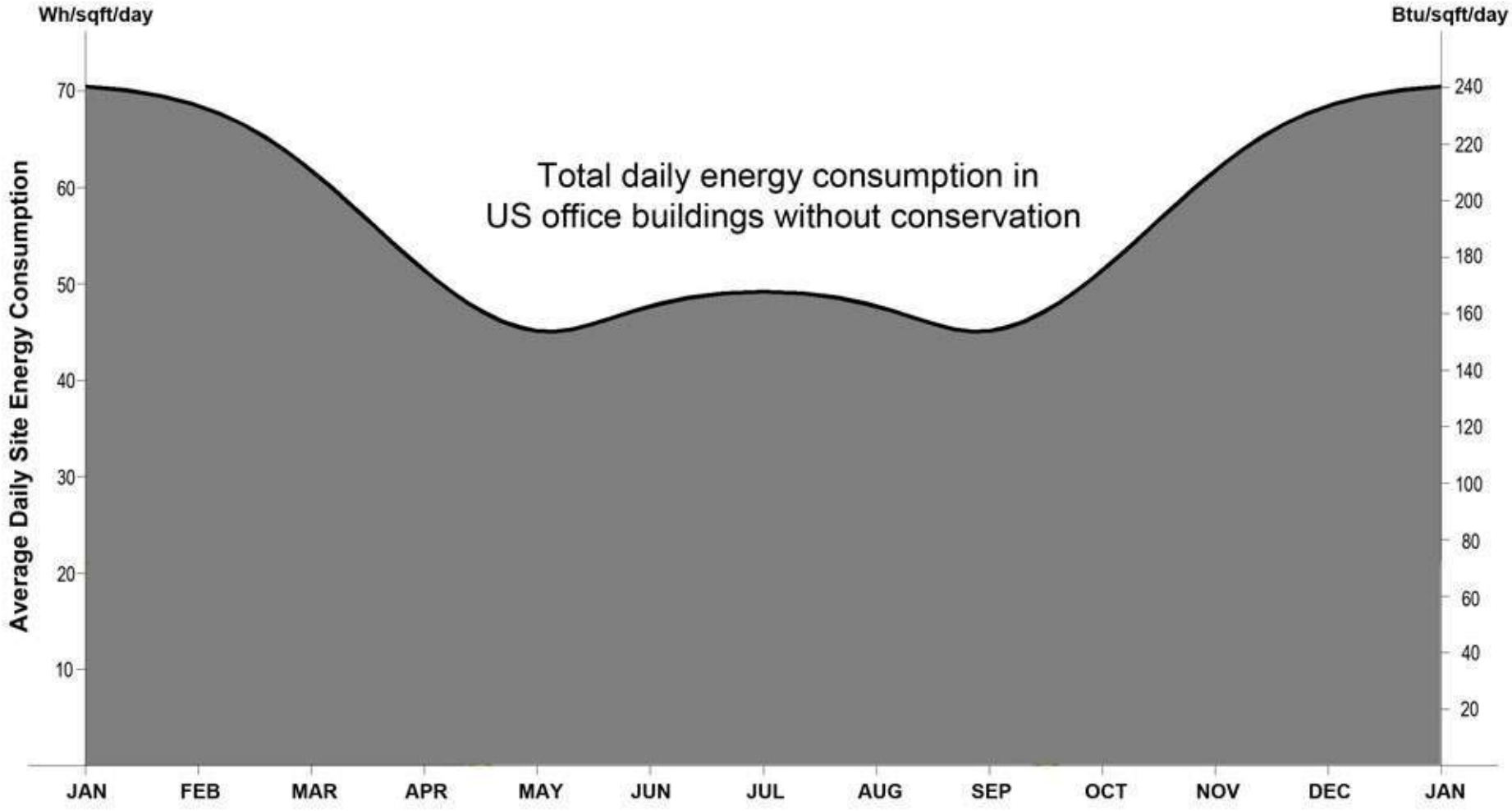

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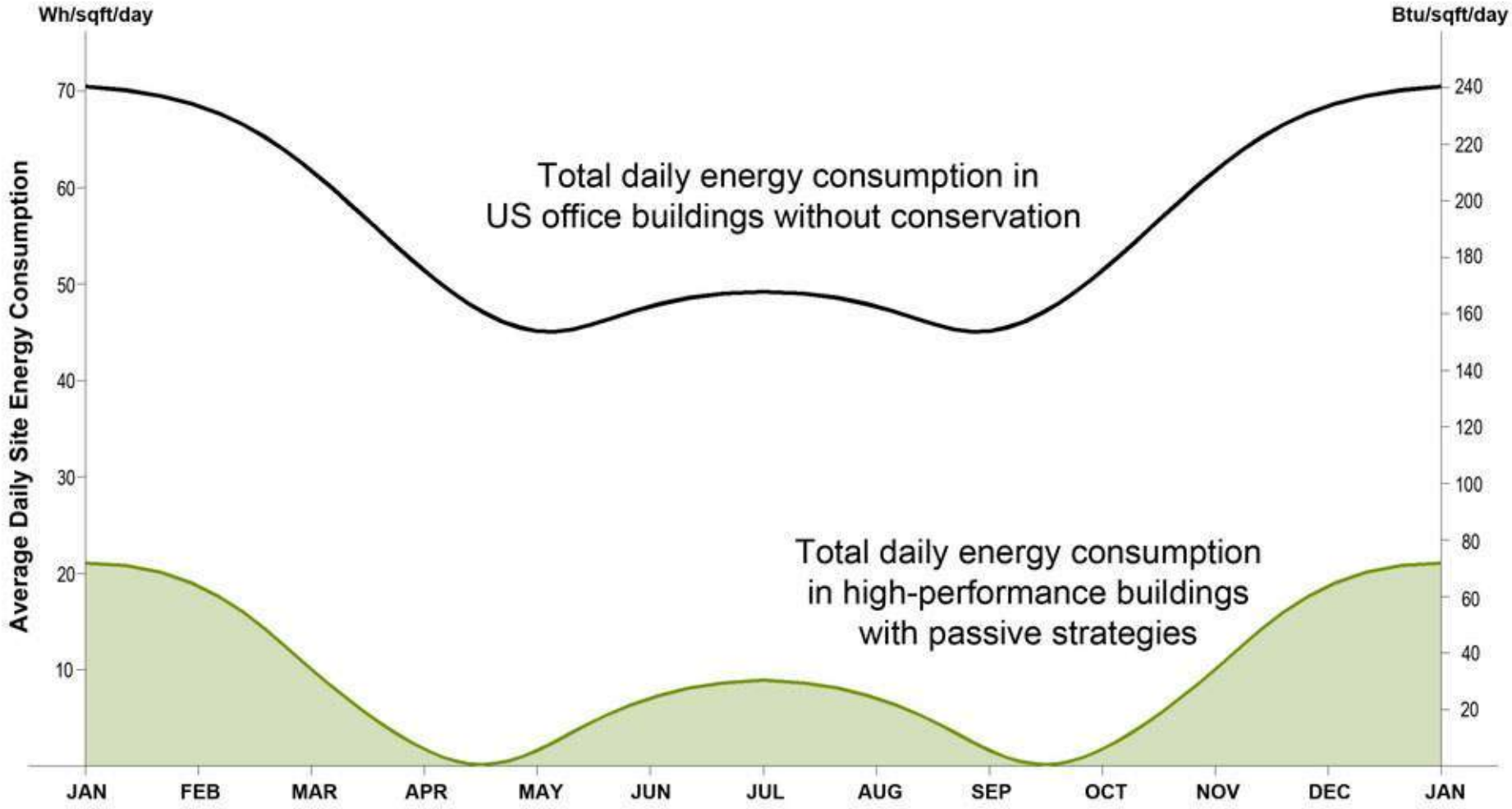
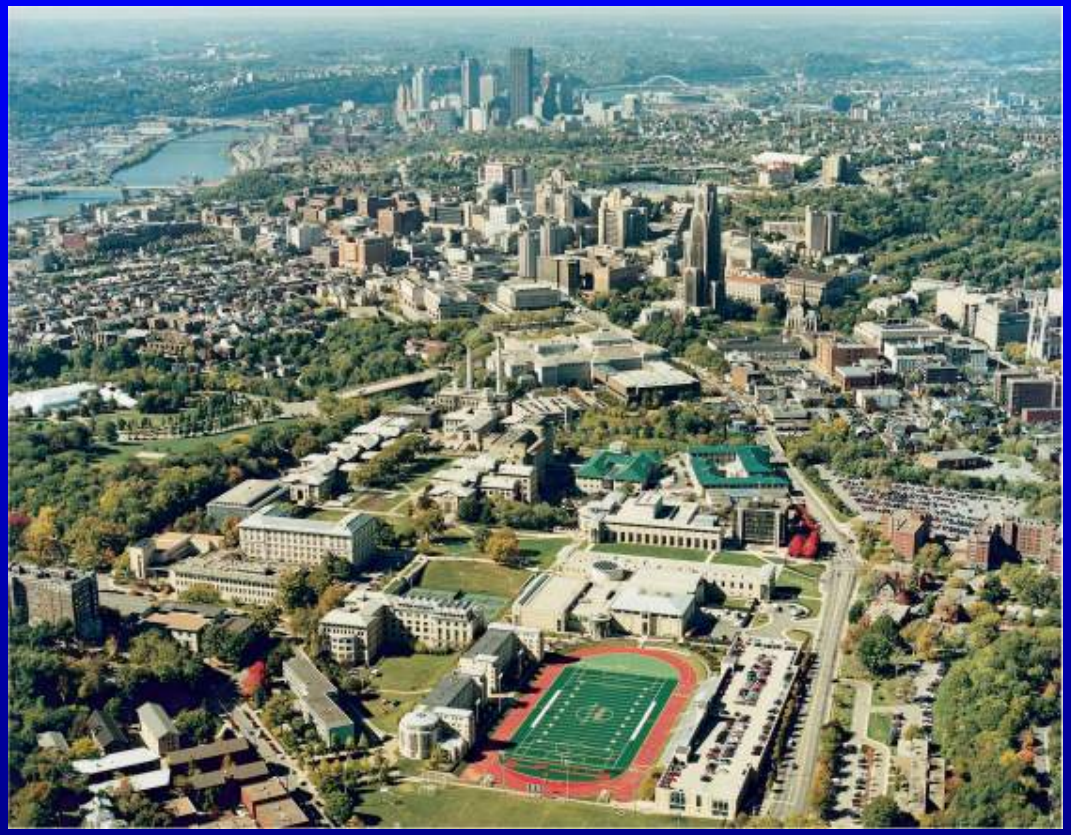


Healthy, Sustainable design depends on changing approaches to Land Use, Community Planning, and Regional Infrastructures

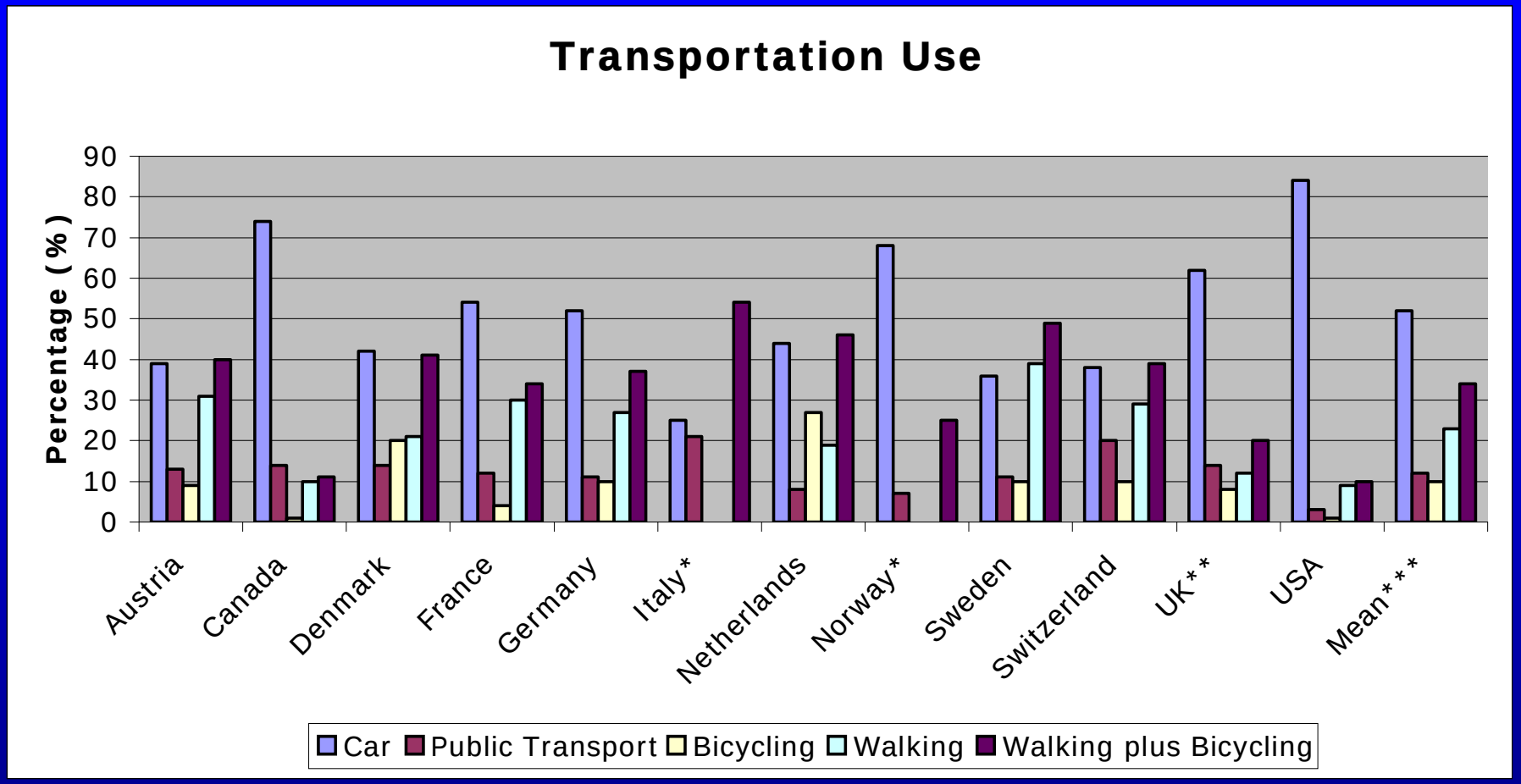


Design for live-work-walk - mixed use communities
Design for mobility- mixed mode transportation
The beauty of regenerative landscapes

Which future?

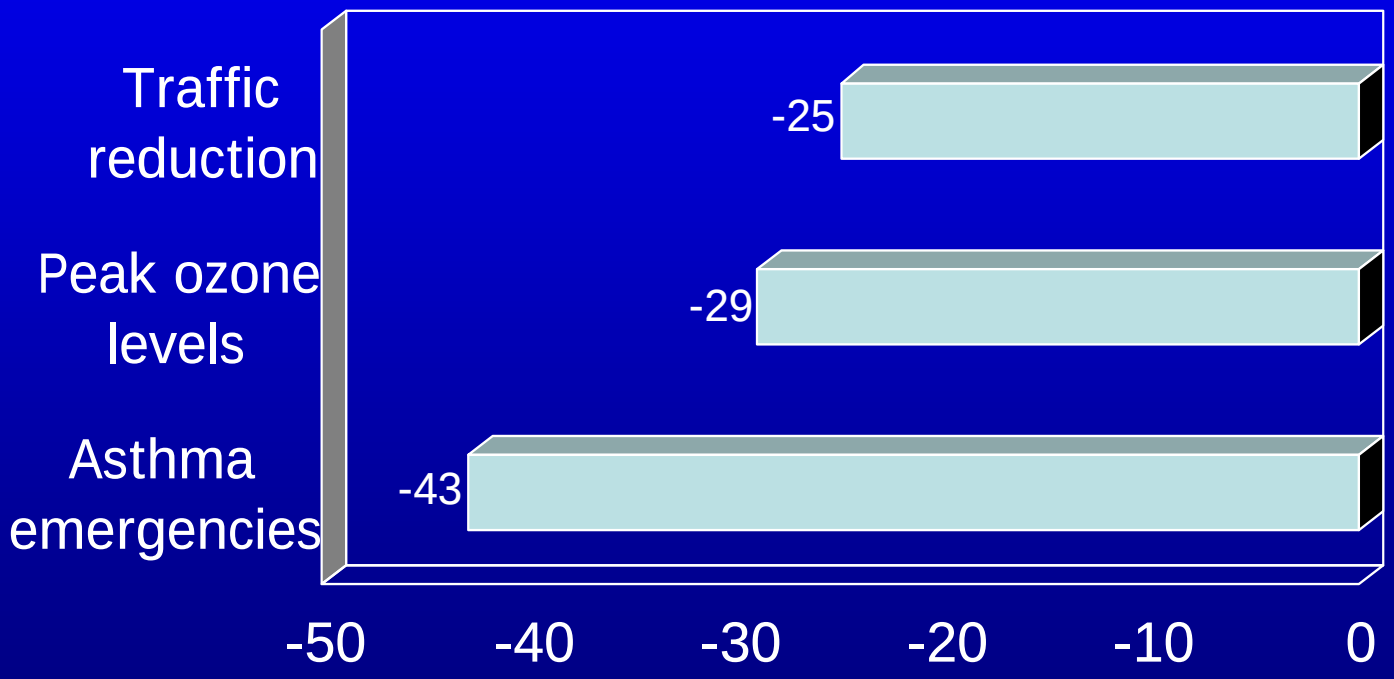
Vehicle miles have risen by 80% from 1980 to 2000, while population rose only 21.5%, creating both energy and health consequences.

www.pedbikeimages.org / Dan Burden



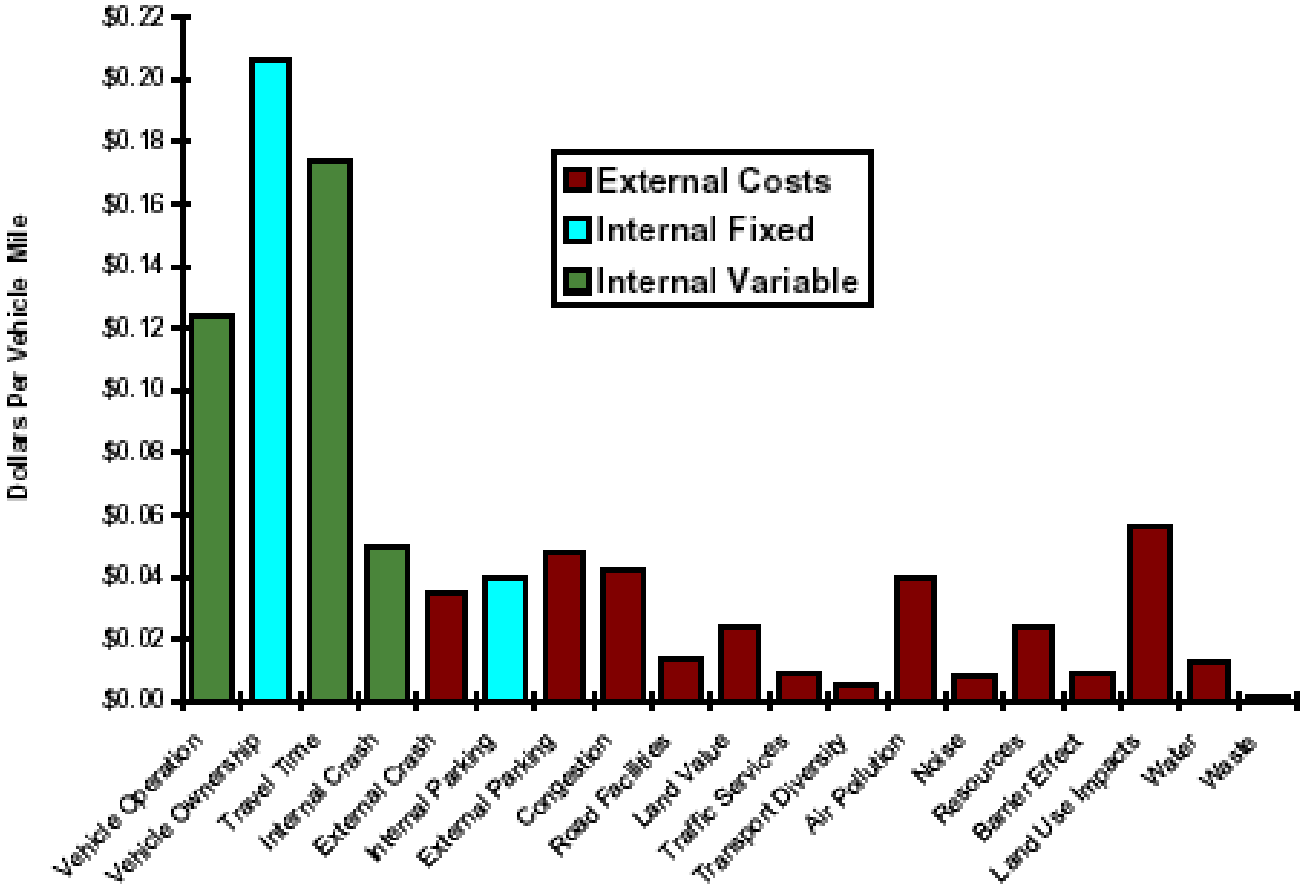
The CDC has identified that obesity is lowest in countries and neighborhoods with significant walking and biking.

During the 1996 Olympics in Atlanta, city officials reduced vehicle traffic by 22.5% and asthmas related emergencies decreased 41.6%



Source: Friedman et al., 2001 (CDC/*JAMA*)

Figure 6-1 Costs Per Vehicle Mile for Average Car



This figure shows Average Car costs per vehicle mile.

2004 Transportation Cost and Benefit Analysis

Victoria Transport Policy Institute (www.vtpi.org)

Typical Strip Commercial Development
Pearl City, Hawaii

Courtesy Benjamin Lee, FAIA

Design alternatives for strip commercial development

Courtesy Benjamin Lee, FAIA

Design alternatives for strip commercial development

Courtesy Benjamin Lee, FAIA

Design alternatives for strip commercial development

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Design alternatives for strip commercial development

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Design alternatives for a “big box” development

Courtesy Benjamin Lee, FAIA

Design alternatives for a “big box” development

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Design alternatives for a “big box” development

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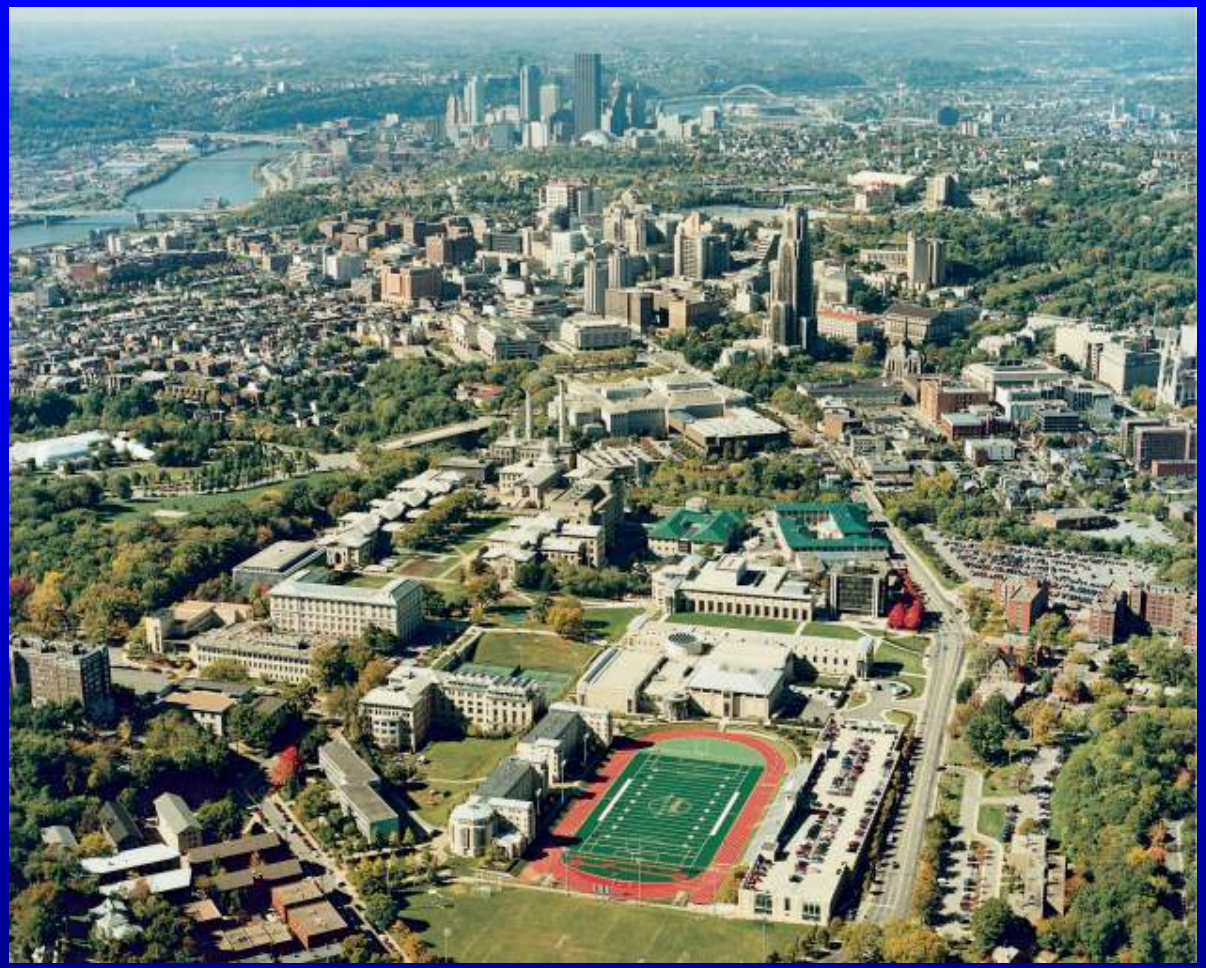
Design alternatives for a “big box” development

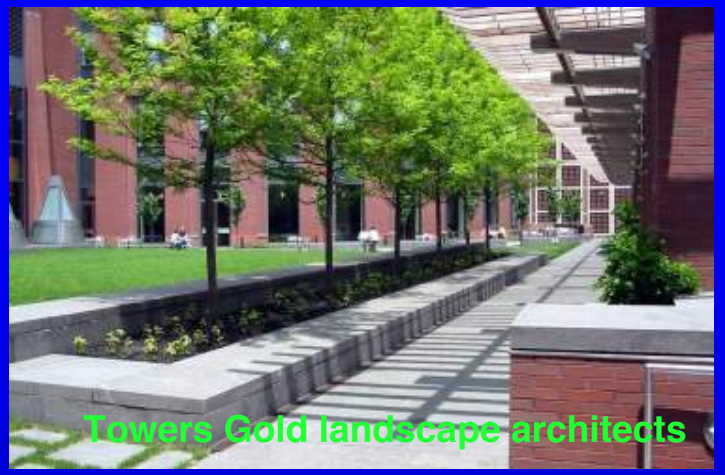
Ecological footprints



pedestrian oriented development = transportation shed,
watersheds, air sheds, energy sheds
material sheds, food sheds, waste sheds

Sustainable design depends on the promotion of infrastructures to neighborhood amenities.

landscape for water management, mobility and energy sources



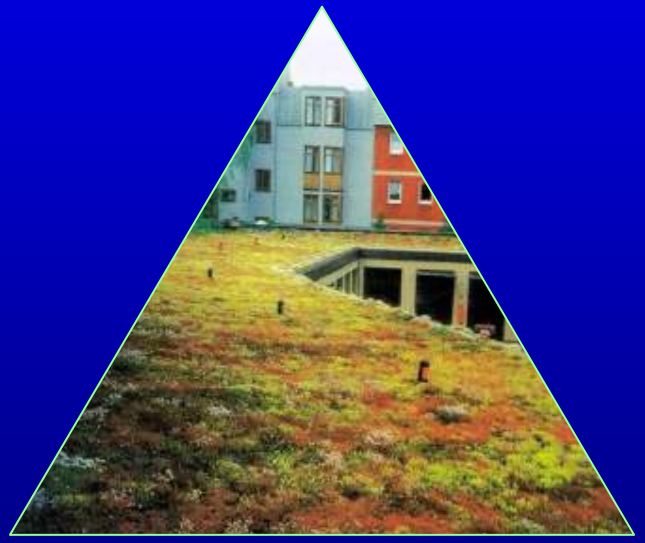
Cool Roofs and "Cool Community" developments reduce annual cooling loads by 10% and peak cooling by 5% with carbon sequestration, storm runoff management, and a 6-8% reduction in smog.

Stata Center Stormwater Schematic Cross-Section

Green Roof Triple Bottom Line

Profit

Roof longevity
Energy conservation
Real estate value



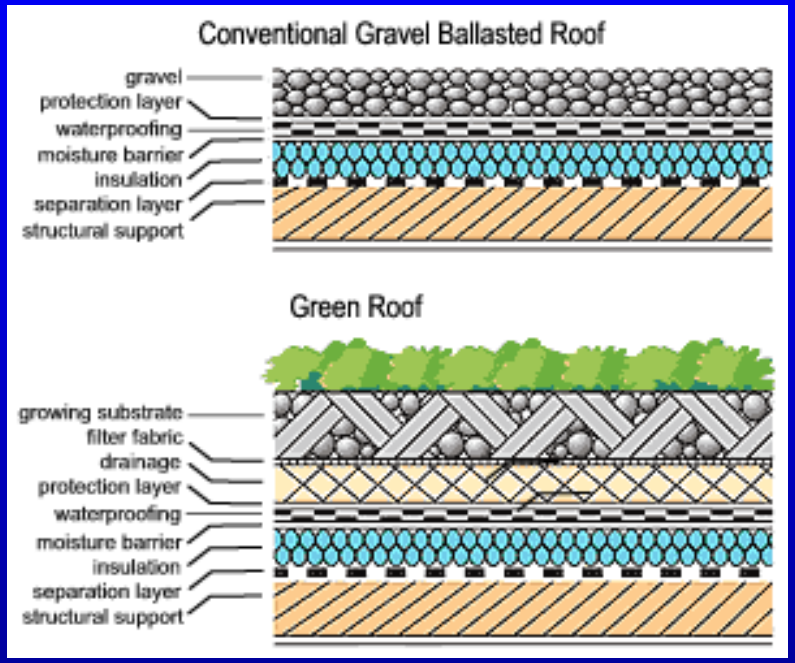
People

Noise abatement
Occupant health, well-being, productivity
New industry/ job creation

Planet

Storm-water runoff benefits
Erosion reduction
Urban heat island mitigation
Wildlife habitat creation
Improved outdoor air quality
Carbon sequestration

Green Roof Components



- Mix of vegetation
- Growing medium
- Layer for water storage, drainage, filtration, aeration
- Root barrier
- Waterproof membrane
- Insulation layer

Optional: Walkways, terraces and sitting areas
Curbs and railings
Lighting
Irrigation systems
Leak detection systems

Types of Green Roofs

Extensive

>6 inch growing medium
>35 pounds / ft^2
Sedums, herbs
Low maintenance
Lowest cost
Inaccessible

Semi-intensive

6-12 inch growing medium
35-50 pounds / ft^2
Height variation, meadow plants
Maintenance varies
Moderate cost
Partially accessible

Intensive

>12 inch growing medium
50-300 pounds / ft^2
Gardens, canopies
High maintenance
High cost
Accessible

Ways to Install Green Roofs

Pre-vegetated mats

Extensive type only
Fast installation
Immediately green
Low flexibility for change
Relatively lower cost

Pre-planted modular containers

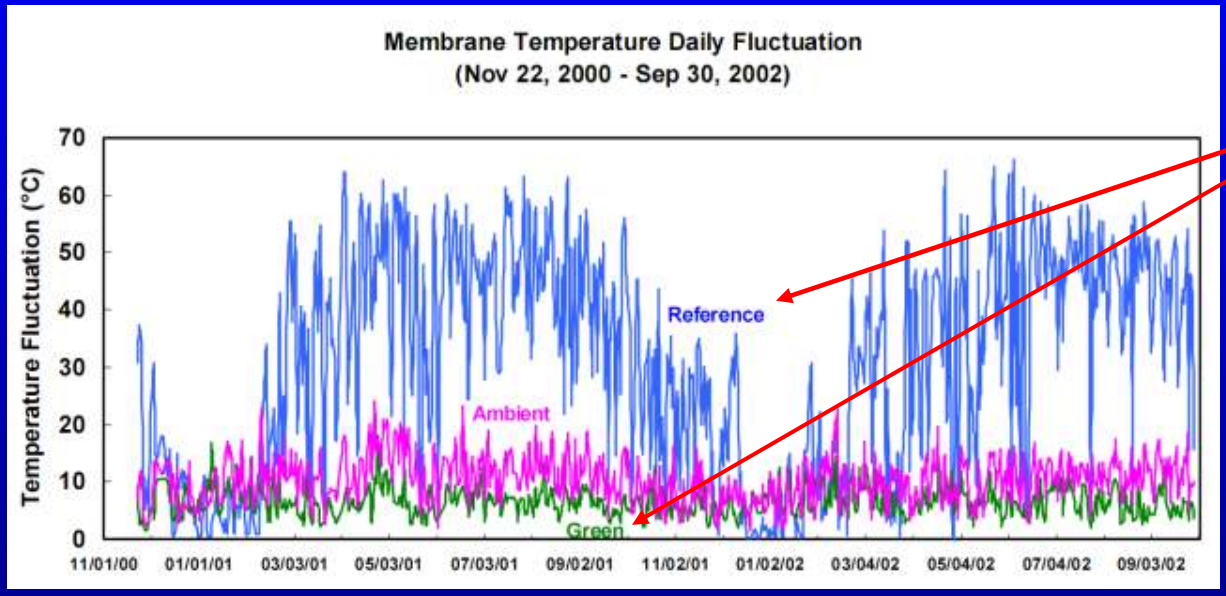
All types
Fast installation
Pre-"green" as desired
High flexibility for change
Relatively lower cost

Built-in-place systems

All types
Slow installation
Up to 2 years for full coverage
Low flexibility for change
Relatively higher cost

Profit: Roof longevity

Green roof shades membrane from UV and thermal stress



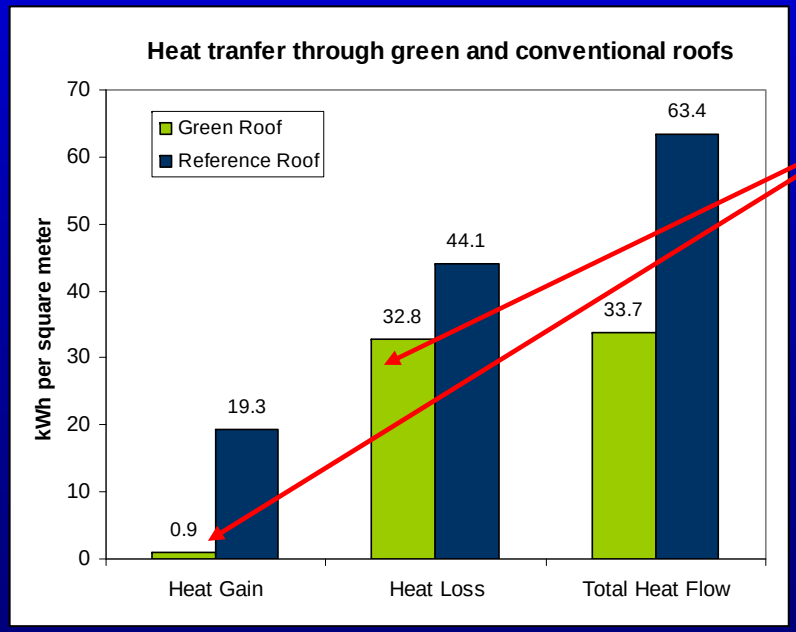
Median daily temperature swing of conventional dark-colored roof = 45ºC, compared to 6ºC for green roof[1]

Increases membrane life by 2-4X; up to 50 years[2]

1) Liu and Baskaran 2003
2) Kosareo and Ries 2007

Profit: Energy Conservation

- Direct roof shading
- Evaporative cooling from the plants and growing medium
- Additional thermal mass in the roof
- Additional insulation in the roof assembly



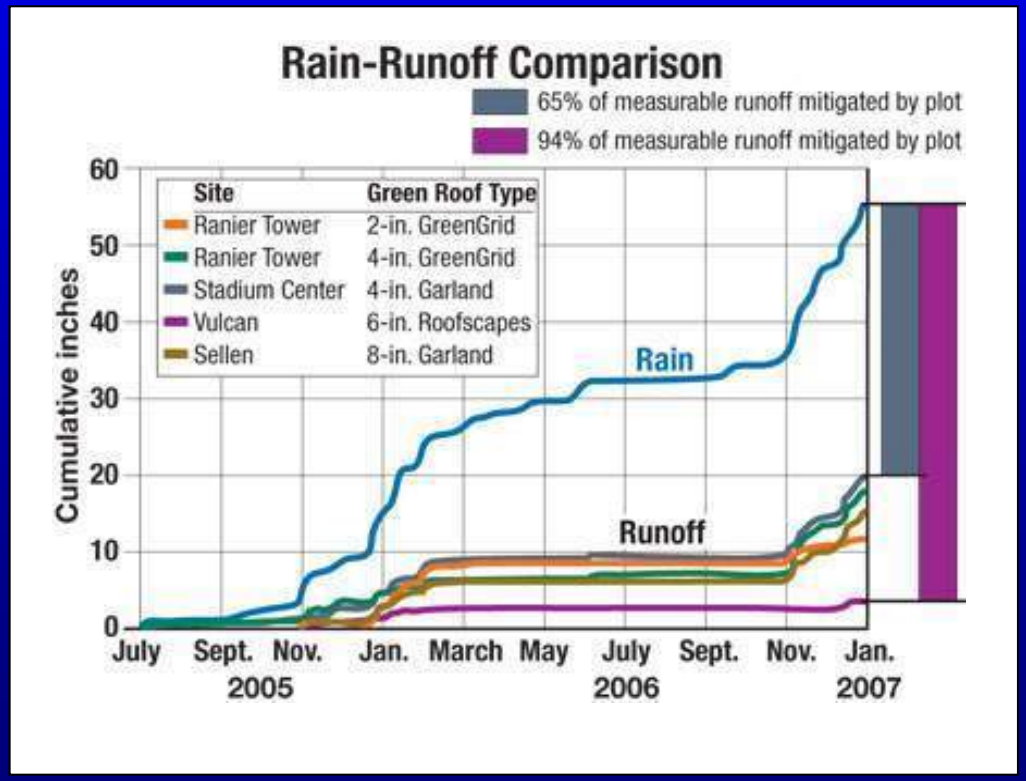
Green roof reduced summer heat gain through the roof by 95%, and reduced winter heat loss through the roof by approximately 26%[3]

3) Liu and Baskaran 2003

Profit or Planet? Stormwater Runoff & Erosion

Excessive runoff during rainstorms results in:

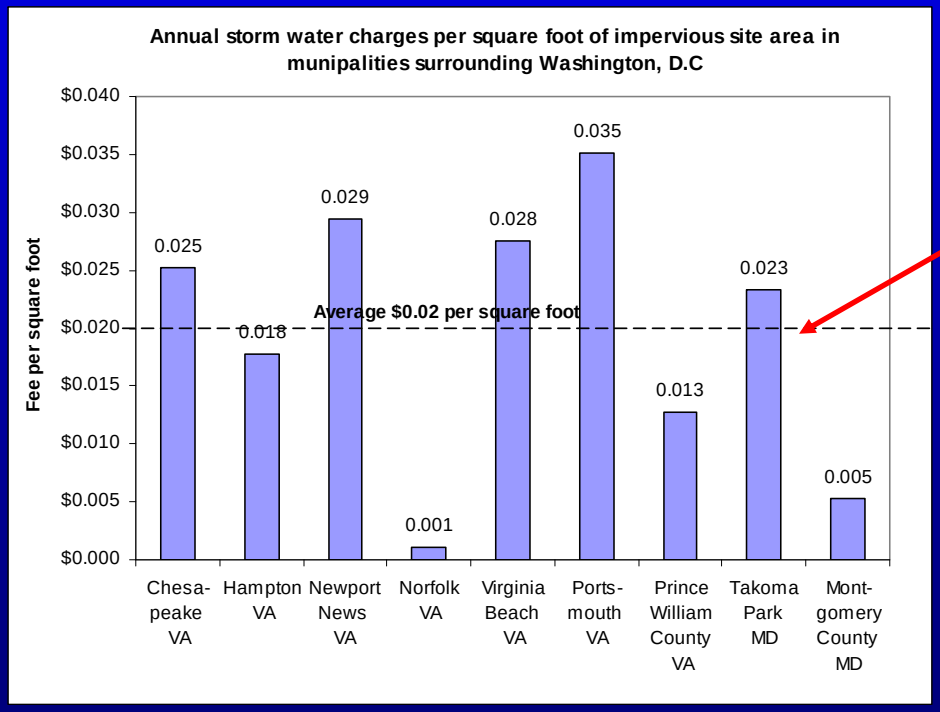
- Sewage overflow to the Potomac & Anacostia Rivers and Rock Creek (CSOs)
- Erosion of runoff paths and at downspout outlets



Green roofs retain more than 50% of the rainwater that falls on them.
Magnusson Klemencic 2007

Stormwater Fees & Savings

- Stormwater fee: individual building owners pay for storm water runoff that leaves their building site.
- Rates per impervious area of a parcel, including the roof surface
- DCWASA is planning to implement a similar fee system



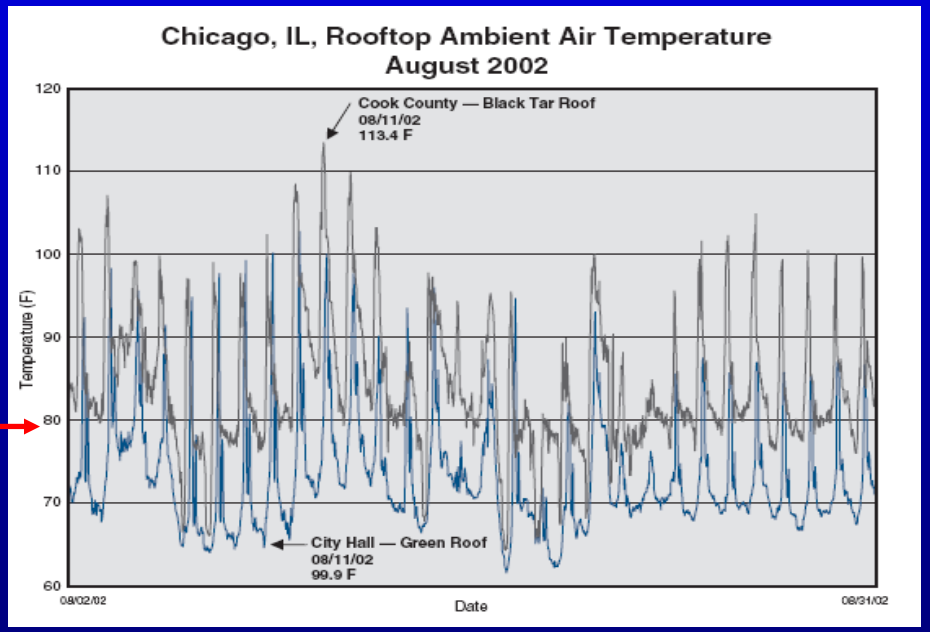
Given the average stormwater rate of surrounding municipalities, the Dirksen SOB green roof would avoid $11,900 in stormwater fees over a 25-year life cycle.

Planet: Urban Heat Island Mitigation

Urban heat island: can result in temperature differences of between rural and urban areas, which: up to 10°F

- Increases the use of air conditioning equipment
- Increases building cooling load
- Increases peak energy penalties

A green roof mitigates the heat island effect by cooling rooftop air through evapo-transpiration.



FEMP/DOE Federal Technology Alert DOE/EE-2098

Planet: Peak Load Reduction

- 0.334 kW - 0.359 kW peak load reduction per 1,000 ft^2 green (cool) roof area (pre-1980 building, Washington, D.C. climate)[5]
- $600 per kW to bring a new power plant online to supply additional load[6]

Peak capacity savings due to Dirksen SOB green roofs:

$5,900 - $6,900

5) Akbari et al 2005
6) Banting et al 2005

Planet: Habitat Creation

- Green roofs can attract migratory and other birds, insects, and invertebrate soil-dwelling organisms.
- May function as ecological corridors through developed areas, linking larger green spaces
- ‘Features’ known to attract wildlife[6]

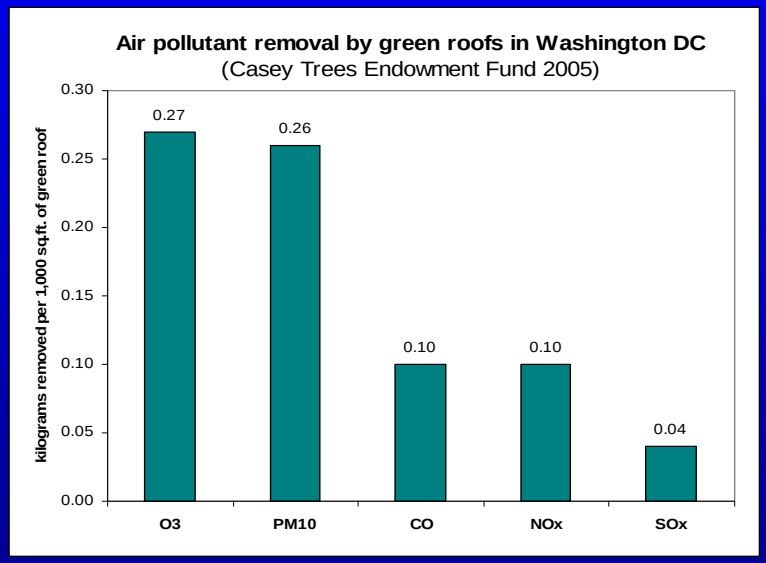
Variety in height and slope of soil
Sparsely and densely planted areas
Freely and poorly draining areas
Diverse plant population

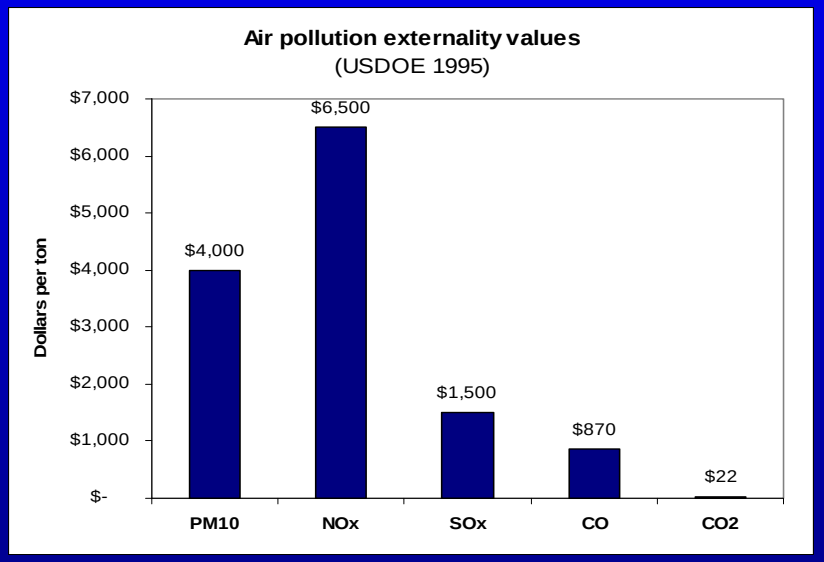
Northern lapwing on a Swiss green roof

6) Brenneisen 2003

Planet: Outdoor Air Quality

- Rooftop plants can trap particulates and sequester gaseous pollutants with their leaves
- Reduced power plant emissions due to energy savings





25-year life cycle emissions savings for Dirksen SOB green roof: $56,400 - $56,900

People: Noise abatement

Unlike hard surface roofs,
green roofs absorb sound rather than reflect it.

- Green roof with 4-inch growing medium reduces transmission of airport noise into building by at least 5 decibels.[7]
- GAP Inc. headquarters green roof attenuates airplane sound to 50dB
- Many airport authorities offer cash to improve building enclosures;
  In 2004, the average noise mitigation paid by airport authorities to qualifying households was $12,500 ($5 per square foot)[9]

Noise abatement value of
Dirksen SOB green roof: $34,000

7) Dunnett and Kingsbury 2004
9) Landrum & Brown 2005

People: Productivity Benefits

A 2003 study by the Heschong-Mahone Group found a 6% improvement in call center average handling time for workers with the highest rated views, as compared to workers with no view at all.

Range of improvement from 0.5 percent to 1.4 percent per one point increase in view rating

In the Dirksen SOB, the productivity gain for staffers who will now have a view of a vegetated roof, is estimated at 2.9% and valued at $65,000 per year.

People: New Industry & Job Creation

Emerging US industry?

Germany's green roof industry growing 15-20% a year
10% of all flat roofed buildings in Germany now green
over 500 million square feet of roof spurred by taxes and incentives:

fees for storm water management

subsidies to avoid infrastructure replacement

indirect subsidies to substitute green roofs as open space

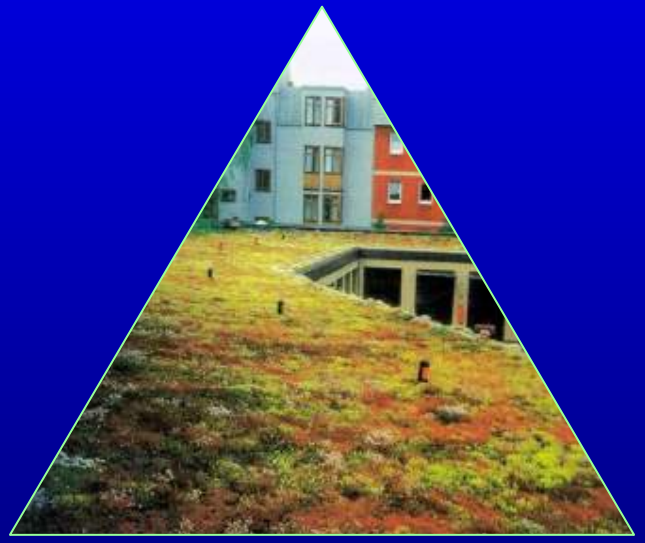
Local job development?

design/engineering
manufacturing
installation

Green Roof Triple Bottom Line

Profit

Roof longevity
Energy conservation
Real estate value



People

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Improved outdoor air quality
Carbon sequestration

The Intelligent Workplace… and next

Carnegie Mellon University

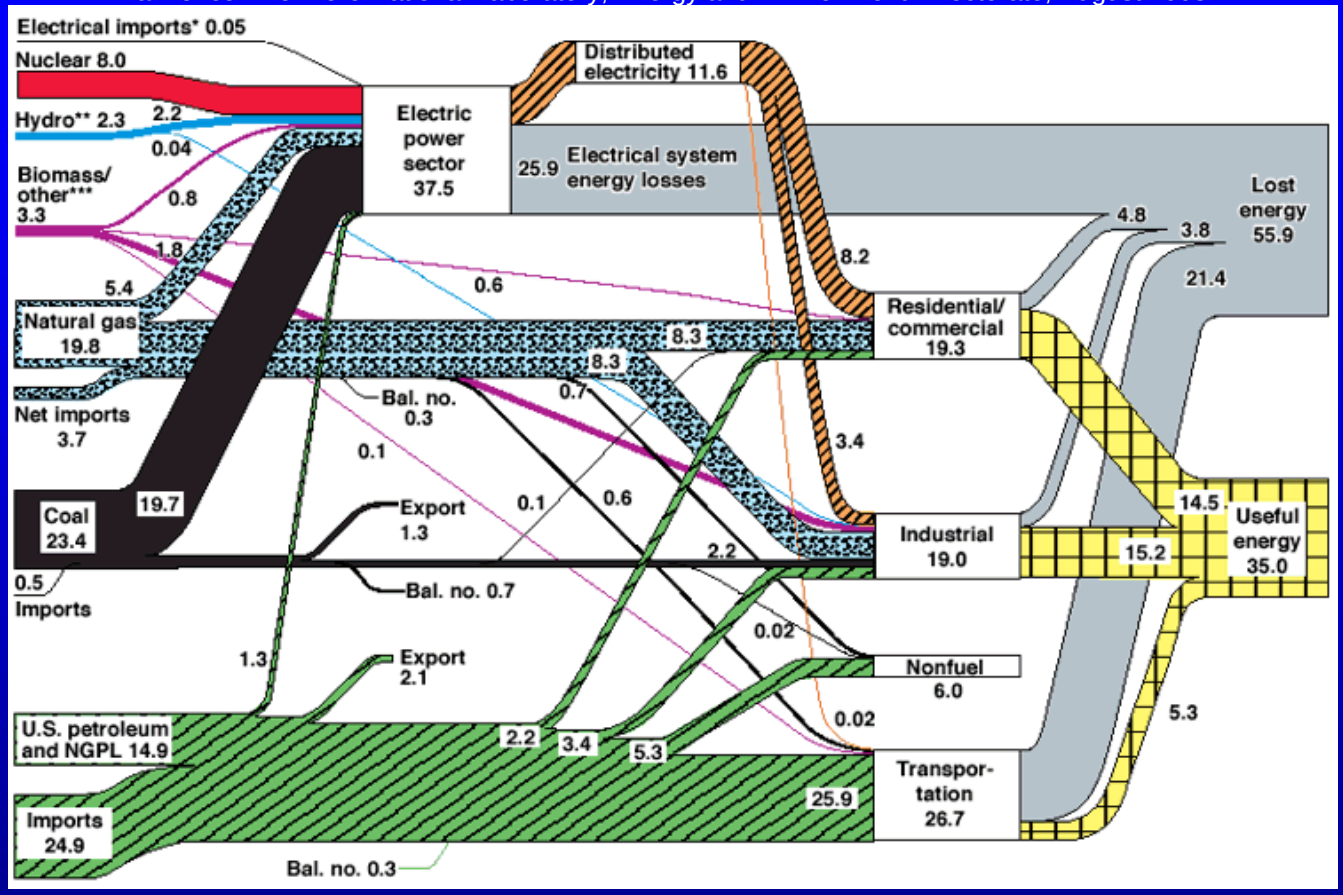
A Living Laboratory for Building Environmental Research

Carnegie Mellon's Building as Power Plant:
merging ascending and cascading energy systems

On-site generation and energy cascades
can shift generation efficiencies from 30% to 70%.

Add renewable sources and buildings can generate more power than they use.

1. Lawrence Livermore National Laboratory, Energy and Environment Directorate, August 2003.



In 2003, the US wasted 60% more energy than it consumed, due to generation and transmission losses - losses that Distributed Gen & CHP can dramatically reduce.

Sustainable Workplaces for Human Health and Productivity

Vivian Loftness, FAIA