# Green Design
# for a Sustainable & Shared Quality of Life

AIA Ohio January 2011

**Vivian Loftness, FAIA LEEDAP**
Carnegie Mellon University Center for Building Performance & Diagnostics
IW - A Living Laboratory for Building Environmental Research
USGBC Board of Directors

## Ecological Footprints for a Shared Quality of Life

access to affordable energy

access to nature

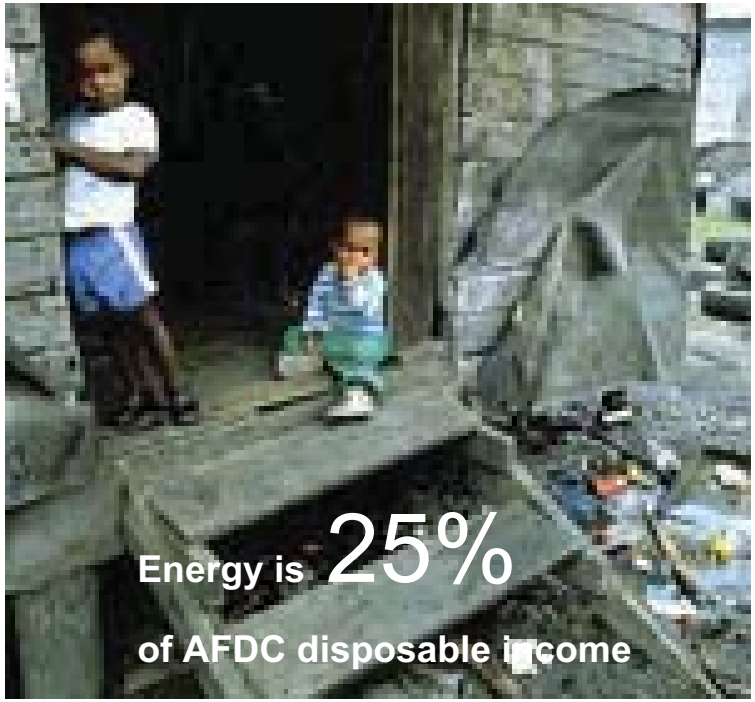
access to healthy air

access to clean water

access to material resources

access to transportation/ mobility

access to community



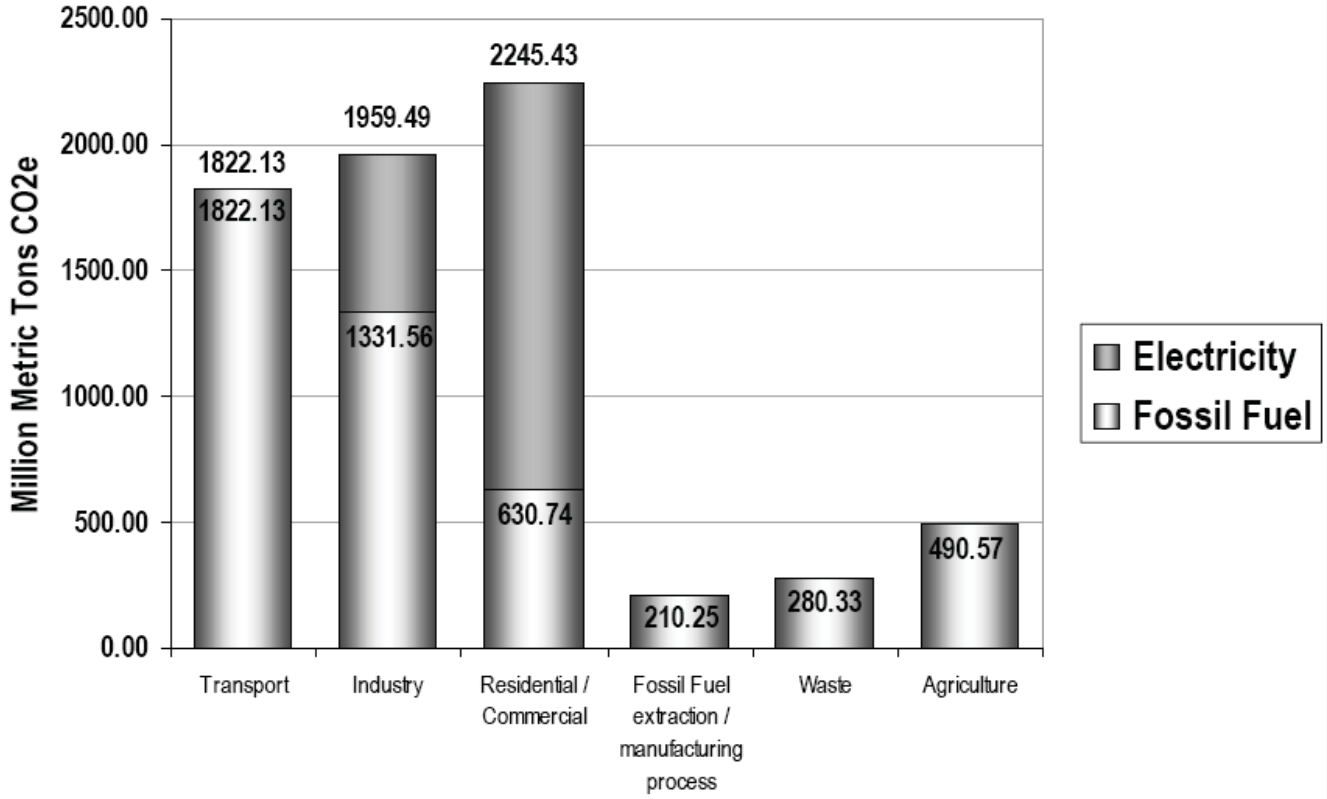


## 1 Shared access to affordable energy

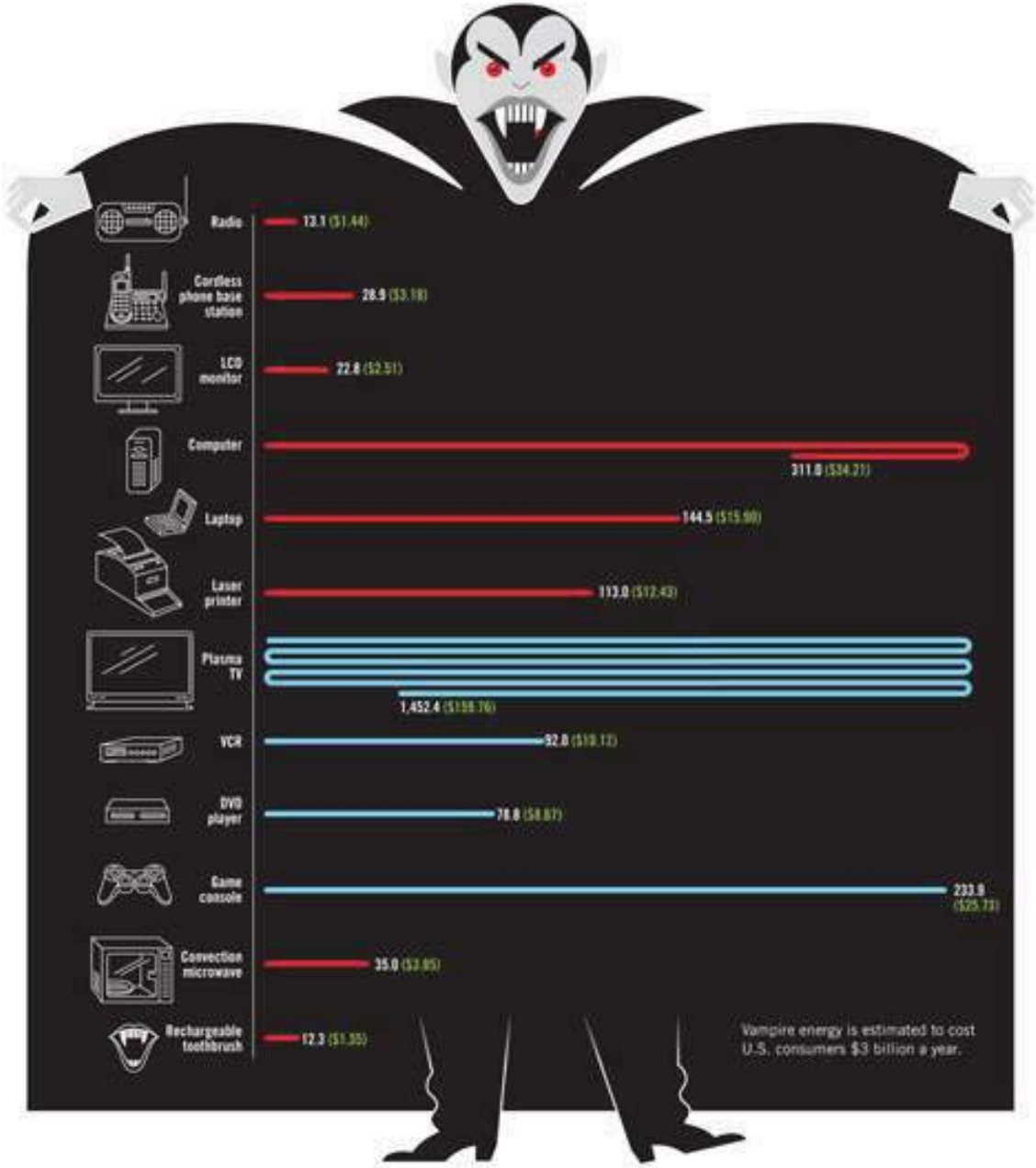
**Heating, cooling, power, transportation costs dramatically reduce disposable income for the poor and those living on social security.**

**Design to ensure all energy is for highest and best use.**

# US - Gross GHG emission production by Sector - 2000



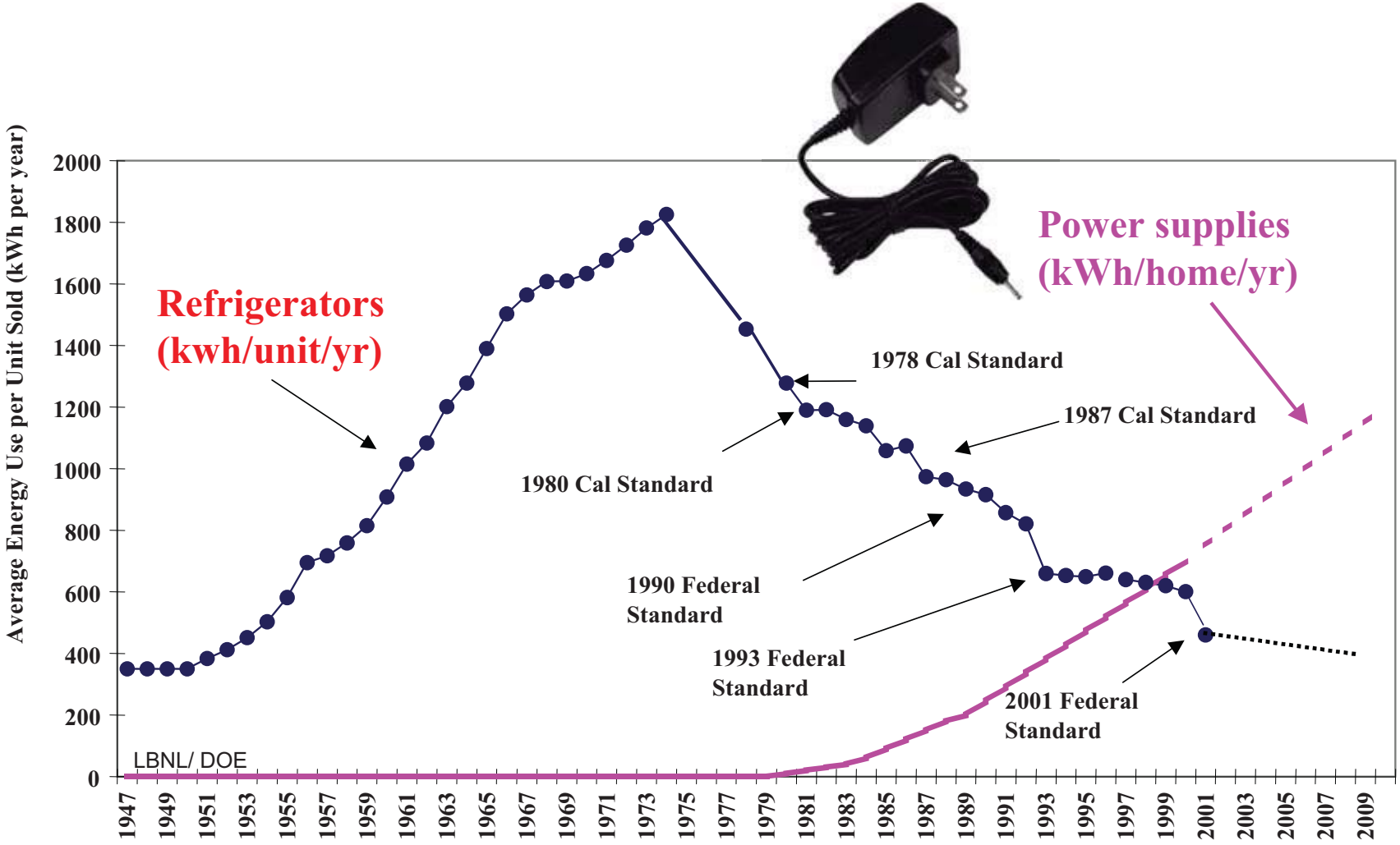

CBPD 2009 from - Baillie A., Jamison A., (2006), Pennsylvania Green House Gas Inventory and Reference Case Projections - Draft, prepared for the: Pennsylvania Environmental Council
- www.epa.gov/climatechange/emissions
- http://apps1.eere.energy.gov/states/electricity.cfm/state=PA



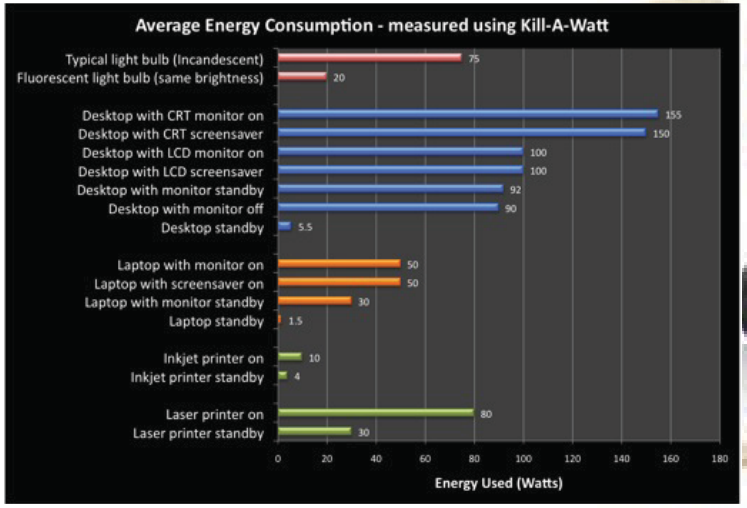

Passive standby

Active standby

# Stop Vampire Loads!



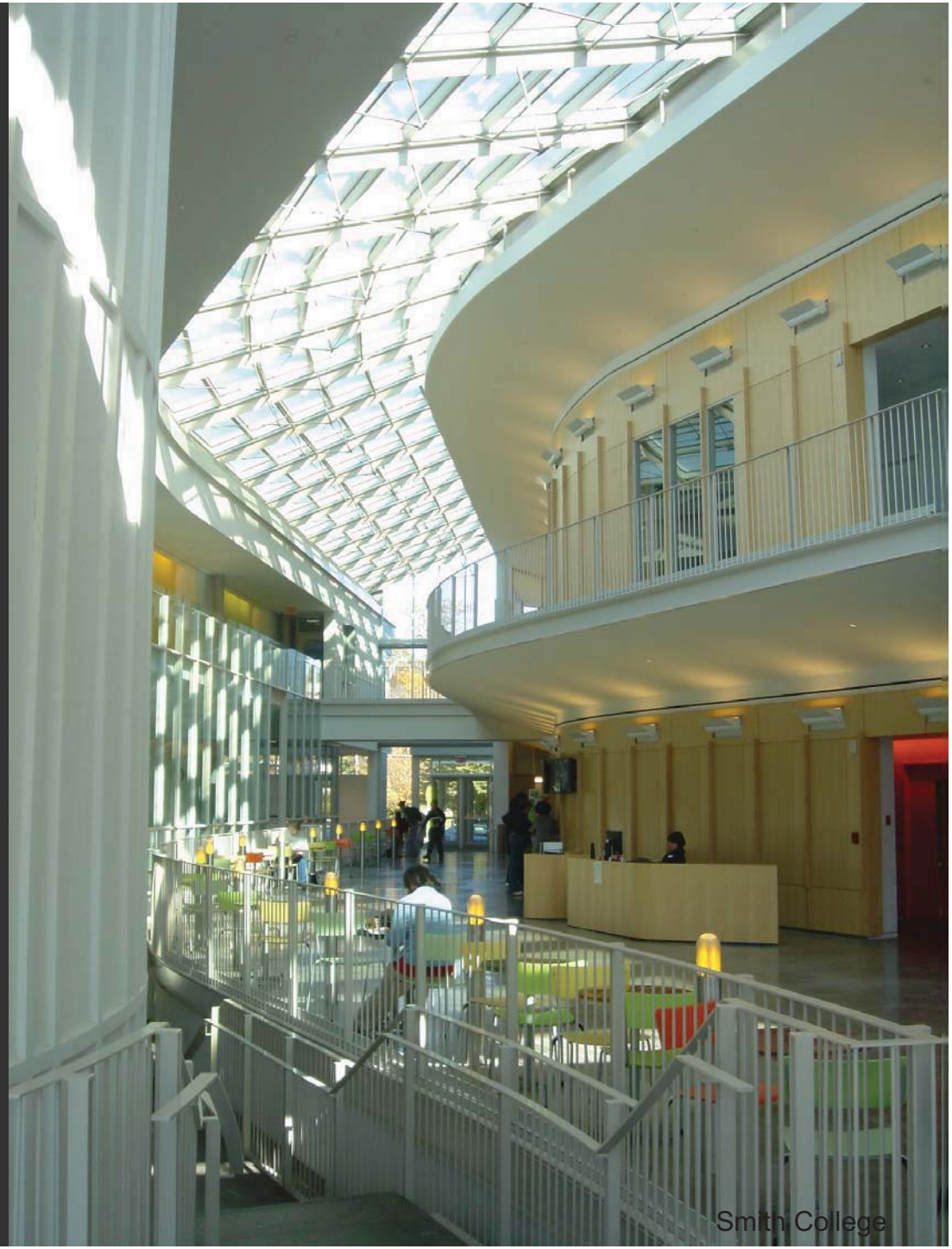

why power supplies are important

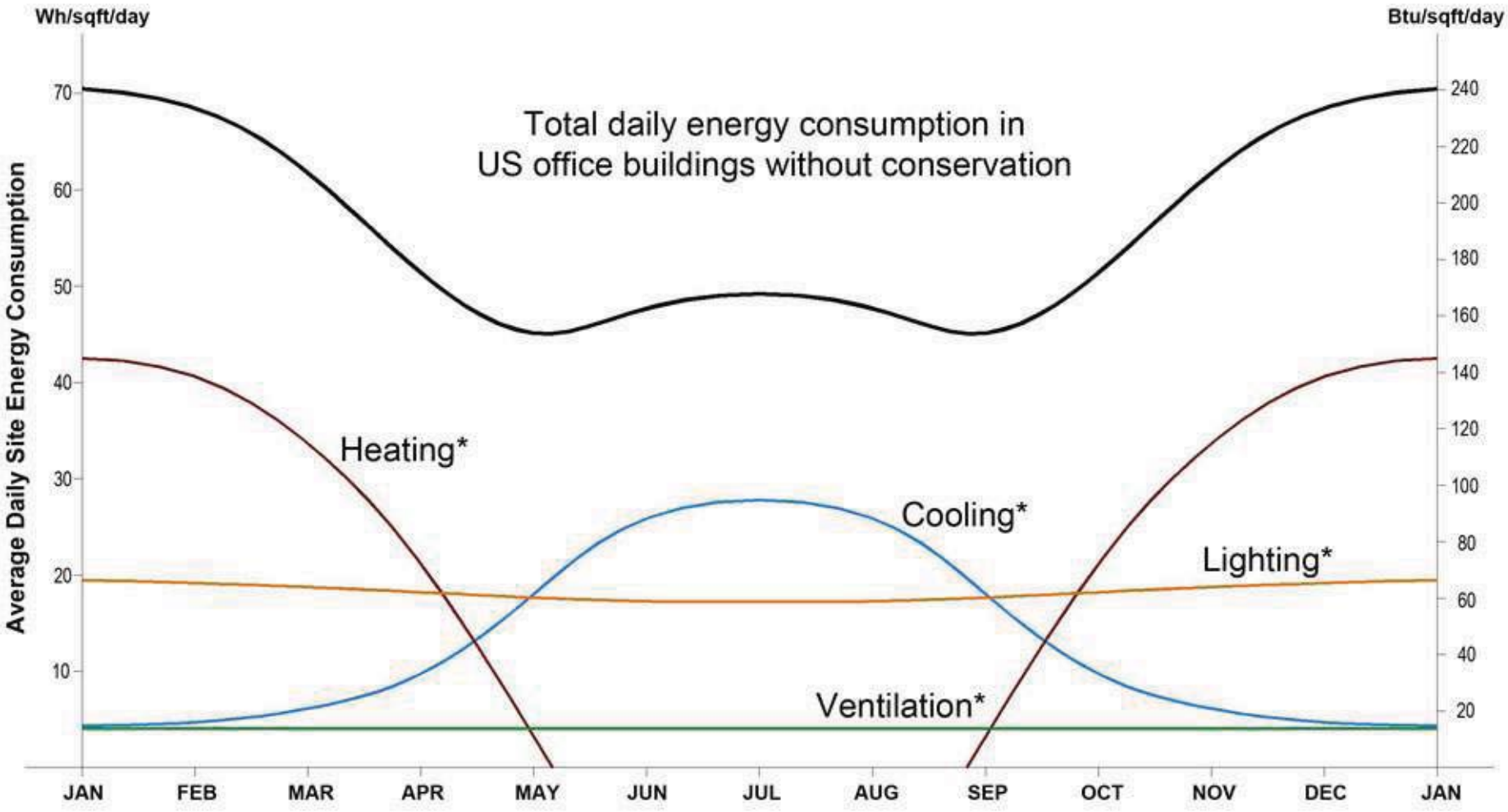

maximize sleep

## Support Environmental ‘Coasting’!

**Embrace nature region by region**

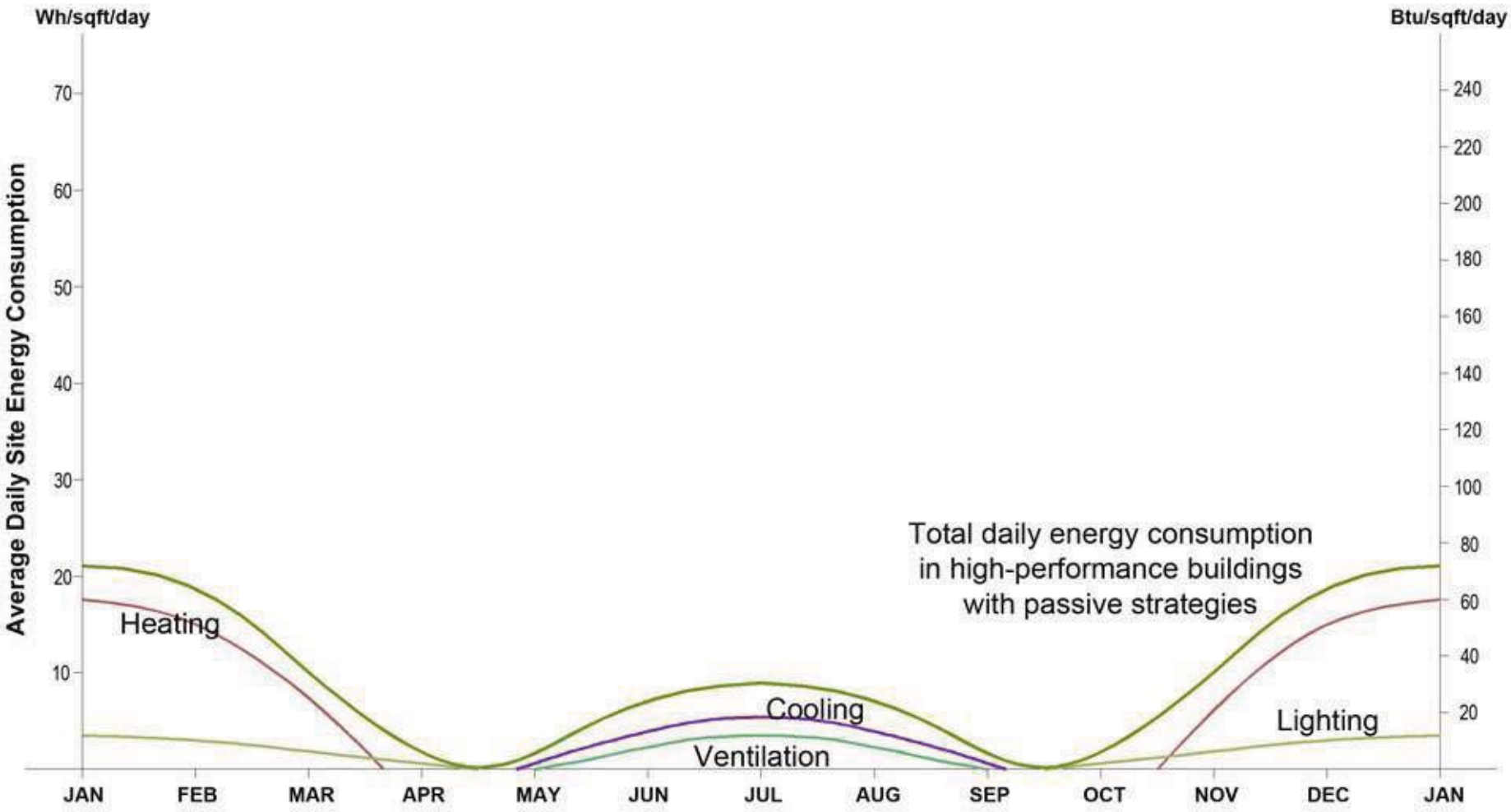


Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University

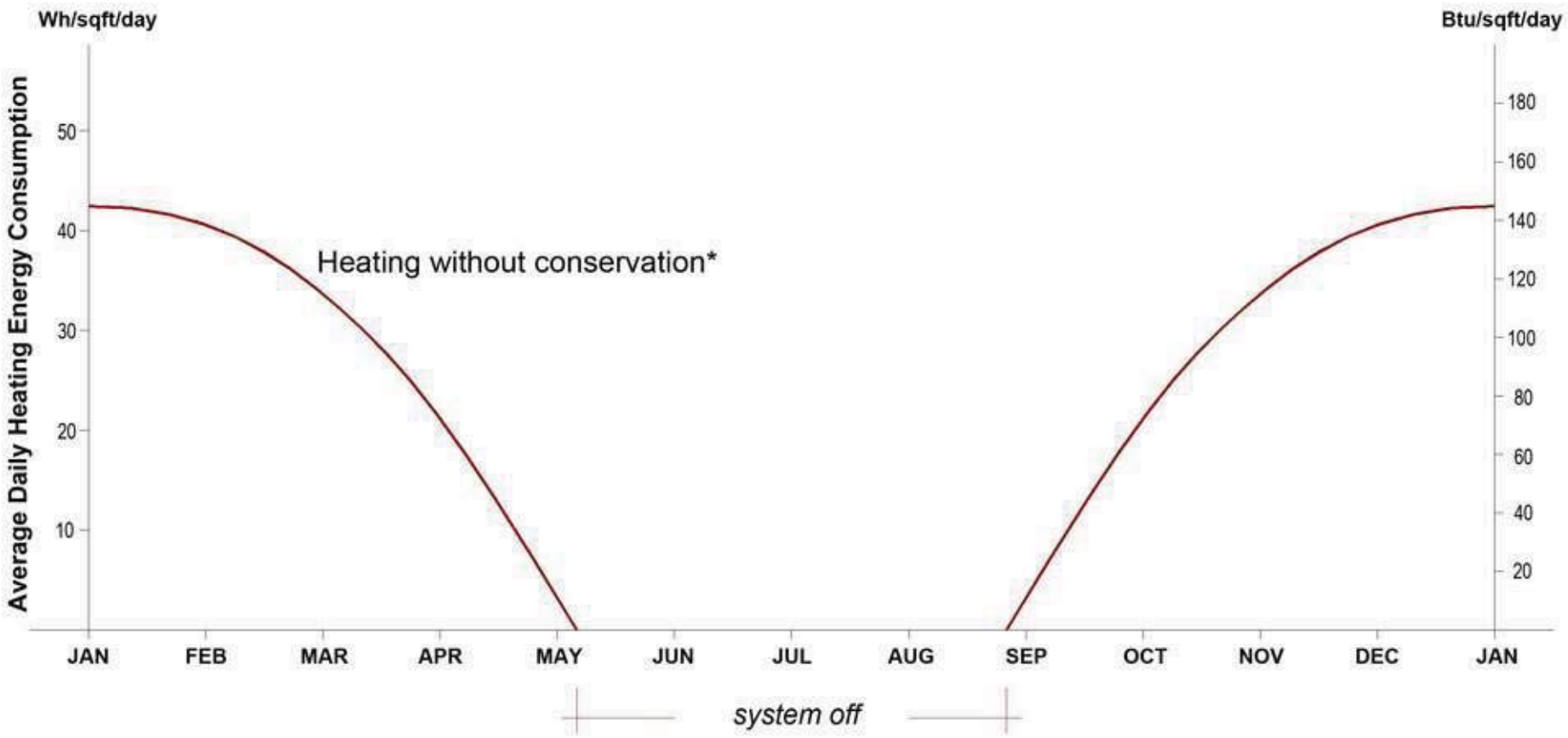



* Total annual heating, cooling, ventilation and lighting energy consumption refers to EIA-CBECS 1995 &1999

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

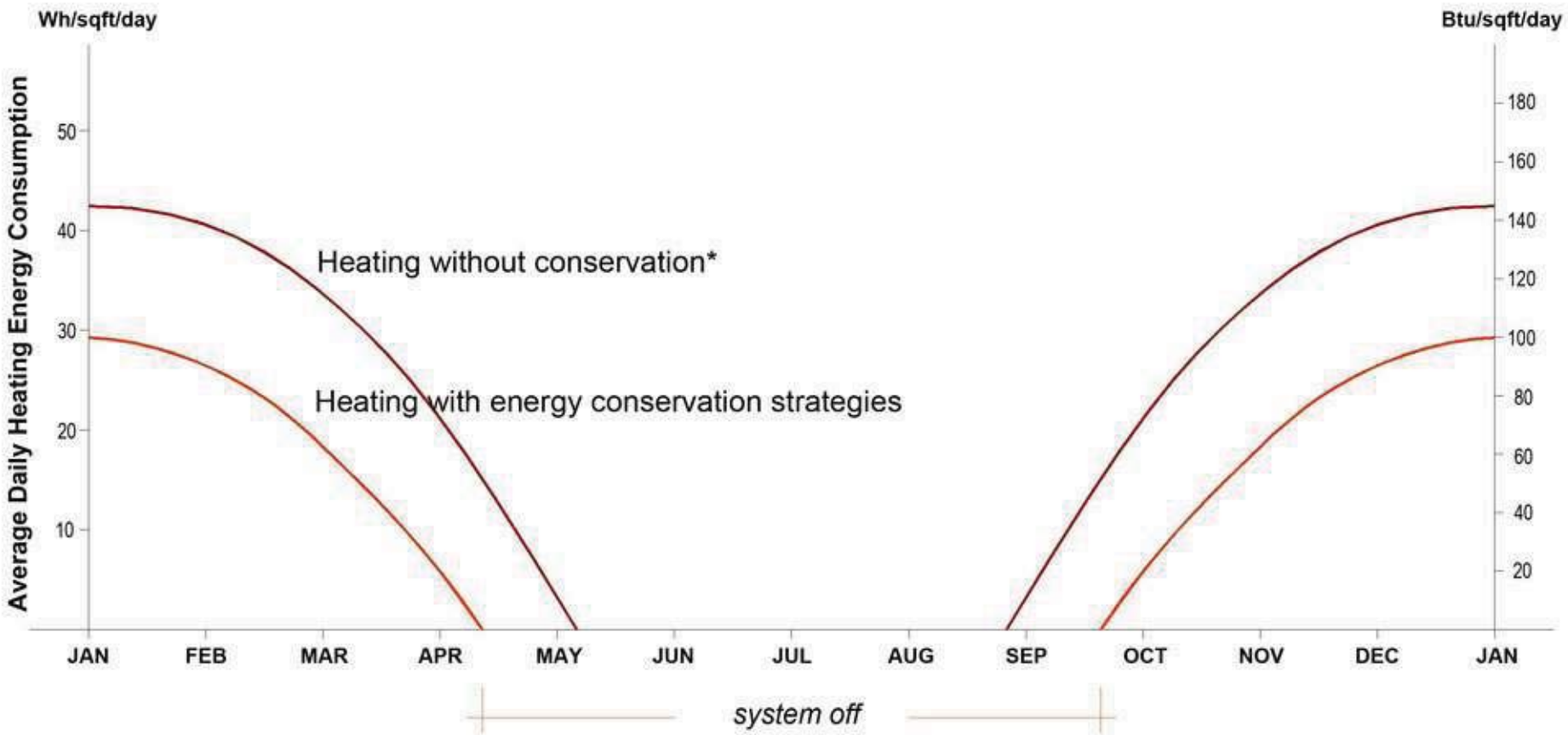


Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University



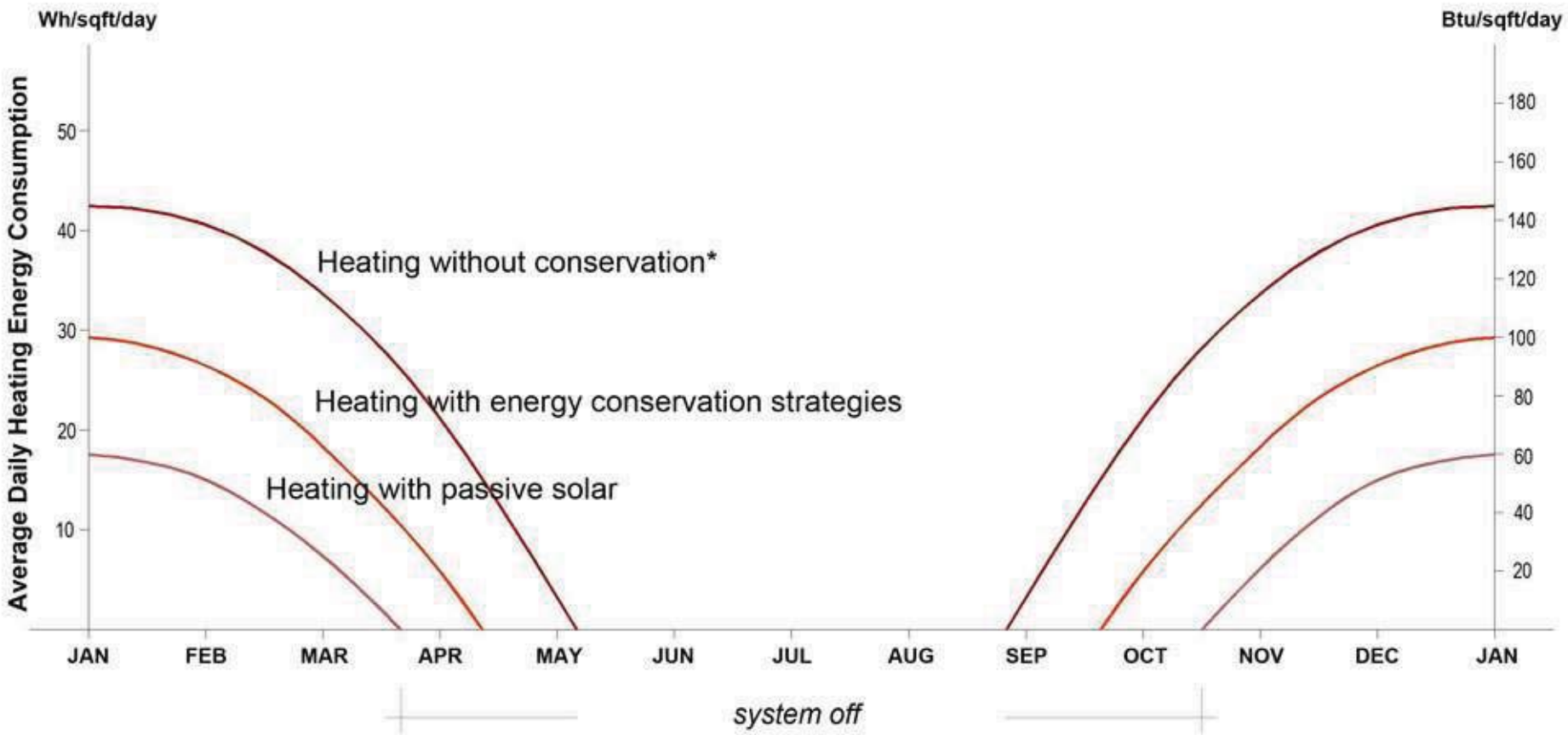

* Total annual heating energy consumption refers to EIA-CBECS 1995 &1999

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

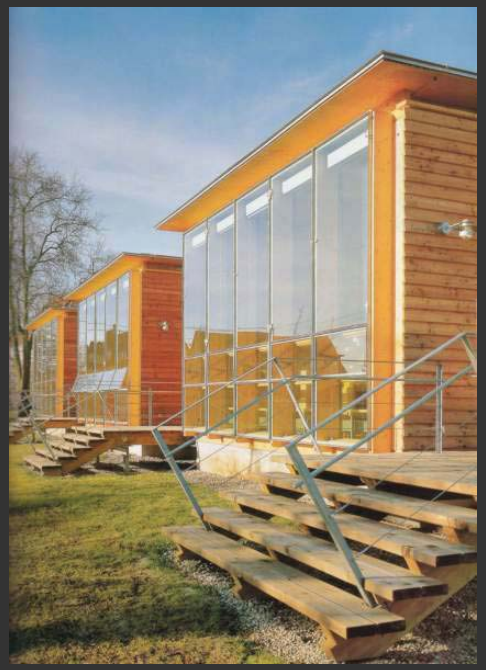



* Total annual heating energy consumption refers to EIA-CBECS 1995 &1999

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

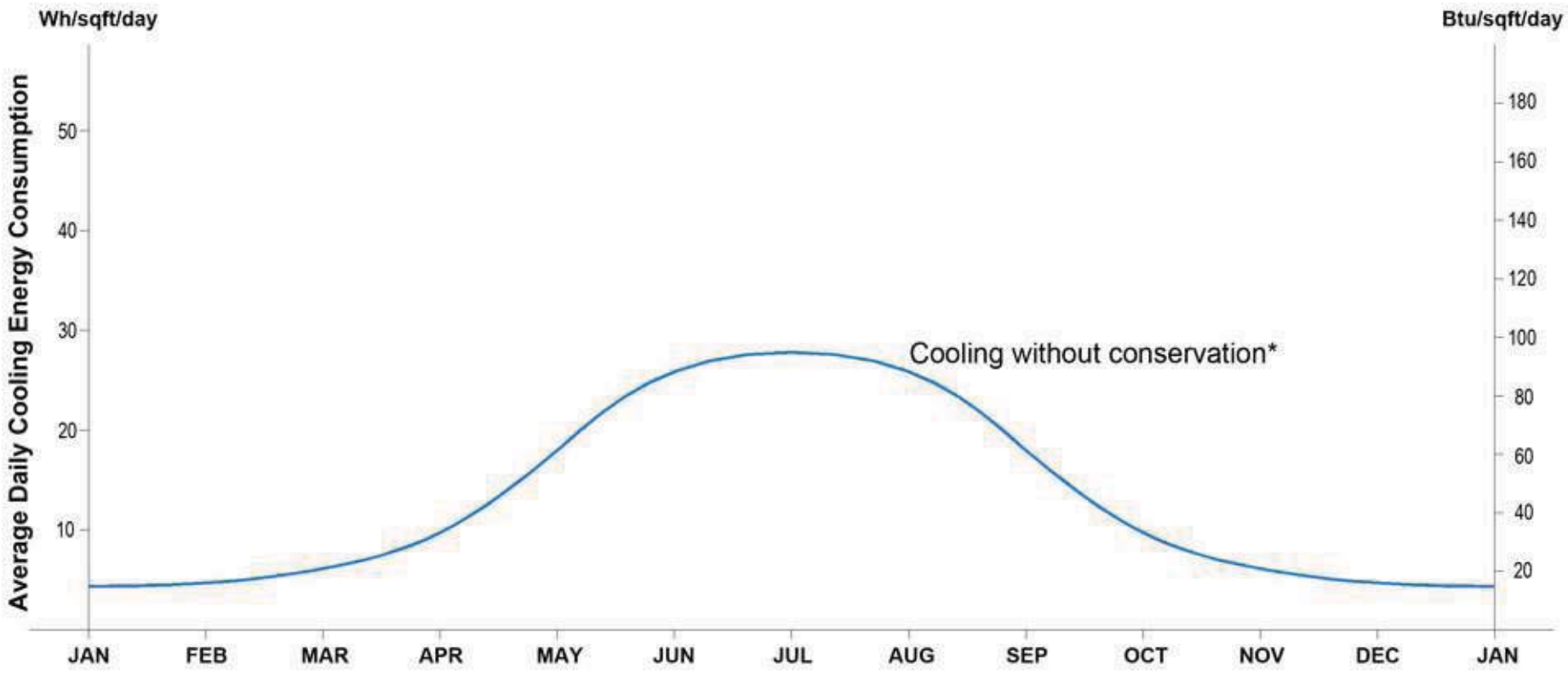



* Total annual heating energy consumption refers to EIA-CBECS 1995 &1999



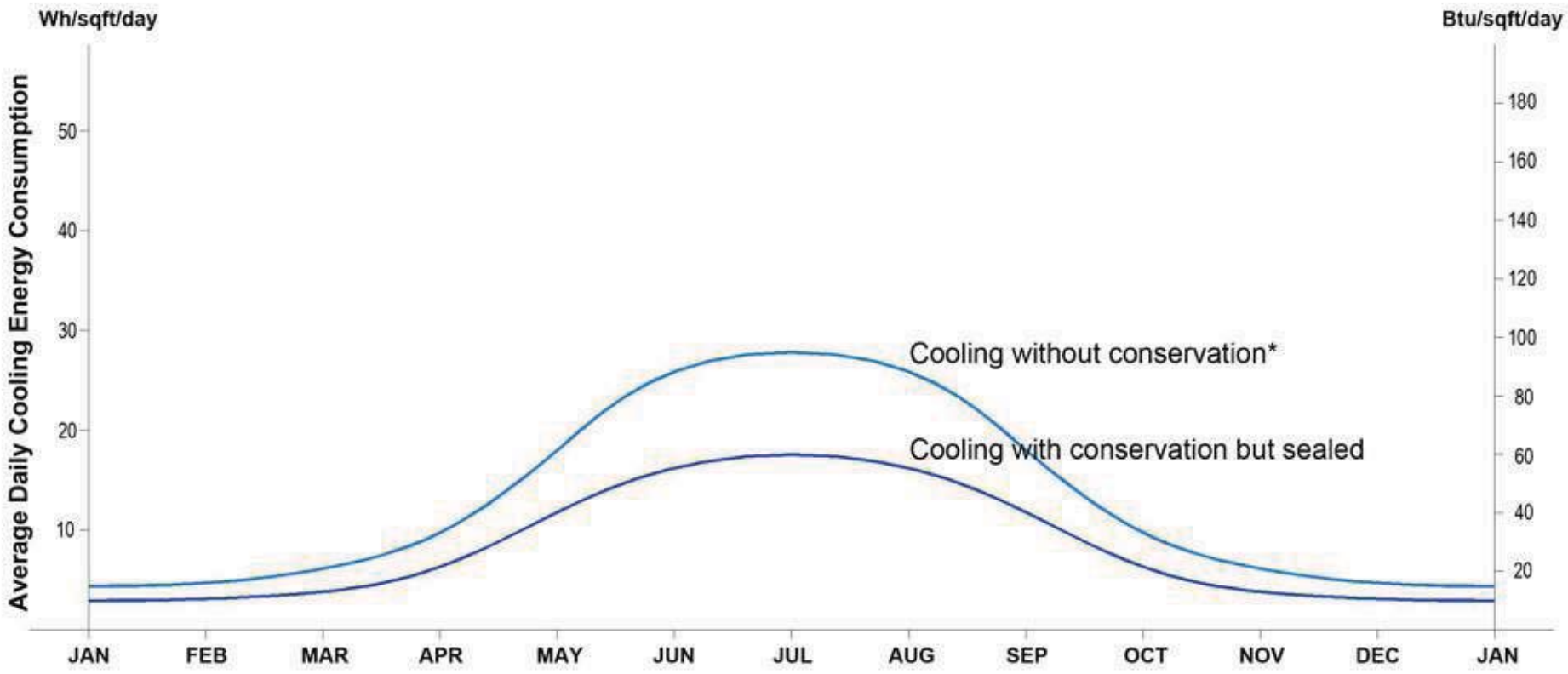
**Passive solar can displace 20-40% of today's heating**

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



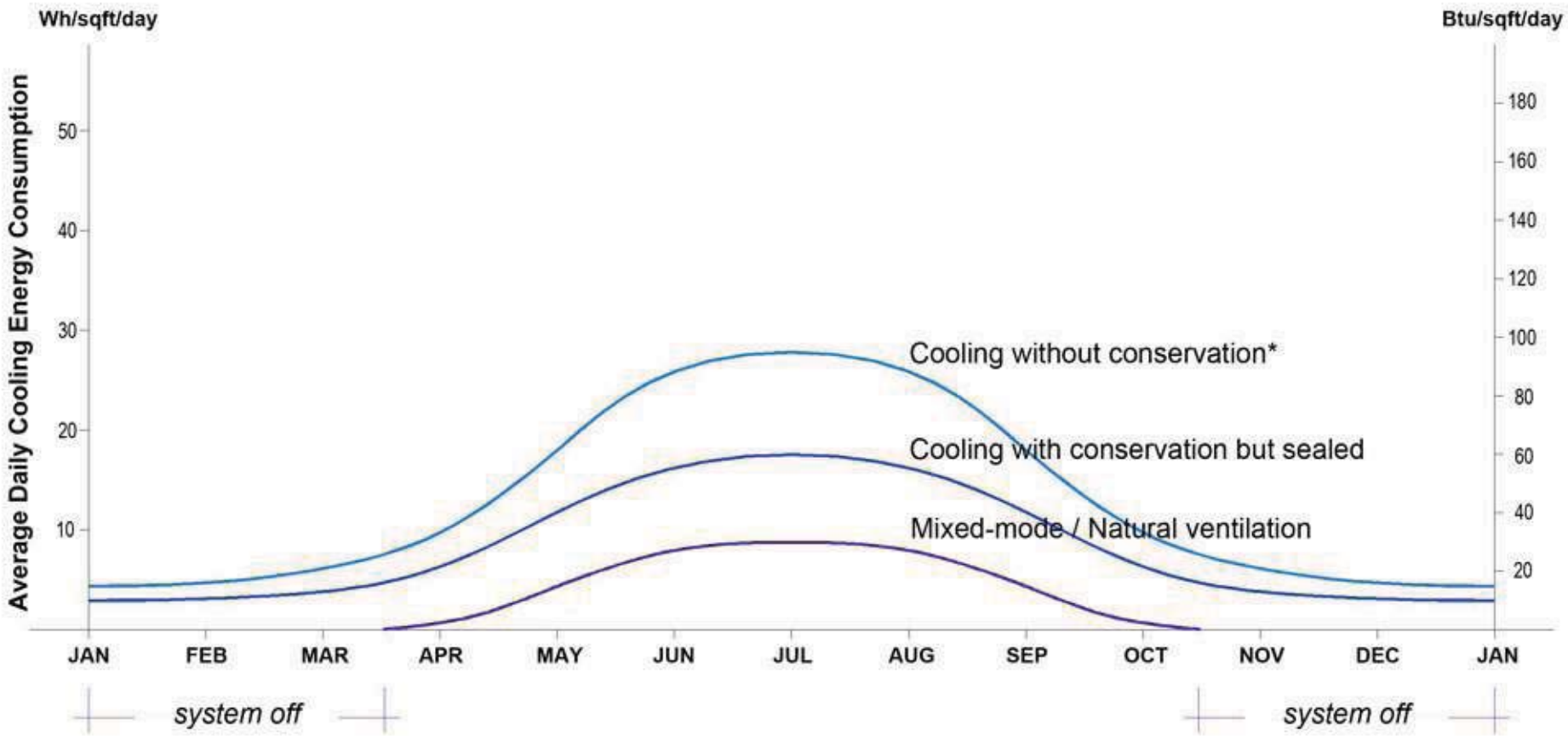

* Total annual cooling energy consumption refers to EIA-CBECS 1995 &1999

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



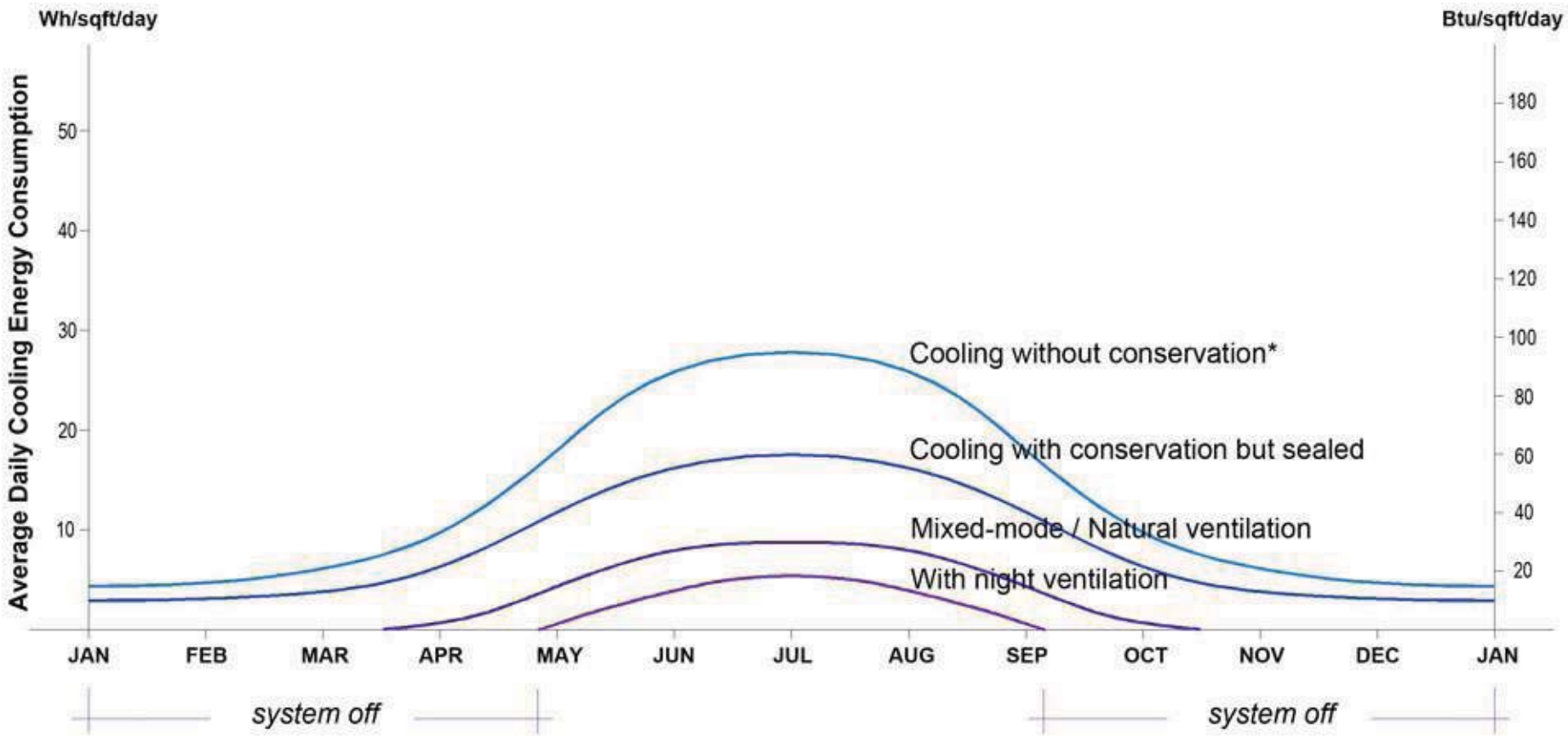

* Total annual cooling energy consumption refers to EIA-CBECS 1995 &1999

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




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

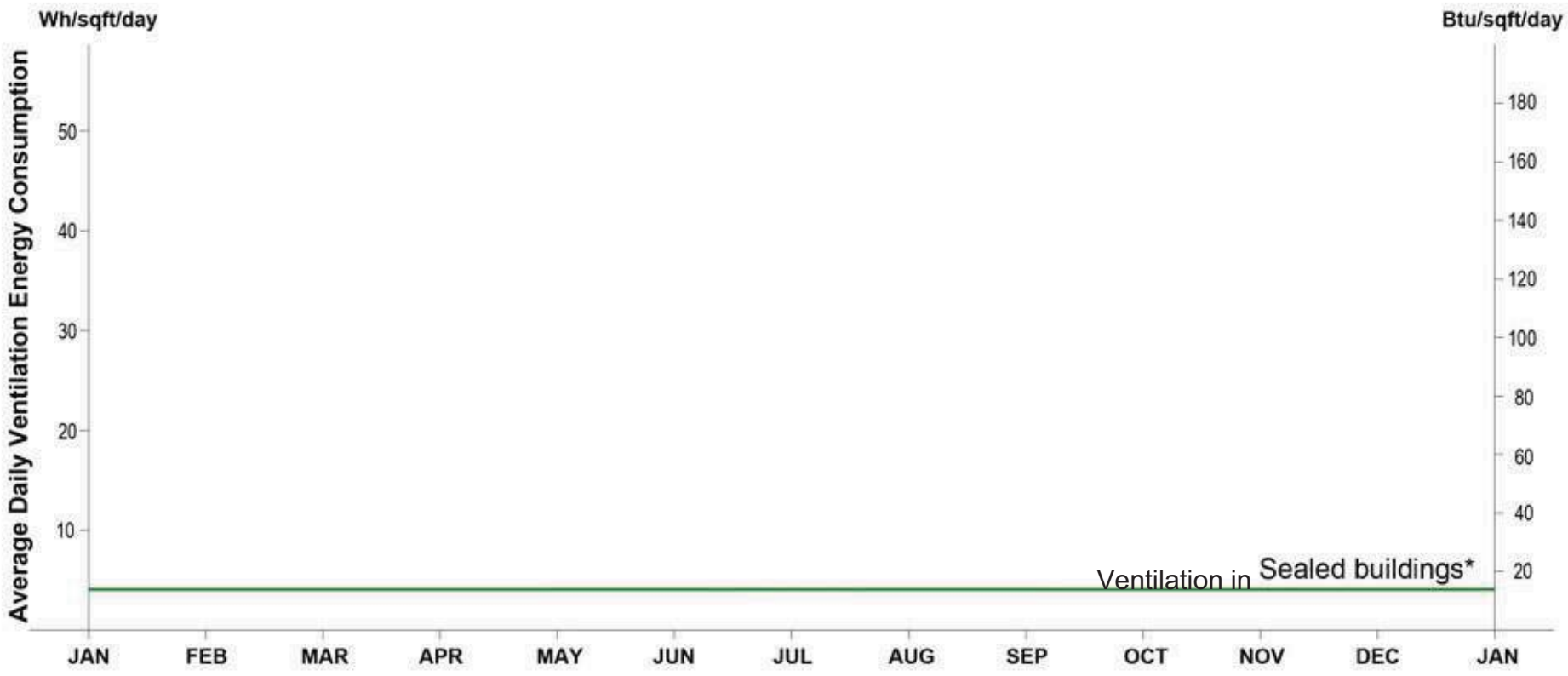
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University




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

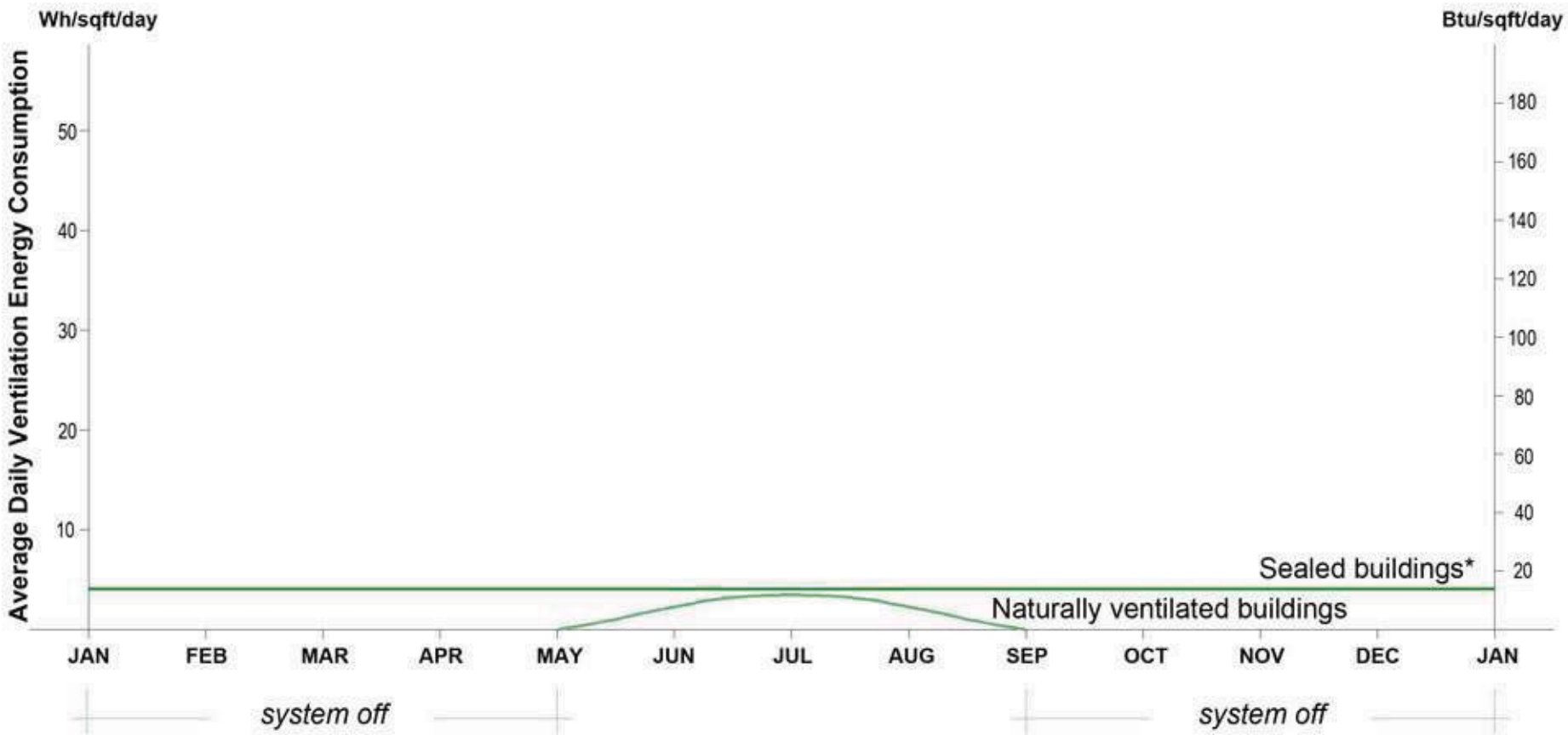
**Shade can displace 20-40% of today's cooling**

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




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

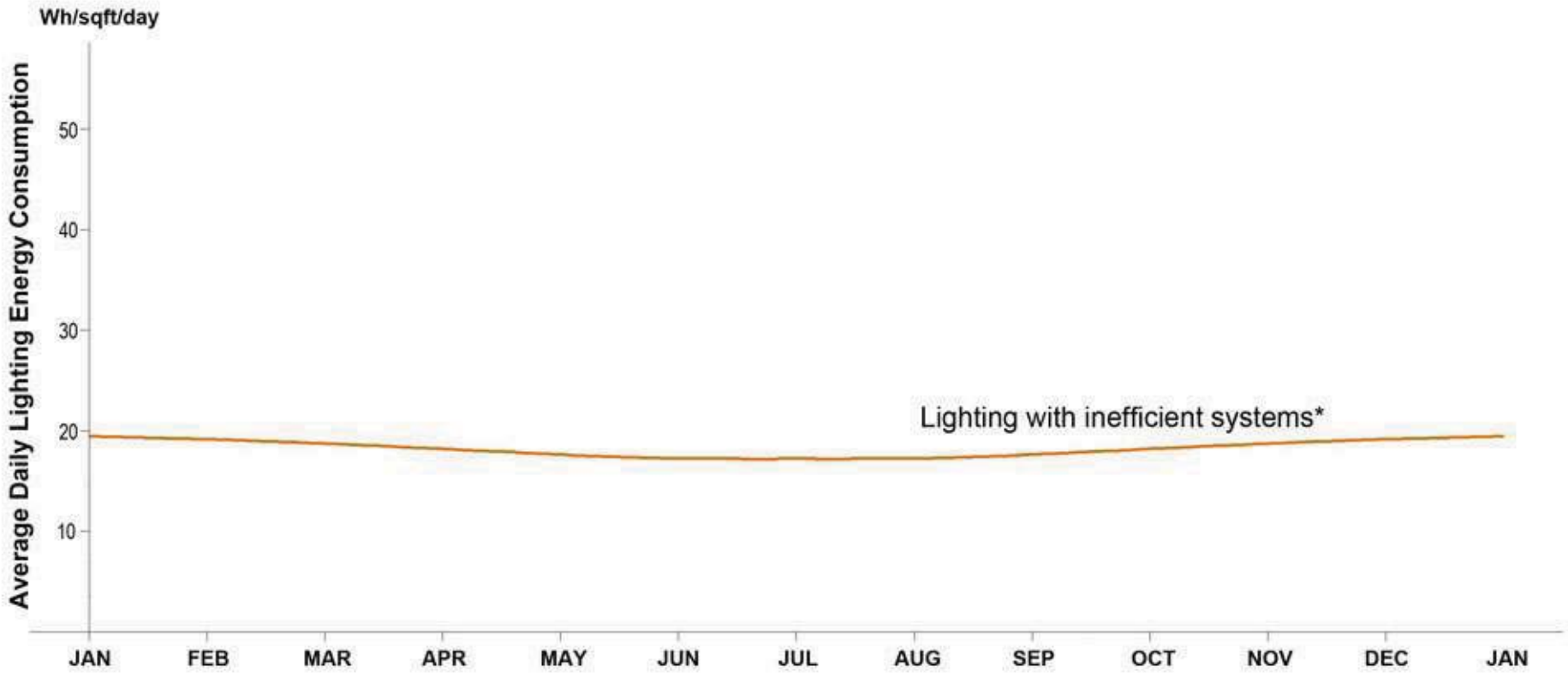
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University




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

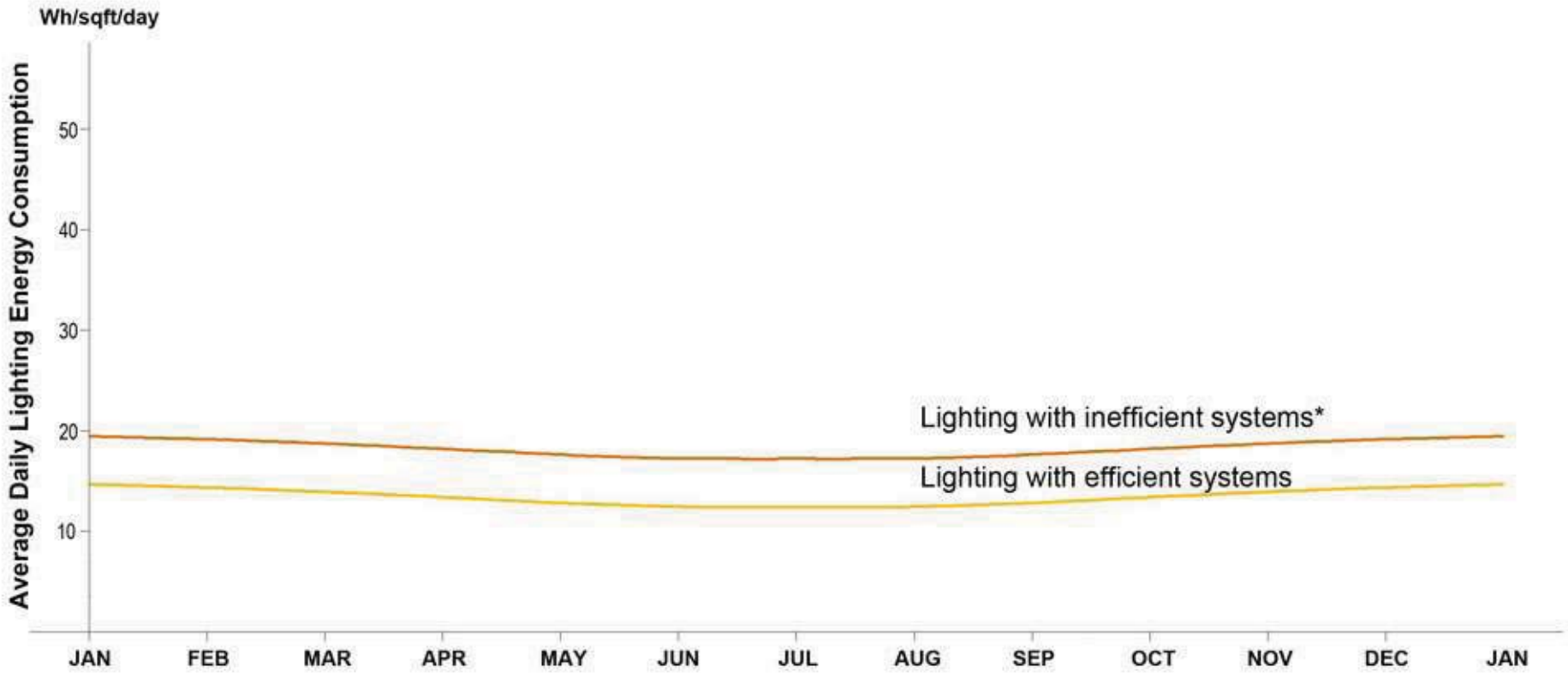
**Natural ventilation can displace 20-40% of today's cooling**

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



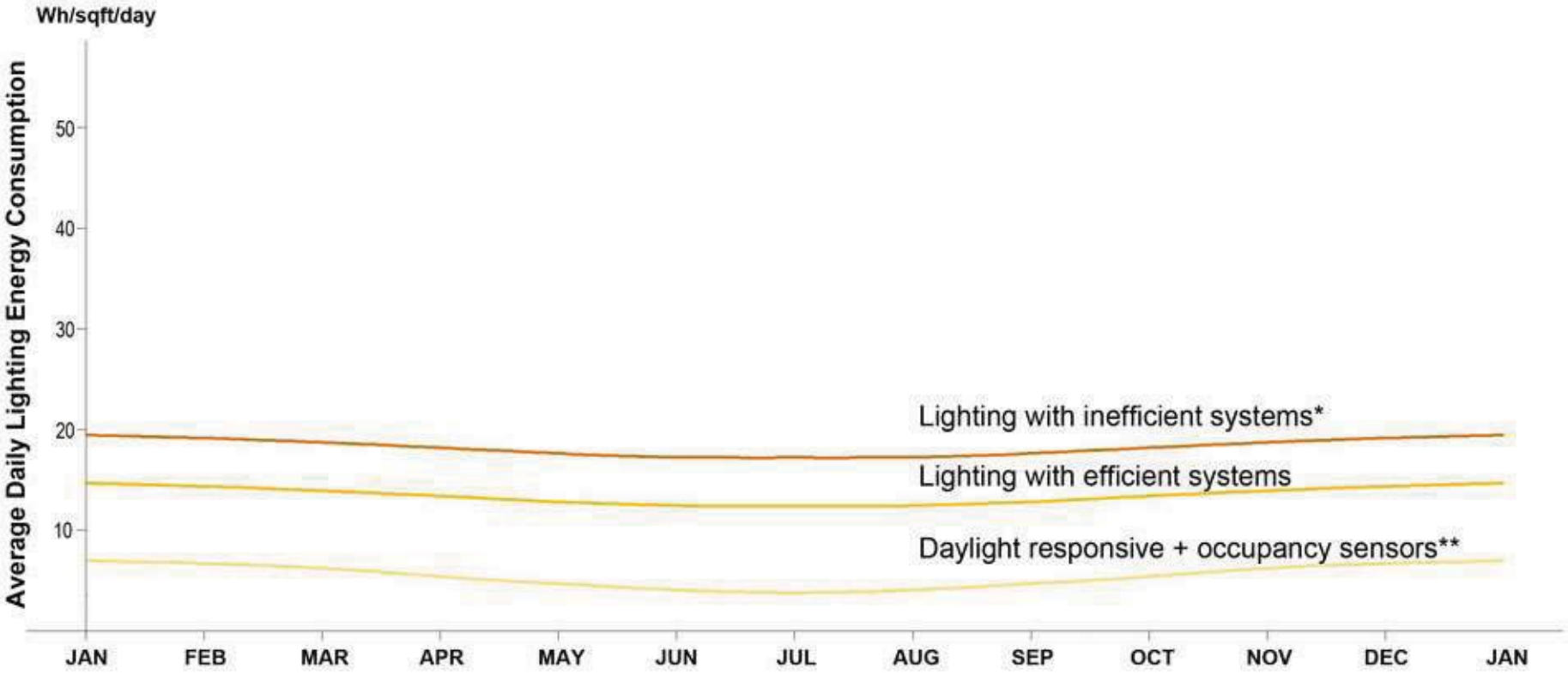

* Total annual lighting energy consumption refers to EIA-CBECS 1995 &1999

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




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

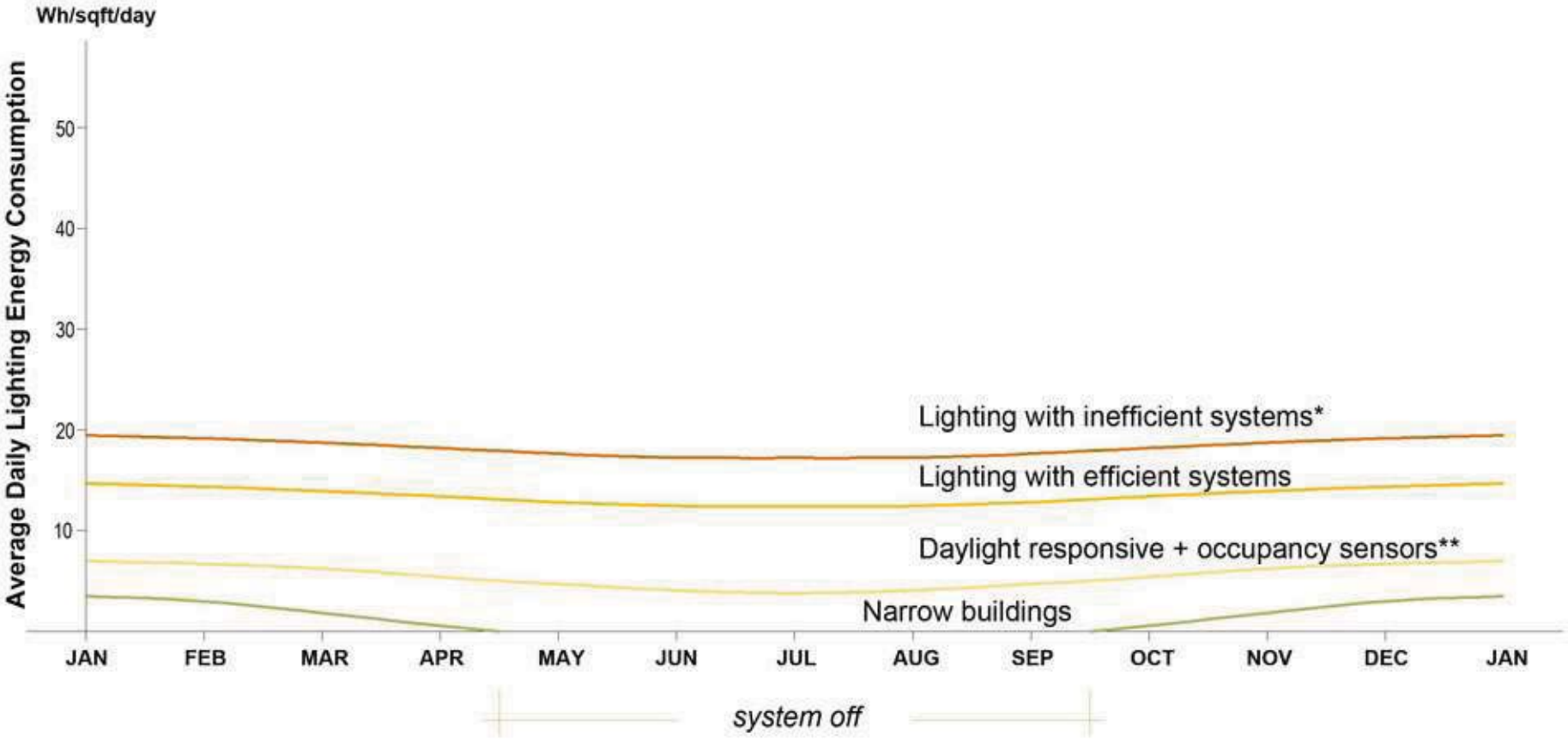
Loftness, V. & Hua, Y., Center for Building Performance & Diagnostics, Carnegie Mellon University




* 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

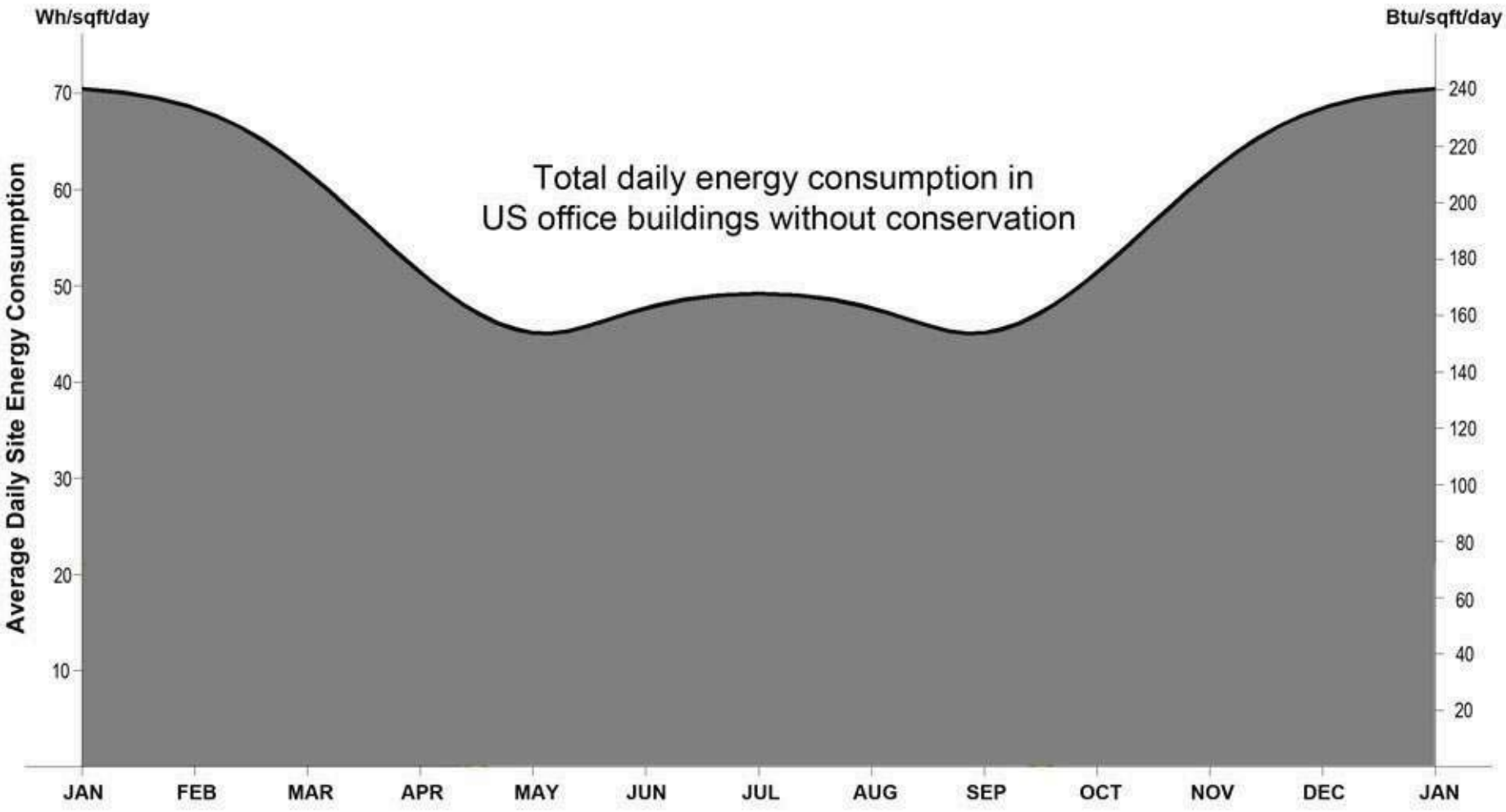



* Total annual lighting energy consumption refers to EIA-CBECS 1995 &1999

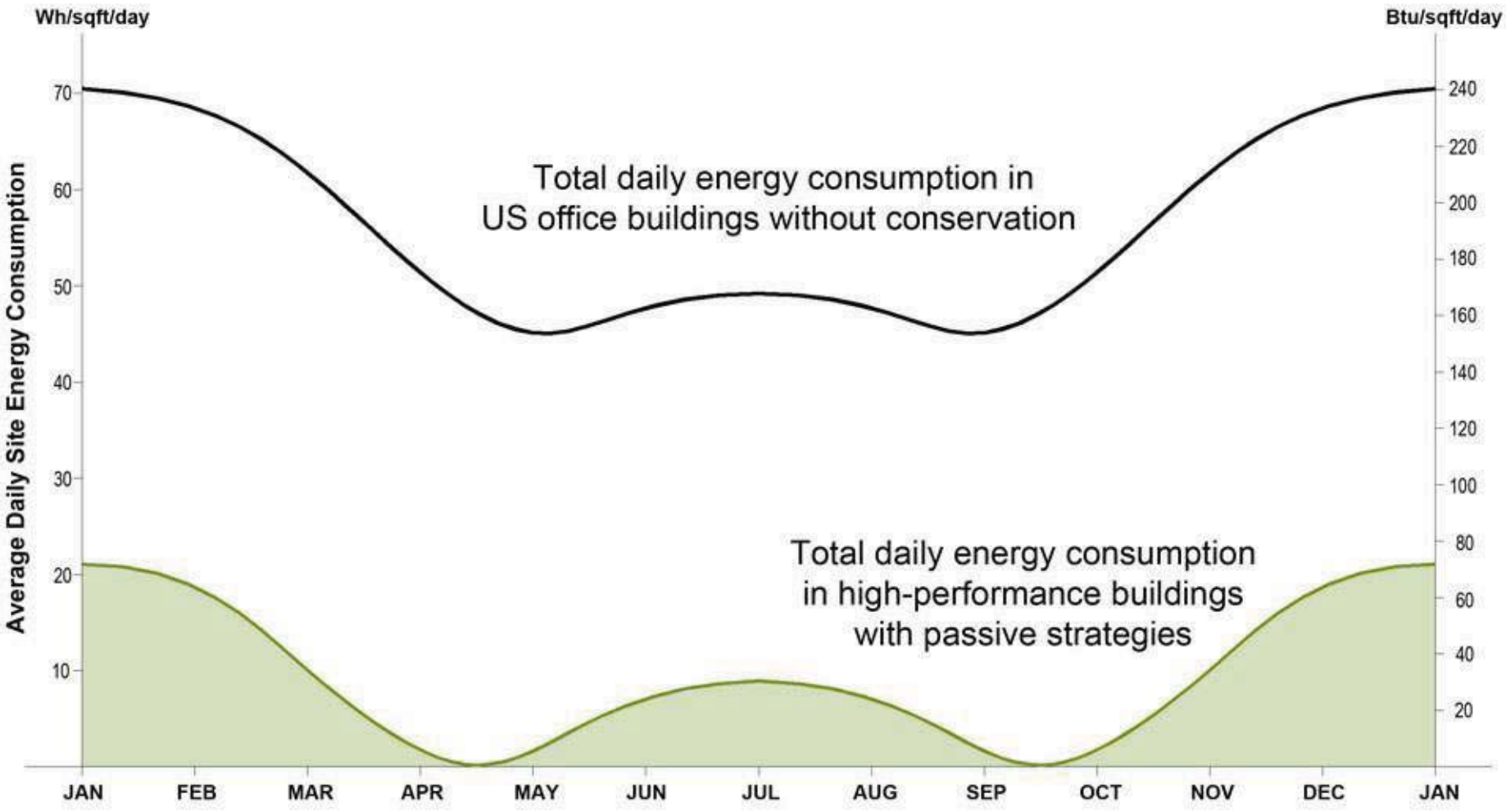
** Monthly lighting energy profile refers to McDougall, T., Nordmeyer, K. & Klaassen, C. J. (2006). Low-Energy building case study: IAMU office and training headquarters. ASHRAE Transactions, Vol.12, pp312-320


Daylight can displace 35-75% of today's lighting

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



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

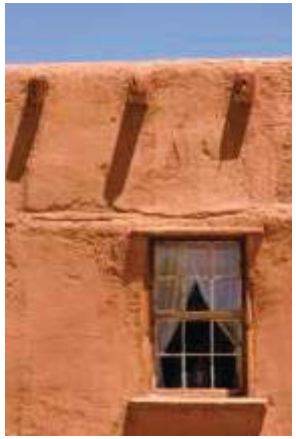


sharing energy = survivability & culture







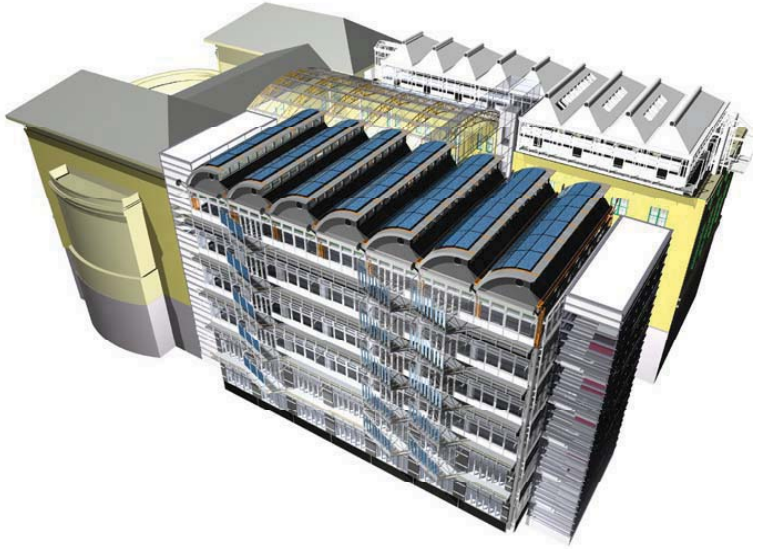
Recognizing the importance of regionalism for zero energy

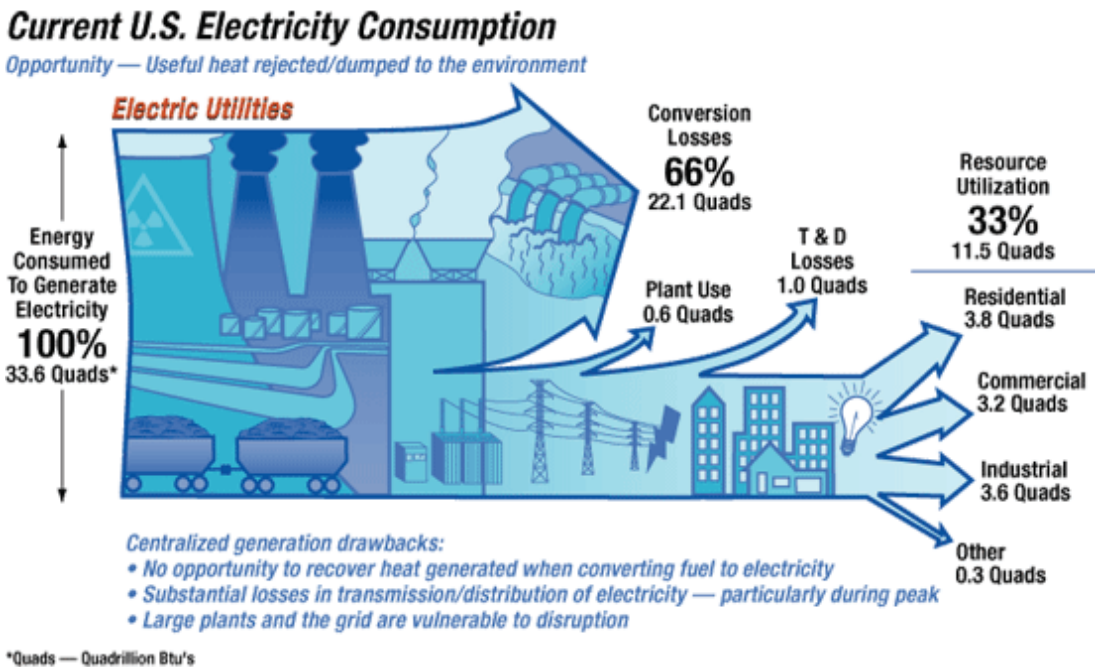

## Shared access to healthy outside, and inside, air

**Power plants create serious air pollution.**
**Power plants are only 30% efficient.**

Distributed energy systems that cascade every drop of energy,
Combined with a portfolio of renewables
will dramatically reduce pollution from power plants.

Stop dumping needed
Heat into the air and water!






Power plants and data centers for district heating ...
and every new building
an energy exporter
(Building as power plant)

## Guidelines for Indoor Air Quality

**evidenced based design**

| | Air Quality |
|---|---|
| Architectural | ● |
| Mechanical | ● |
| Electrical | ● |
| Lighting | |
| Acoustical | |
| Structural | ○ |
| Interior | ● |
| Energy Consultant | ● |

### Separate ventilation and thermal conditioning

2. Increase outside air, including natural ventilation
3. Provide task air and Individual control
4. Control pollutant sources
5. Improve air filtration
6. Control humidity and moisture

## Increased outside air = Health

### Myatt et al 2004 (Office)

In a 2004 multiple building study of three office buildings in Boston, Myatt et al identify a 6.8% reduction in risk of exposure to airborne-transmitted rhinovirus (colds) for workers in offices with indoor CO2 differential (indoor minus outdoor CO2) less than 100 ppm, as compared to those in offices with indoor CO2 differential higher than 100 ppm.

Estimated effect of exhaled breath (aka CO2 ppm) on the frequency of detecting rhinovirus on air filters

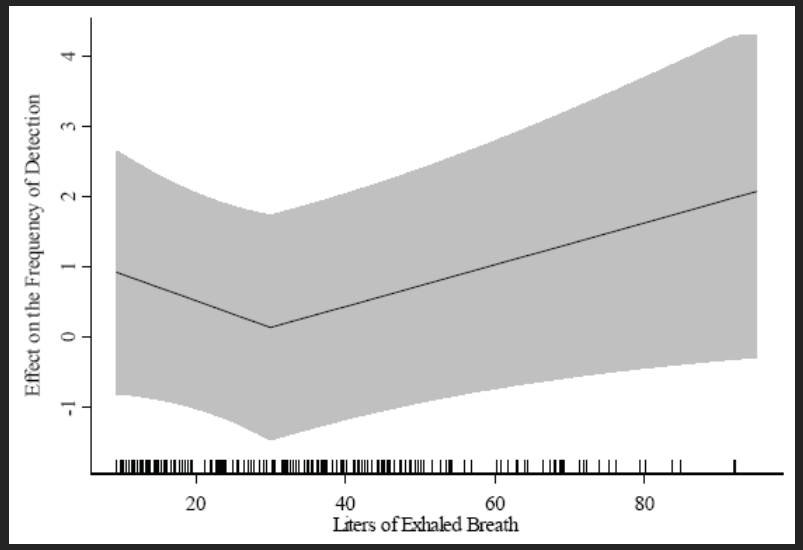



Chart: Myatt et al 2004

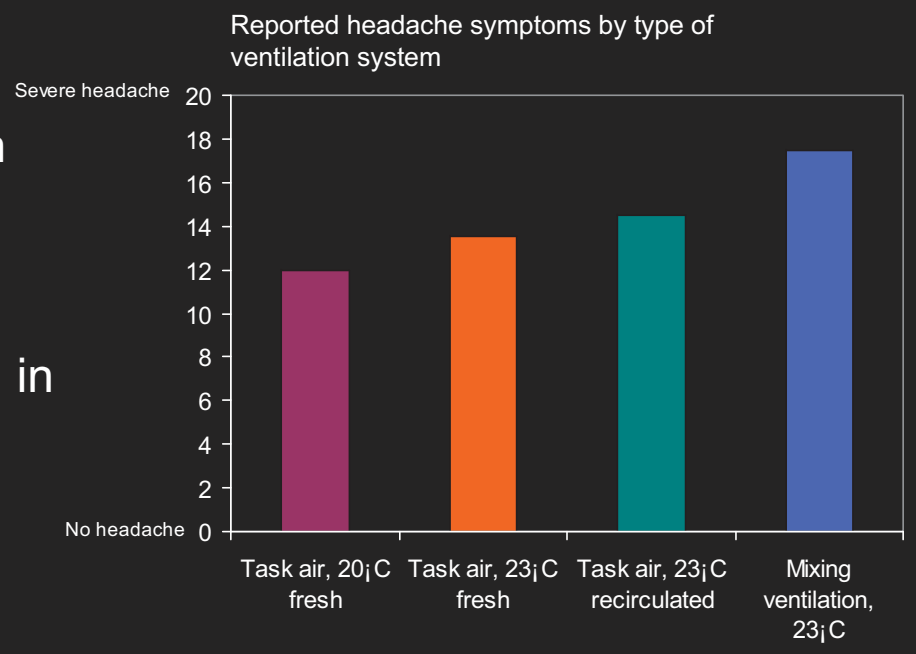
| | |
|---|---|
| First cost increase: | $6 / employee |
| Annual energy cost increase: | $9 / employee |
| Annual health savings: | $3 / employee |
| Annual productivity savings: | $9 / employee |
| **ROI:** | **50%** |

Reference: Myatt, TA, SL Johnston, Z Zuo, M Wand, T Kebadze, S Rudnick and DK Milton (2004) Detection of Airborne Rhinovirus and Its Relation to Outdoor Air Supply in Office Environments. American Journal of Respiratory and Critical Care Medicine, v169, pp. 1187-1190.

## Individual air control + Increased outside air = Health

### Kaczmarczyk et al 2002

In a 2002 controlled experiment, Kaczmarczyk et al identify a 23.5% reduction in headache symptoms when workers are provided with individually-controlled task air systems supplying outdoor air, as compared to a conventional mixing ventilation system, in a room with a typical office pollutant source.



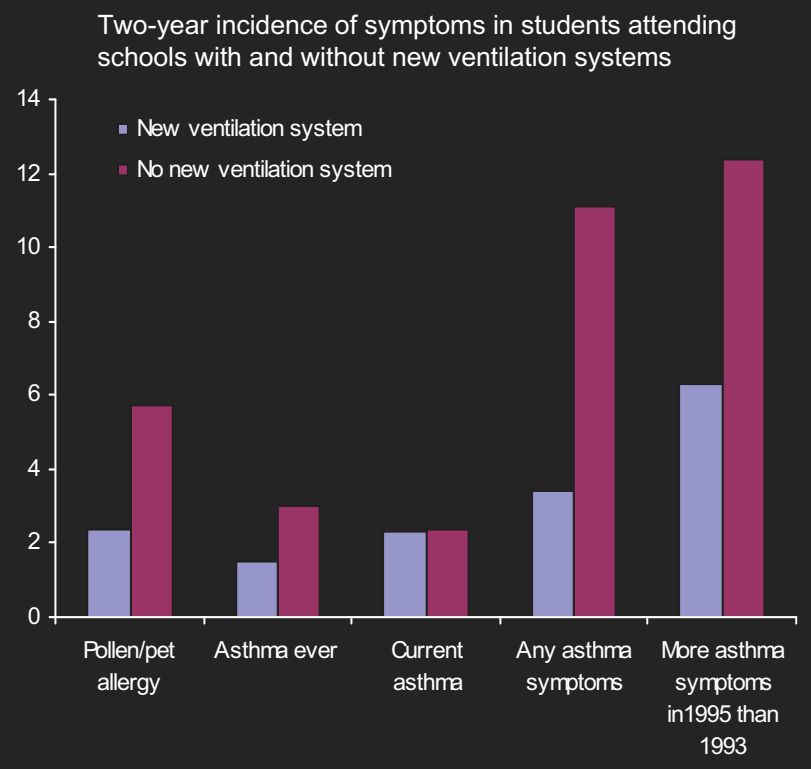

| | |
|---|---|
| First cost increase: | $800 / employee |
| Annual energy cost increase: | $8 / employee |
| Annual health savings: | $17 / employee |
| Annual productivity savings: | $106 / employee |
| **ROI:** | **14%** |

Reference: Kaczmarczyk, J., Zeng, Q., Melikov, A., and Fanger, P.O. (2002) The effect of a personalized ventilation system on perceived air quality and SBS symptoms. In Proceedings of Indoor Air 2002, Monterey, CA, June 30-July 5, 2002; Office of Pollution Prevention and Toxics, U.S. Environmental Protection Agency. Cost of Illness Handbook. http://www.epa.gov/oppt/coi; Schwartz et al (1997) Lost Workdays and Reduced Work Effectiveness Associated with Headache in the Workplace. Journal of Occupational and Environmental Medicine. 39(4), pp. 320-327.

## 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.

Sustainable Material Selection for Health

Specify materials that:

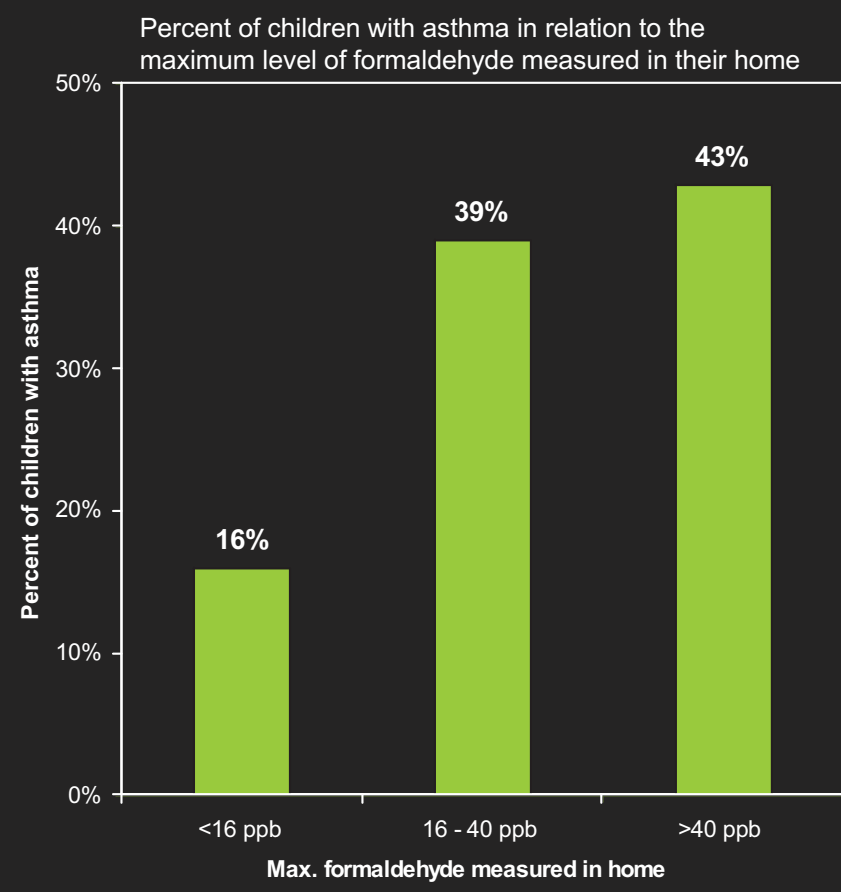
- do not irritate the skin with contact to avoid dermatological conditions
- do not outgas toxins to avoid respiratory/allergy and asthma
- do not degenerate into respirable fibers or emit radon to avoid cancers
- are not fire hazards causing respiratory illness or death
- do not foster mold or mildew leading to respiratory symptoms
- with low embodied energy and low transportation costs to reduce outdoor air pollution/GW ( LCA)

## Pollutant source control = Health

Garrett et al 1996 (home)

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.

## Shared access to material resources

**Building materials are often rare or toxic.
Buildings consume over 40% of all raw materials,
increasing with the architecture of excess
and design for obsolescence.**

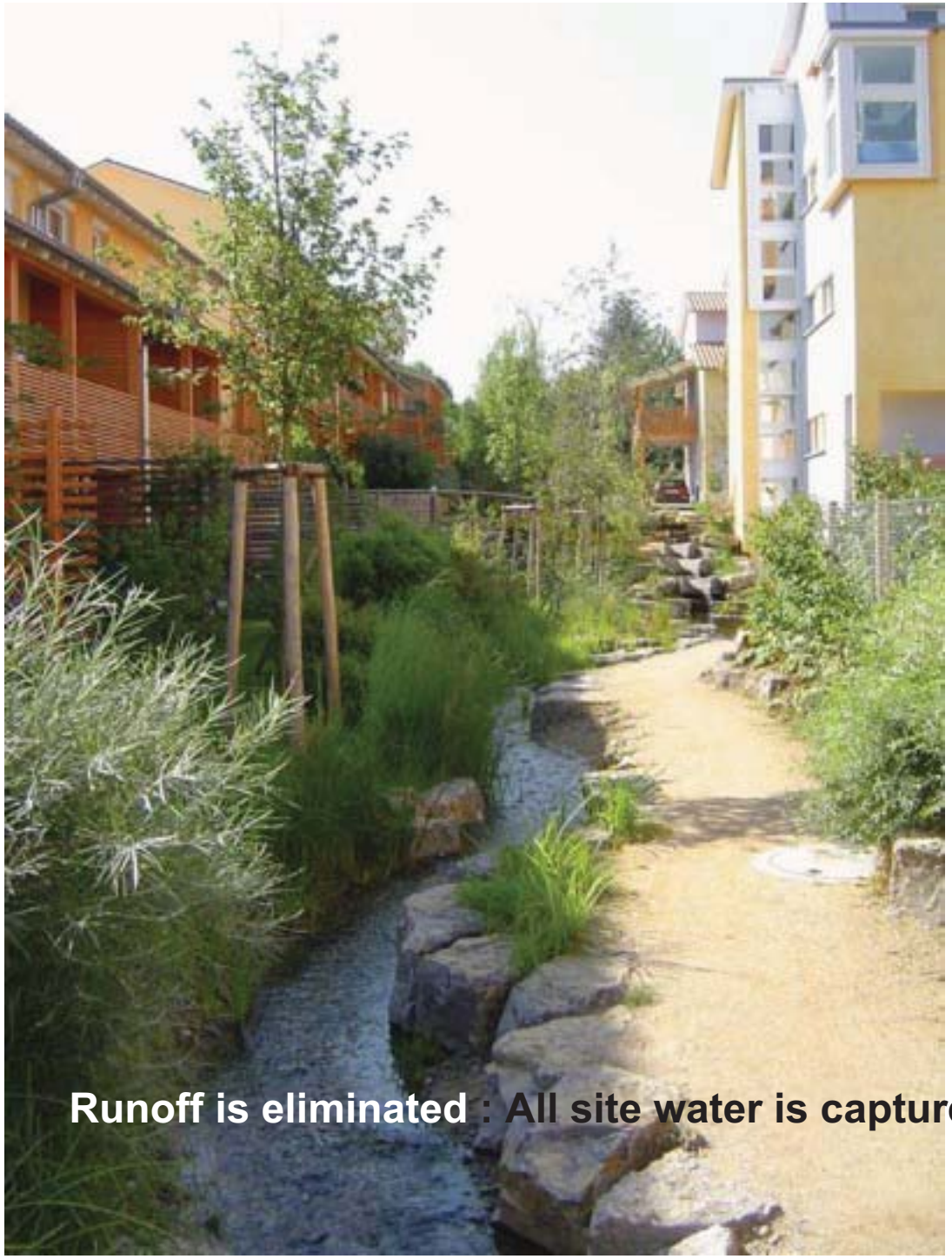
Adaptive reuse, design with less, design with sustainable materials,
design for change, and design for disassembly define creativity.

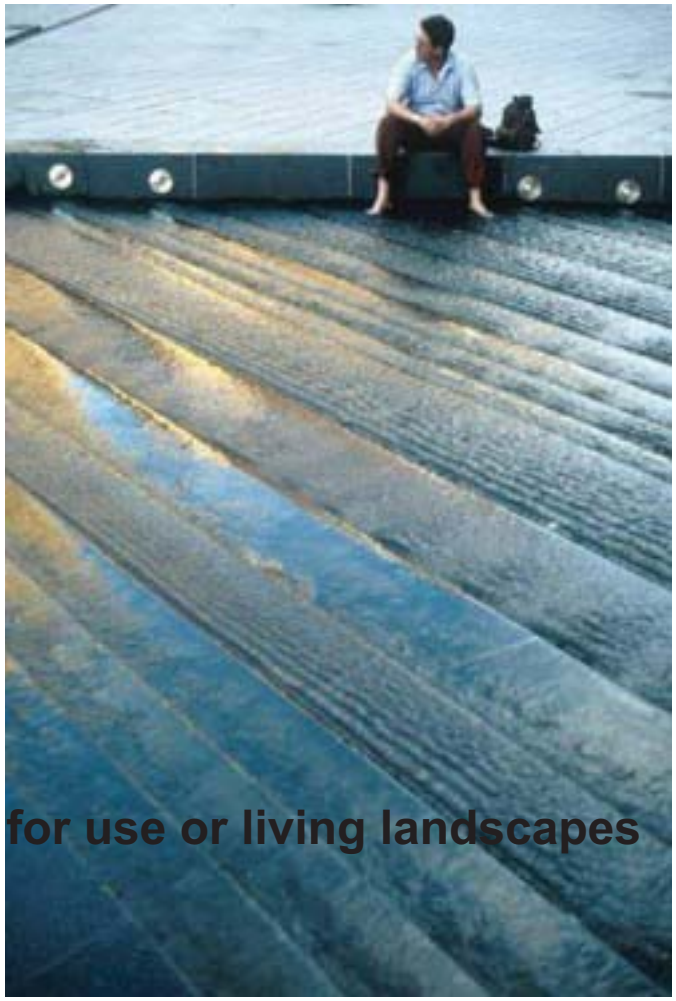
## Shared access to fresh water

**We consume the most water per capita, without QOL gain.**
**We use potable water for everything, once.**
**We flood our cities and contaminate our rivers.**

**sharing water = beauty & recreation**


**all water infrastructures become visual & recreational amenities**

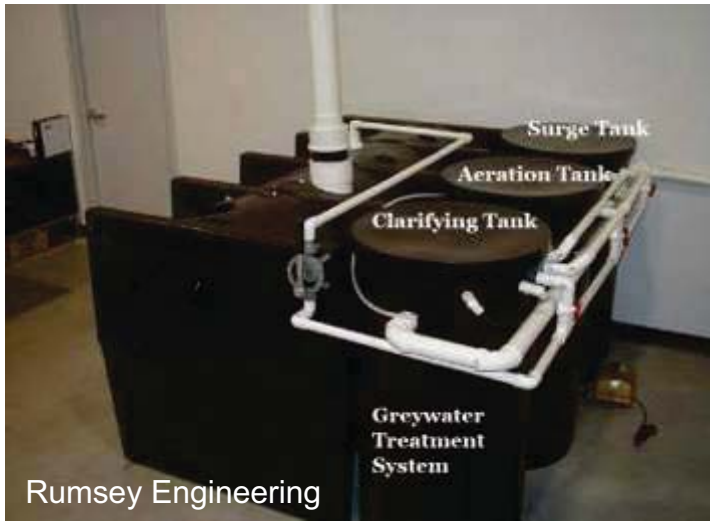


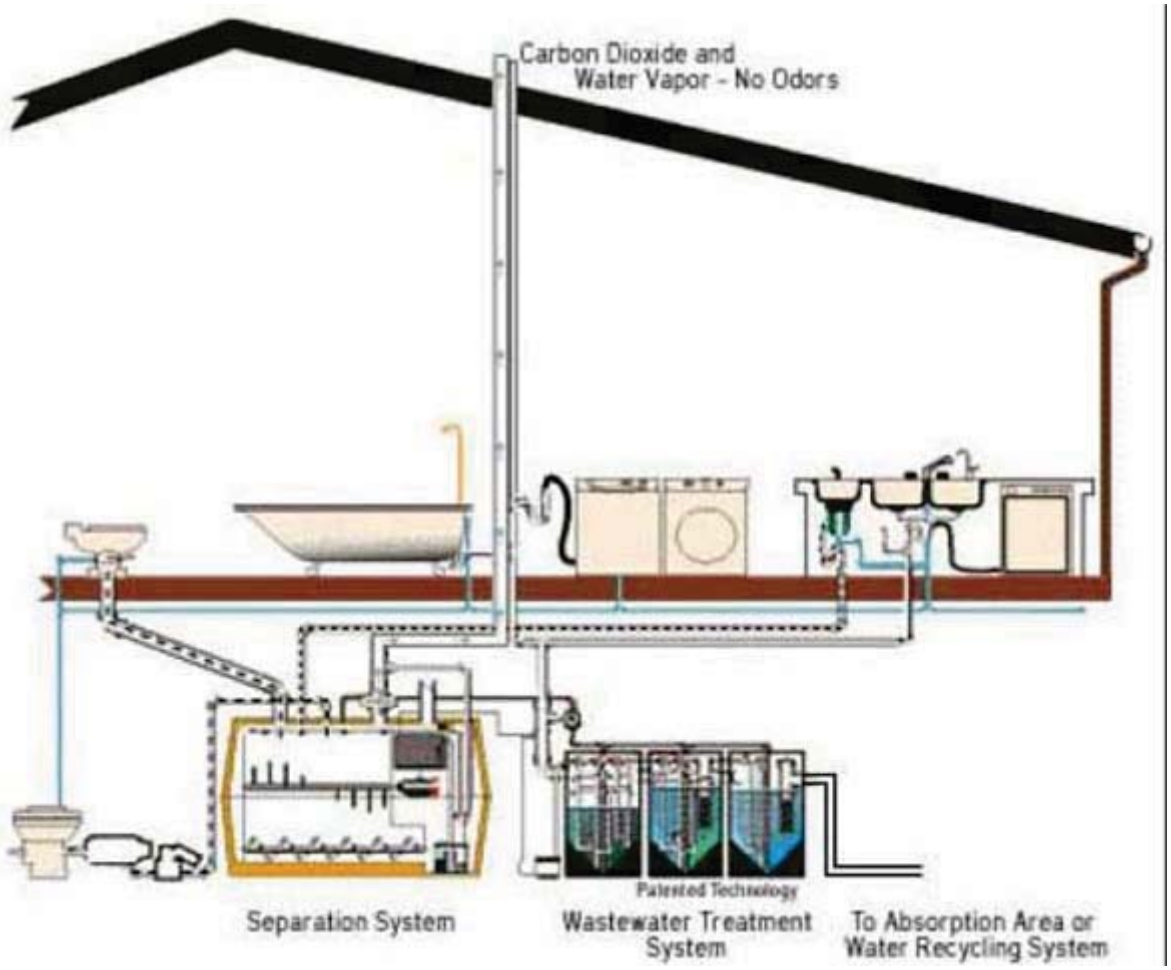


**Runoff is eliminated : All site water is captured for use or living landscapes**

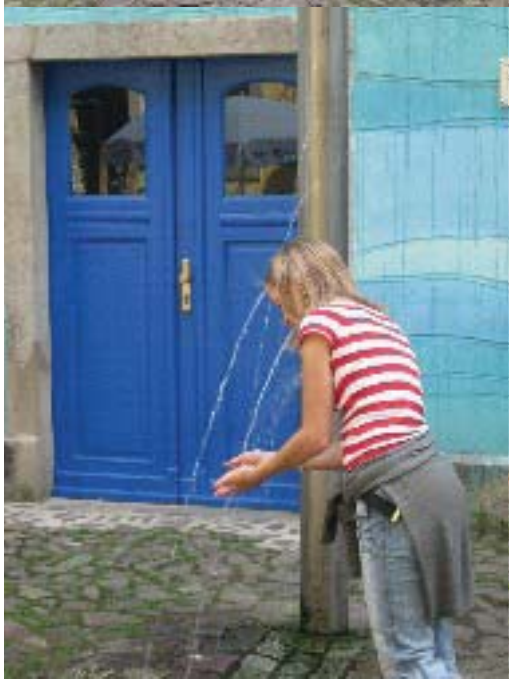
**a concrete budget is issued: non-porous surfaces are severely taxed**

## all water is used three times: potable, grey and black



Dresden Kunsthofpassage



**all rain and storm water becomes a recreational amenity**


**all roofs become visual amenities - the fifth façade - and produce water or habitat**

# Green Roof Benefits

and the importance of triple bottom line accounting

## 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

# Dirksen Senate Office Building
# Green Roof Triple Bottom Line


**Entech Engineering, Inc.**

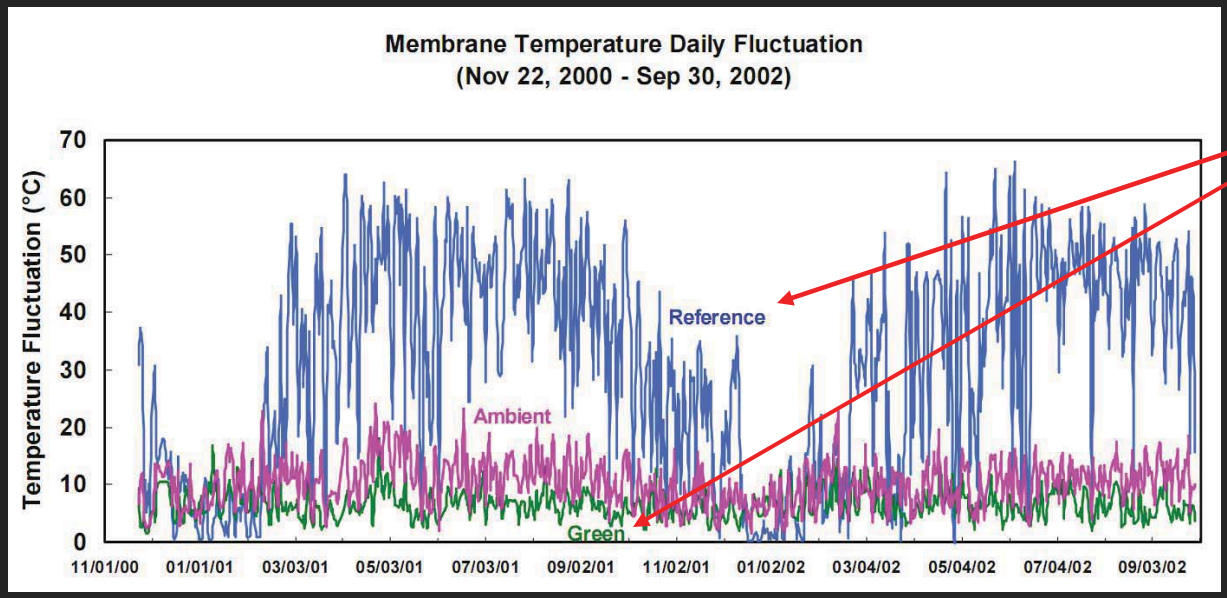
**Carnegie Mellon University**
**Sustainable Design Consultants**

**Derck & Edson Associates, LLP**
**Landscape Architectural Consultants**

**WDP Associates, Inc.**
**Structural Consultants**

# Profit: Roof longevity

Green roof shades membrane from UV and thermal stress



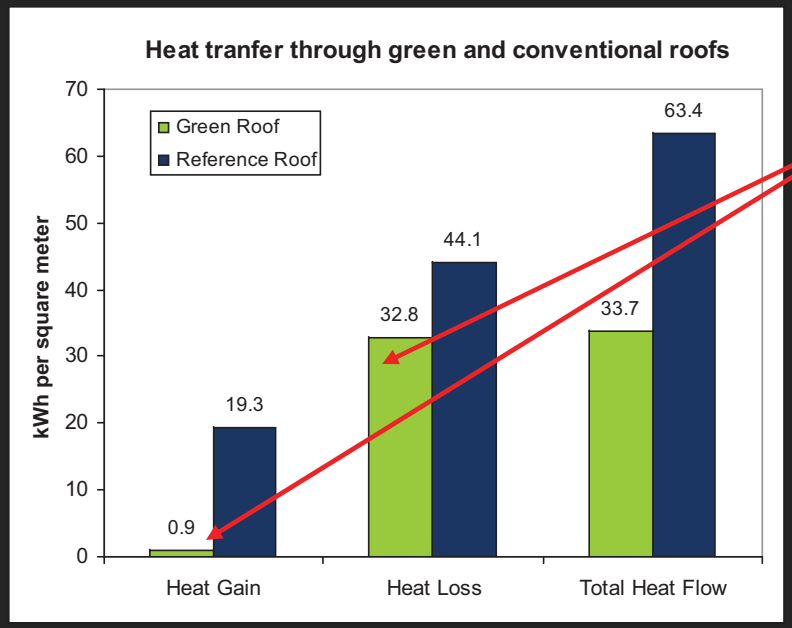

Median daily temperature swing of conventional dark-colored roof = 45ºC, compared to 6ºC for green roof[1]

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

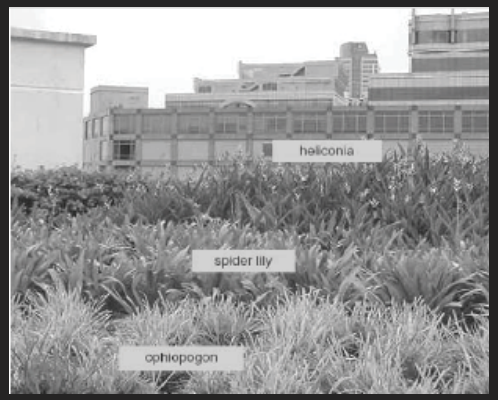



Green roof reduced summer heat gain through the roof by 95%, and reduced winter heat loss through the roof by approximately 26%[3]

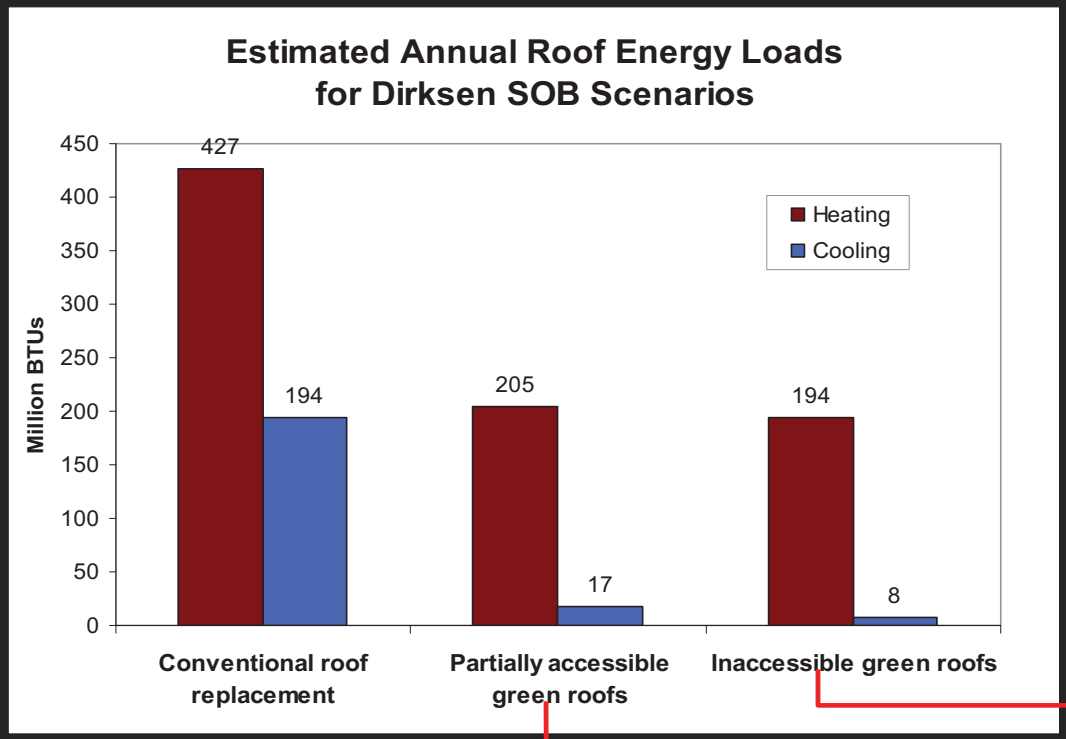
3) Liu and Baskaran 2003

Wong et al 2002

Rooftop Garden = Energy savings




In a 2002 controlled experiment of rooftop gardens, Wong et al identified that roofs composed of shrubs outperform those with both turfing and trees. Shrubs provide the optimum insulation and can result in 15% savings in total annual energy consumption, including a 79% reduction in cooling load, and a 79% reduction in peak load over conventional built up roofing.




25-year life cycle savings:

$149,900

(400 million BTU)

25-year life cycle savings:

$142,900

# Profit: Real Estate Value

- Extensive green roof = visual amenity
- Intensive green roof = visual amenity + square footage

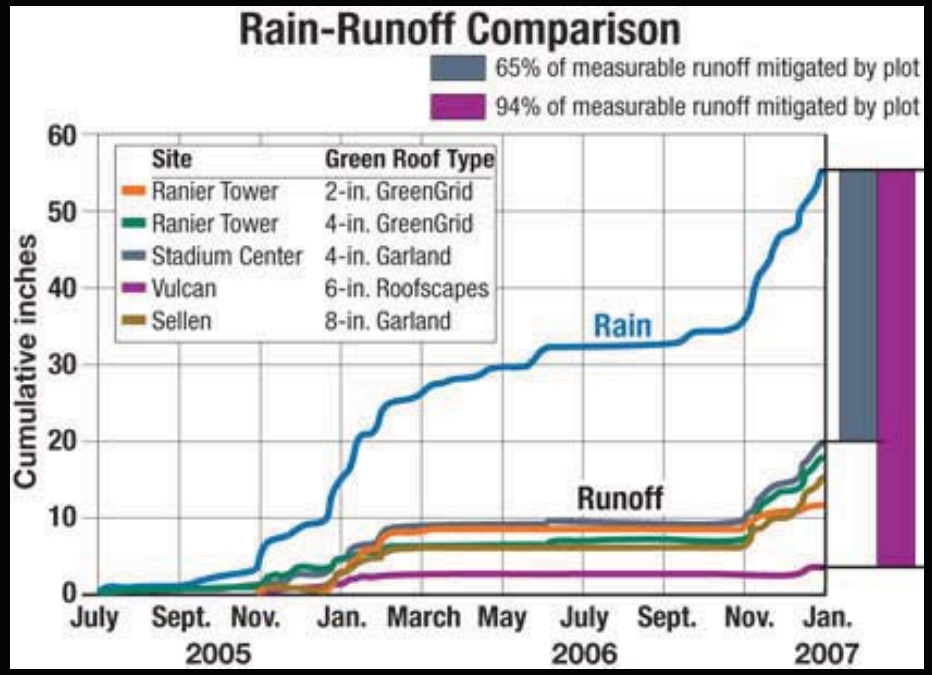
Four Seasons Hotel, Boston
Hotel room value rises 20%

Extensive news coverage, marketing

# Profit or Planet? Stormwater Runoff & Erosion

Excessive runoff during rainstorms results in:

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

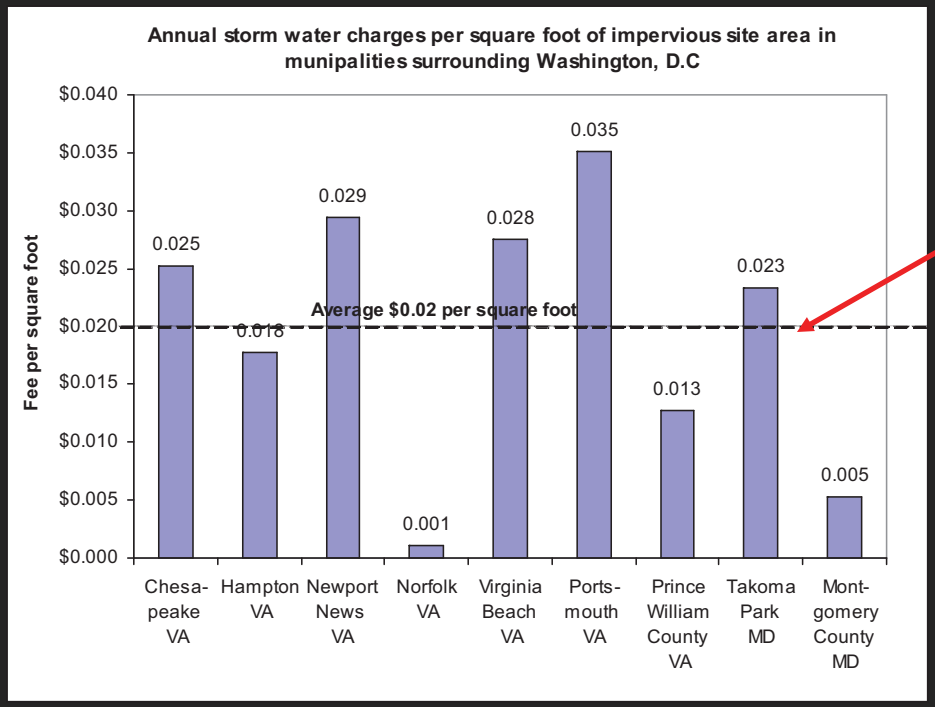



Green roofs retain more than 50% of the rainwater that falls on them.

Magnusson Klemencic 2007

# Stormwater Fees & Savings

- Stormwater fee: individual building owners pay for all 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



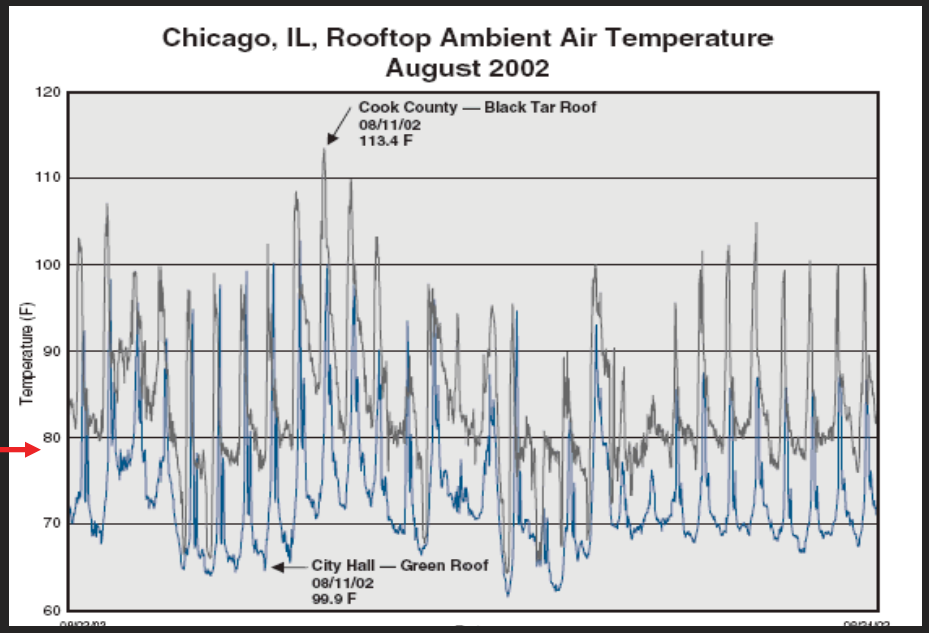

Given the average storm-water rate of surrounding municipalities, the Dirksen green roof would avoid $11,900 in storm-water fees over 25 yr life cycle.

# Planet: Urban Heat Island Mitigation

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

- Increases the use of air conditioning equipment
- Increases building cooling load
- w/ 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 Capacity Cost Savings

- 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 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]

Key attributes:

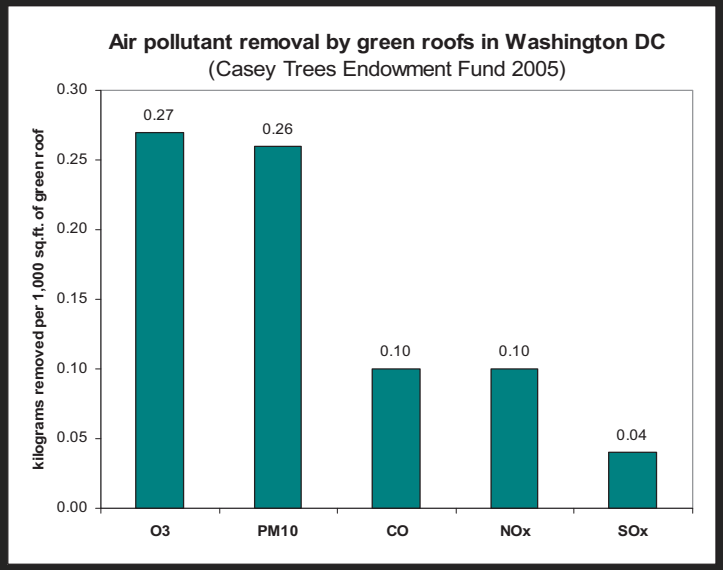
Variety in height and slope of soil
Sparsely and densely planted areas
Freely and poorly draining areas
Diverse plant population

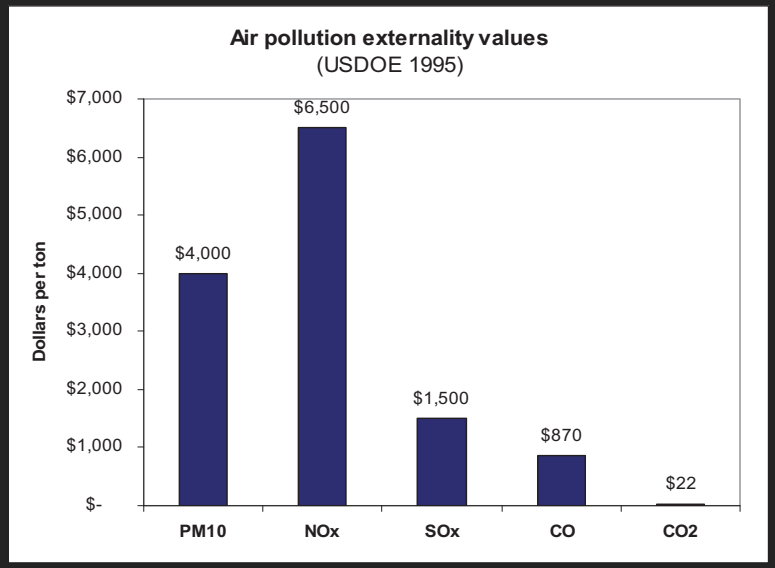
Northern lapwing on a Swiss green roof

6) Brenneisen 2003

# Planet: Outdoor Air Quality

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




25-year life cycle emissions savings for Dirksen 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]
- The GAP 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.

The range of improvement was from 0.5 percent to 1.4 percent per one point increase in view rating

## Seated Views = Individual productivity

SMUD Call Center /Heschong Mahone 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 per employee: $1,000
Annual productivity per employee: $2,990

ROI: 299%

In the Dirksen Senate Office Building, 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 grows 15-20% a year
*10% of all flat roofed buildings in Germany are now green*
*over 500 million square feet of roof spurred by :*

- fees for storm water management
- subsidies to avoid infrastructure replacement
- indirect subsidies to substitute green roofs as open space

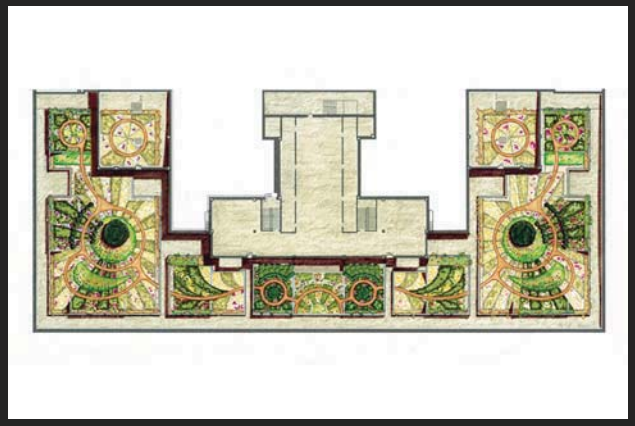
## Local job development?

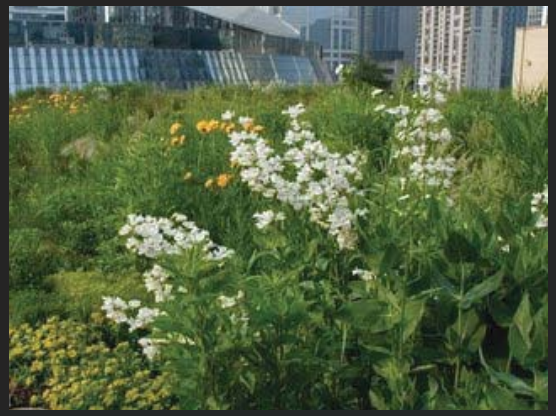
design/engineering
manufacturing
installation

# LCA = Full Triple Bottom Line for Civic Buildings

| | | Green Roof Option 1 (Accessible Tennis Court) | Green Roof Option 2 (Inaccessible) |
|---|---|---|---|
| | **First cost increase total** | **$2,259,787** | **$1,419,831** |
| | First cost increase per sq ft | $66 | $42 |
| Cost/protit | 15-year savings | $735,029 | $765,915 |
| | Annual savings | $49,002 | $51,061 |
| | **ROI:** | **2.2%** | **3.6%** |
| Planet | 15-year savings | $787,759 | $821,719 |
| | Annual savings | $52,517 | $54,781 |
| | **ROI:** | **2.3%** | **3.9%** |
| People | 15-year savings | $1,597,895 | $1,631,855 |
| | Annual cost (amortized) | $106,526 | $108,790 |
| | **ROI:** | **4.7%** | **7.7%** |

(Relative to copper roof replacement and tennis court renewal)





For Profit, Cool Roofs and “Cool Community” developments reduce annual cooling loads by 10% and peak cooling by 5%.

For the Planet, they provide carbon sequestration, storm runoff management, and a 6-8% reduction in smog.

For People, cool roofs and cool communities create jobs and improve health and productivity.

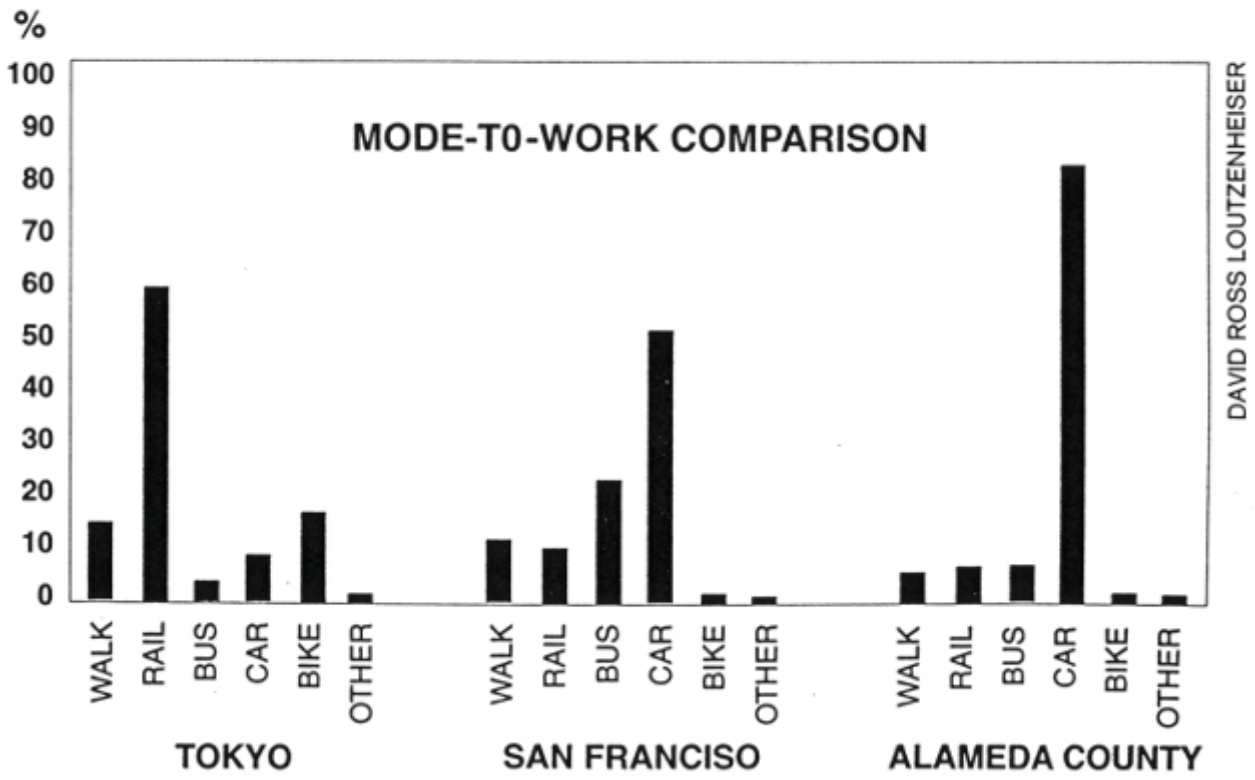

## Shared access to transportation and mobility

**Single use zoning and car-only access eliminates opportunity for young, old, and poor.**

**20% of poor families + Americans over 80 or under 16 means 33% of all Americans are ‘disabled’ in car-only development.**

**sharing transport = mobility & health**

*from the University of California at Berkeley and in urban planning from the University of Washington.*



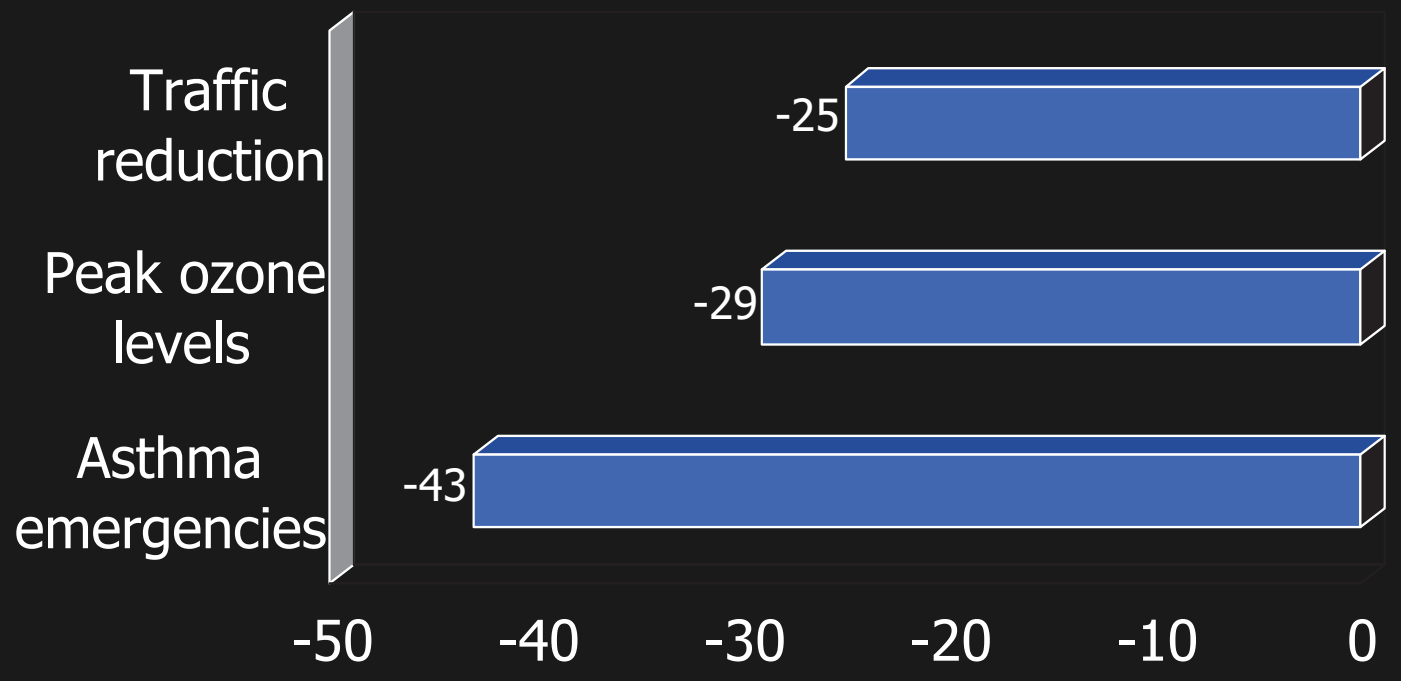

Automobile-only development is transportation poverty

## *Which future?*

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


Walkable, whole life neighborhoods and diverse transportation choices will enhance health and QOL.

*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)

## **COSTS OF SPRAWL** (Urban Ecology 1995)

| | **Suburbs** | **Infill** |
|---|---|---|
| Streets/roads | $3,000 | $800 |
| Utility extensions | $5,000 | $950 |
| Gallons $H_2O$/day | 400 | 200 |
| Therms natural gas | 150 | 60 |
| Kilowatt hrs./year | 10,000 | 6,000 |
| Postal delivery | (300 times the cost) | |

Energy, waste, pollution, accidents, even storm-sewer overloads are results of sprawl.

## Shared access to whole-life communities

**Isolating children, teens, and seniors leads to depression and inactivity.**

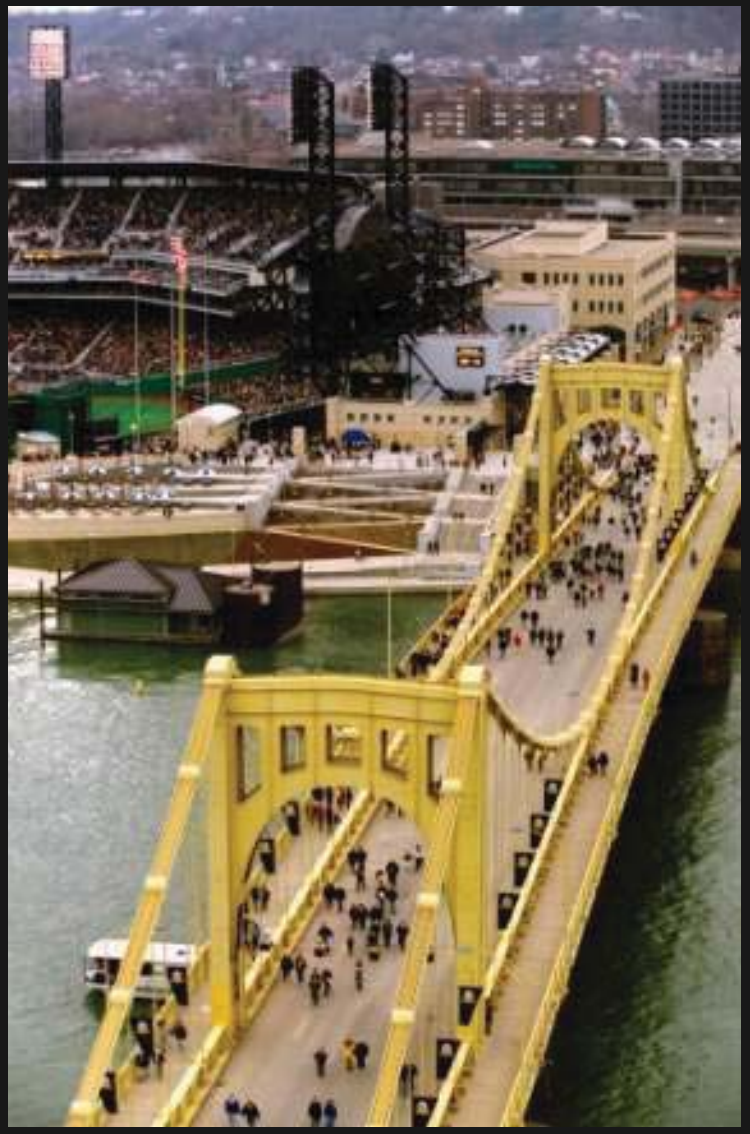
**Separated socio-cultural, economic, and age communities reduces QOL.**

**Shift subsidies to infill over sprawl,**
**to mixed-use, mixed-income communities that celebrate diversity**
**and regional uniqueness, including local food, local jobs, local craft.**

## Obesity is the fastest growing health threat for children

***A San Diego study identified 60% obesity rates in low-density, non-walkable neighborhoods as compared to 35% in mixed-use walkable neighborhoods.***

*(American Journal of Public Health Sept. 2003)*



**Designed for Walking**

Typical Strip Commercial Development - Pearl City, Hawaii


Courtesy Benjamin Lee, FAIA

AIA


Courtesy Benjamin Lee, FAIA

AIA


Courtesy Benjamin Lee, FAIA

AIA


Courtesy Benjamin Lee, FAIA

AIA


Courtesy Benjamin Lee, FAIA

AIA


Courtesy Benjamin Lee, FAIA

AIA


AIA


Courtesy Benjamin Lee, FAIA

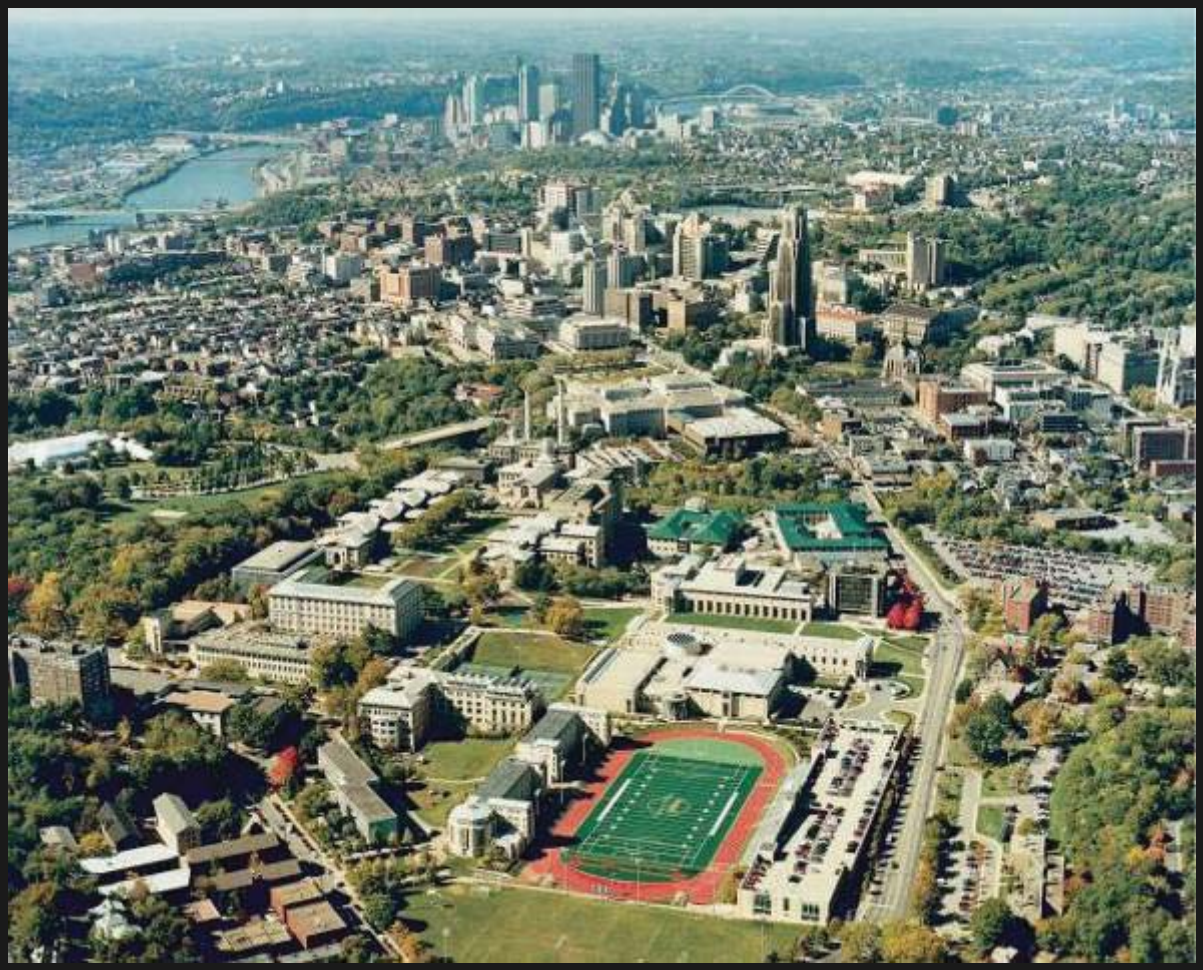
AIA


Courtesy Benjamin Lee, FAIA

AIA


AIA

## Ecological footprints?



design water sheds, energy sheds, air sheds, material sheds, waste sheds, transportation sheds, food sheds = sustainable, humane, delightful


# The Intelligent Workplace

**Carnegie Mellon University**
**A Living Laboratory for Building Environmental Research**