Systems Integration for High Performance Buildings Communities, Urbanities, Regions

Volker Hartkopf, PhD, Dr.h.c.

Director, Center for Building Performance and Diagnostics

Professor, School of Architecture Carnegie Mellon University

hartkopf@cmu.edu

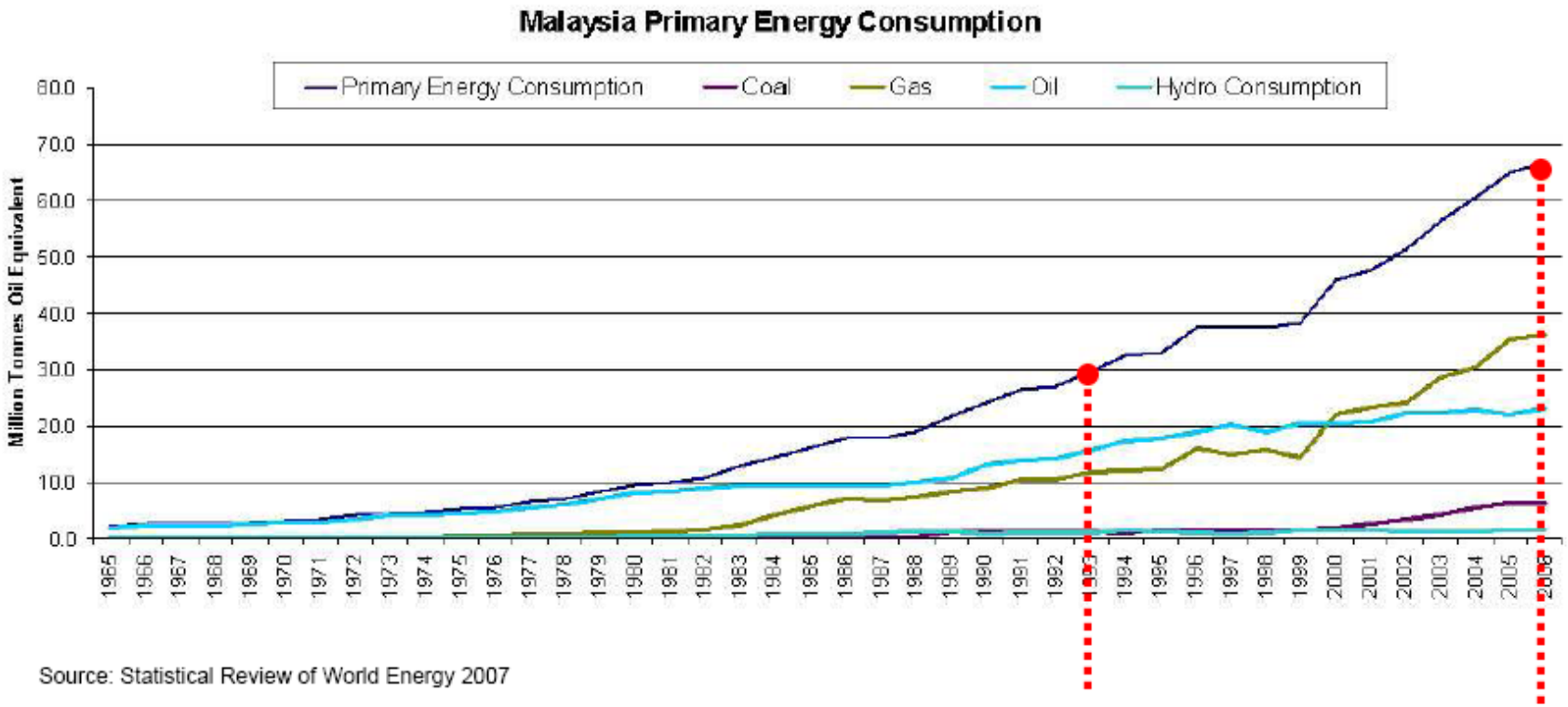
Chair, United Nations Environmental Programme Sustainable Building and Climate Initiative (UNEP/SBCI) Think Tank Benchmarking of Best Practices

Academic Advisor, Bayer EcoCommercial Building Program

ICEBO Keynote New York City 21 Oct 2011

One Strategy…

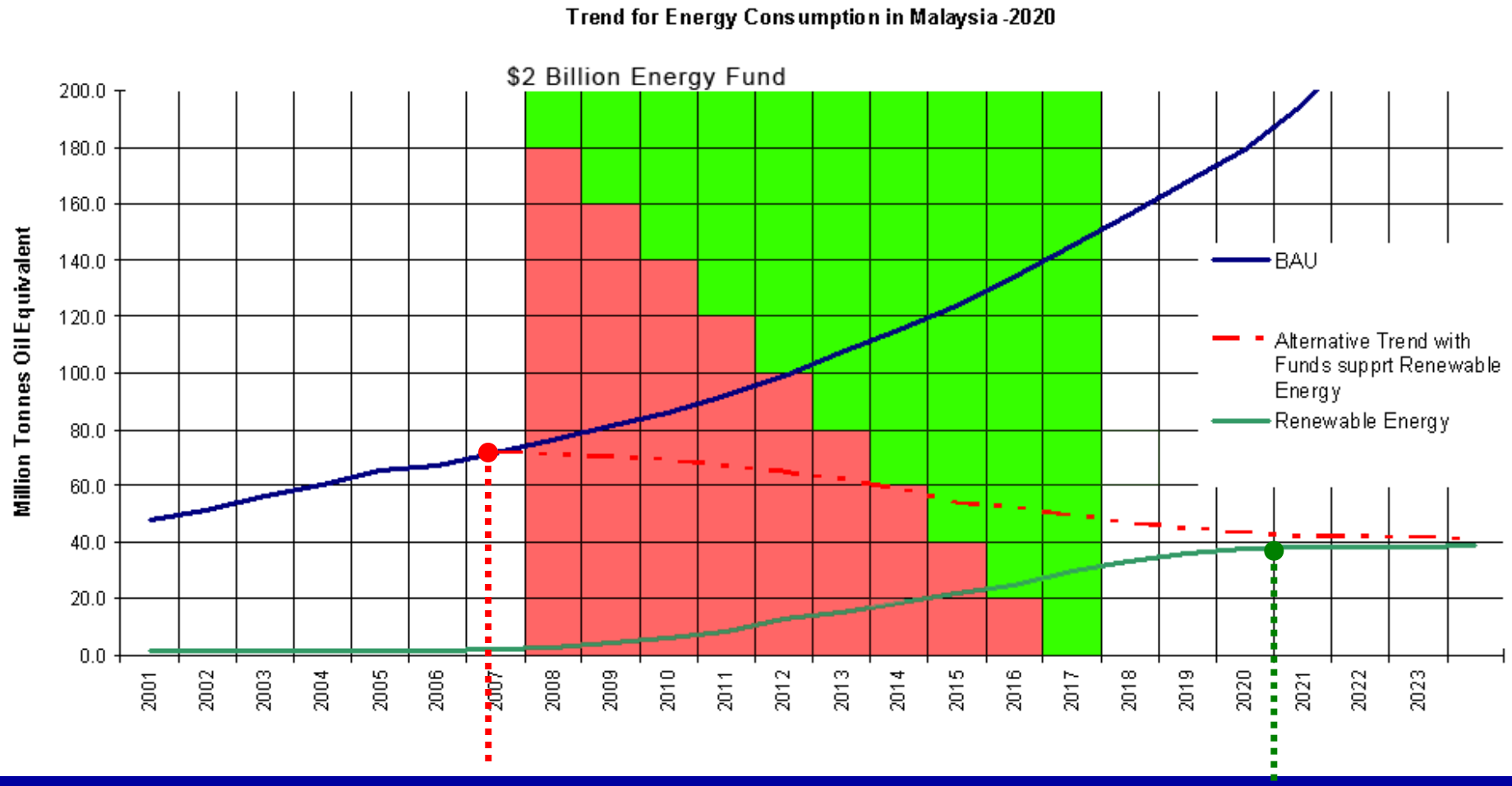
Yuan Yuan Gardens Tea House, Shanghai, China



Source: Statistical Review of World Energy 2007

2000 Watts Society with 19 million people consume 29.6 Mto in the year of 1993

3650 Watts Society with 24 million people consume 67 Mto in the year of 2006



3650 Watts Society with 24 million people consume 67 Million tons Oil Equivalent in the year of 2006

2000 Watts Society with 30 million people consume 46 Mto in the year of 2020

"…hand over to the next generation a country where all the environmental problems have been solved."

Swedish Parliament, 1999

Lessons from Sweden:
How Community Infrastructure Can Reduce Carbon Footprints

Peter Busby, C.M., AIA, FRAIC, MAIBC, MAAA, MOAA, LEED® A.P., DSc (Hon.)
Managing Director

Blair McCarry, P.Eng. PE ASHRAE Fellow, LEED ® A.P.

Ideas + buildings that honor the broader goals of society

BUSBY
PERKINS
+WILL

Hammarby Sjostad, Stockholm

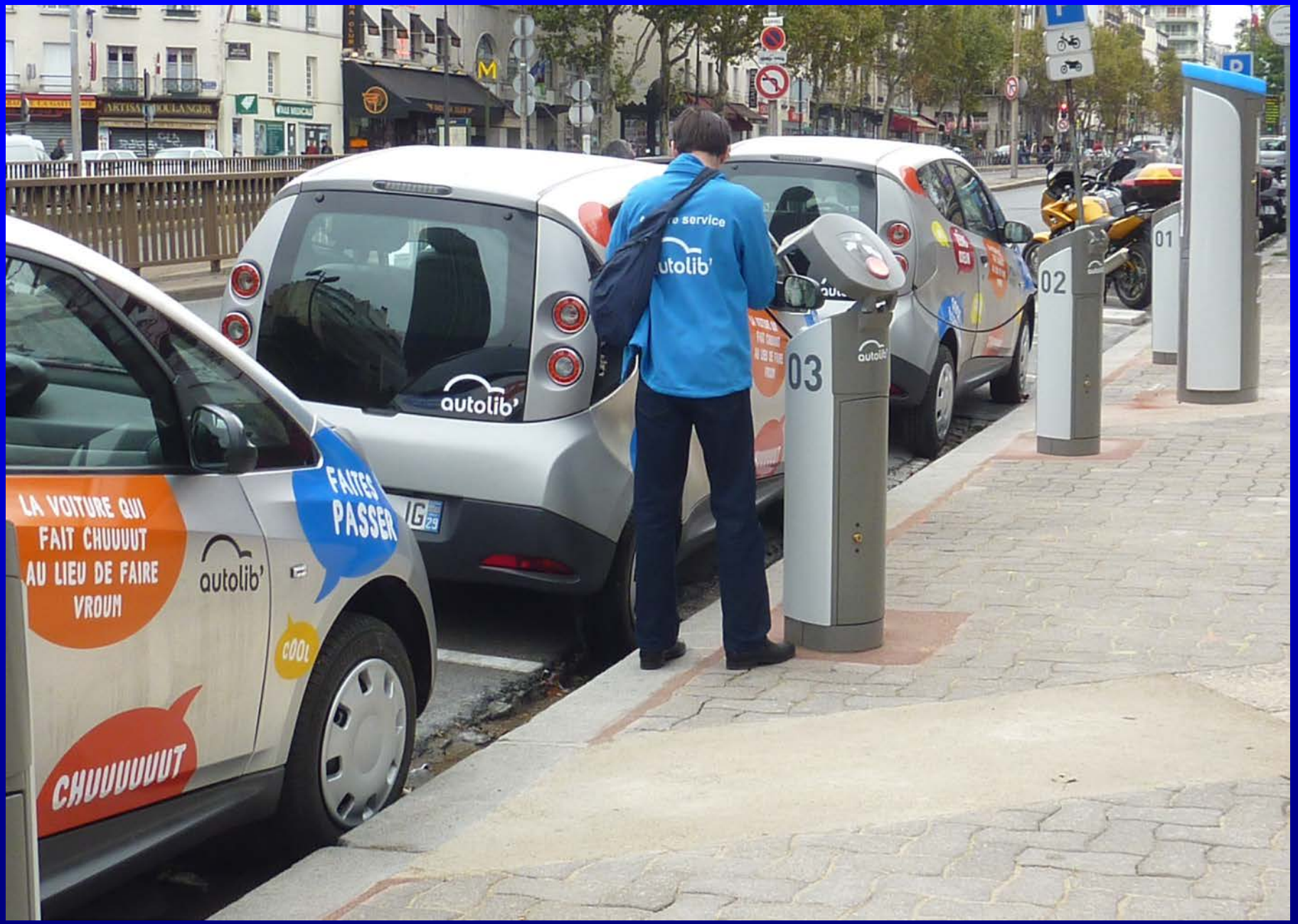
A New Urban Waste Strategy

Resulting in More Available Space

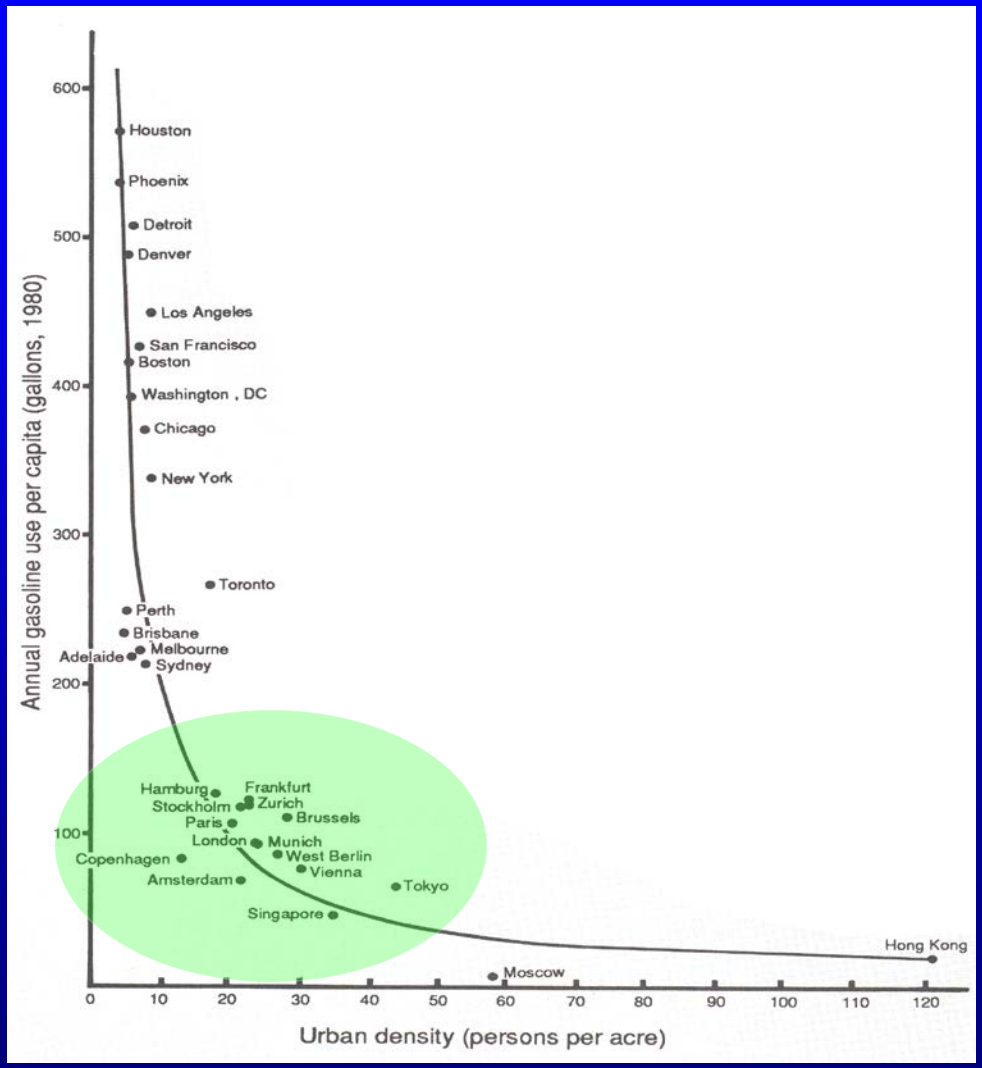
The biogas system


Biogas - Ren
Drivkraft


Ej i trafik
CUX 867
3500

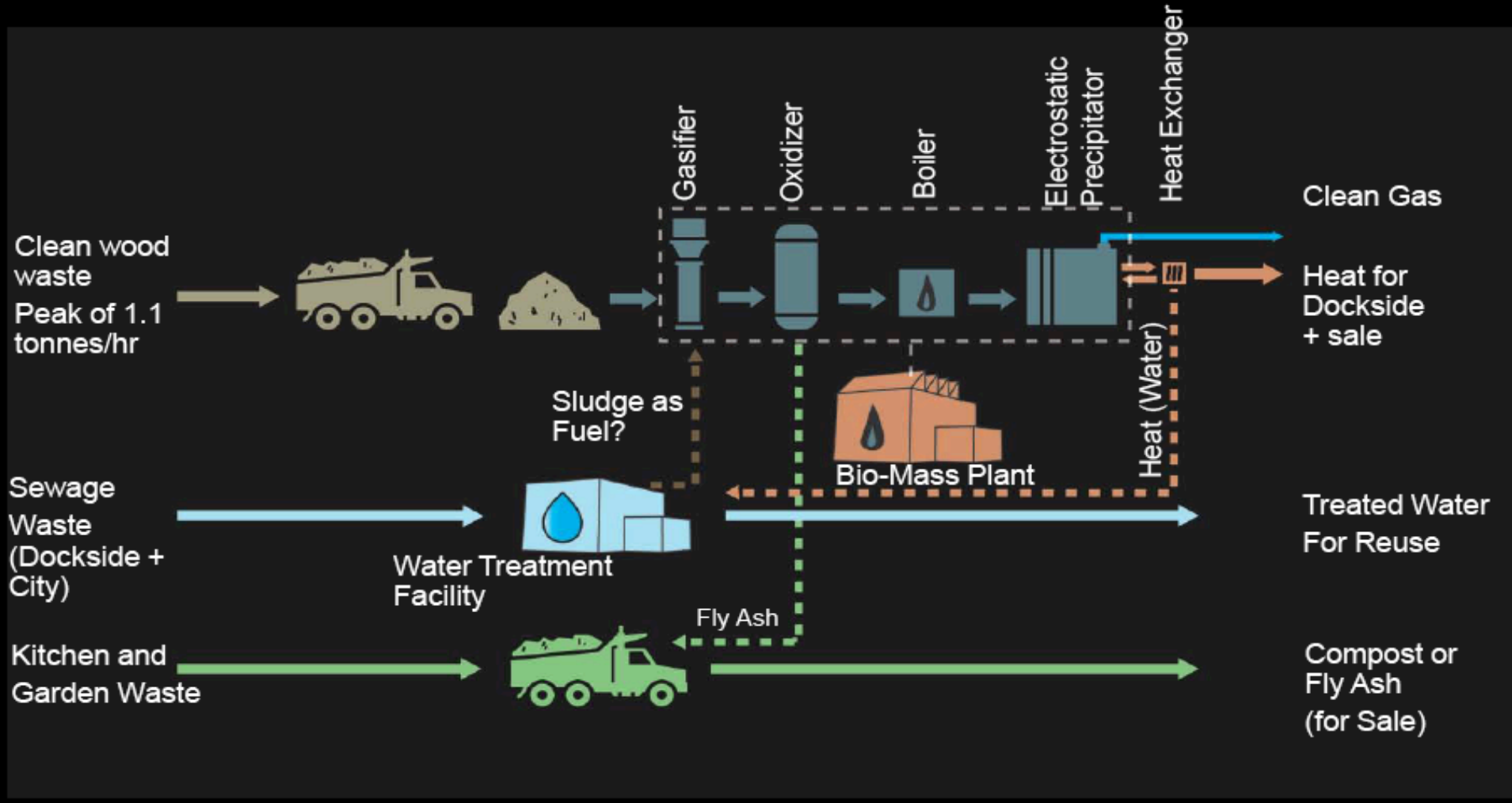

LA VOITURE QUI
FAIT CHUUUUT
AU LIEU DE FAIRE
VROUM
FAITES
PASSER
autolib'
COOL
CHUUUUUUT
autolib'
service
autolib'
01
02
03
autolib'

Gasoline Use per Capita versus Population Density



Data source: P. Newman & J. Kenworthy, Gasoline Consumption and Cities – A Comparison of U.S. Cities with a Global Survey, American Planning Association Journal, Winter 1989

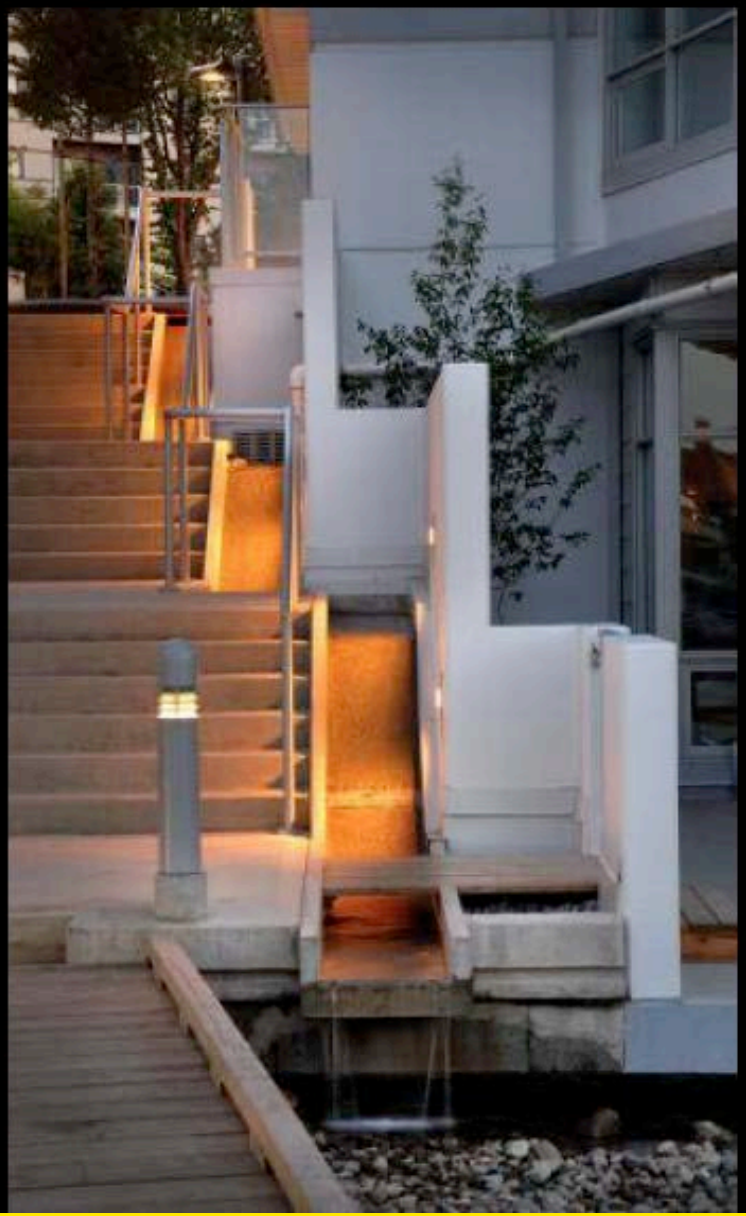
Applying These Lessons at Dockside Green

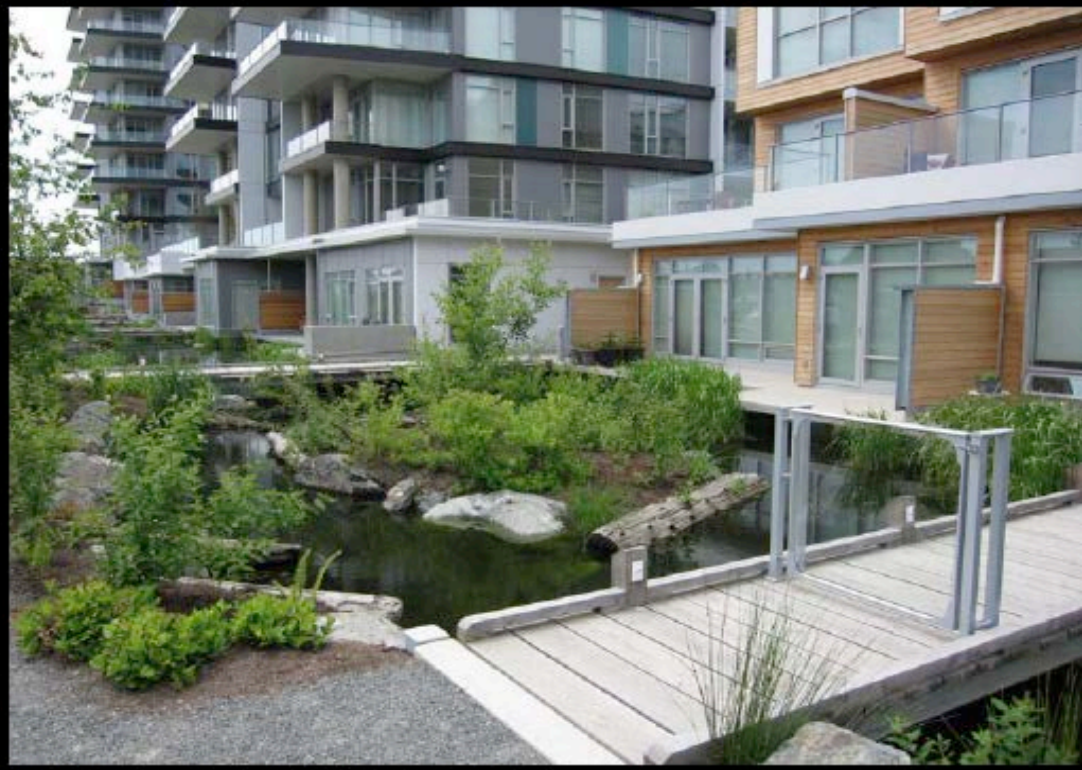


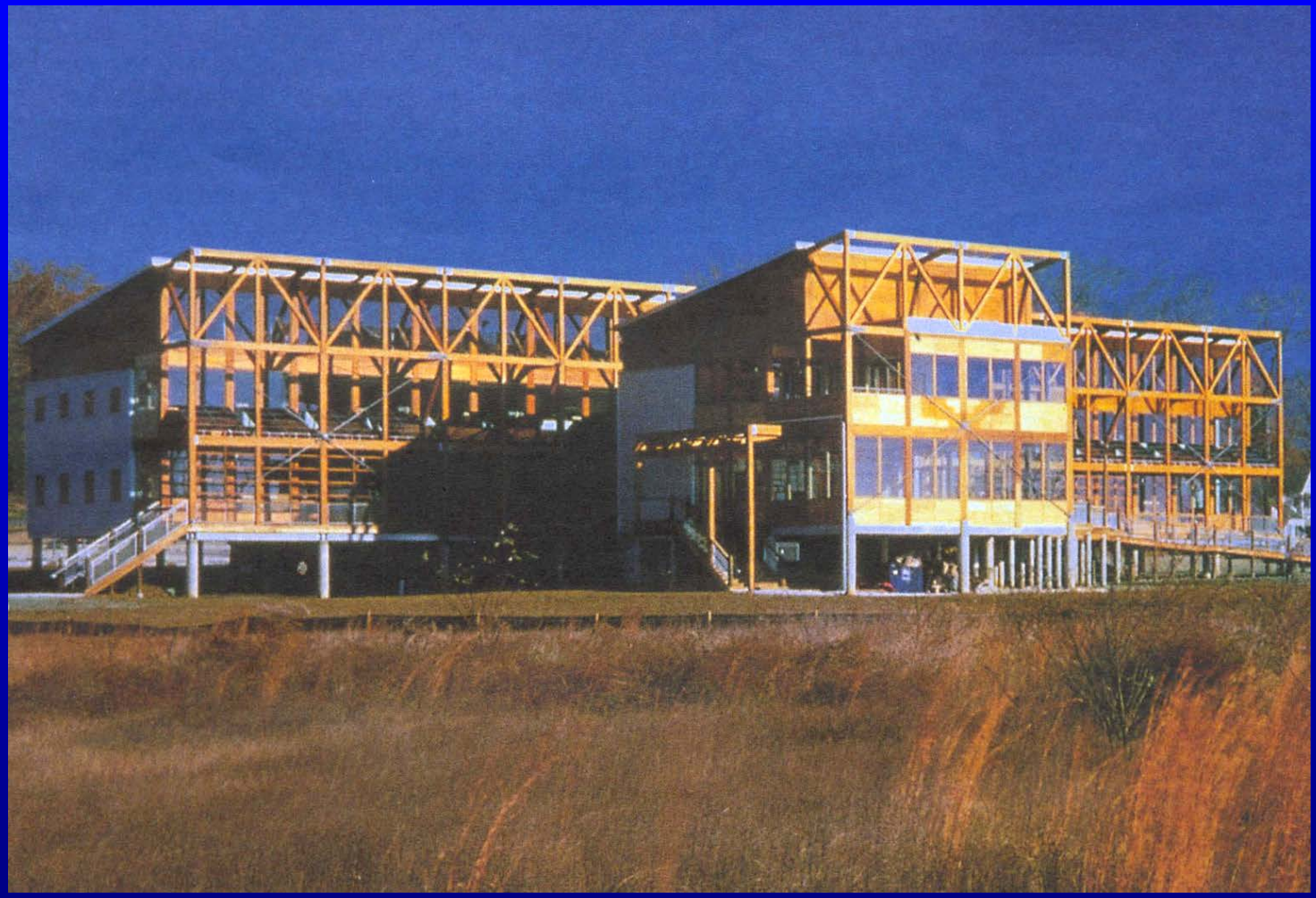
Applying These Lessons at Dockside Green

Busby Perkins Will

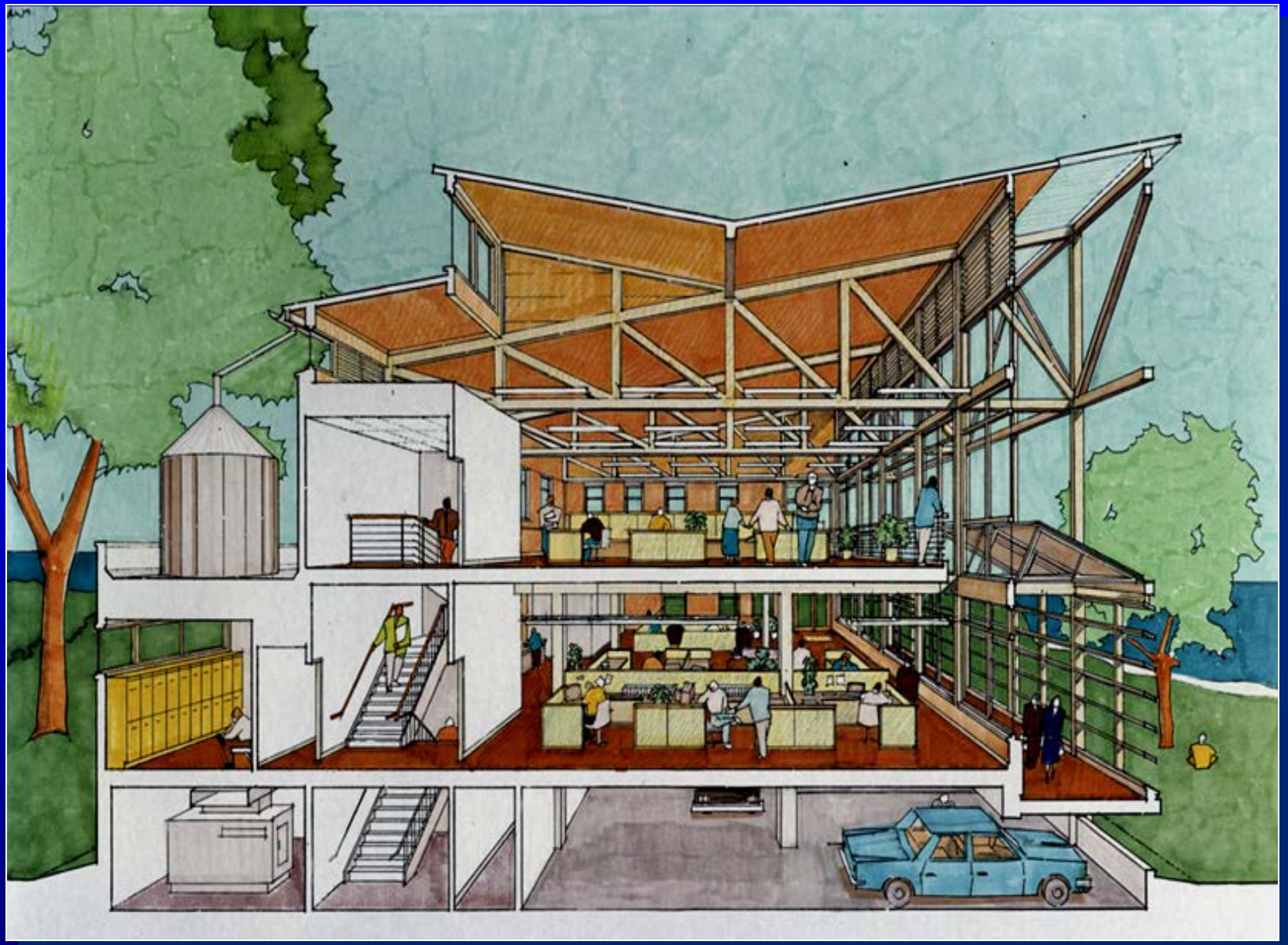
Applying These Lessons at Dockside Green



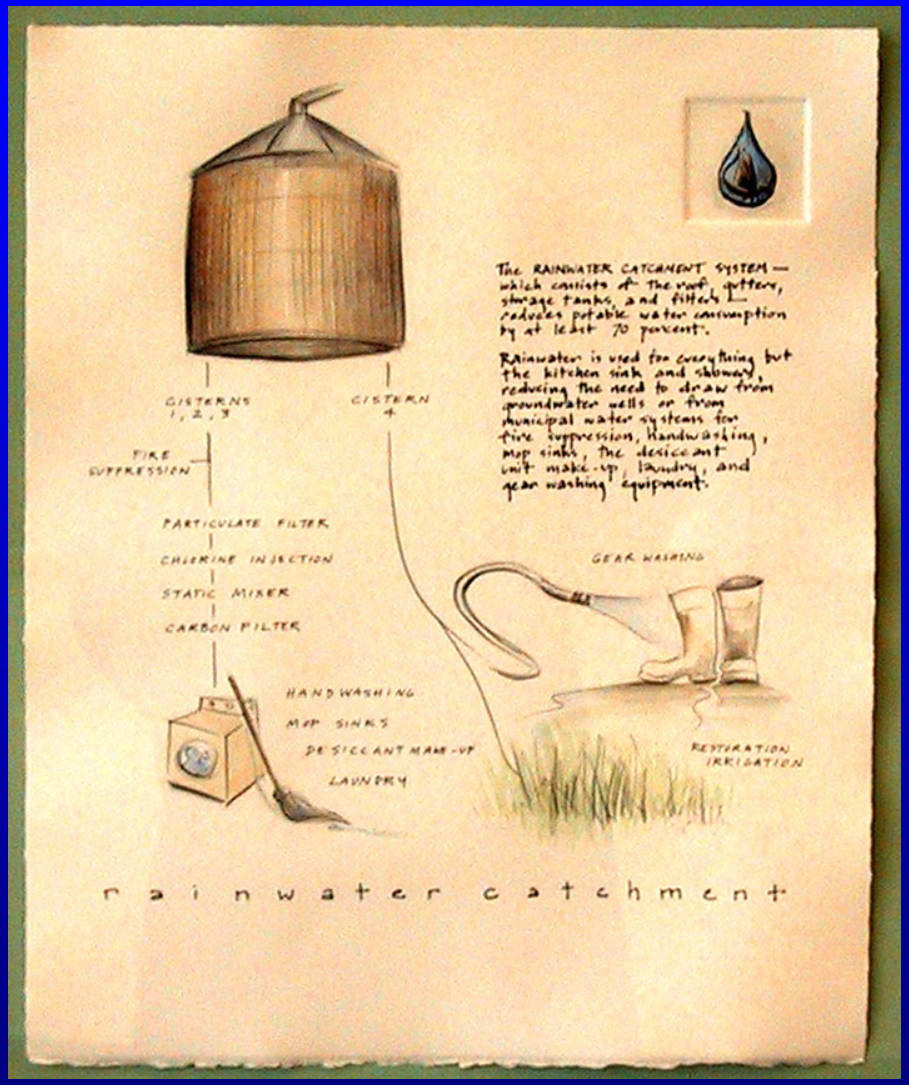




Smith Group Greg Mella with Janet Harrison



Chesapeake Bay Foundation



The rainwater collection system consists of the roof, gutters, cisterns, and filters.

It reduces potable water consumption by 70%

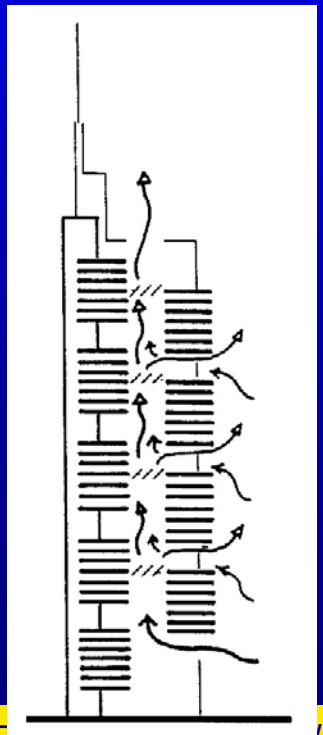
Filtered rainwater is used for everything except the kitchen sink and showers including,
handwashing,
fire suppression,
mop sinks,
HVAC makeup water,
and laundry.

California Academy of Science Renzo Piano Architect Gartner Enclosure

Center for Building Performance and Diagnostics, a NSF/IUCRC, and ABSIC at Carnegie Mellon

Dynamic Facades

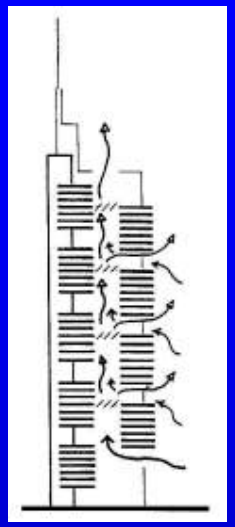
Example 3:
Commerzbank
Frankfurt, Germany
Architect: Norman Foster
Dr. Ing. Fritz Gartner, Josef Gartner& Co
Peter Muschelknautz, Commerzbank



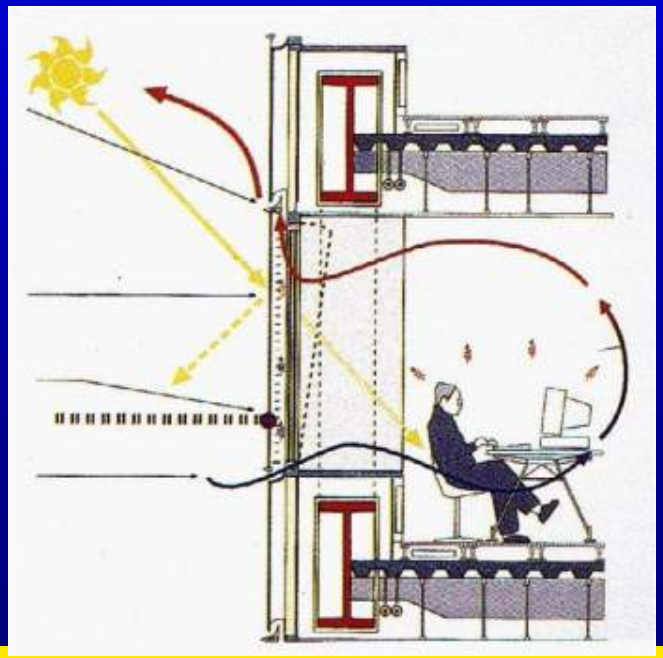
+ Double-skin façade

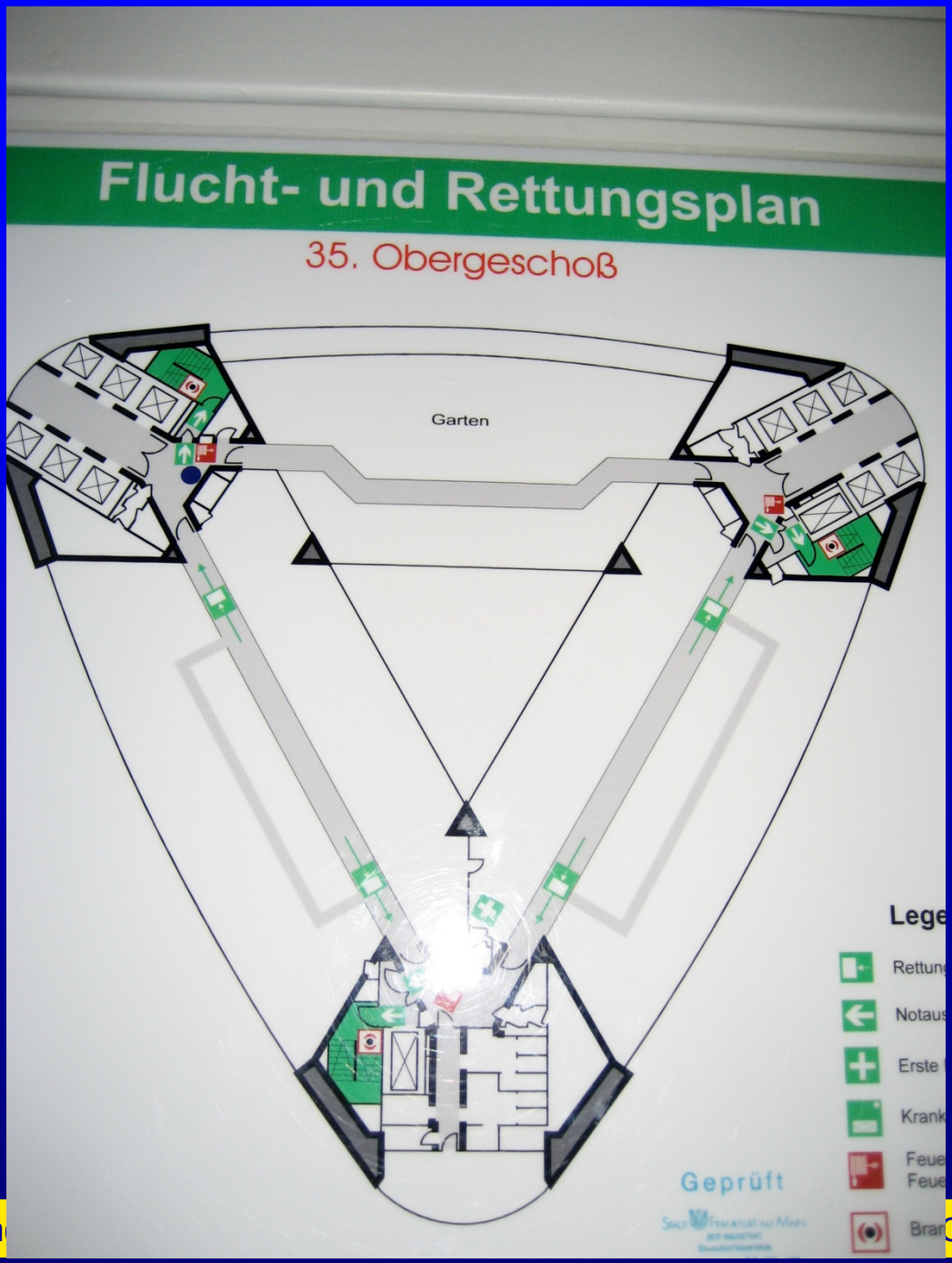
- Unnecessary HVAC back-up (redundant system)

Commerzbank Frankfurt Foster & Arup

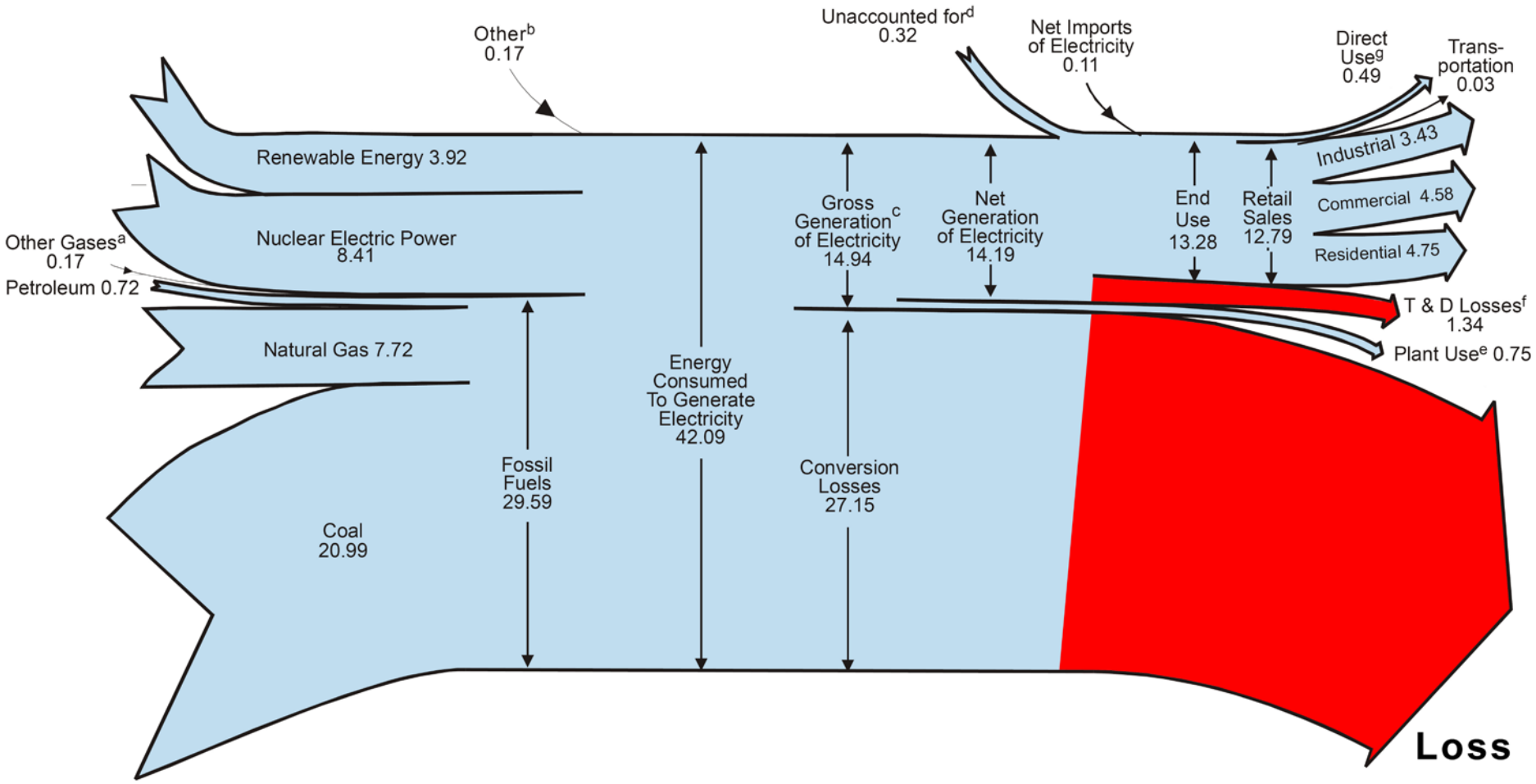


Even high rise offices can be naturally ventilated




Flucht- und Rettungsplan
35. Obergeschoß
Garten
Lege
Geprüft

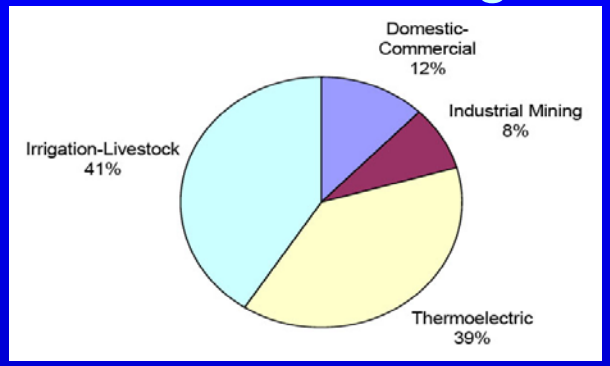
Electricity Flow in the U.S., 2007
(Quadrillion Btu)

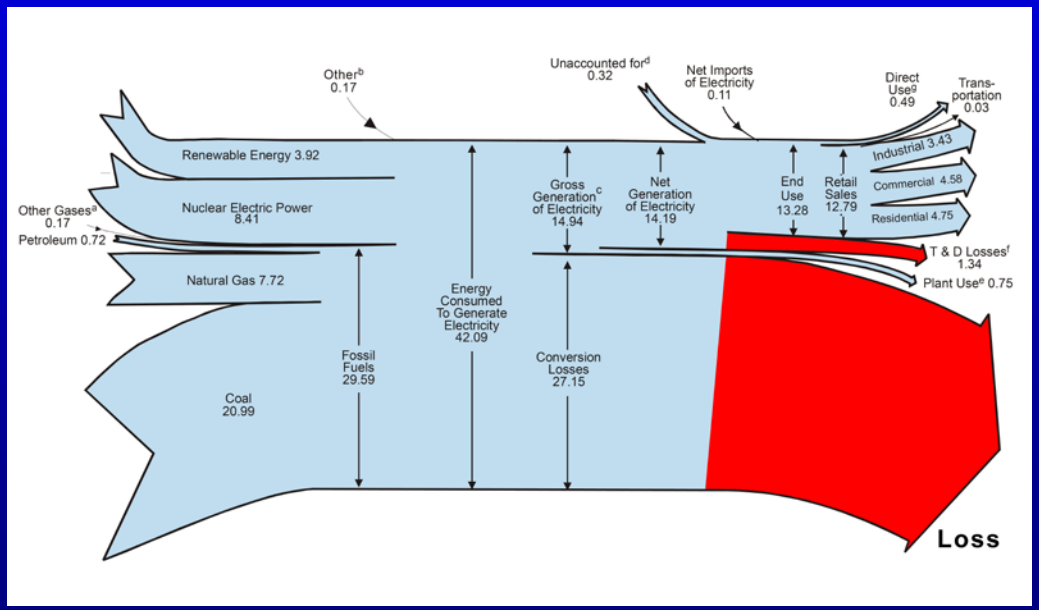


Data Source: Energy Information Administration / Annual Energy Review 2007

Urban/Neighborhood/Building Levels Interconnected Energy, Water, Air and Soil Harvesting-Closing the Cycles

- Electricity Efficiency





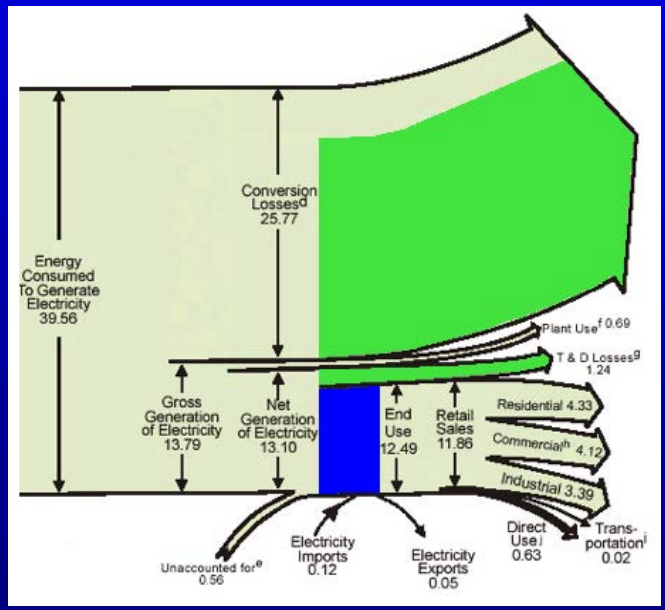
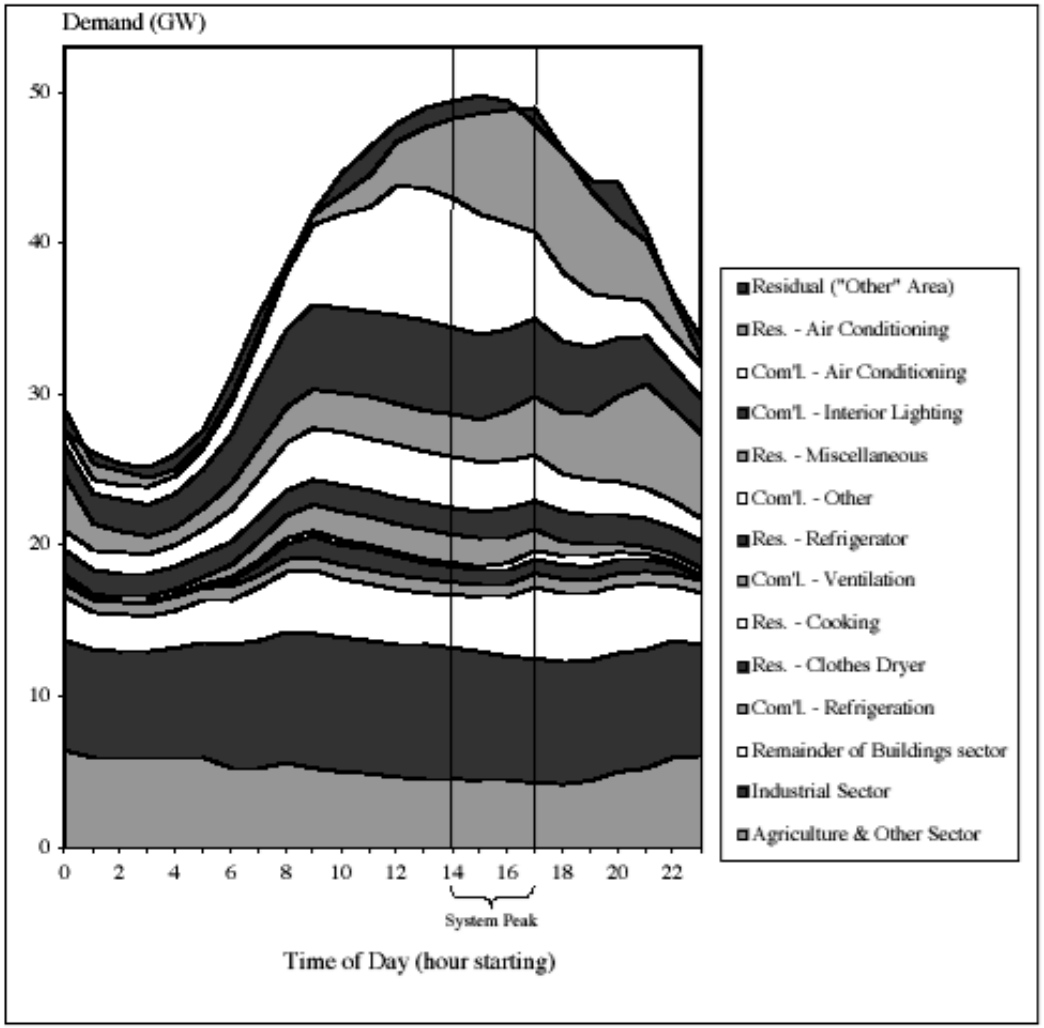
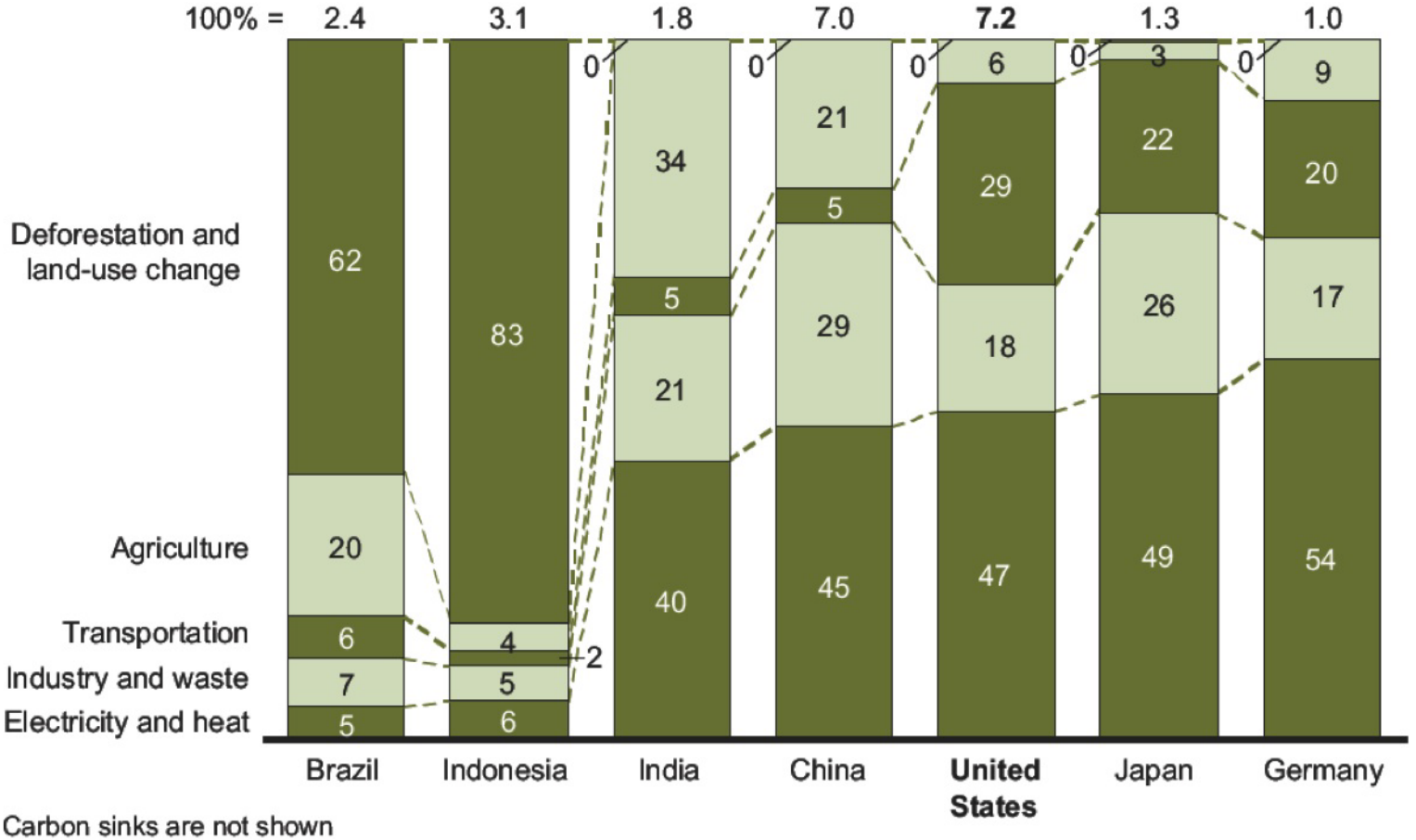


Figure 1: California 1999 Summer Peak-day End-use Load (GW): 10 largest coincident building-sector end-uses and non-building sectors



GHG EMISSIONS PROFILES FOR SELECT COUNTRIES – 2005*

Percent, Gigatons CO_2e



* Carbon sinks are not shown

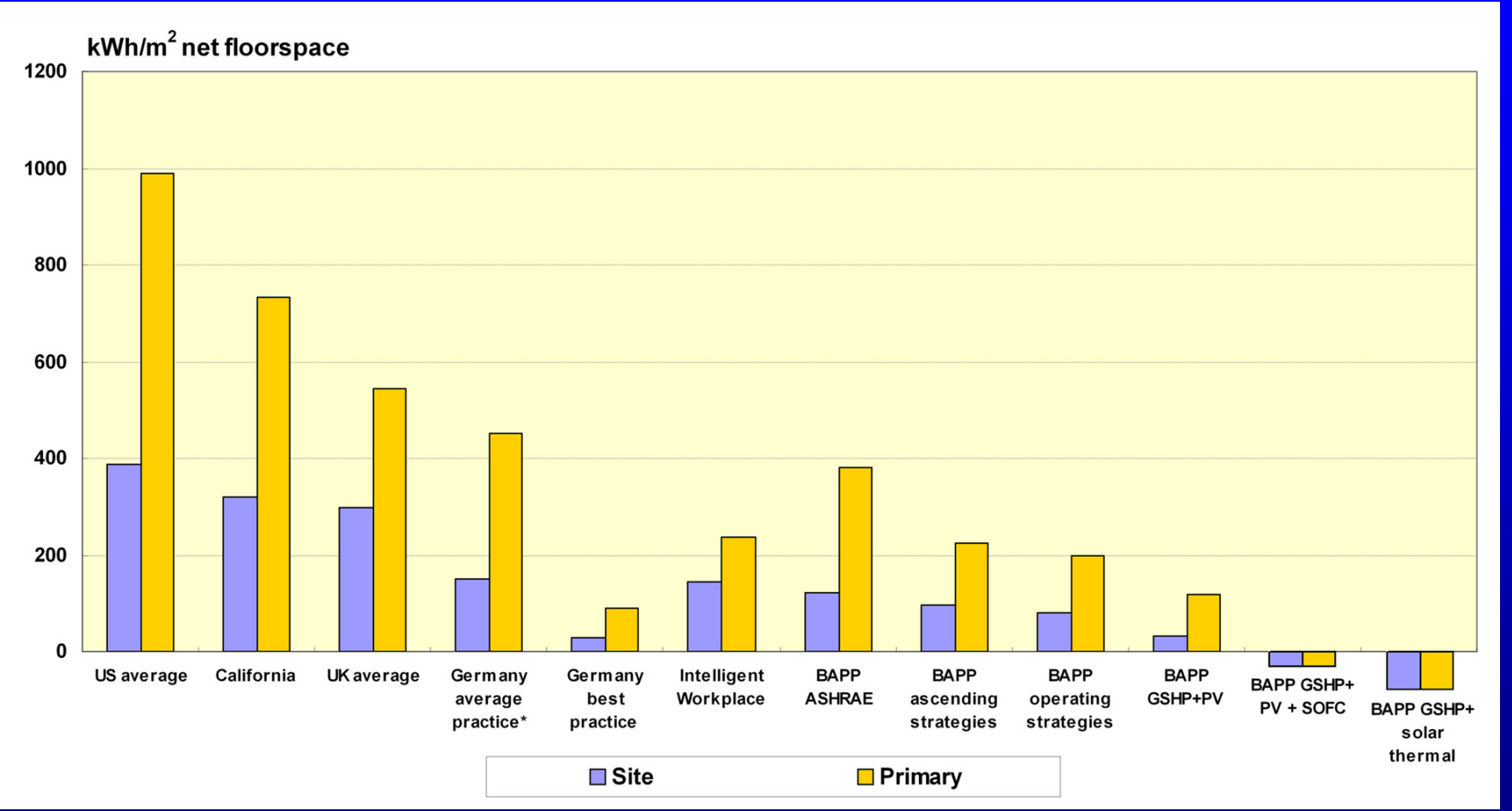
Source: UNFCCC, WRI, IEA, EPA, McKinsey analysis

Source: McKinsey&Company, Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?

Bio-Diesel Co-Generation Engine

Steam Generating and Storage

Annual Site/Primary Energy Consumption in Office Buildings

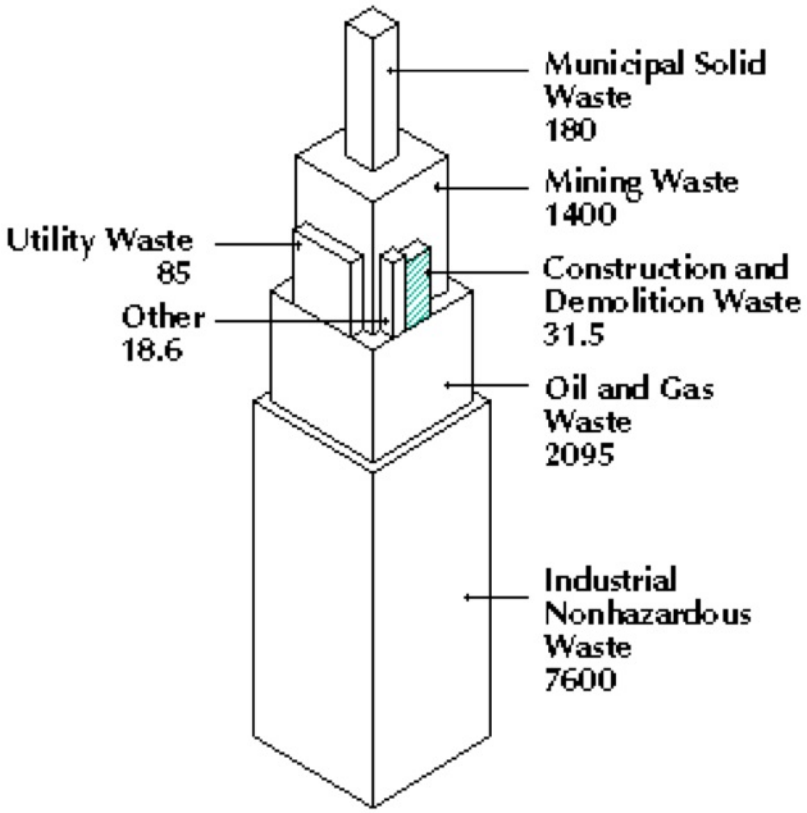


Data source:

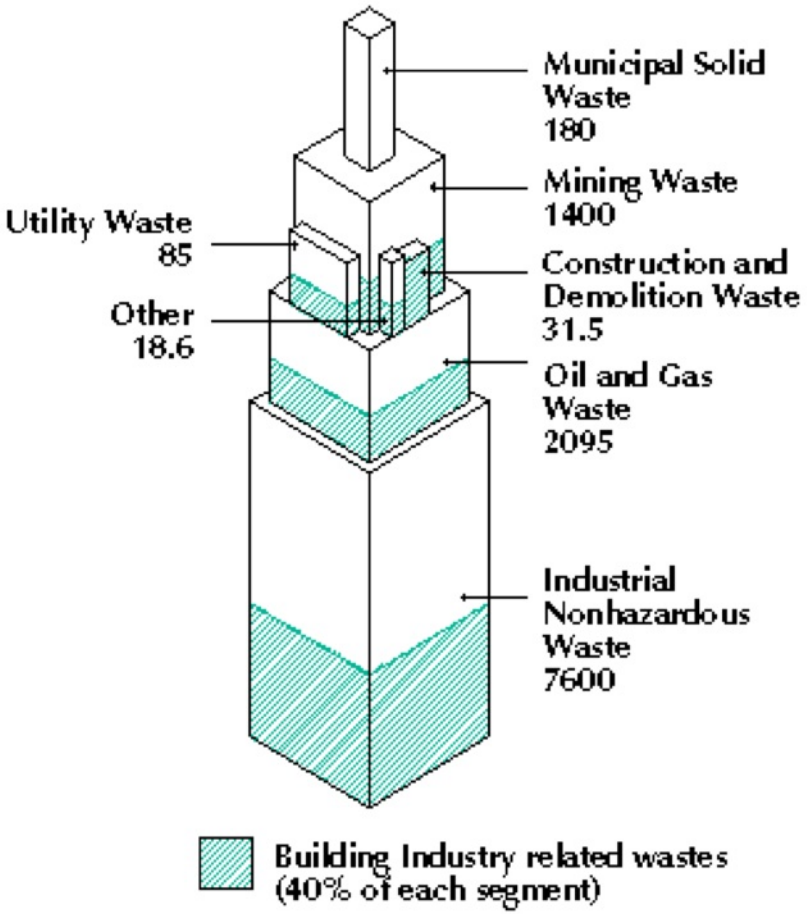
EIA, Commercial Building Energy Consumption Survey 1995; PG&E, Commercial Building Survey Report 1999; UK National Statistics

* Germany average practice is calculated based on the energy consumption measurements of 15 German office buildings built between 1990 and 2002 (with primary energy consumption ranging from 180kWh/m^2 to 1,000kWh/m^2).

Annual Waste Breakdown for the U.S. by Source

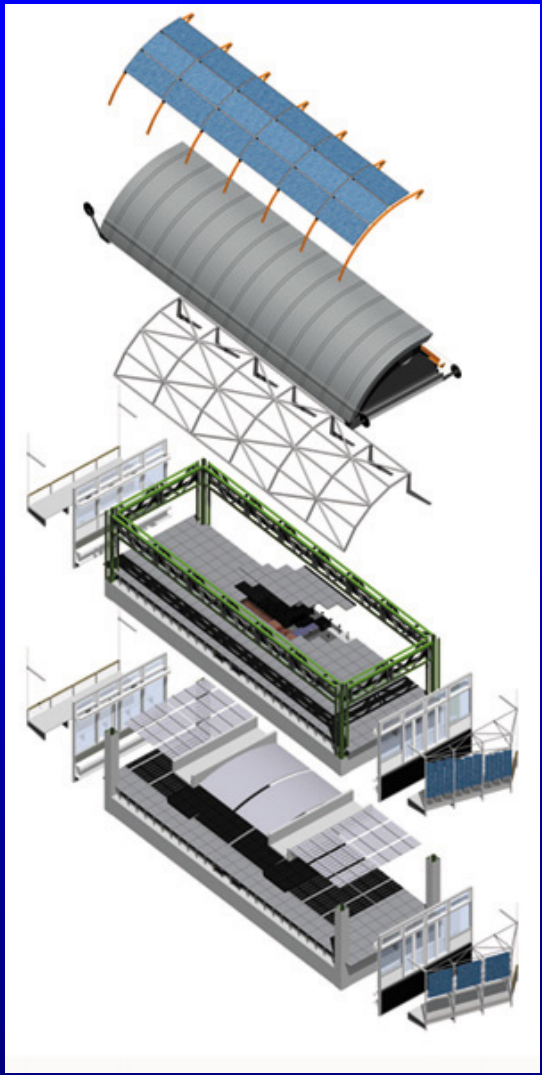


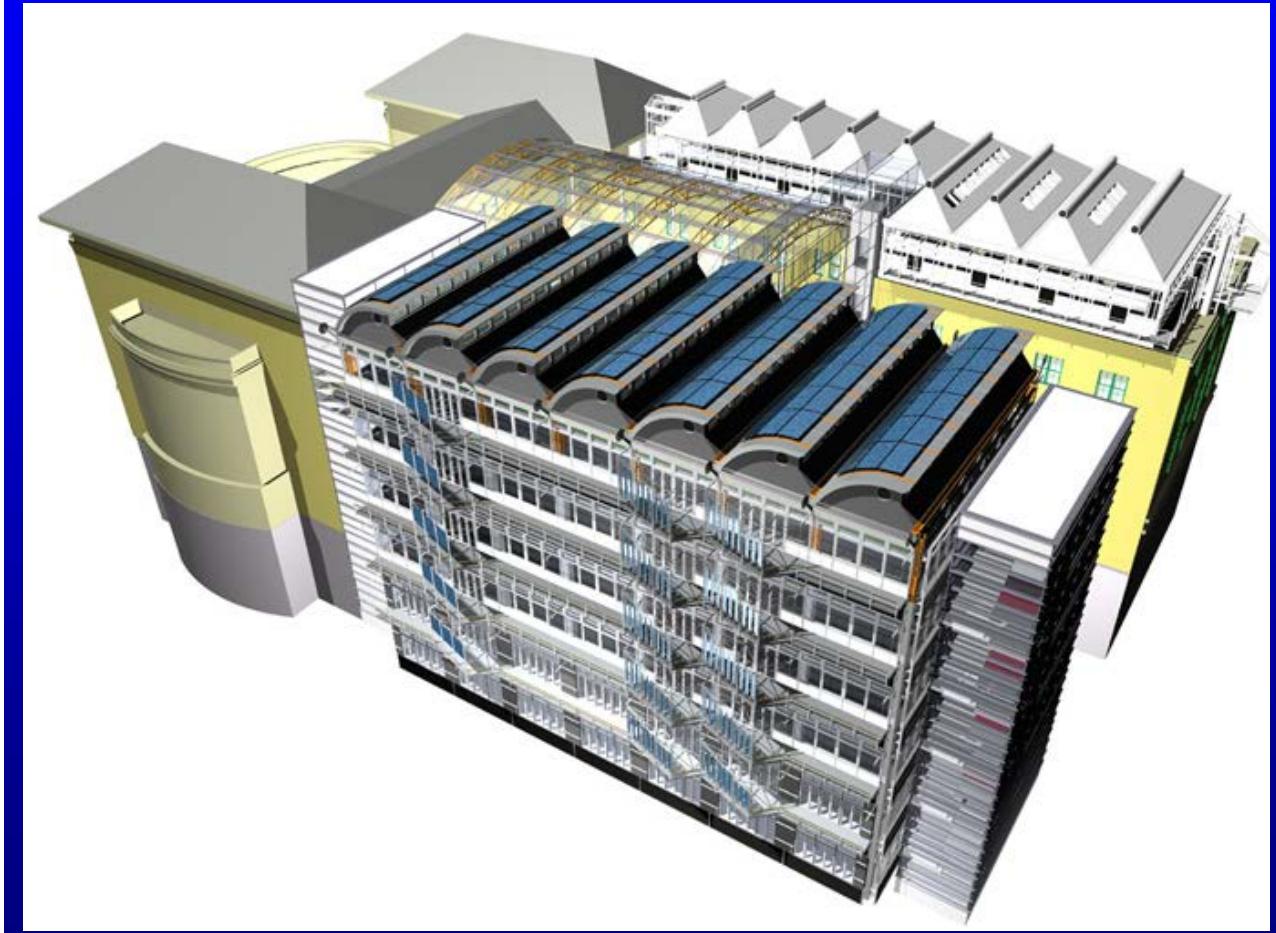
EPA / EPRI ESTIMATE
(in Million Tons)



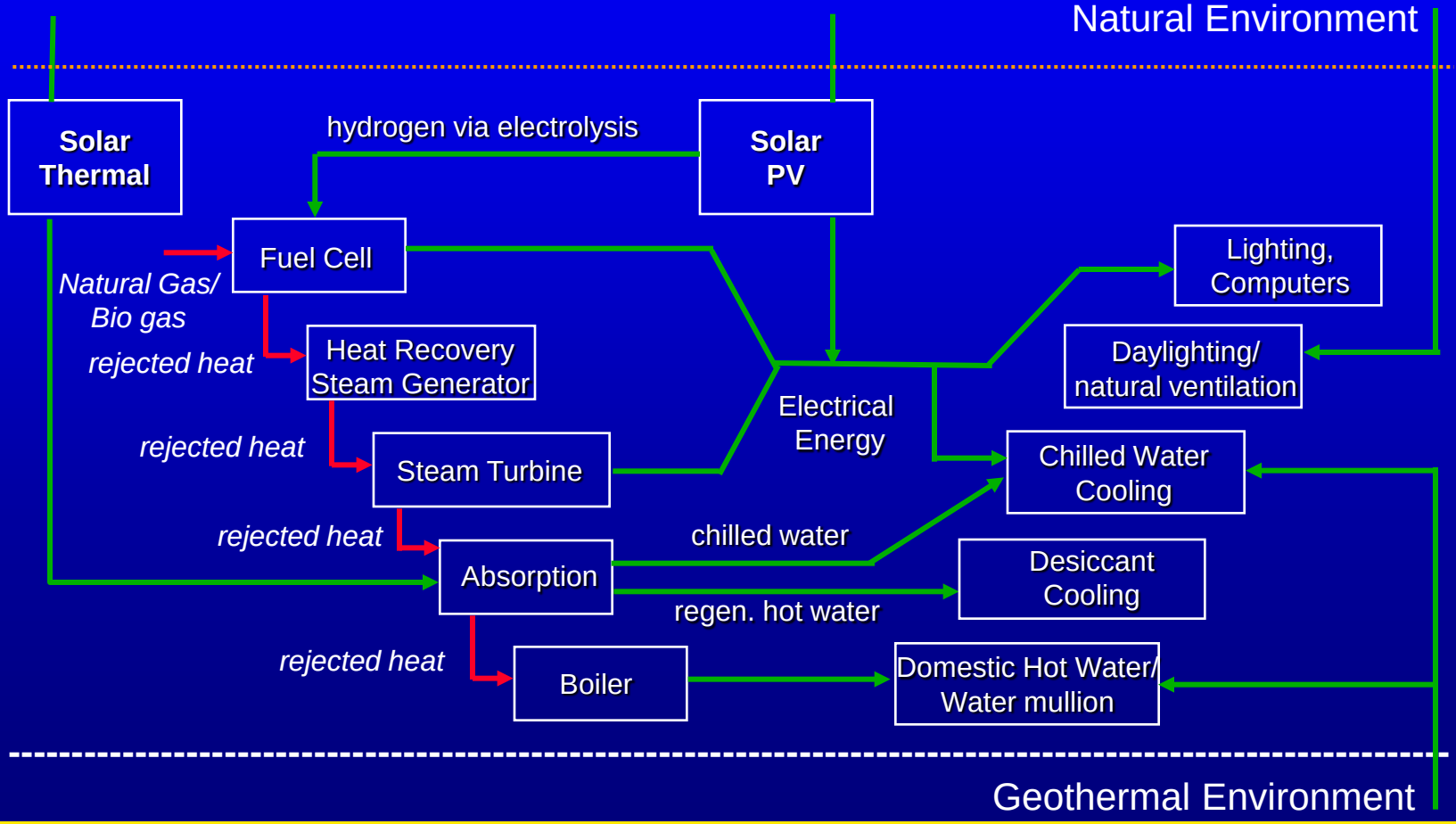
CENTER FOR BUILDING PERFORMANCE & DIAGNOSTICS / ABSIC, VOLKER HARTKOPF ESTIMATE

Building As Power Plant (BAPP)

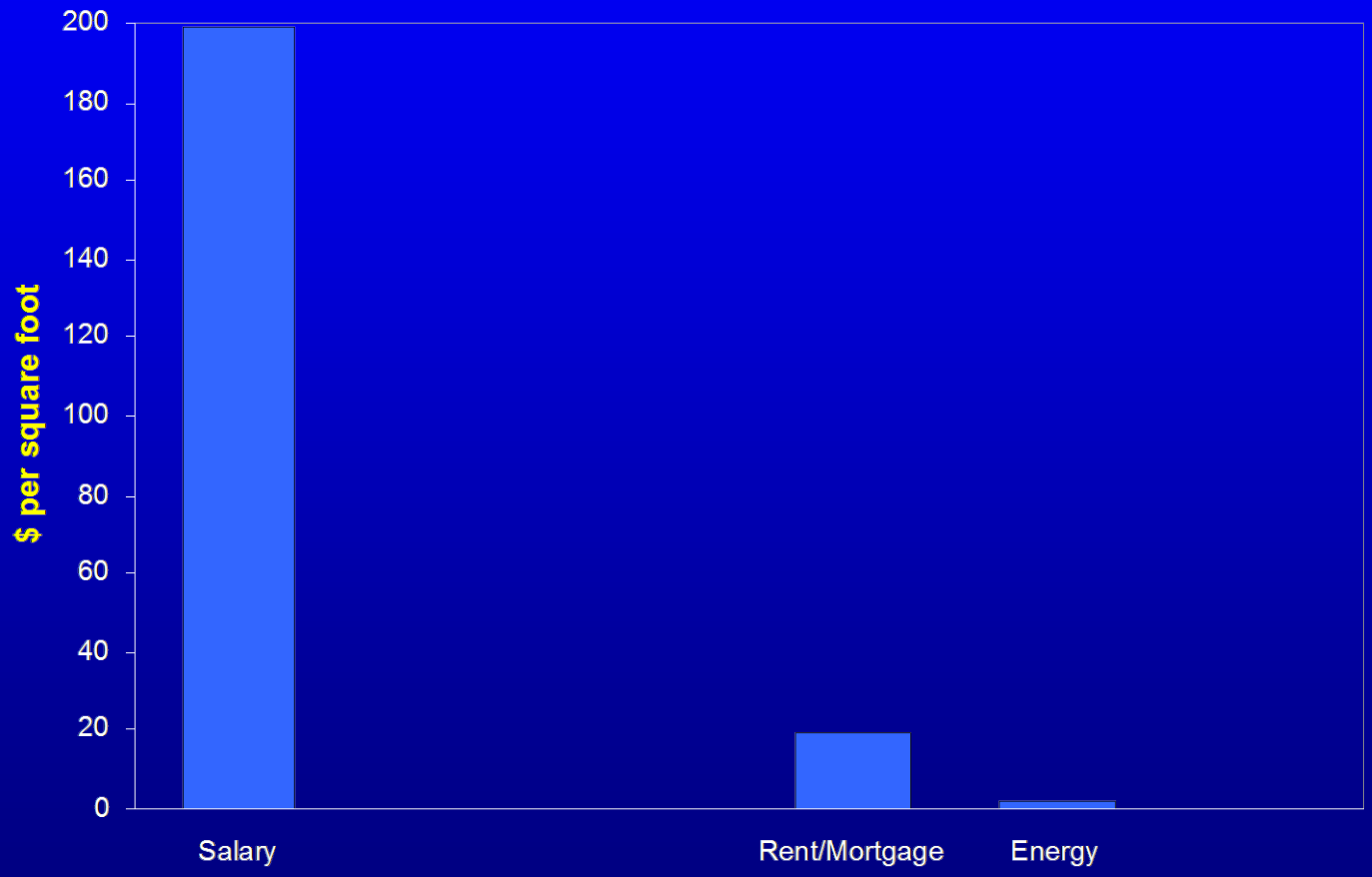




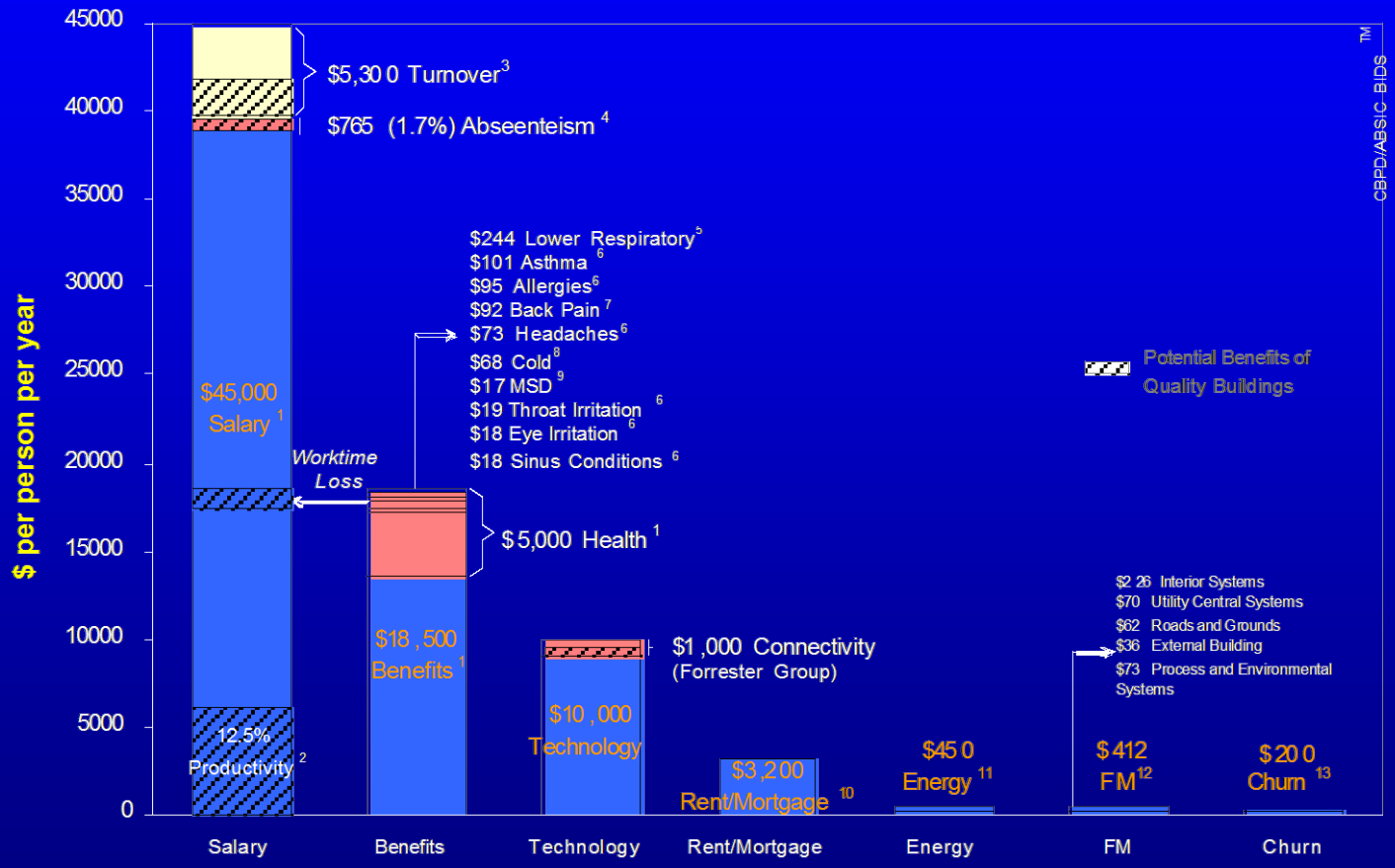
Innovative Energy Systems
Ascending-Descending Strategy



Potential Cost-Benefits for Building Quality Differences - BIDS™



Total Cost of Ownership - Office Workplaces



Current Unit System: US/Imperial Syste

BIDS Tool EVA® Matrix™		First Cost	O & M, Energy	Organizational Churn	Technological Churn	Individual Productivity	Organizational Productivity	Health	Attraction / Retention	Taxes, Litigation Codes, Insurance	Salvage and Waste	Case Study Selection
Air	< > 16/38					V						Fitzner 1985 / EPA 1989 Improved indoor air quality
Temperature Control	< > 2/17					V						West Bend / Kroner et al 1992 Plenum floor vs. conv. clg.
Lighting Control	< > 17/34		V									Vattenfall Bld/Hedenström 01 Upgraded Lighting System
Network Access	< > 1/5		V		V							York 1993 Raised floor vs. poke through
Privacy and Interaction	< > 8/22					V						Banbury and Berry 1998a Acoustic Privacy / Quiet
Ergonomics	< > 7/20					V		V				OSHA 1999c (14) | Silverstein et al 2000 Ergo chairs + keyboards
Access to Nar'l Environment	<> 3/36					V						Heschong et al 2002b / Schools 1 Daylighting in Schools - A
Whole Building	< > 1/57		V			V						VeriFone Inc. / Pape 98 Whole Building

Heschong et al 2002b / Schools 1

INVESTMENT:

$500,000

BENEFITS:

Productivity:
$25,670,518

EVA: $25,170,518

ROI: 675 %

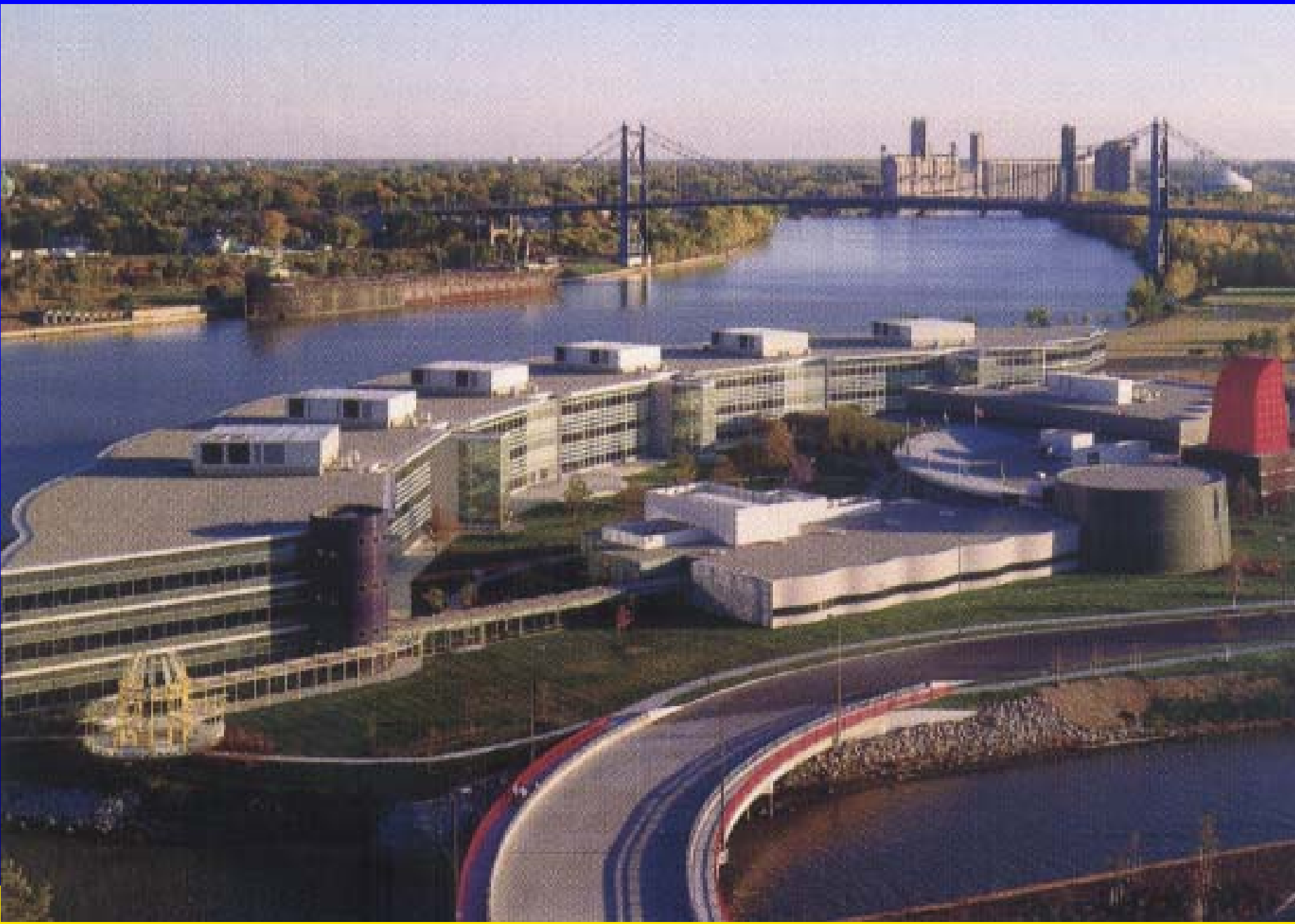
Daylighting = Individual Productivity

Heschong et al 2002b / Schools 1 - Daylighting in Schools - A

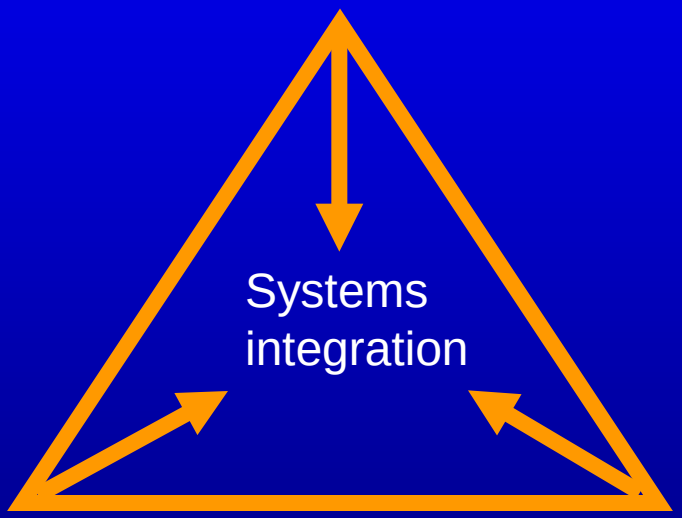
In a 2002 multiple building study, Heschong et al identify 7% to 26% higher test scores for school children in highly daylit classrooms than for children in classrooms with no to very little daylighting. The average 15% improvement in test scores represents a significant measure of individual productivity. more information ...

Edit Case Parameters

New Scenario | Quit



Systems integration Economicology

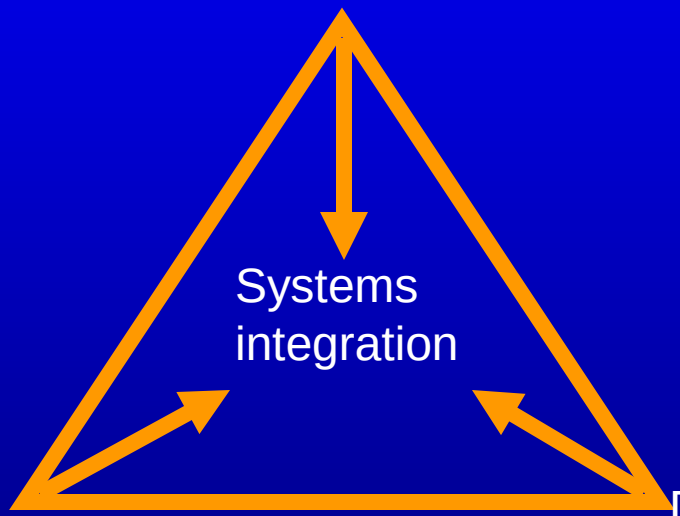


Systems integration to create win-win solutions

- Increase quality of life within and outside buildings
- Reduce resource requirements
- Secure US competitiveness
- Increase national security

Systems integration Economicology

Renewables:
Solar, Wind, Bio-gas,
Day-Lighting, Natural Ventilation
Passive/Active Heating/Cooling



Resource Conservation:
Energy, Water, Materials

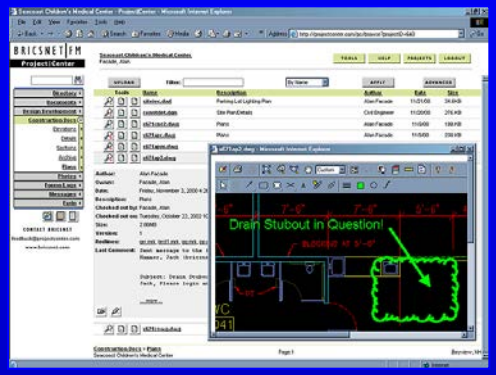
Distributed Generation
Fuel cell, bio-diesel generator

Systems integration to create win-win solutions

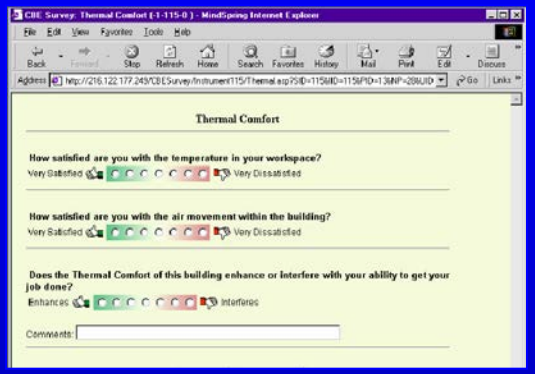
- Increase quality of life within and outside buildings
- Reduce resource requirements
- Secure US competitiveness
- Increase national security

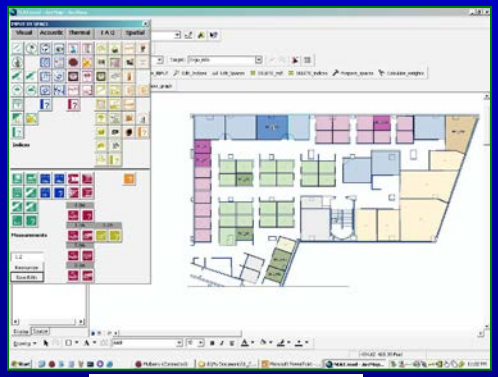

24 HOUR
FITNESS

records collection



user satisfaction questionnaires

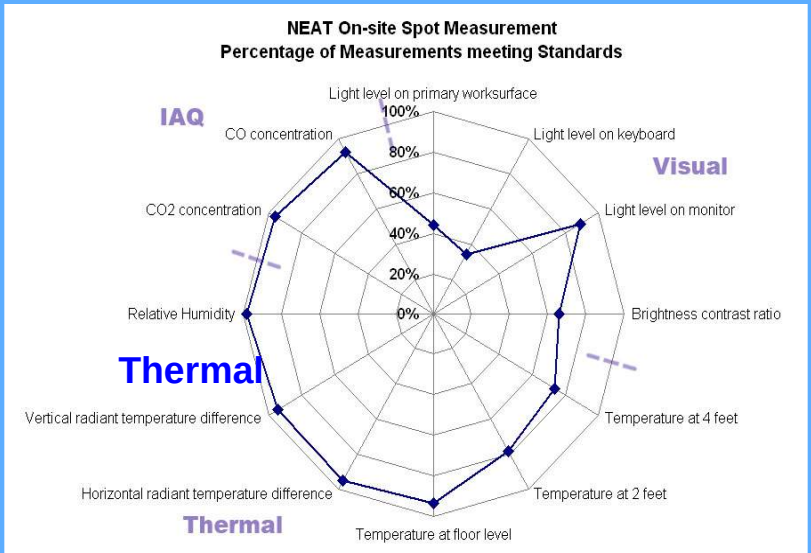




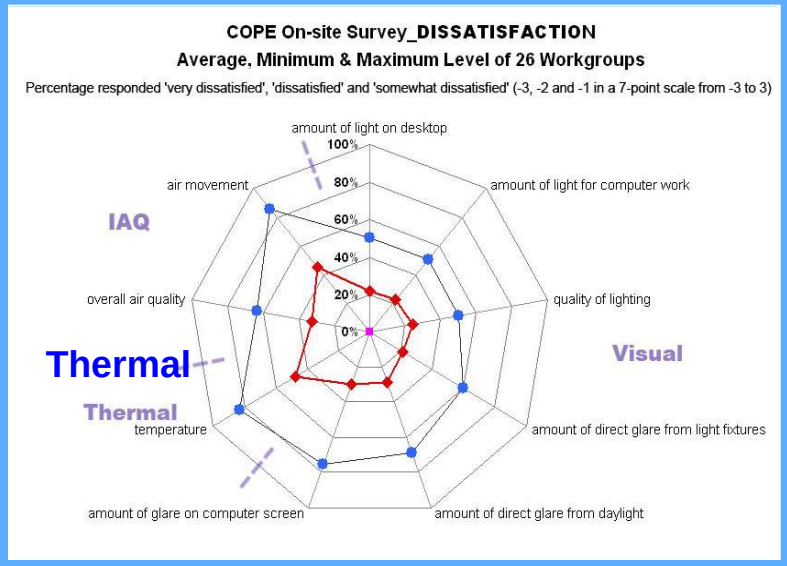
expert walkthrough

technical attributes of building systems (CMU TABS)

CMU NEAT
field instrumentation: spot & 24-hour



Measured: On average, spaces meet Code



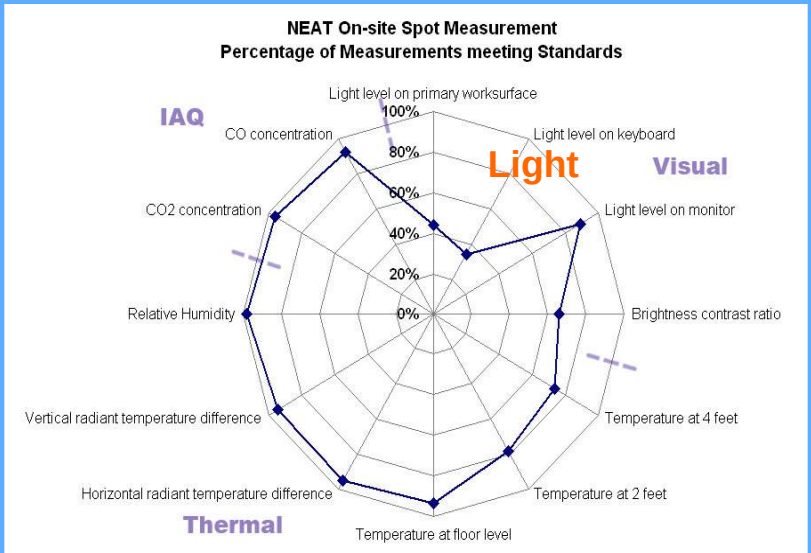
Perception: 50% dissatisfied

Cross Portfolio Analyses

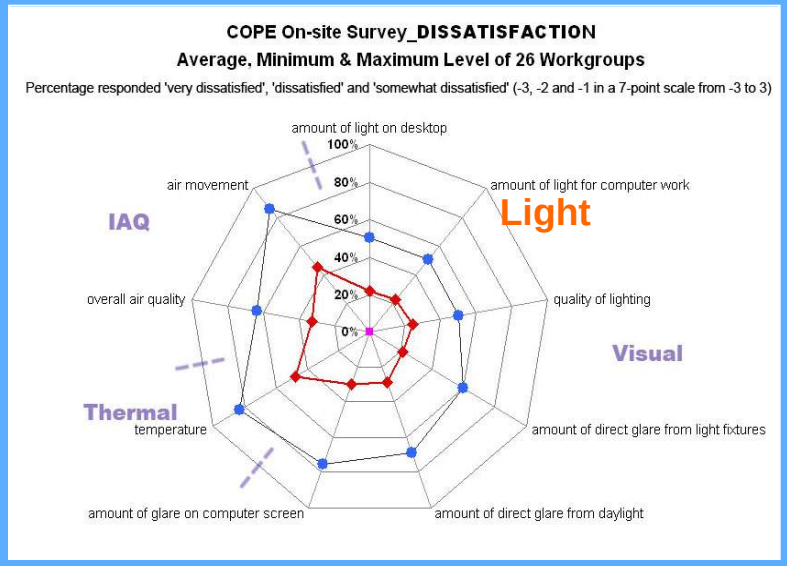
Subjective and Objective Measures

600 workstations
in large US office buildings

While thermal and relative humidity conditions in federal facilities predominantly met ASHRAE comfort standards, users were 50% dissatisfied with temperature and air movement conditions.



Measured: light levels below code



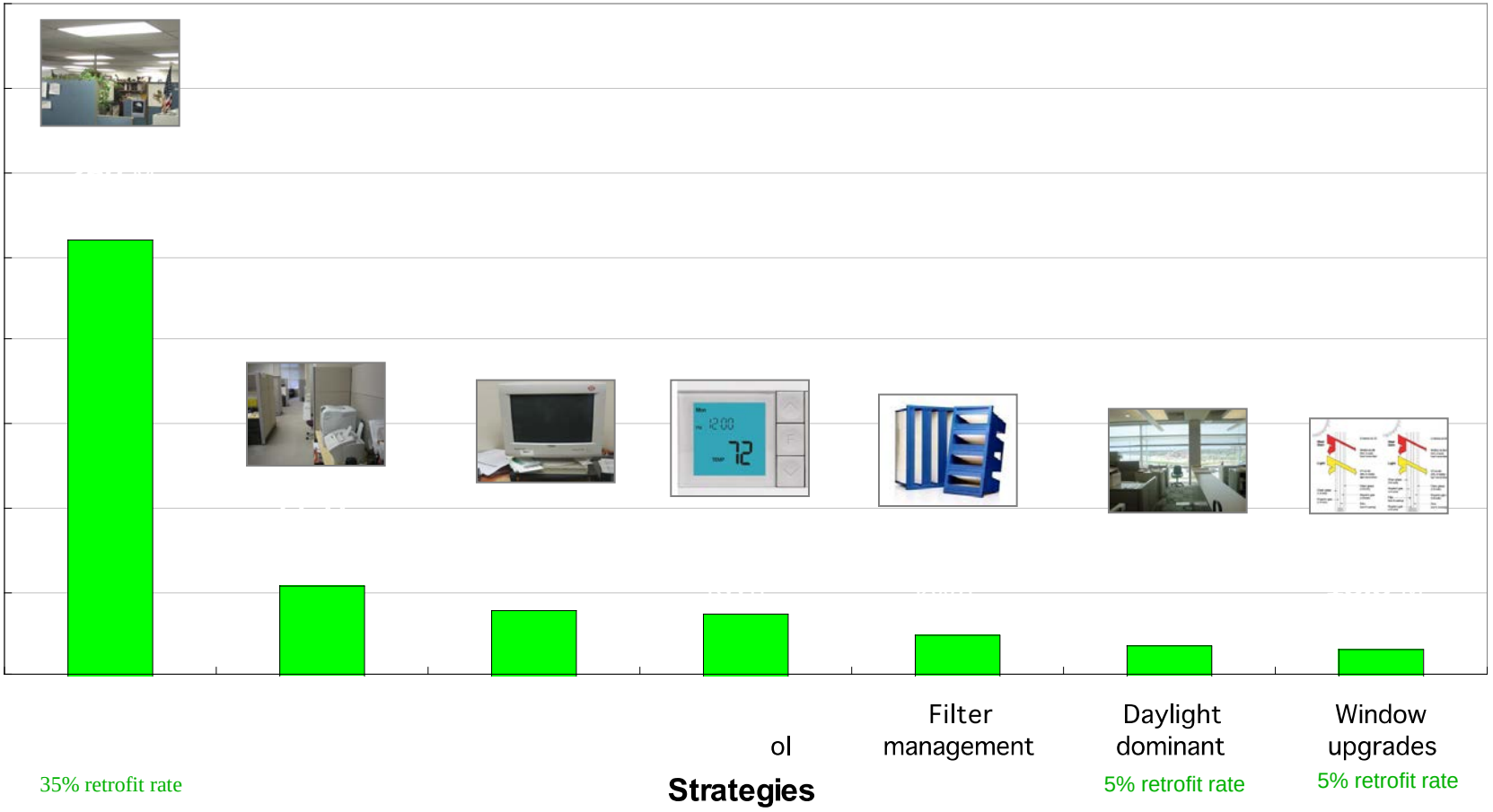
Perception: 20% dissatisfied, 80% satisfied

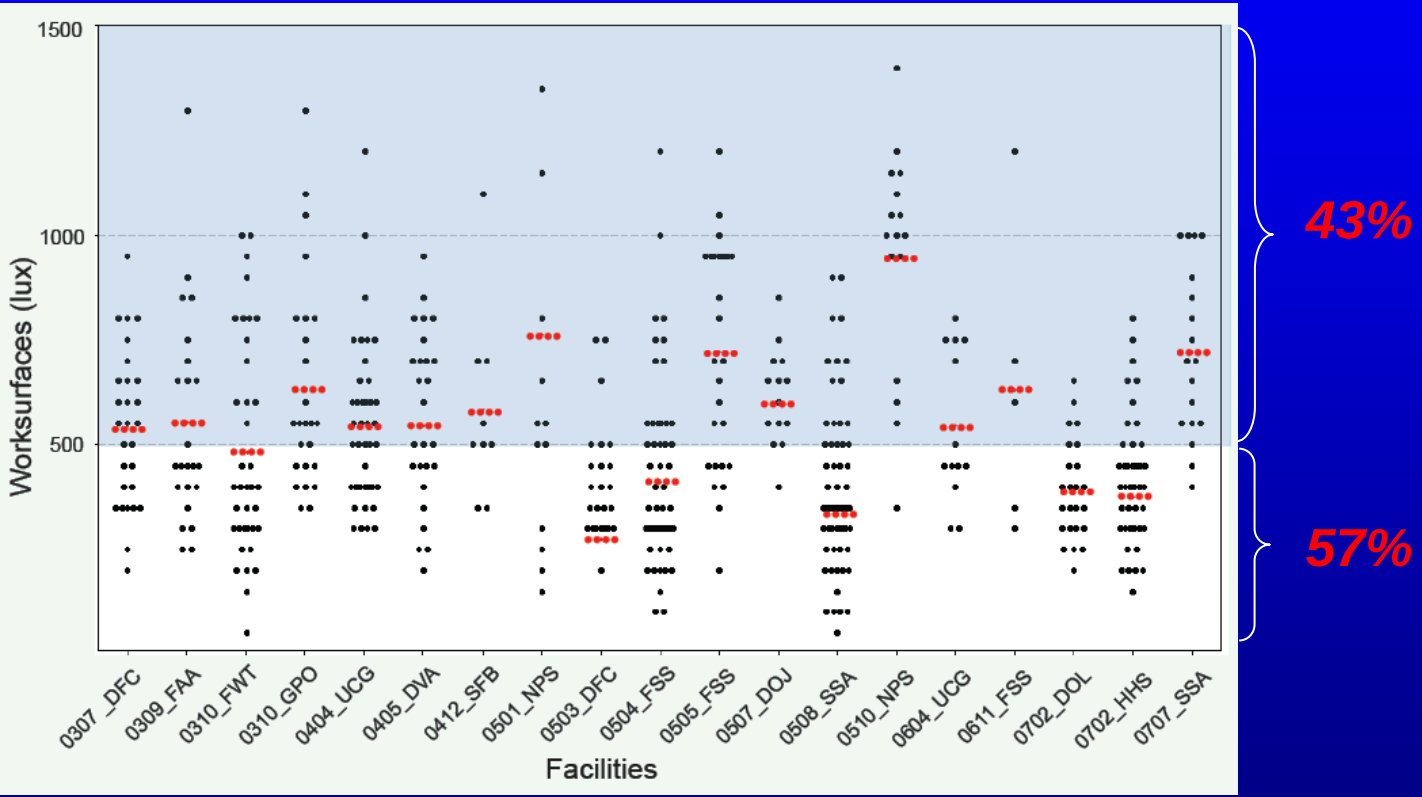
Cross Portfolio Analyses

Subjective and Objective Measures

While light levels in federal facilities often did not meet IES lighting standards, users were 80% satisfied with light levels and quality.

7 Recommendations for Energy Savings + Performance in the GSA Portfolio (to save over 450M kWh/year)

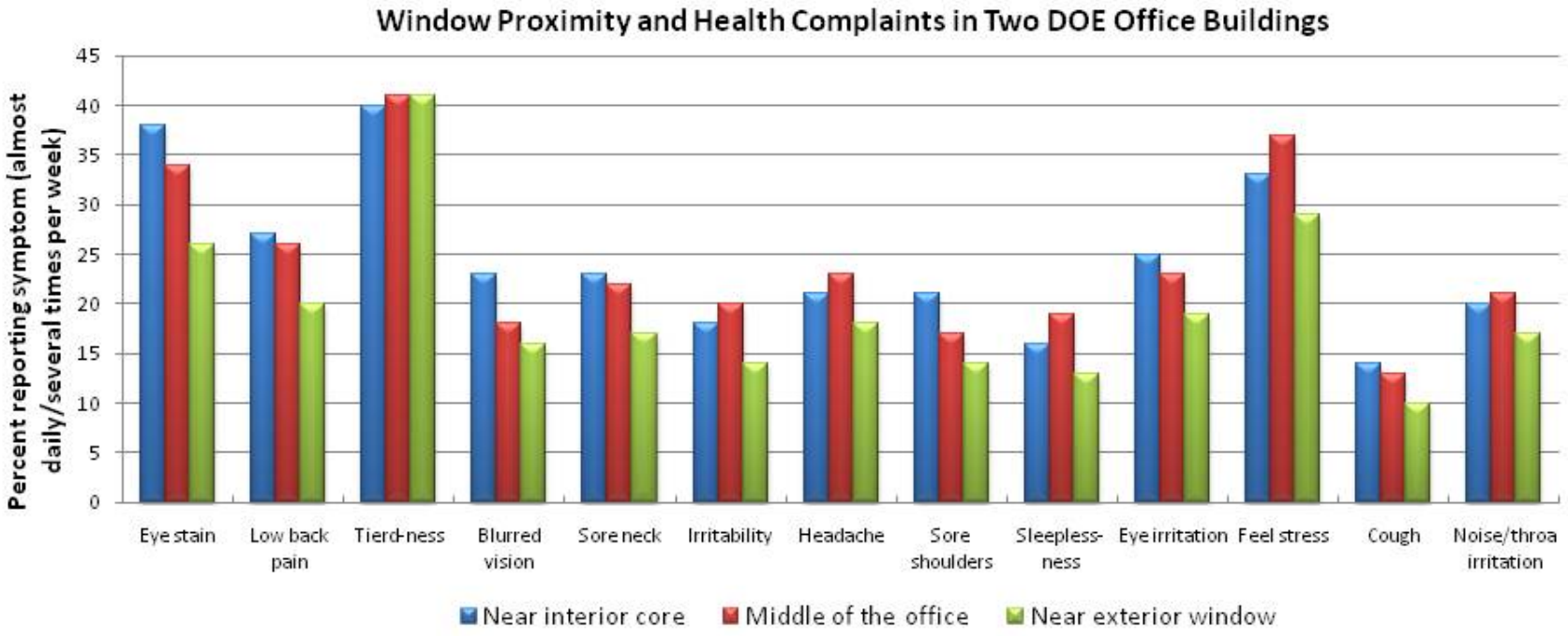




Light Levels on Primary Worksurface in 19 Federal Building Groups with Task Lights On

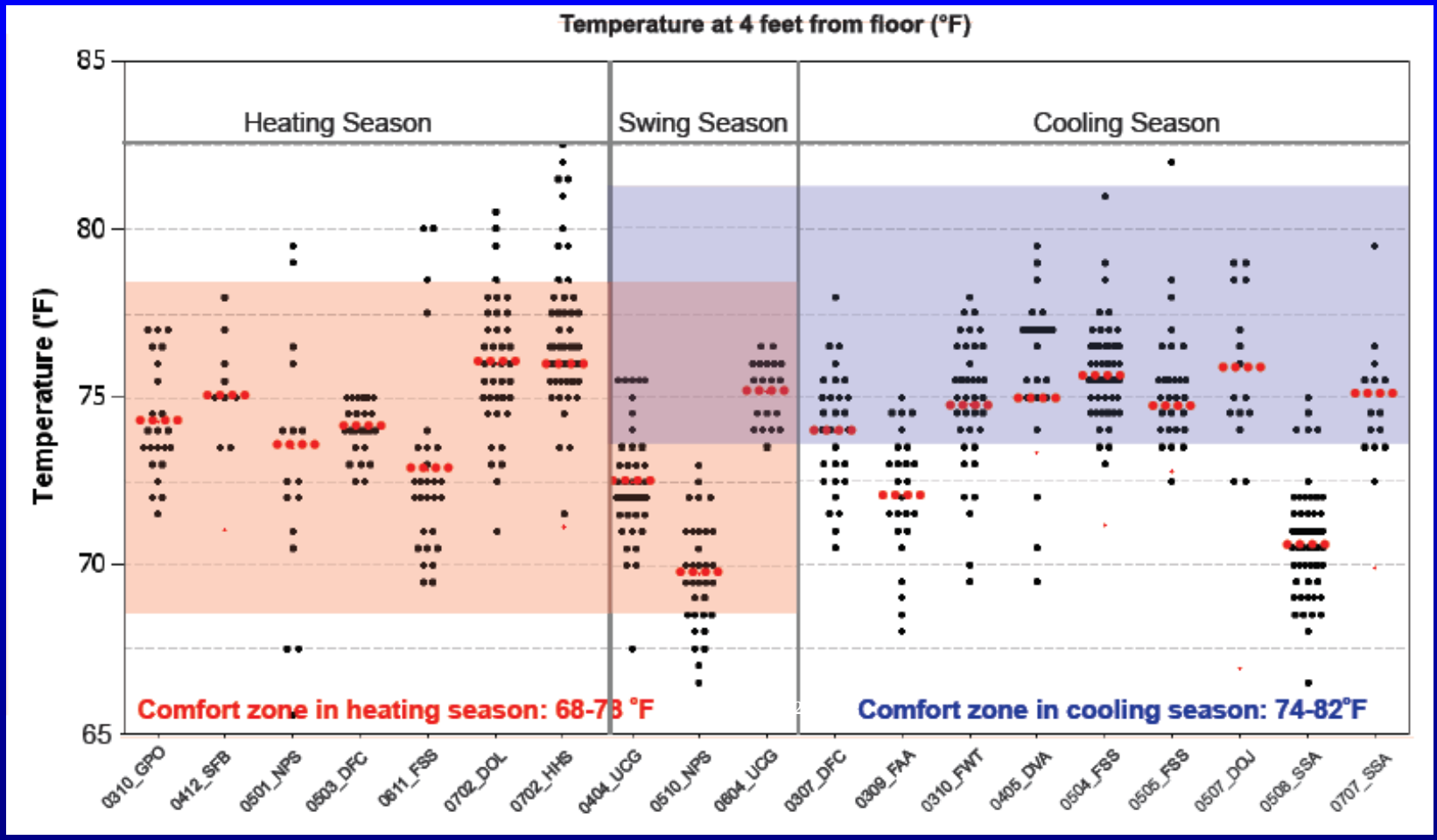
(* IES (2004) recommends **minimum 500** lux light levels on worksurface for paper based work)

(A statistical sample of 286 workstations were measured for light levels on primary work surfaces and screens, and user satisfaction questionnaires were distributed for comparison)



In a 1994 study of 2000 workers in DOE facilities in Washington DC, user perception of health symptoms was statistically lower among workers with seated views of windows.

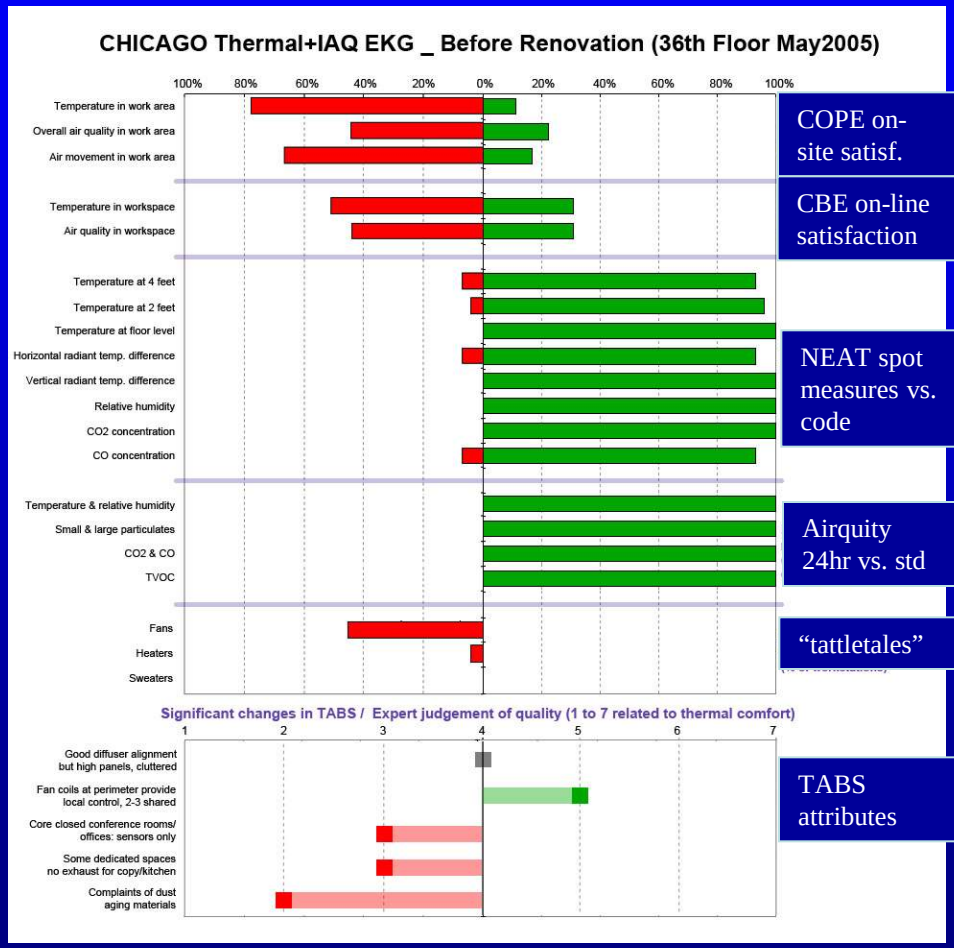
Measured air temperature distribution in GSA buildings reveals 40% "'too cold' conditions in summer

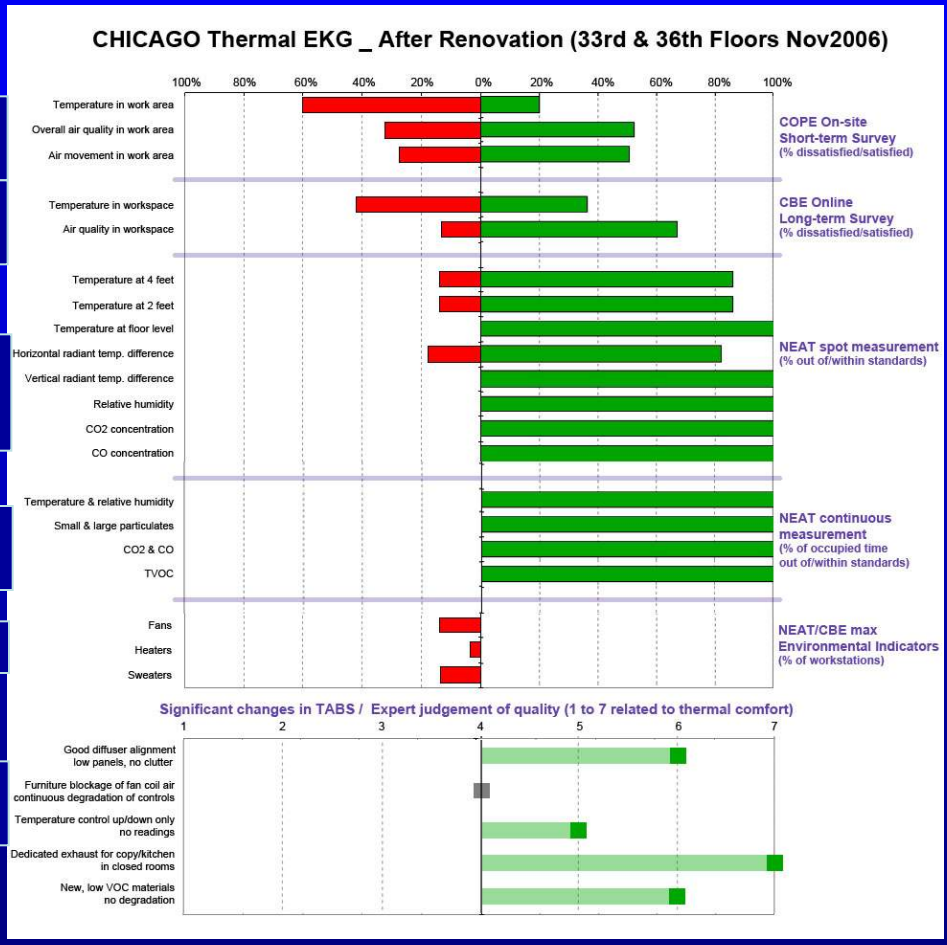


(In 22 federal office buildings nationwide, on 43 office floors, a statistical sample of 624 workstations)

Drawing Conclusions:

Before and After Thermal & IAQ "EKGs"

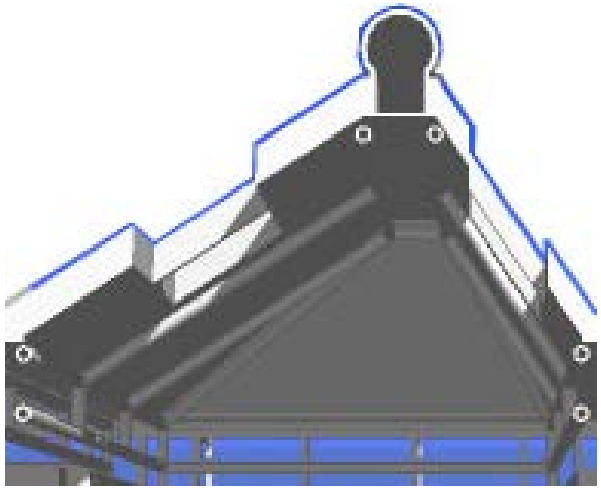




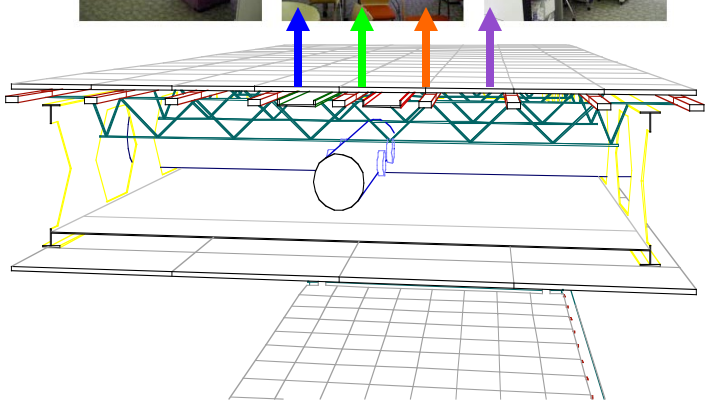
Center for Building Performance and Diagnostics, a NSF/IUCRC, and ABSIC at Carnegie Mellon

Energy Services

- Security
- Reliability
- Quality
- Effectiveness



Distributed Energy Generation and Supply



THEATER

Stage set

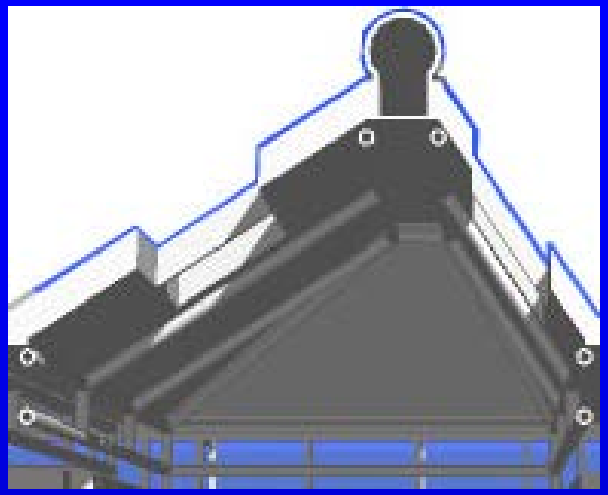
- Flexibility

PLATFORM

Air/ Water Heating/Cooling

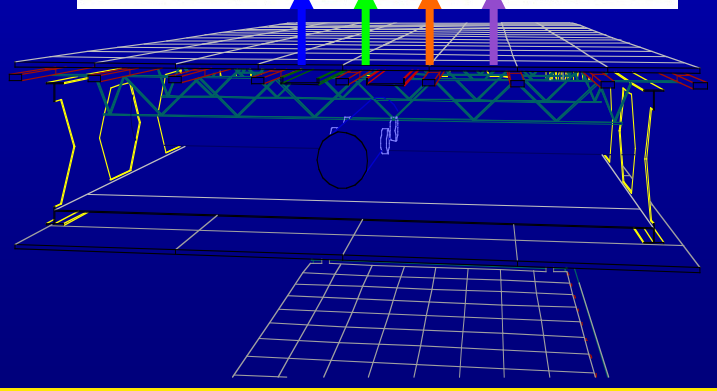
PVD

- (power, voice, data, video)



Flexibility

Platform



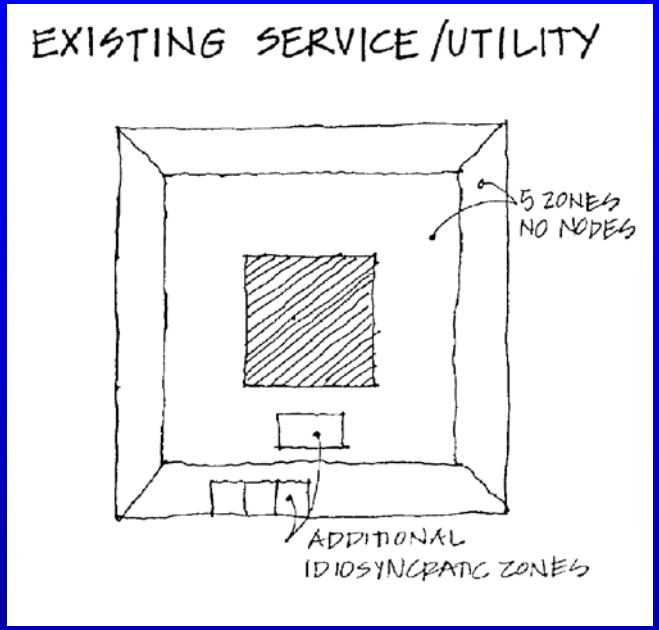
Sustainability

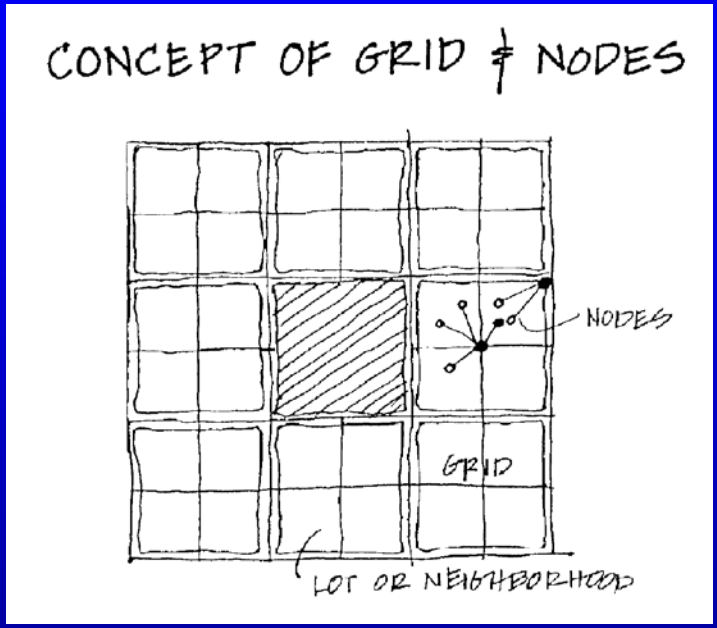
Application Layer

Interactive Service Layer

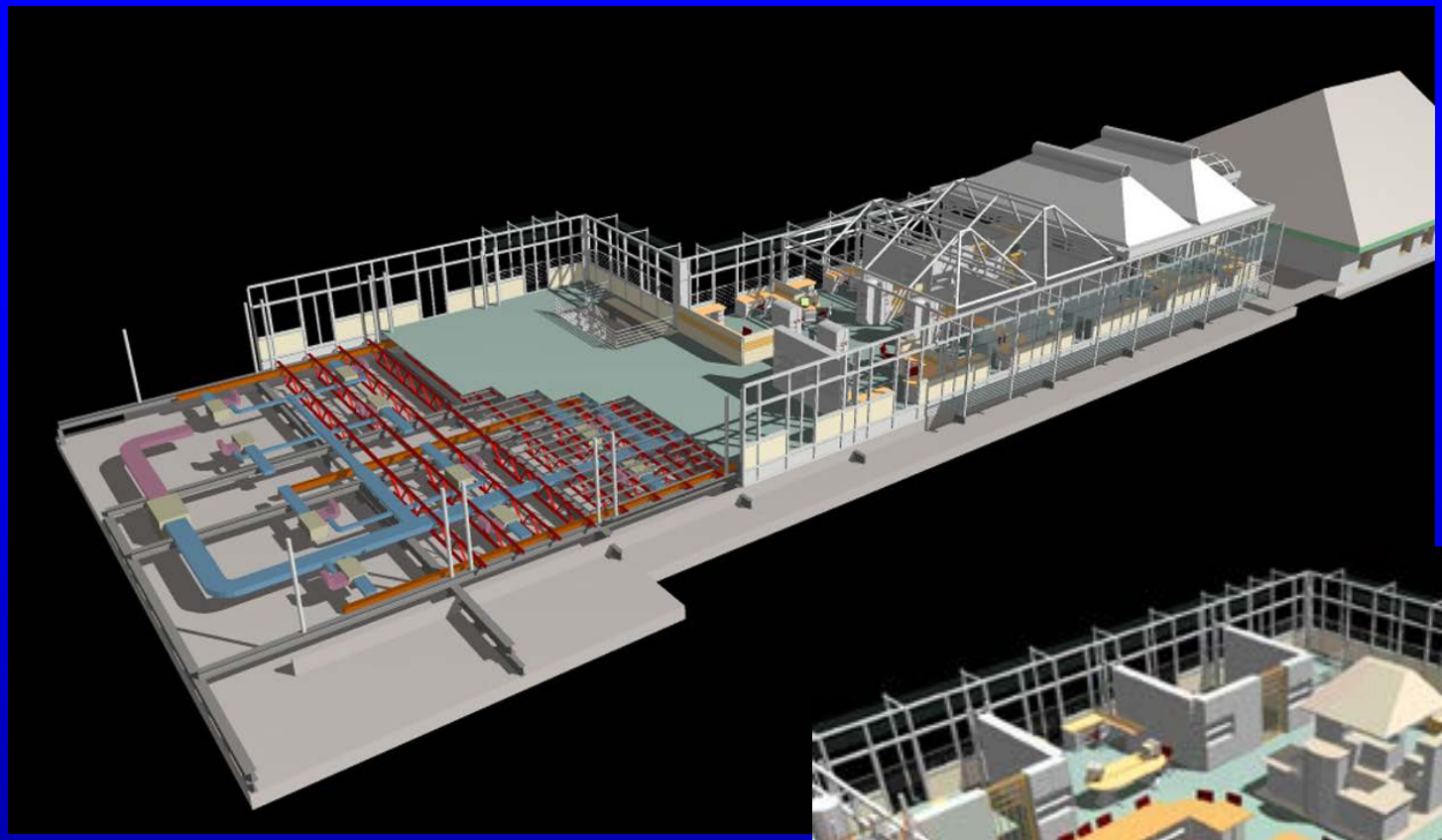
Network Infrastructure Layer

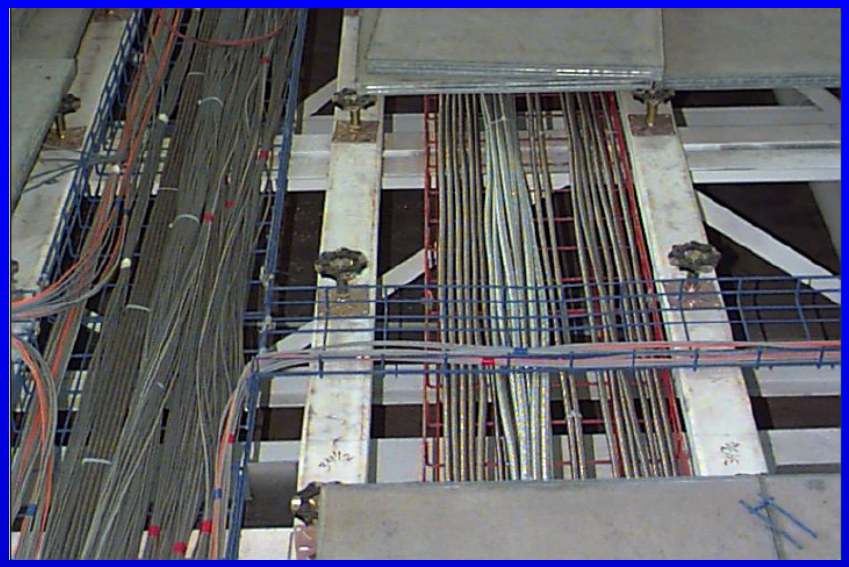
Sustainable design depends on the design of flexible, plug and play systems.

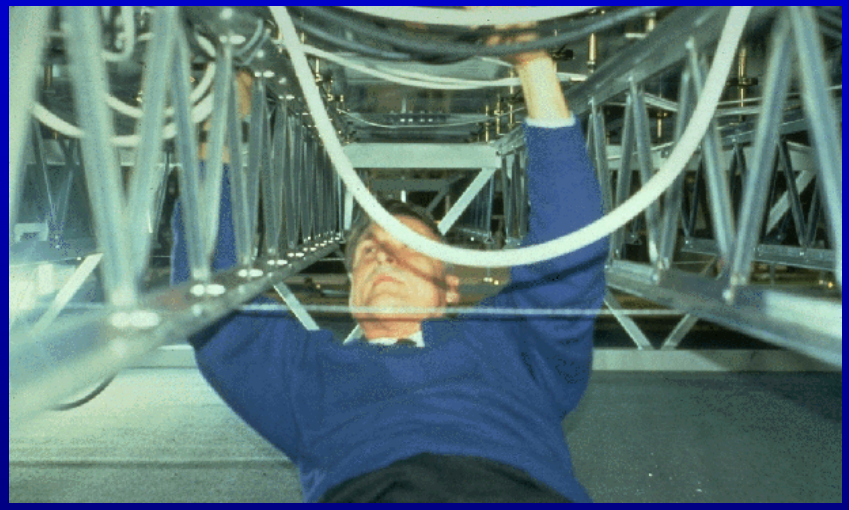


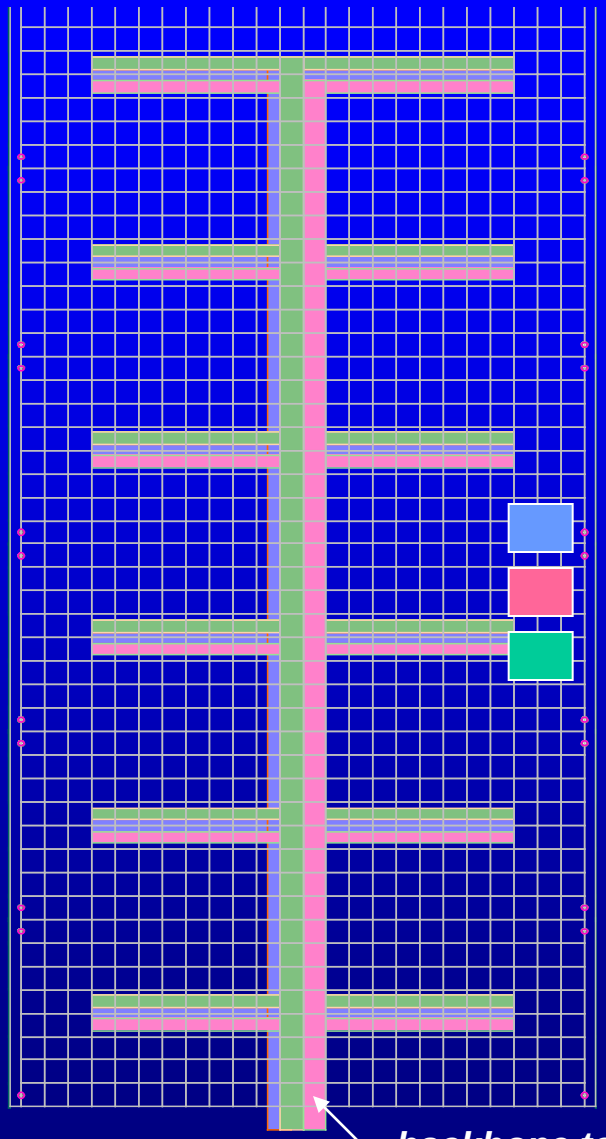


are a constellation of building subsystems that permit each individual to set the location and density of HVAC, lighting, telecommunications, and furniture, and the level of workspace enclosure (ABSIC/CMU).









Under-floor Infrastructure distribution


EXIT

The Intelligent Workplace, CMU

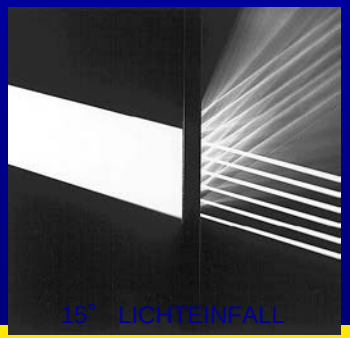
“Service Pub” :
equipment, ergonomics, places to pause and sit, interactive tools

Project Room

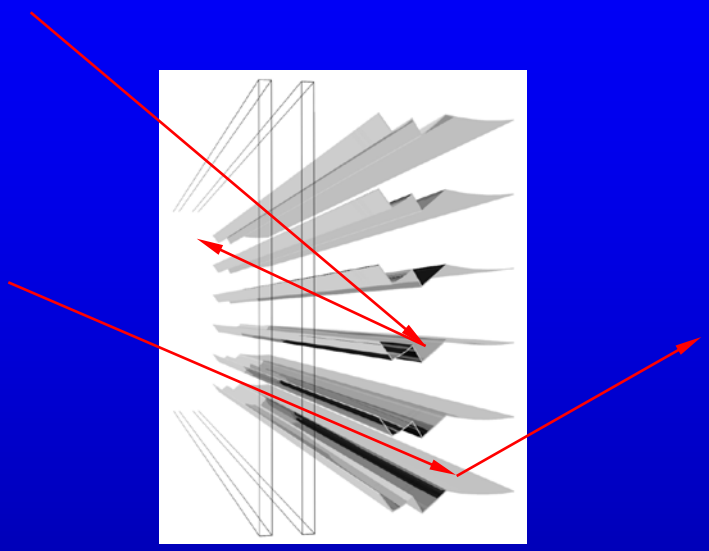
Conference Room (pre “service pub”)

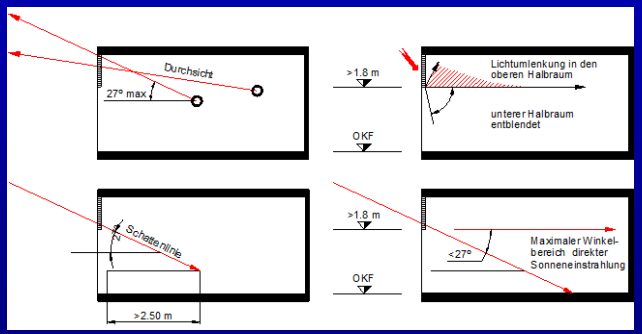
Intelligent Workplace at Carnegie Mellon University, built in 1997

TAGESLICHTLENKSYSTEME - RETRO *Lux*



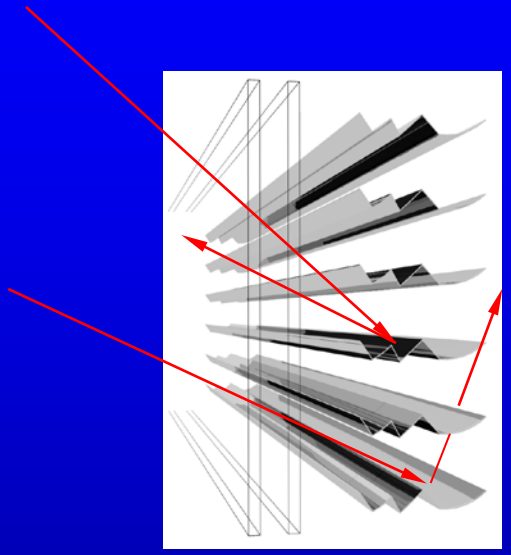
RETRO *Lux O*

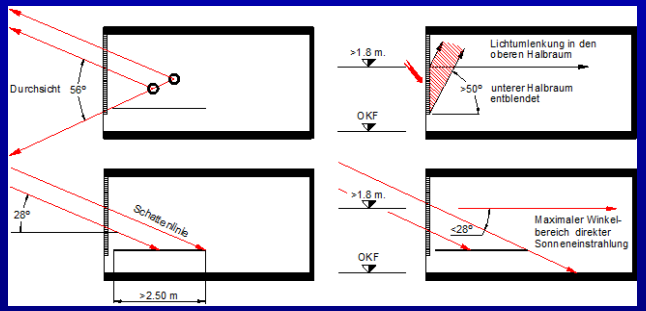




Funktionen der Lichtlenkung bei Horizontalpositionierung

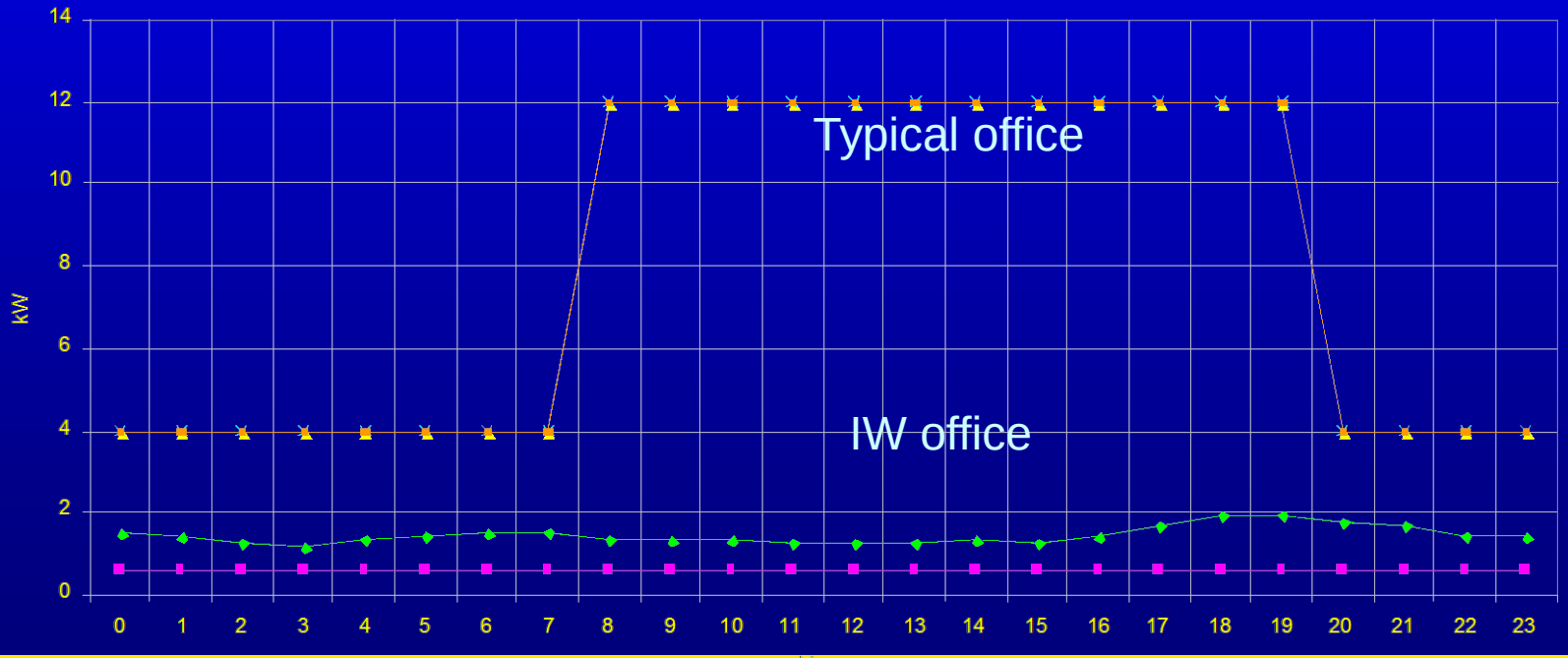
RETRO *Lux U*





Funktionen der Lichtlenkung bei Horizontalpositionierung

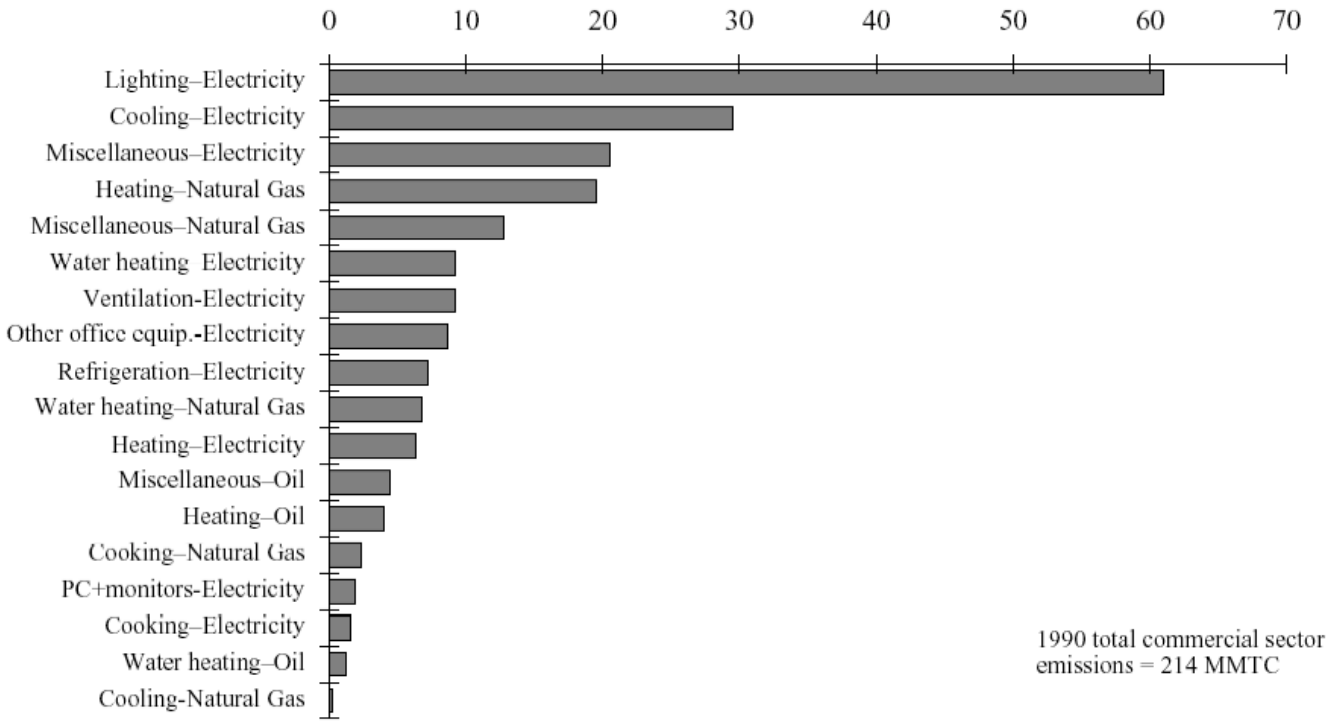
IW Average Lighting Energy Flow



Develop **innovative control systems** for lighting, thermal conditioning and ventilation as well as plug load management

Sebastian Peters, CBPD Intern from Technical University Munich, Germany

Figure 2: U.S. commercial sector carbon emissions by end-use 1990 (million metric tonnes of carbon)

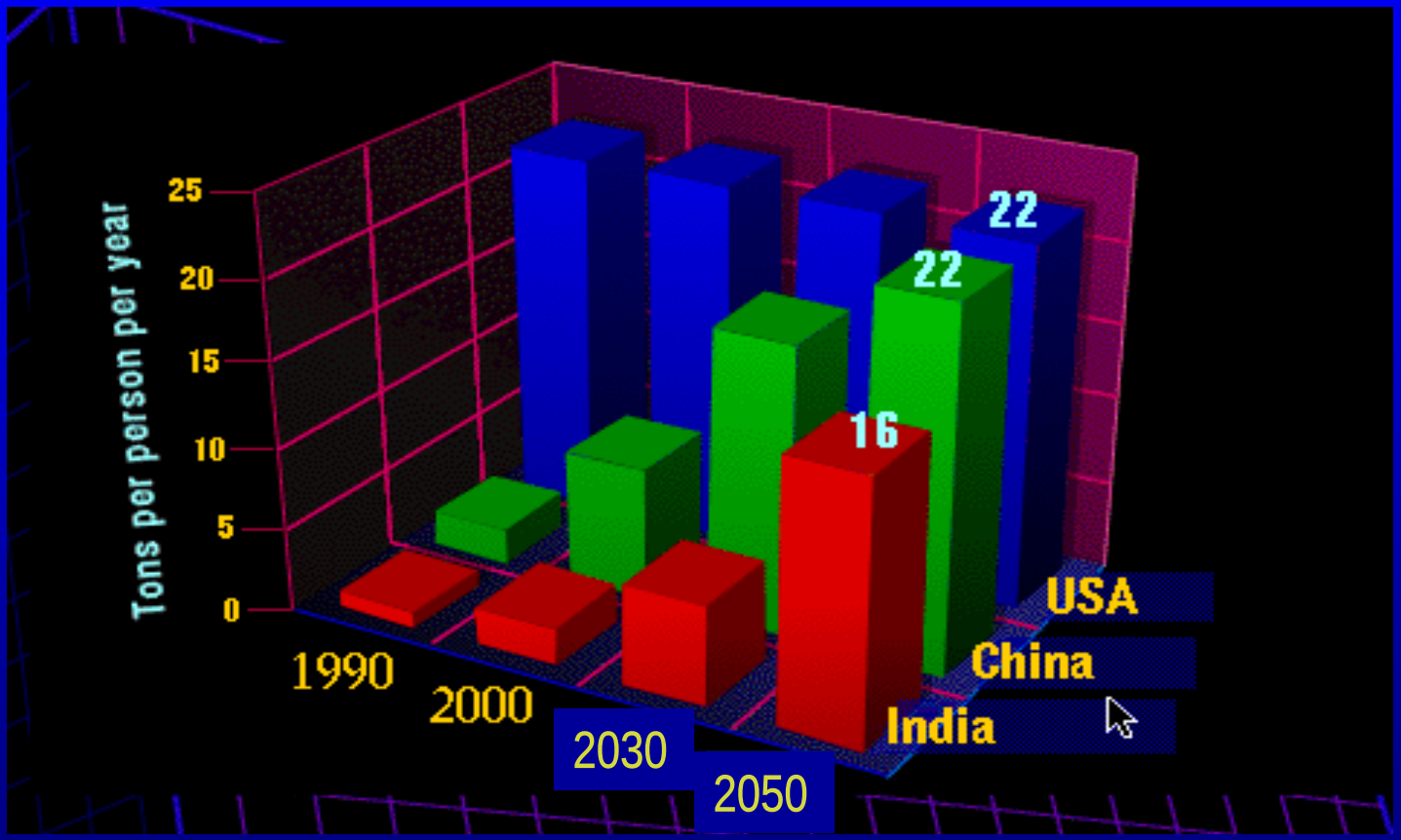


Koomey 1996

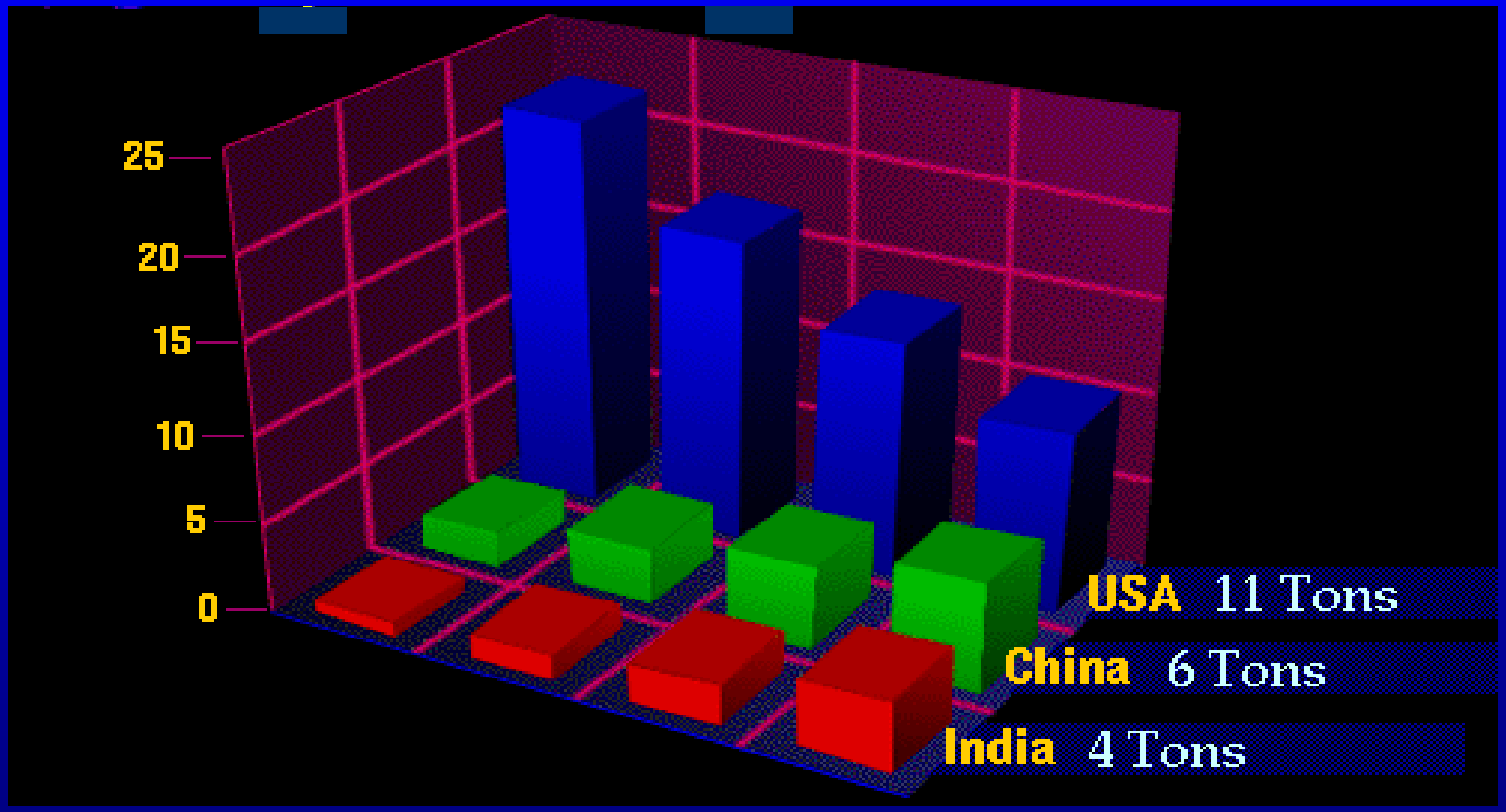
Charlie Brown FAIA Lighting Day-lighting Design

Berlin-Eberswalde County Building GAP Architects Berlin

What happens if China and India achieve our level?



Building programs can reduce USA CO_2 emissions and export technology to China and India



CO_2 Emissions (Tons) per $1 million GDP

China 781 (Trade Surplus with USA $250 Billion)

USA 171 (Trade deficit $750 billion)

Germany 86 (Trade Surplus $250 Billion)

Japan 80

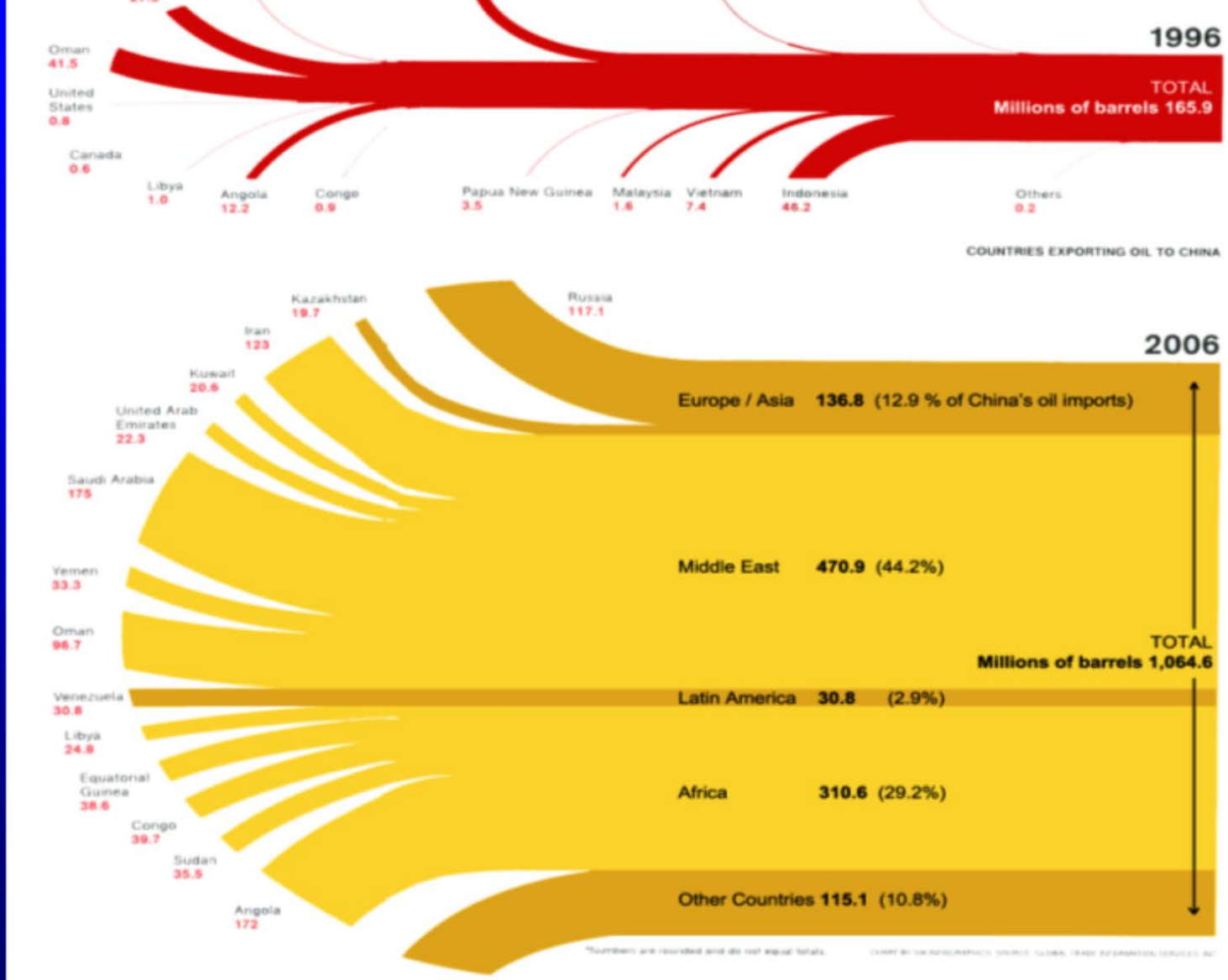
France 50

Source: World Bank 2006

CHINA 2006
Imports more than 1 billion barrels of Oil/year
(6x more than 10 years ago)

US OIL Consumption 19.6 million barrels per day 6.6 billion/year
Source: EIA

Source: National Geographic, p172-173, May 2008



Chinas oil importation needs from 1996 – 2006.
Note, oil imports from Saudi Arabia increased 100x Until 2006 and DOUBLED from 2006-2009!

Ministry of Science and Technology - MOST

Beijing, China

In December 1999 the US Department of Energy (DOE) held a workshop in the Robert L Preger Intelligent Workplace (IW) attended by 100 Chinese Government Officials, Professionals and University Researchers to discuss opportunities for bi-lateral co-operation.

Subsequently, a team was formed between US DOE officials and researchers from National DOE laboratories (NREL and LBNL), the CBPD at CMU and the Natural Resources Defense Council. Workshops were conducted in IW which led to the re-design of the MOST building. Volker Hartkopf was invited to act as systems integrator and participate in workshops in Beijing, China.

The resulting 12 thousand square meter (about 135 thousand square feet) building houses the Chinese Climate Change professionals of MOST. The building has been operating for over 18 months and the measured energy consumption is 87% below the consumption of an ASHRAE 90.1 base building.

The MOST Agenda 21 building has become known as one of the most energy effective buildings in all of China and has been prominently featured in an exhibition and the official keynote speech during the First International Green Building Conference in China, held in Beijing in March 2005.

Design Concepts and Systems Integrators
Center for Building Performance and Diagnostics
Volker Hartkopf

Tsinghua University

Low-Energy Demo Building
Beijing, China

Tsinghua University is the leading technical and scientific university of China. During the 1990s Volker Hartkopf was invited to be the keynote speaker at several conferences held at Tsinghua. Subsequently, key faculty and researchers came to experience the Robert L Preger Intelligent Workplace. The School of Architecture, with funding from the CBPD, accepted very well educated PhD students, coming highly recommended from Tsinghua university.

Based on these experiences, Tsinghua University's School of Architecture decided to create the Tsinghua University Low Energy Building modeled after the IW. Volker Hartkopf was asked to advise the design and engineering team of the university on systems integration, interior flexibility, as well as material and component choices. Volker Hartkopf gave a keynote speech during the opening ceremonies in March 2005. He now serves on the University's Building Energy Academic Advisory Board.

Design Concepts and Systems Integrators
Center for Building Performance and Diagnostics
Volker Hartkopf

US-China are key to international agreement on climate change

- U.S.
  - House passed American Clean Energy & Security Act in June
  - Senate released Clean Energy Jobs and American Power Act in Oct
  - Obama to visit China on Nov 16-18
  - Hill briefing on Nov 17, sponsored by the Senate Foreign Relations Committee
- China
  - President Hu Jintao announced to cut carbon intensity by a notable margin
  - Increase its renewable energy share in its energy portfolio

	Installed capacity by 2008	2020 target set in 2007	2020 target revised in May 2009	Proposed new 2020 target
wind	12.17 gW	30 gW	100 gW	150 gW
solar	140 mW	1.8 gW	10 gW+	20 gW

Source: Kevin Mo, NRDC

Global Network of Universities

- Proposal to create a global network of best practices at universities and communities to be supported by (prior recommendations slide..)
  - Who in the Singaporean Government could become interested in this idea?