Opportunities for Energy Efficiency in Buildings

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School of Architecture and Planning
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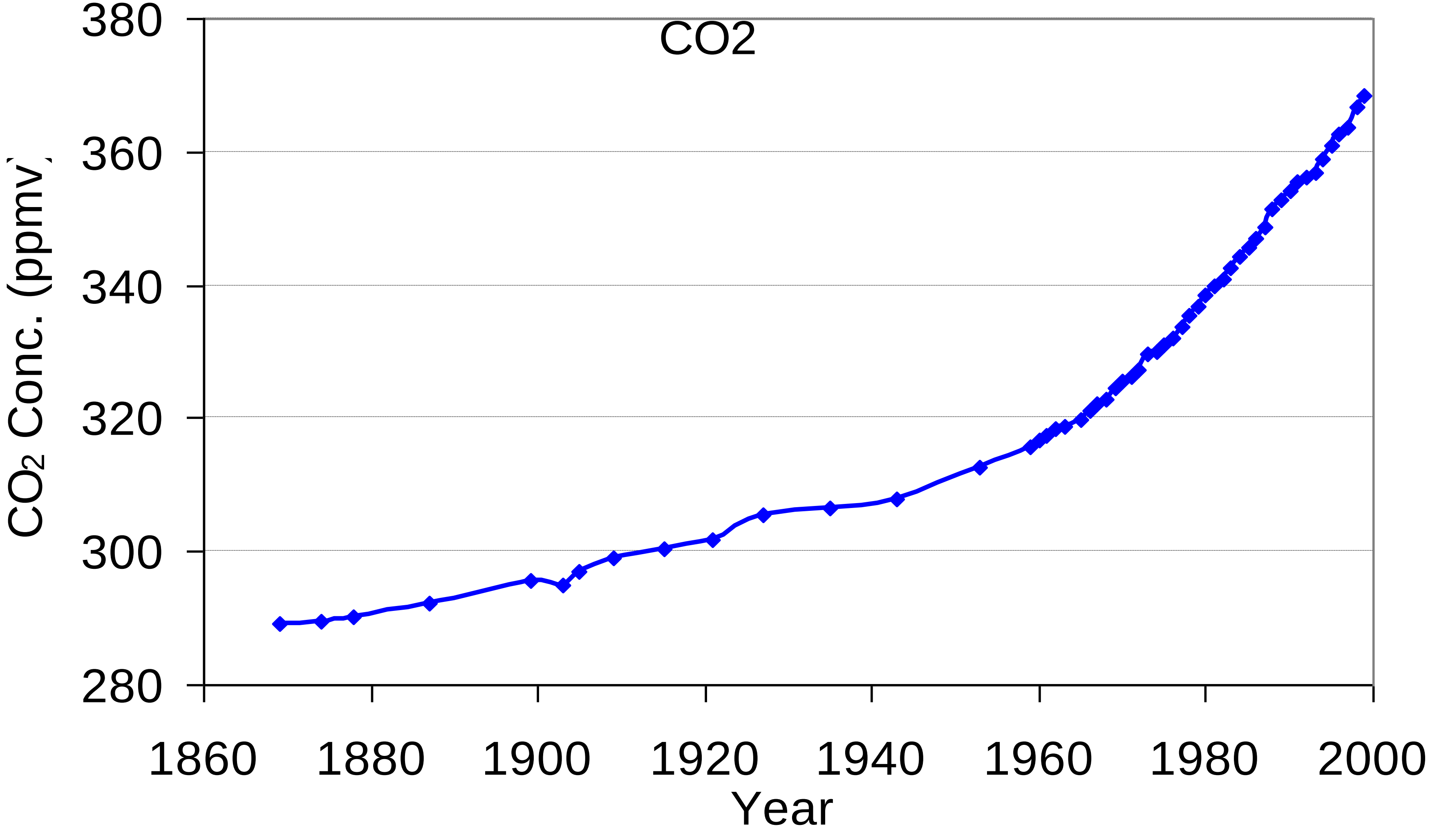
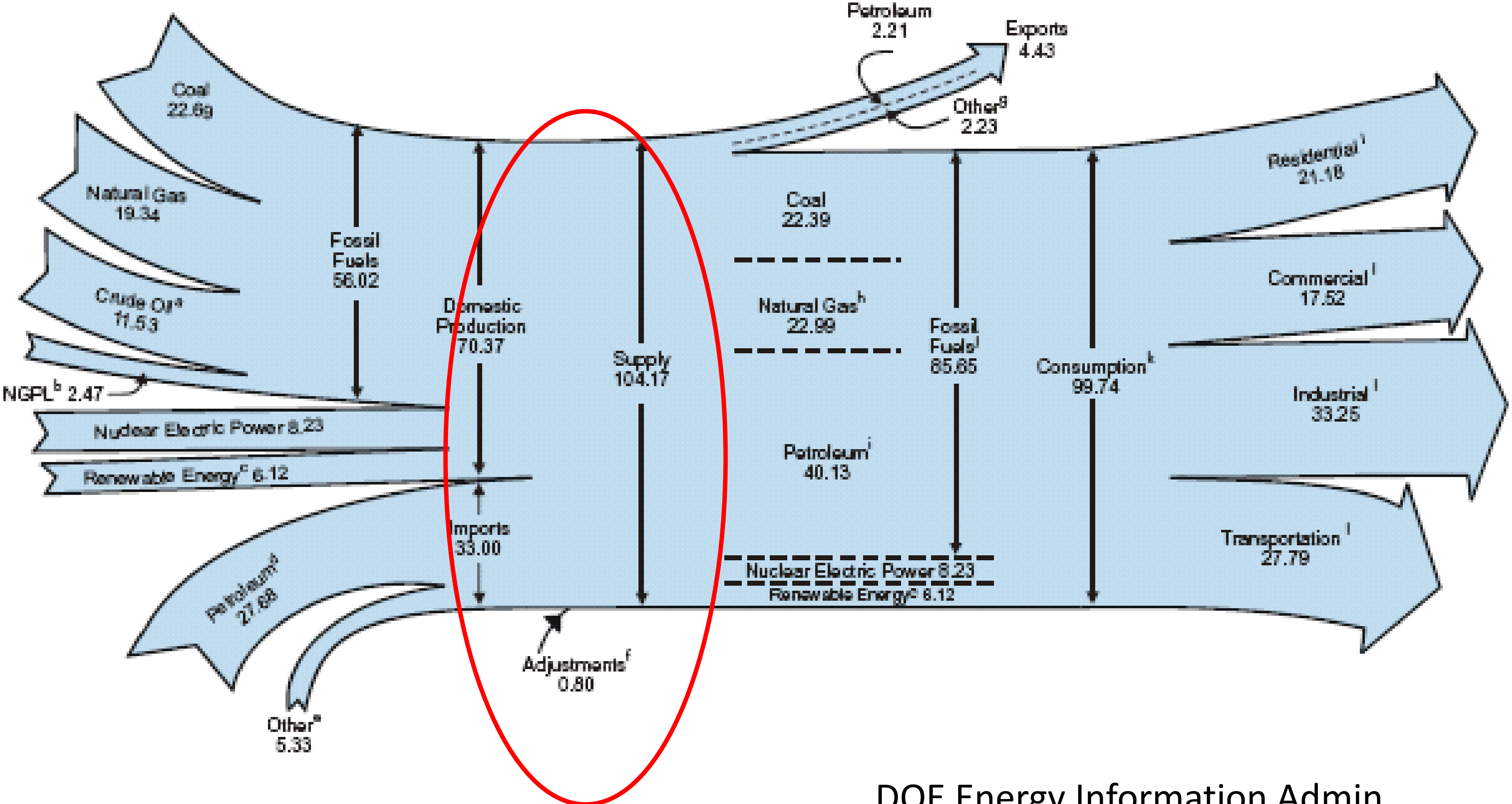
May 26, 2011

Atmospheric CO_2 Concentration

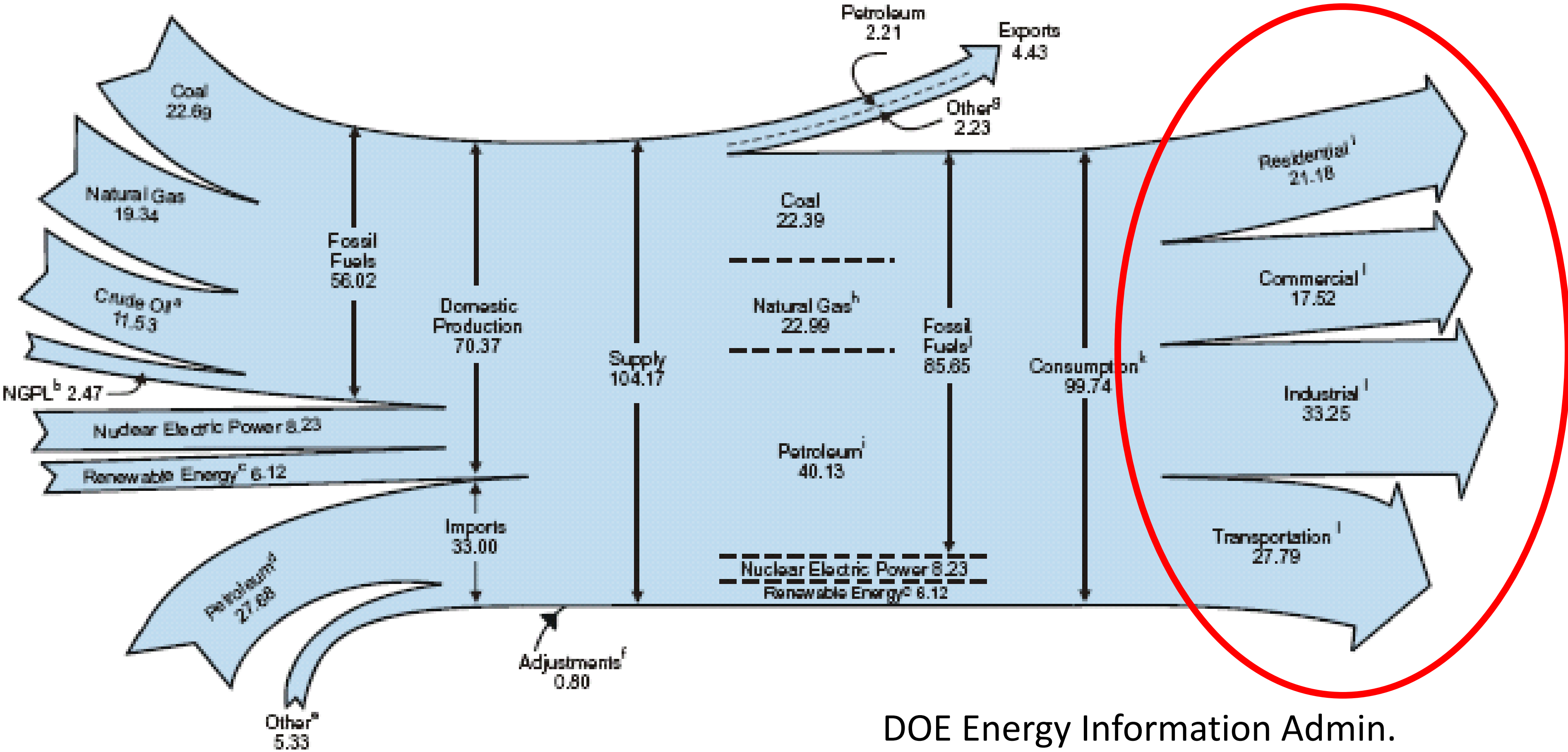


U.S. Energy Flow 2004
Traditional Solution Focus



DOE Energy Information Admin.

U.S. Energy Flow 2004
Neglected Focus



DOE Energy Information Admin.

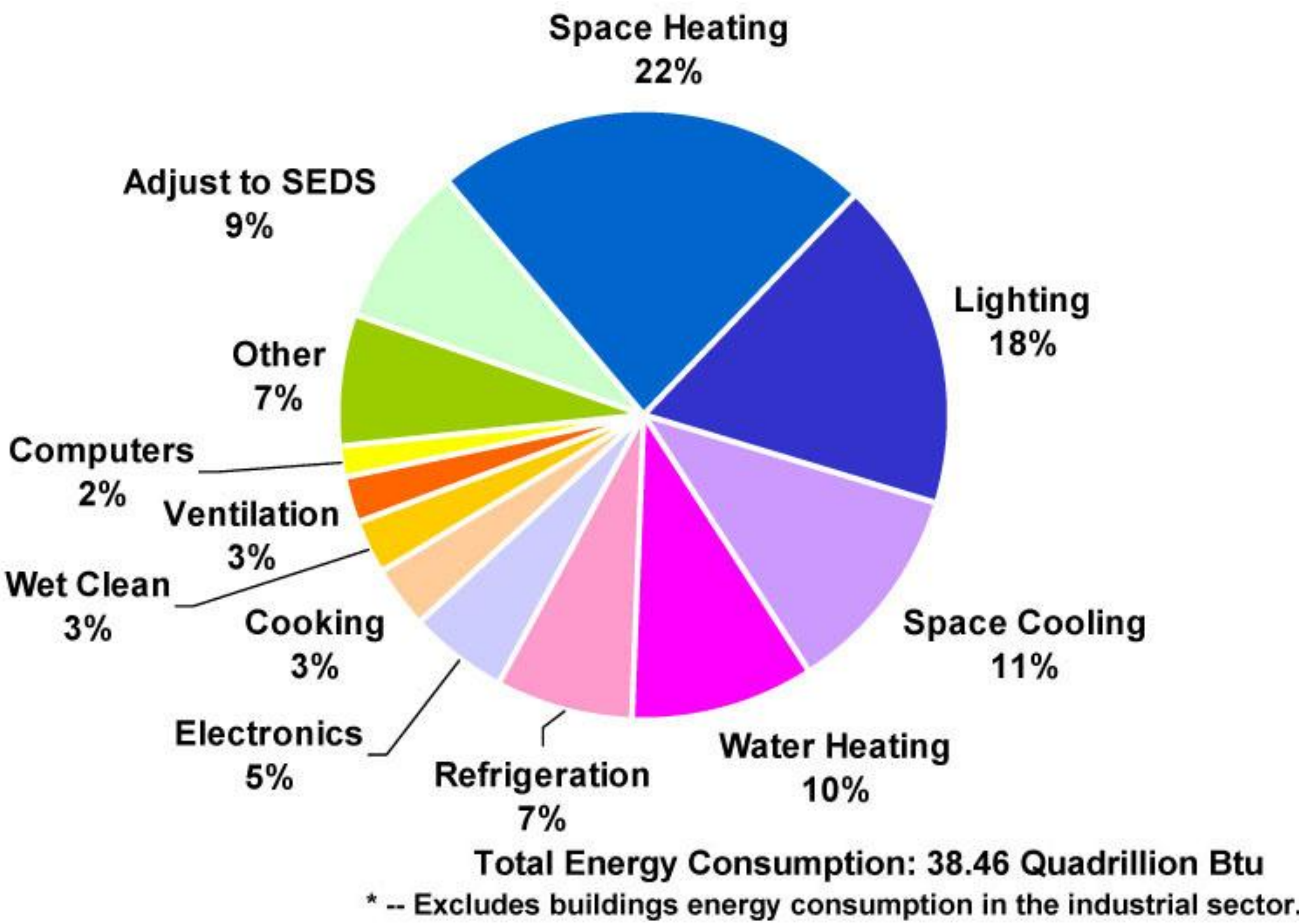
Energy Efficient Buildings

- Building Efficiency is an Important Solution to Energy Problem
- Cost Effective when Done Properly
- Requires Integrated Approach
- Important Contributions
  - New Technology
  - New Assessment Tools: Virtual Building
- Challenges in the future

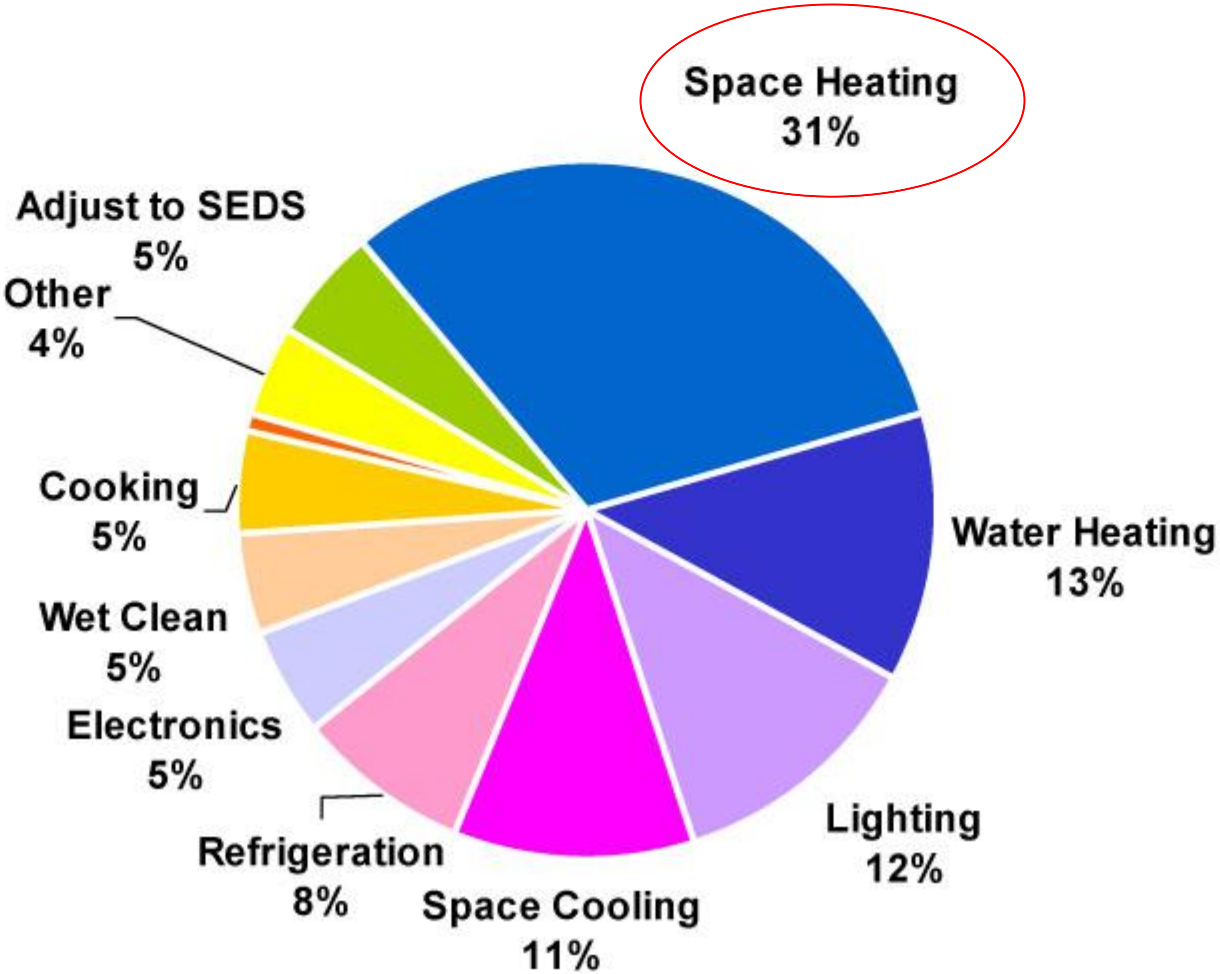
U.S. Buildings

- 39 % of total energy (in UK 50 %)
- 72 % of electricity
- 90% of time spent indoors
- Major health problems: indoor climate

2004 U.S. Buildings End Use

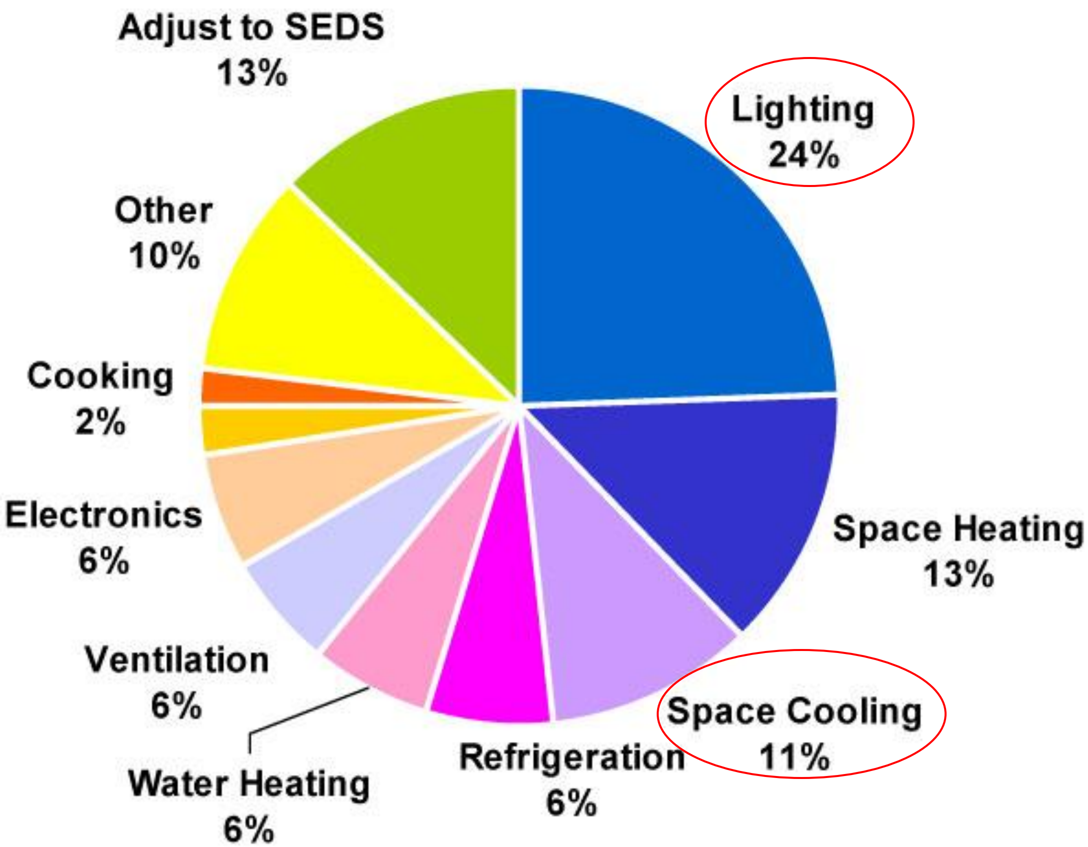


2004 Residential End Uses



Total Energy Consumption: 21.07 Quadrillion Btu

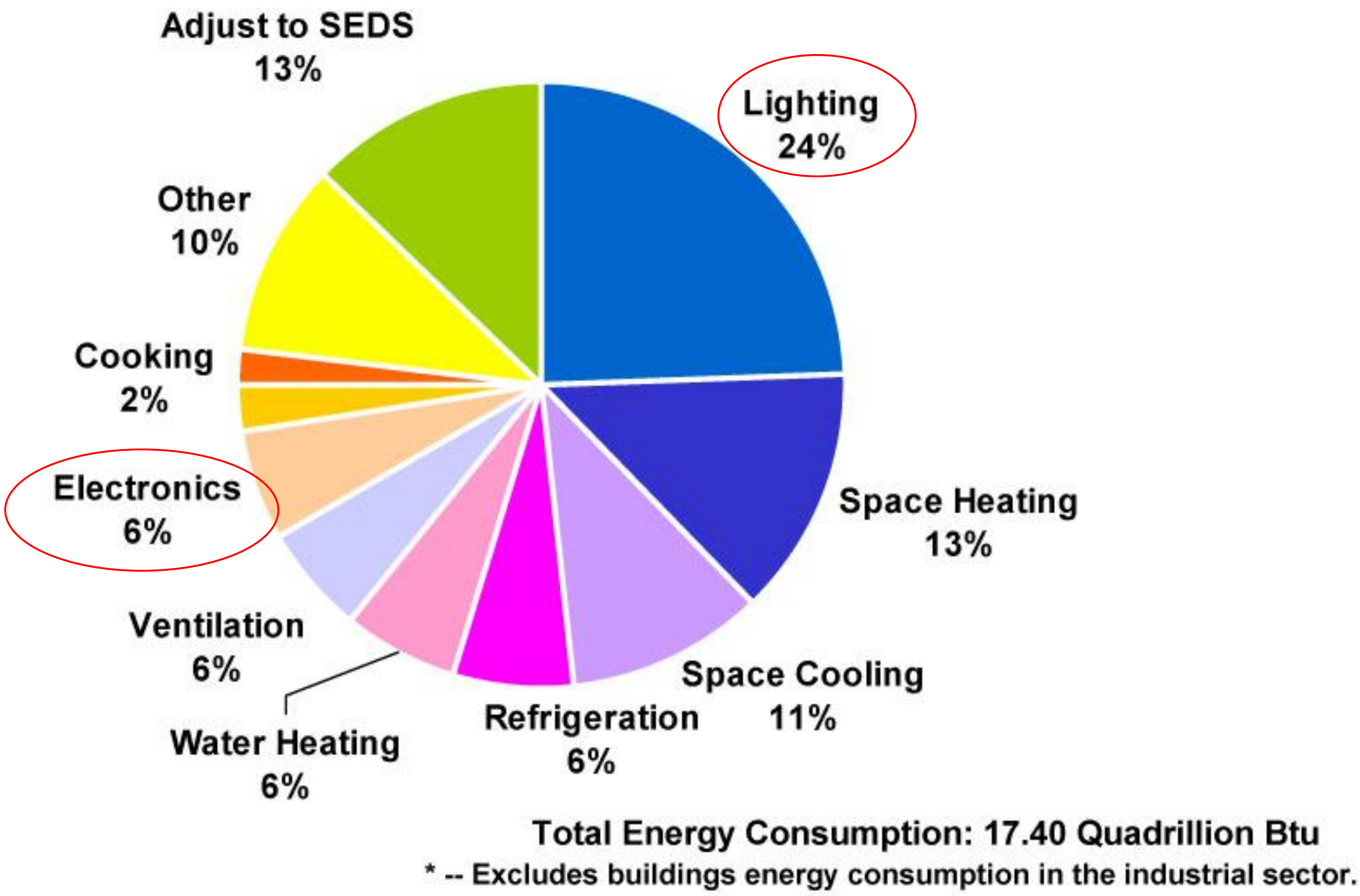
2004 Commercial Buildings End Use



Total Energy Consumption: 17.40 Quadrillion Btu

* -- Excludes buildings energy consumption in the industrial sector.

2004 Commercial Buildings End Use



Physical Limits of Performance

Commercial Buildings
For example: green roof, cool roof??
Zero net energy high rise?
 Cover entire surface with PV, what % of building energy?

Wind

Economic Limits

Electric Power Costs

Technology	Cents/kWe-hr
Nuclear	4-7
Gas/Combined Cycle	4-6
Coal	4

Sources: Deutch and Moniz, MIT study 2003; Langcake, Renewable Energy World, 2003; Kats, California study, 2003

Electric Power Costs

Technology	Cents/kWe-hr
Nuclear	4-7
Gas/Combined Cycle	4-6
Coal	4
Renewable	
Wind	3-8
Biomass (25MW)	4-9
Small Hydro	5-10
Solar Thermal Electric	12-18
Solar PV	30-80

Sources: Deutch and Moniz, MIT study 2003; Langcake, Renewable Energy World, 2003; Kats, California study, 2003

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Solar PV	30-80
Efficiency of Consumption	
Advanced Buildings	0-6

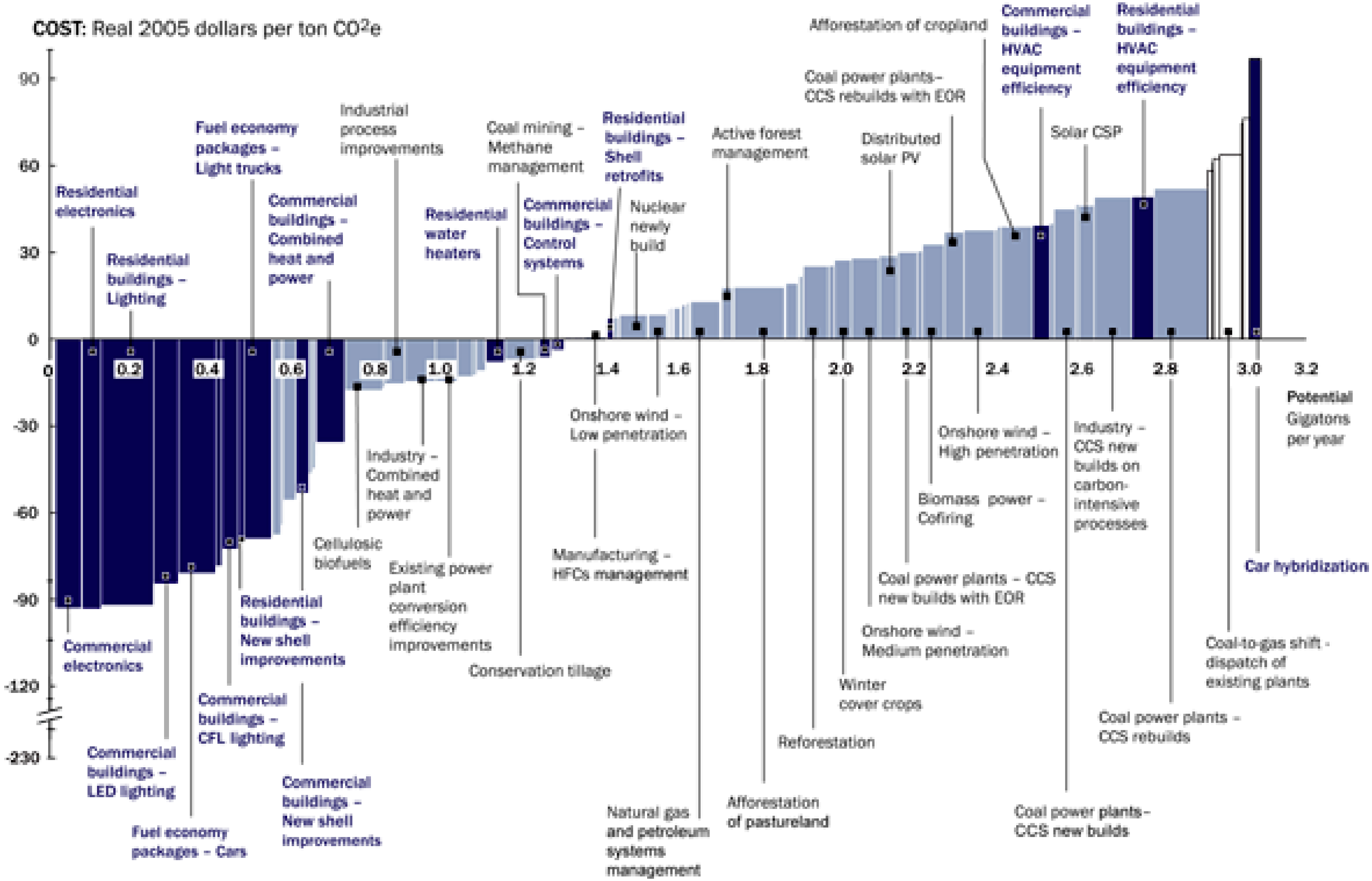
Sources: Glicksman Physics Today 2008 Deutch and Moniz, MIT study 2003; Langcake, Renewable Energy World, 2003; Kats, California study, 2003

Figure 2

U.S. mid-range abatement curve - 2030

Carbon dioxide abatement: estimated removal cost per ton of CO^2 in 2005 dollars and removal potential in gigatons/yr for various strategies.

Transportation and building efficiency measures



Energy Efficient Buildings

- Building Efficiency is an Important Solution to Energy Problem
- Cost Effective when Done Properly
- Why don’t more US homes adopt efficient measures?

Barriers

- Conservative Industry
- Fragmented Field
- Lowest First Cost
- Lack of Incentives
- Poor Education
- Lack of information
  - Performance Projections
  - Results from New Buildings
- Linear Designs

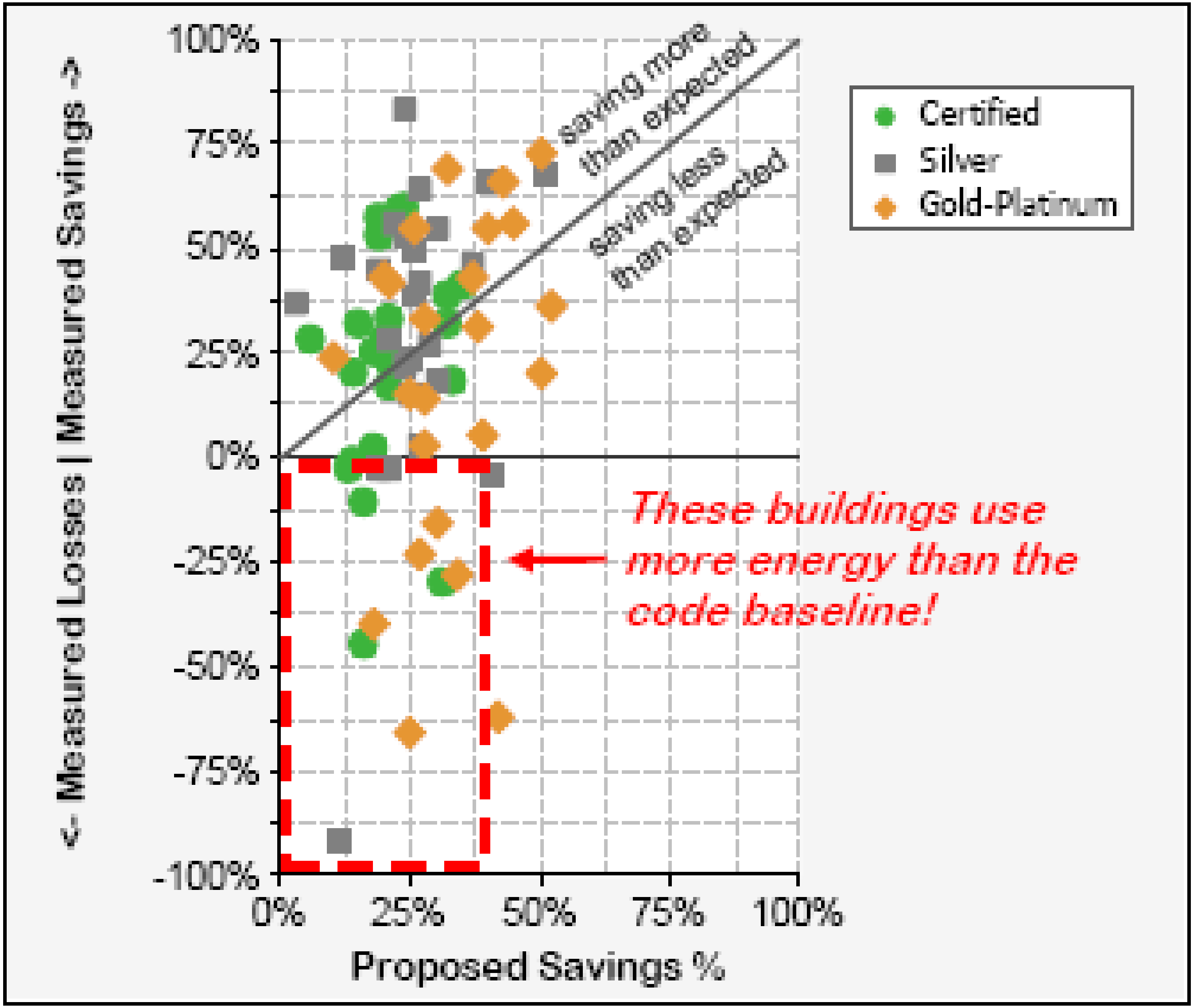


Figure ES- 5: Measured versus Proposed Savings Percentages

There's no single silver bullet to solve the energy problem

There's silver buckshot

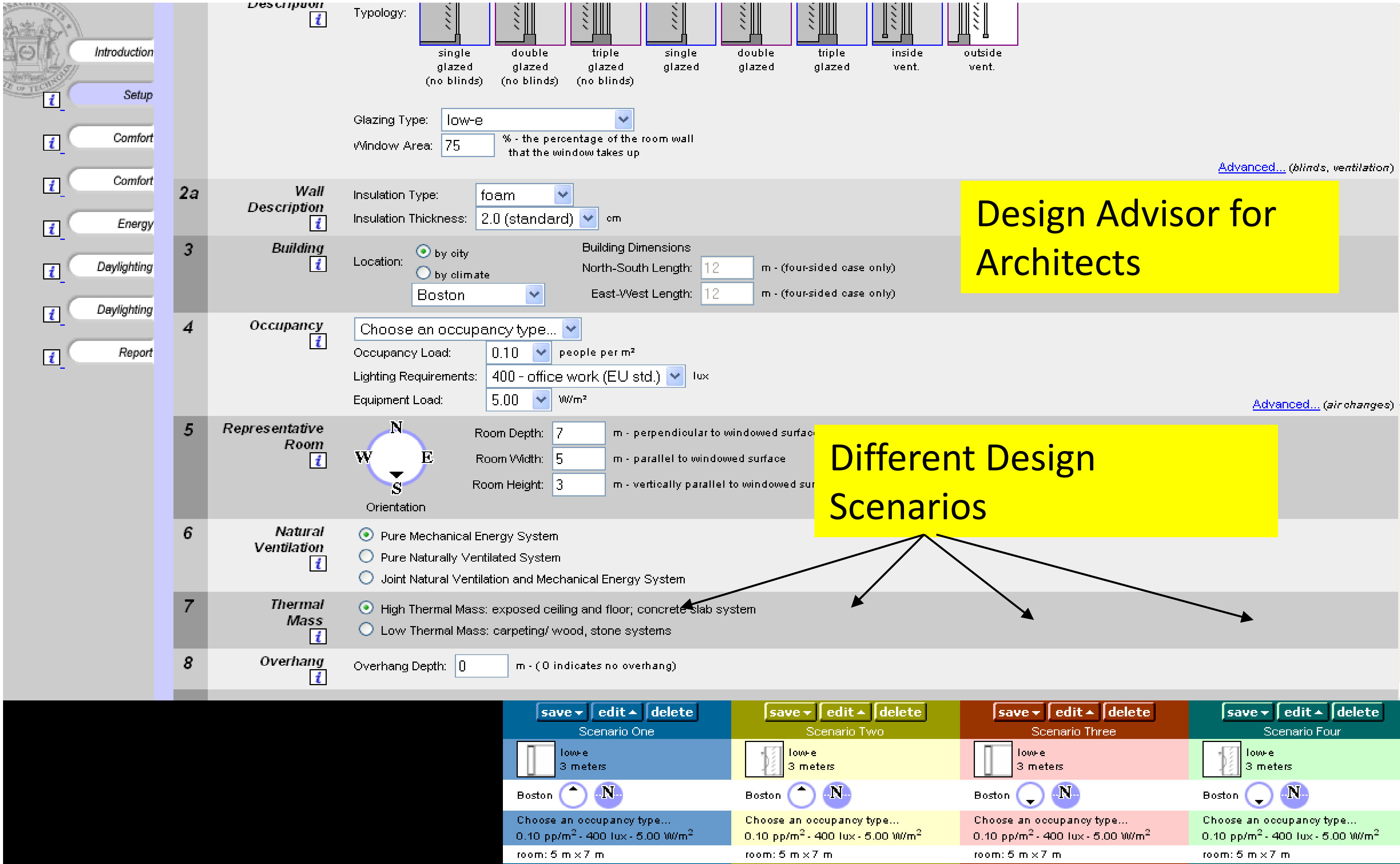
Building Technology Program at MIT

- Joint program Architecture and Engineering
- 5 full time faculty
- 25 graduate students
- Research on the next generation of technology
  - Materials
  - Energy efficient operations
  - Community level impact

- Research on integrated design
  - Optimized design
  - Trade off: energy efficiency- renewables

Virtual Design Tools - some examples:

MIT Design Advisor



Commercial Roof Types

modified bitumen roof

ballasted roof

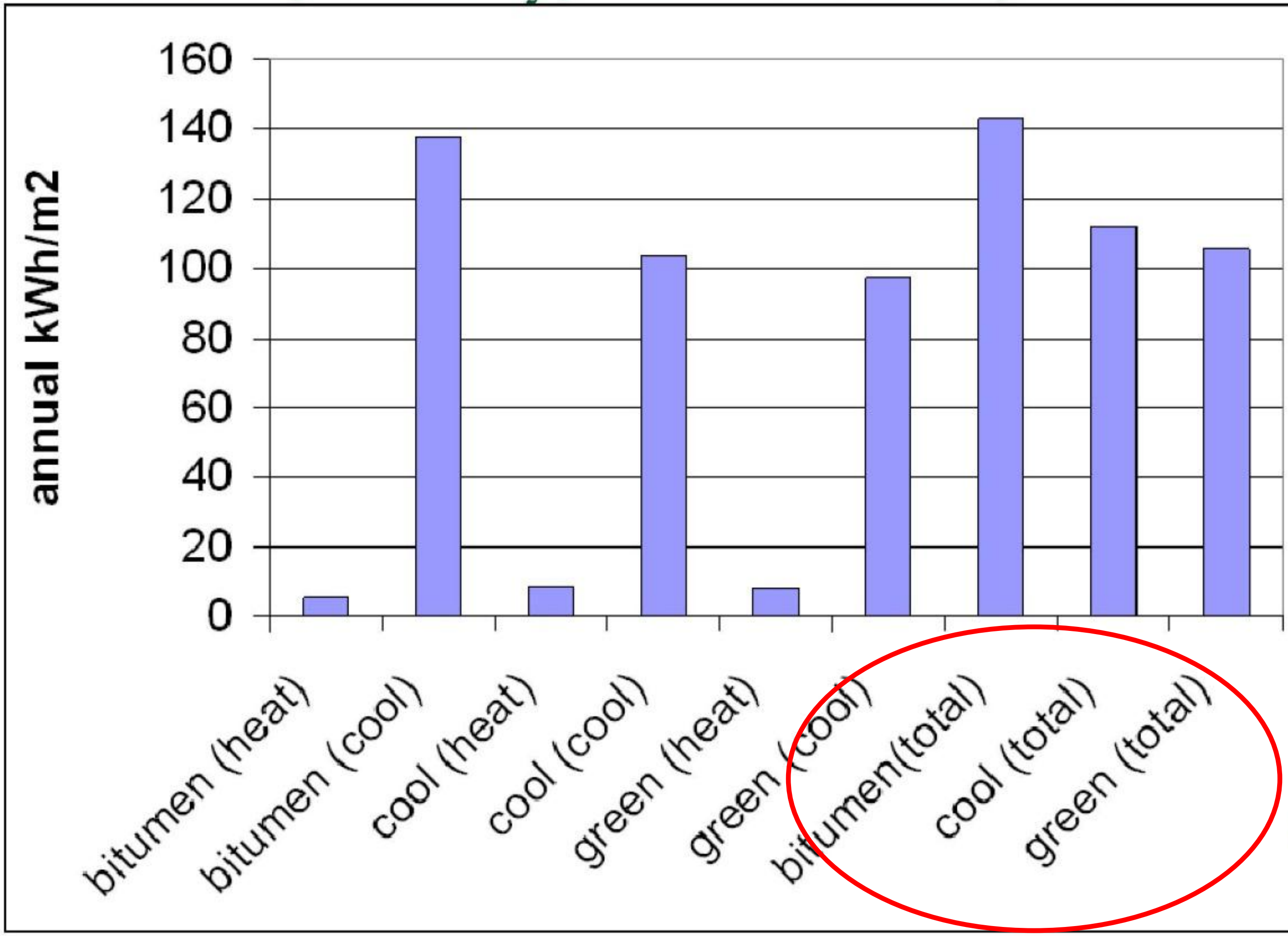
cool roof

green roof

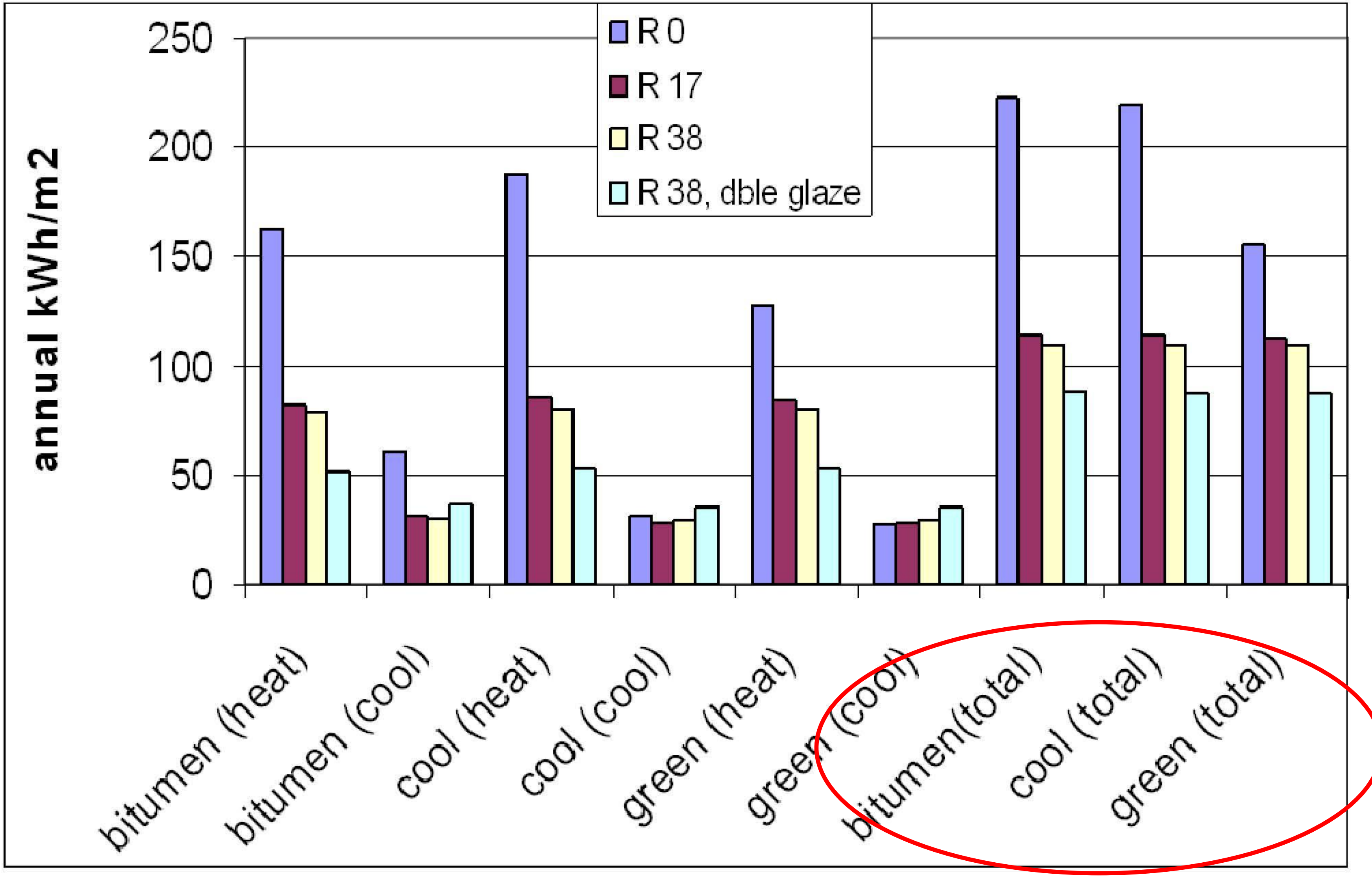
http://www.lexiscoatings.com/wp-content/uploads/mod-splash.jpg
http://home.att.net/~wavetrader/spf6.JPG

https://ssl2.msstate.edu/vpfa/admin/fm/conprojects/conprojimages/00000441.jpg
http://www.epa.gov/region8/images/greenroof_terrace.jpg

Phoenix, 1-story, no windows, R 9



Boston, 3-story, 50% glazing in each room



Supply ⟷ **Demand**

- -Renewables
- -Distributed generation

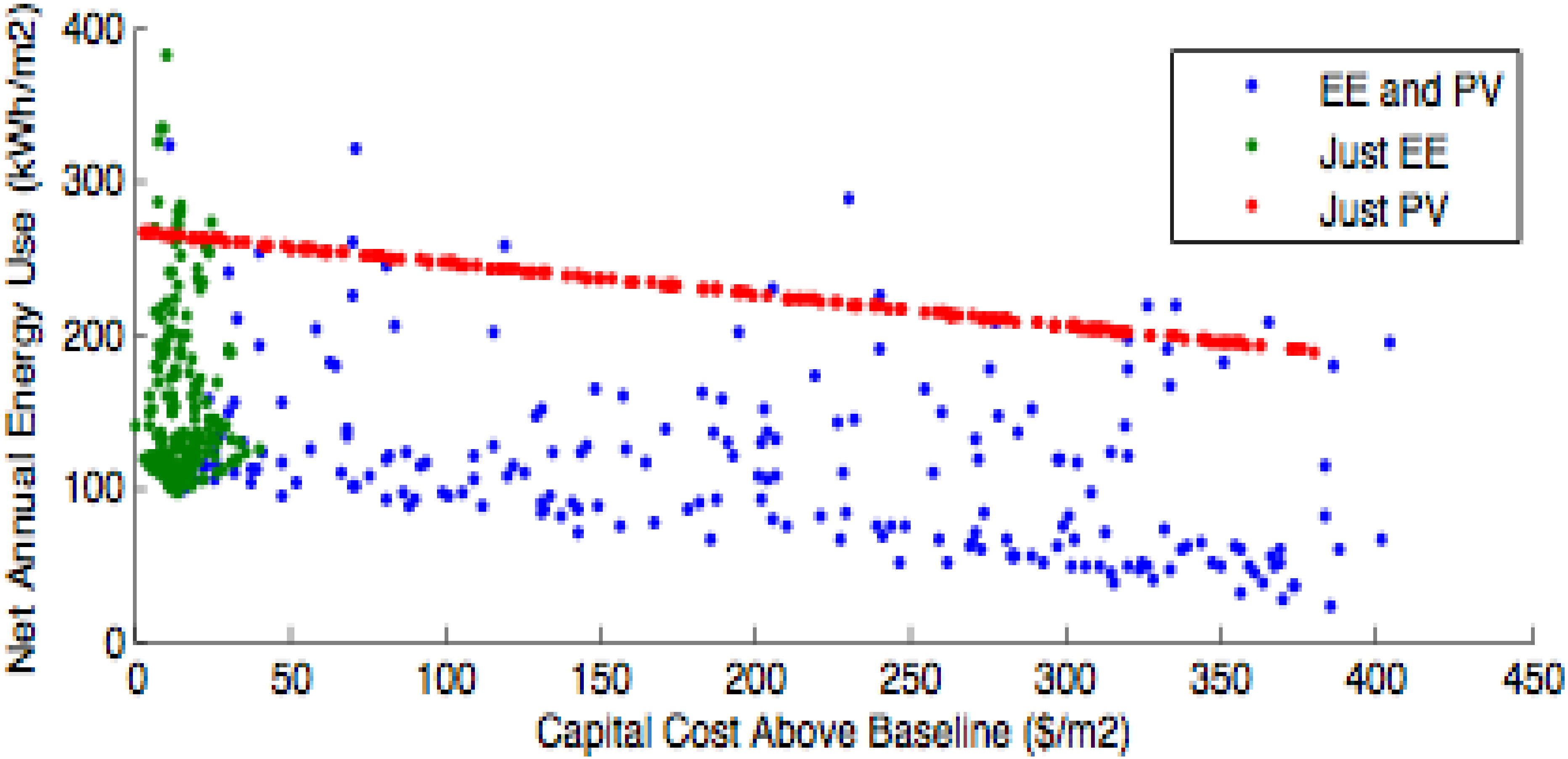
"Negawatts"

- Energy efficiency
- Smart controls
- Smart people

Toward net zero energy systems

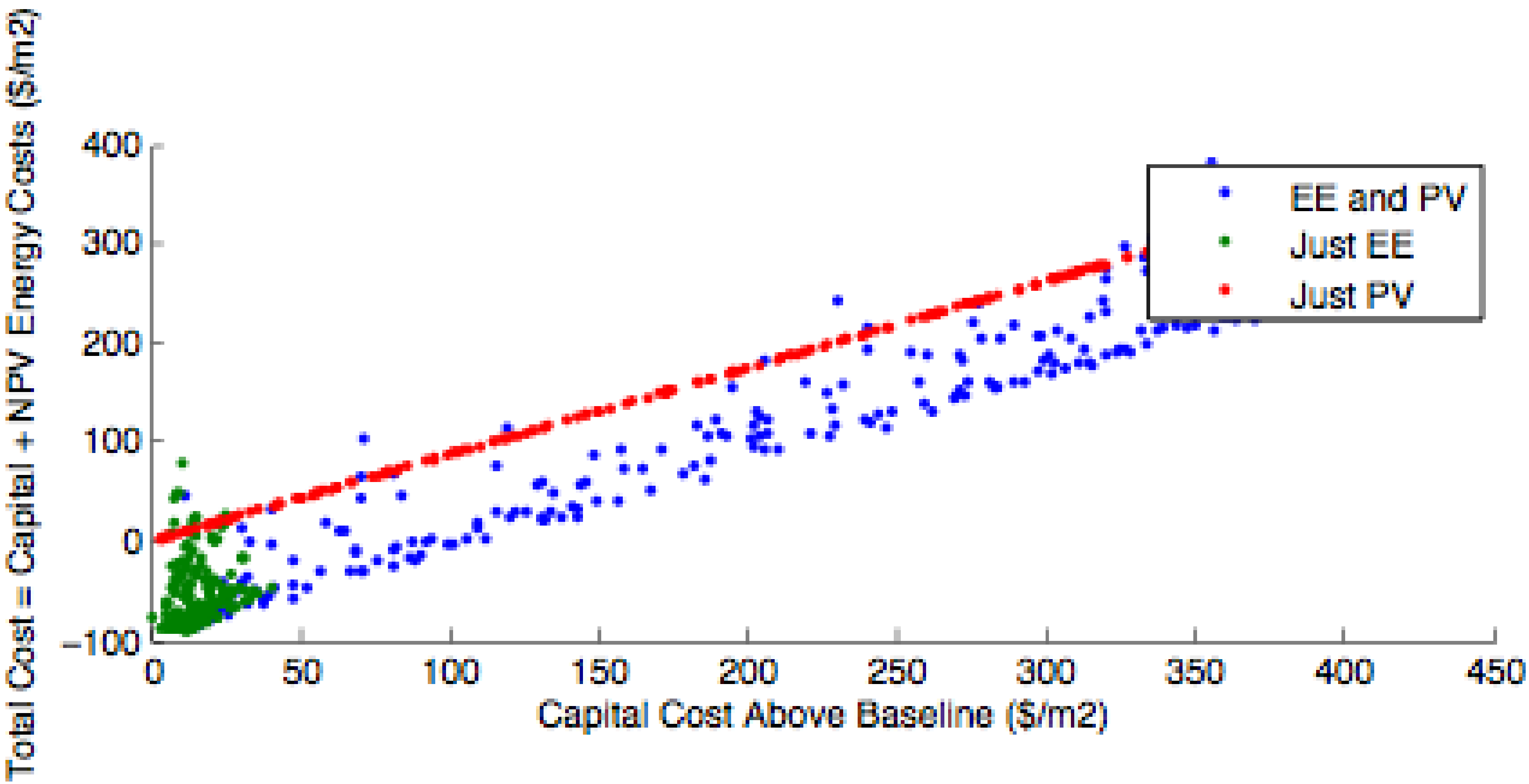
ABU-DHABI MASDAR DEVELOPMENT
Goal: Zero Carbon

Foster and Partners



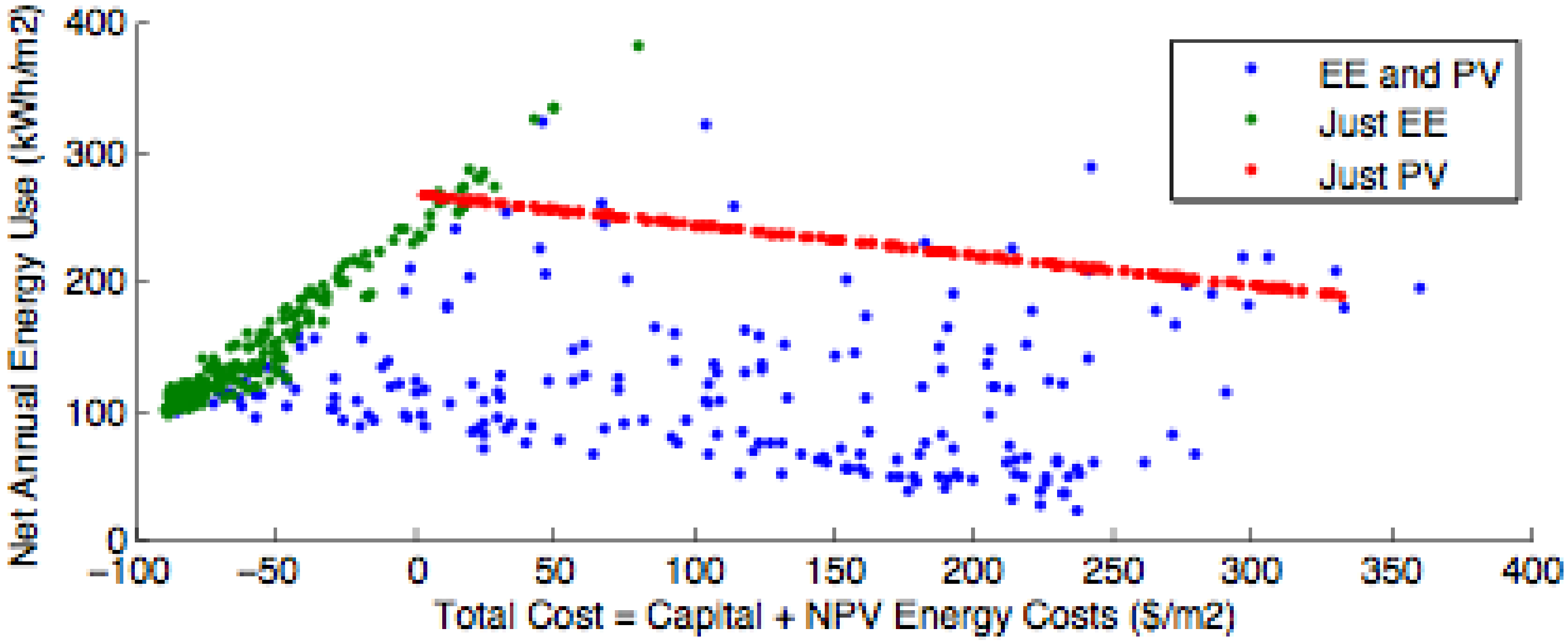
Energy Use vs Additional Capital Cost Above Baseline Commercial Building
PV $4/W over 5 years.

Total Cost vs Capital Cost



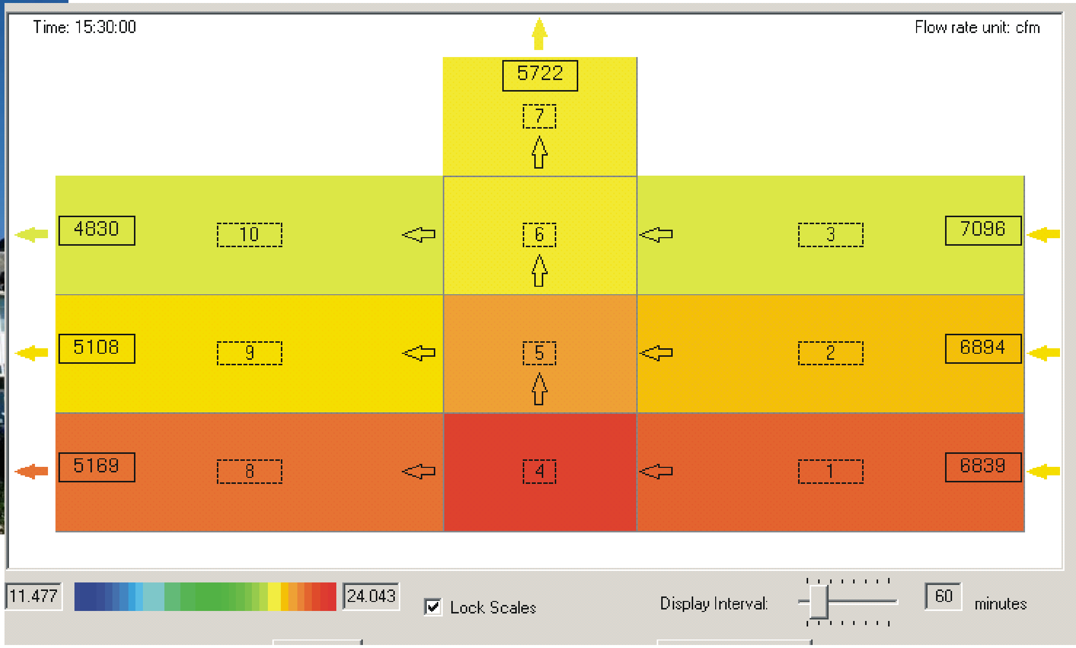
Updated output

$4/W over 5 years.



Natural Ventilation

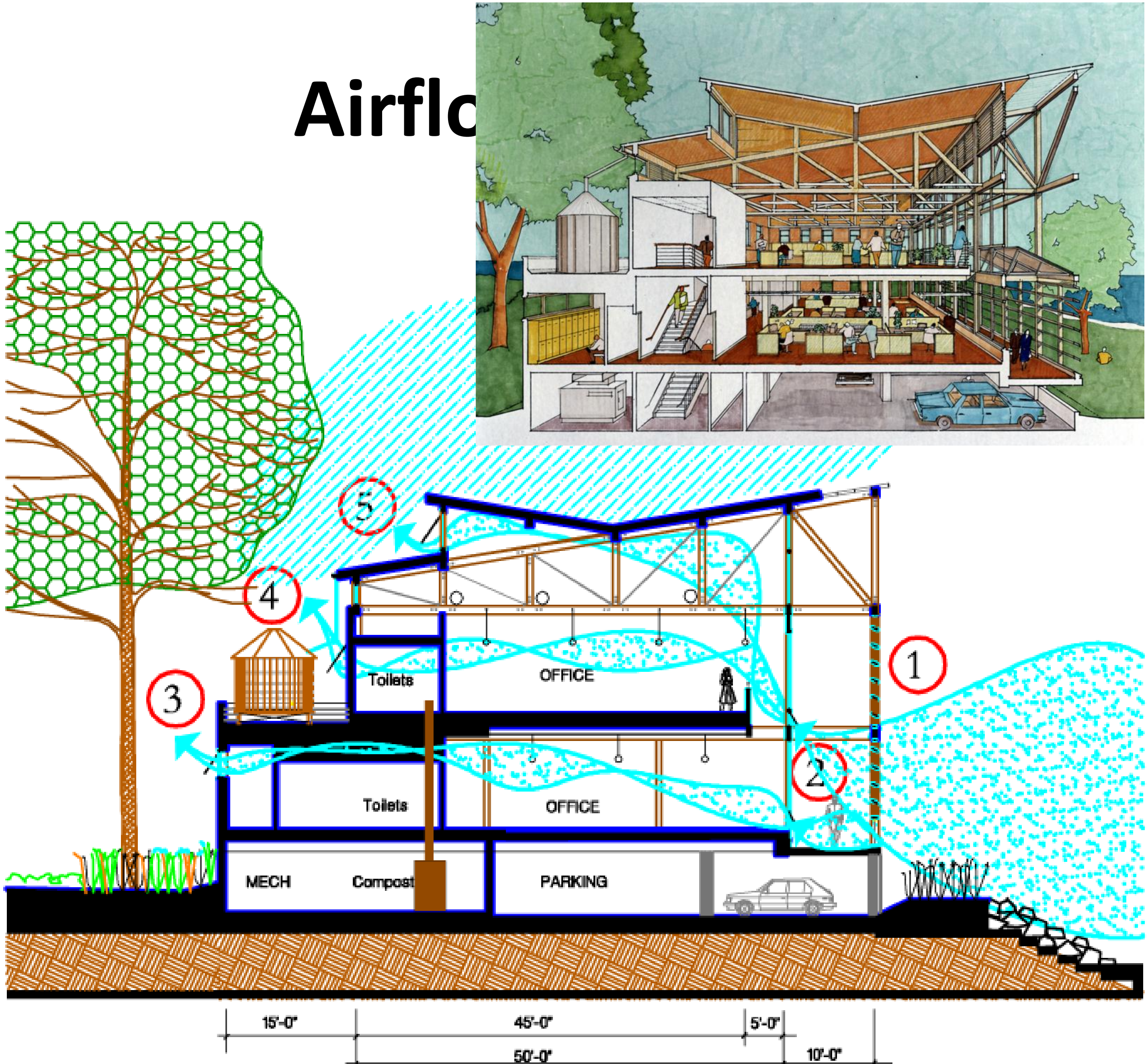
Luton, England
MIT- Cambridge University
Monitoring and Simulation



MIT CoolVent Design Program

Test Building 2
Philip Merrill Environmental Center

Airflo

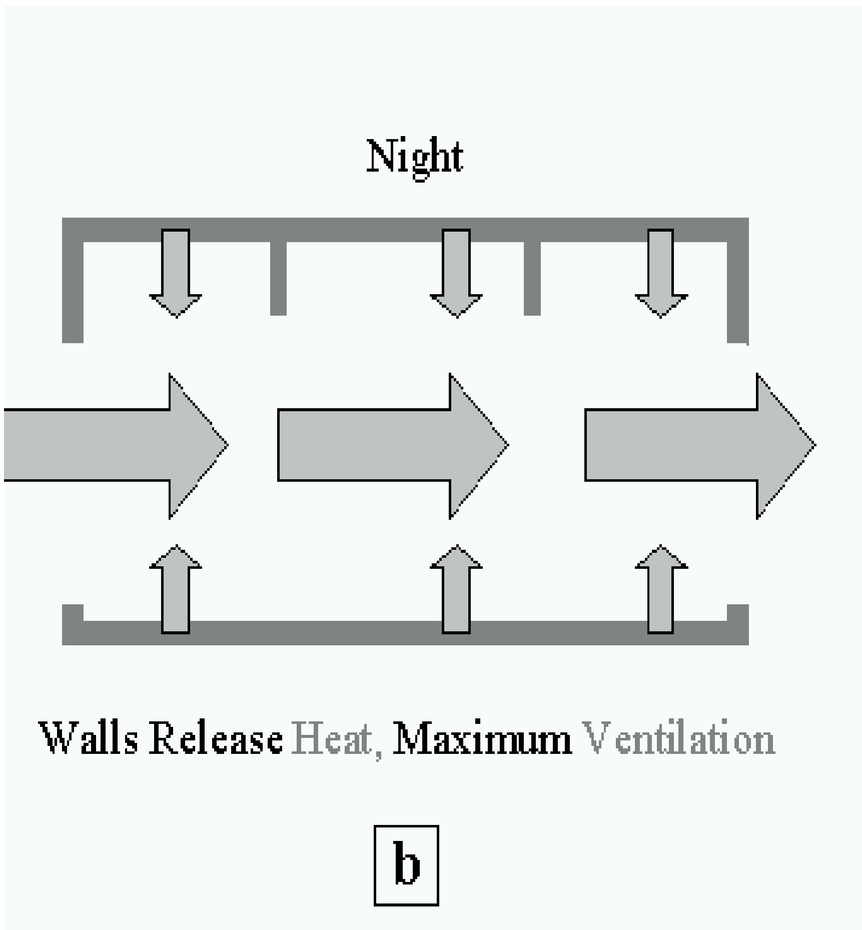


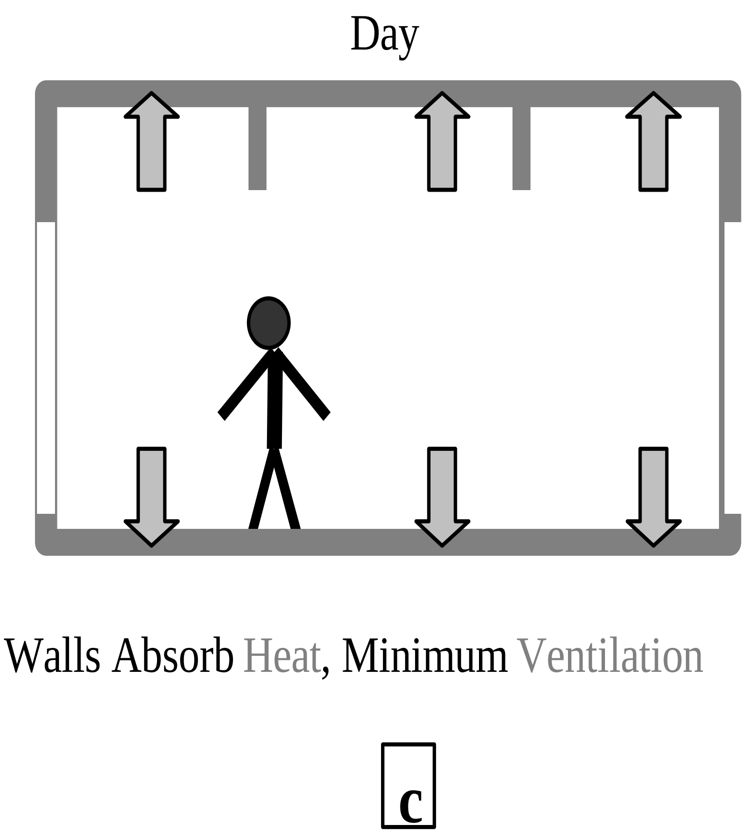
5
4
3
1
2
Toilets
OFFICE
Toilets
OFFICE
MECH
Compost
PARKING
15'-0"
45'-0"
5'-0"
50'-0"
10'-0"

Natural Ventilated Building, Luton England

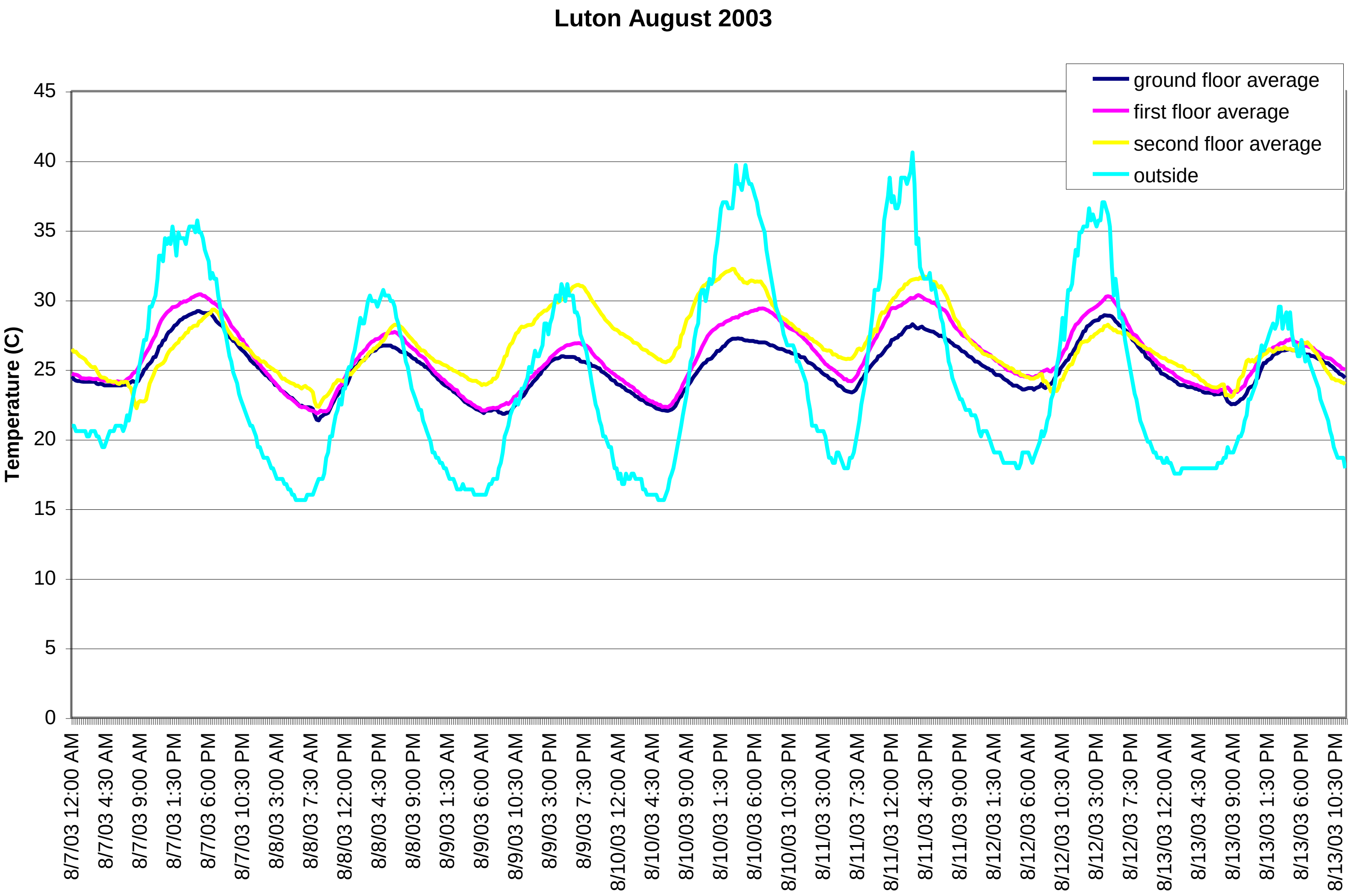
Luton Building Interior

Cross Ventilation Design:
Night cooling



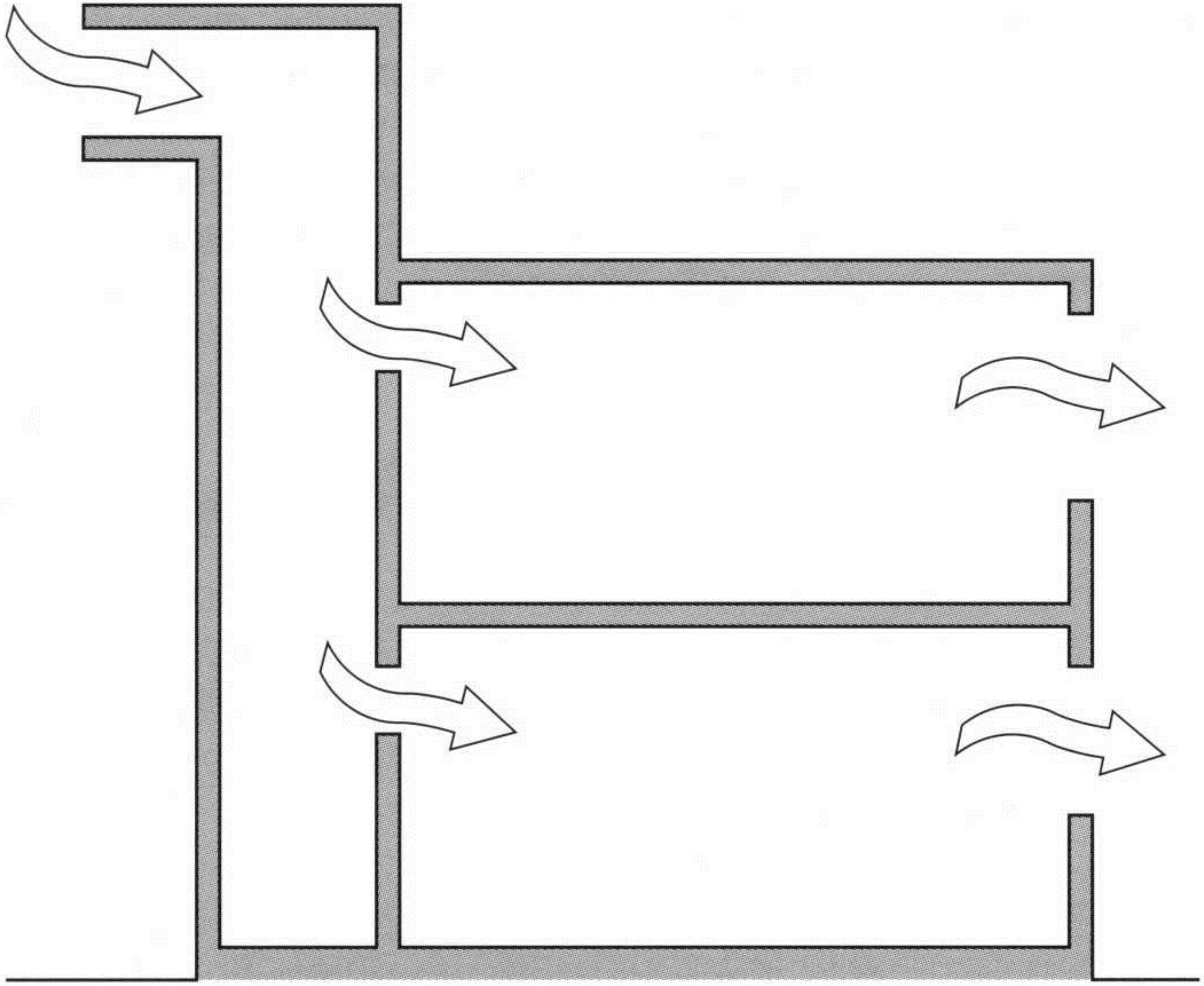


Luton Interior Temperatures: August 2003

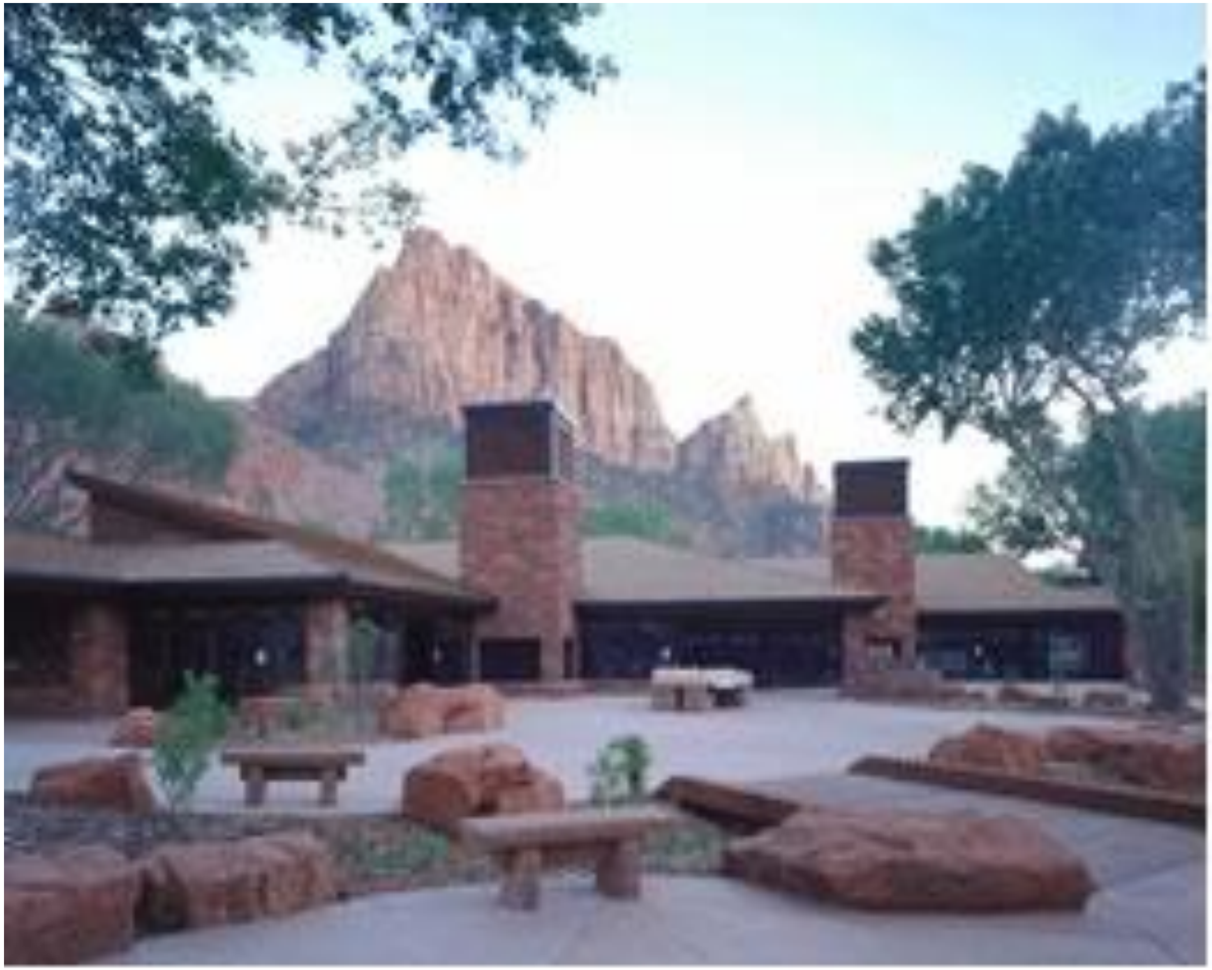


Natural Ventilation:
Wind scoop

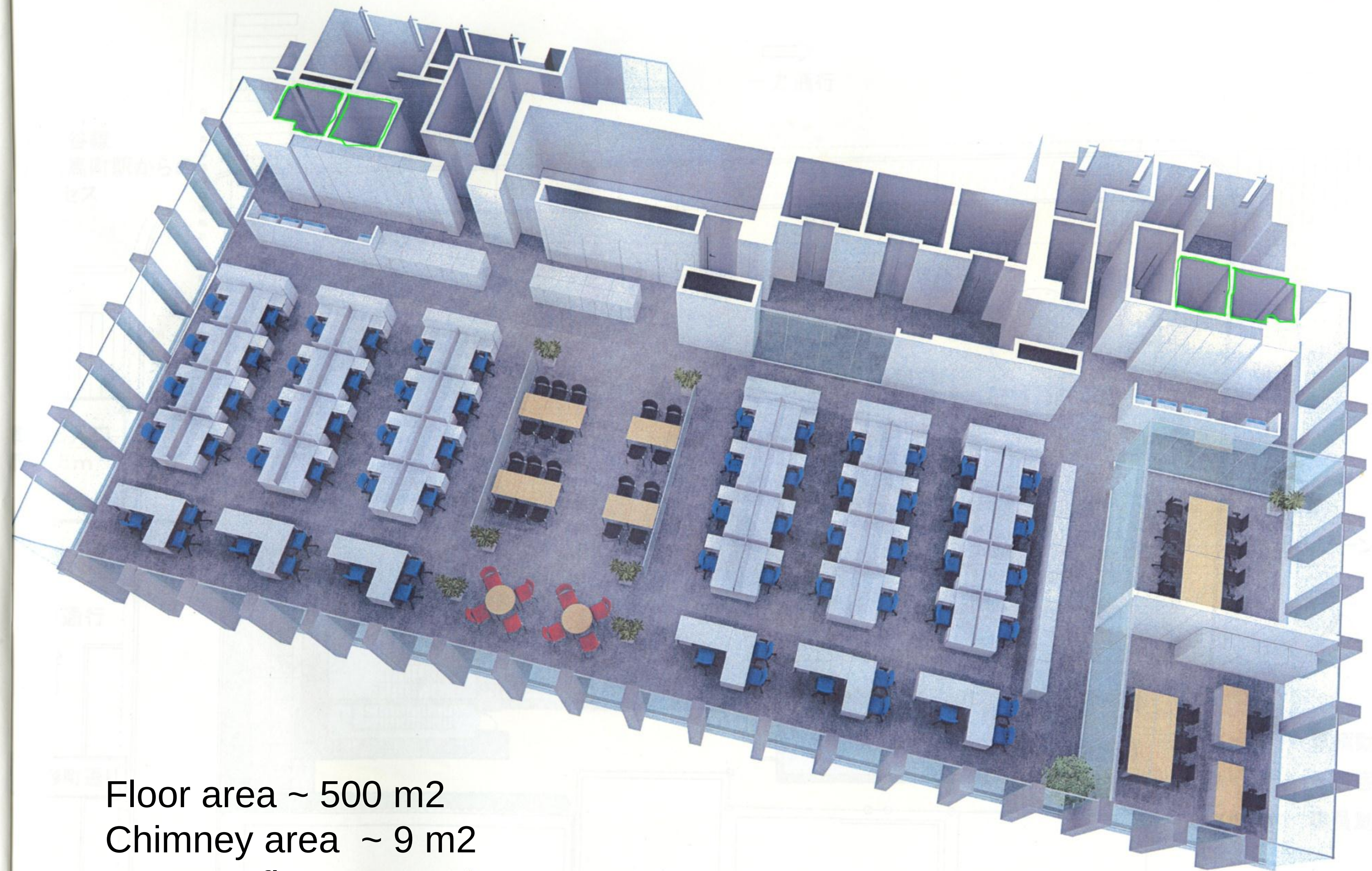
Natural Ventilation:
Wind scoop



Zion National Part Visitor Center

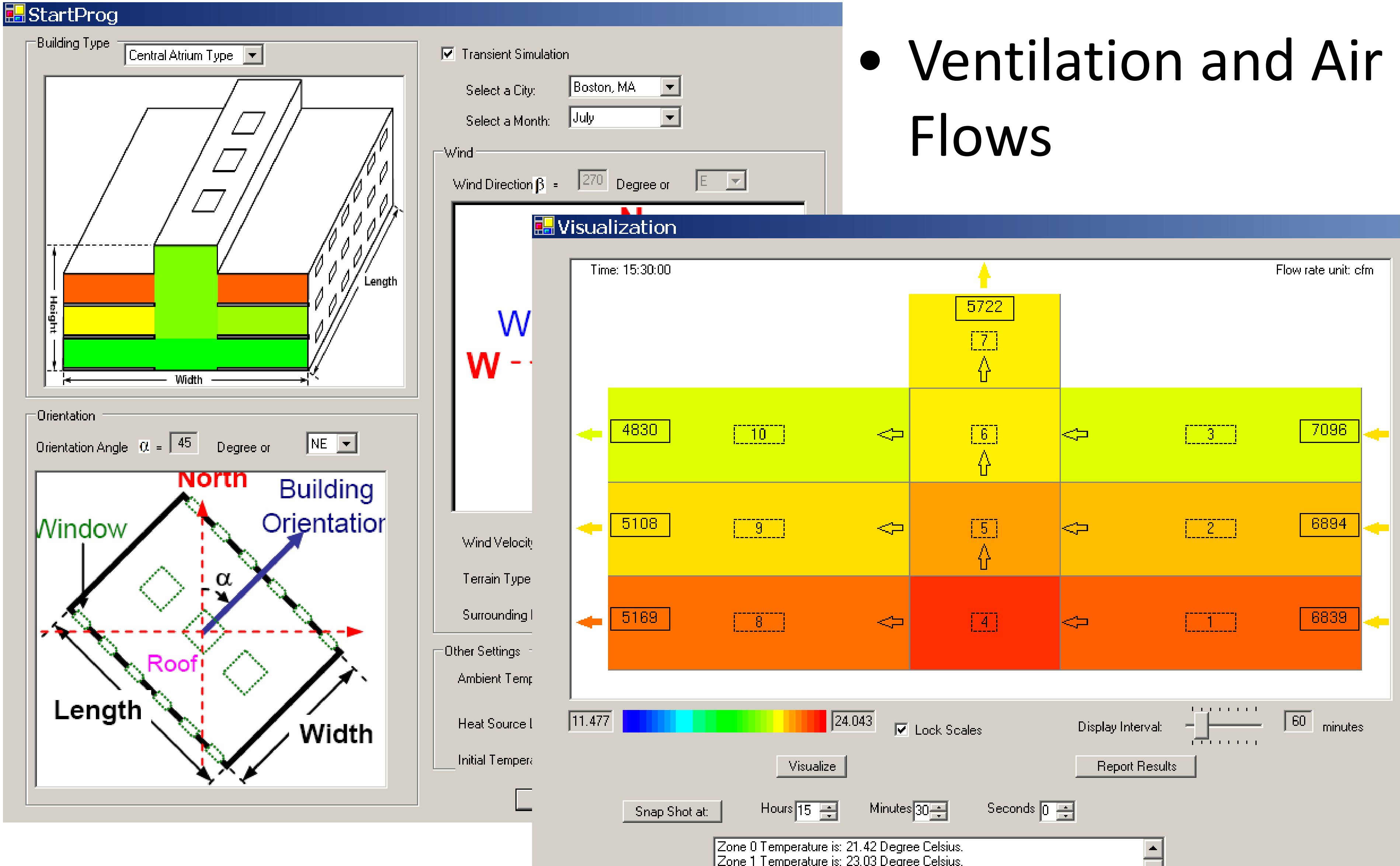


通りからの外観



Floor area ~ 500 m2
Chimney area ~ 9 m2
to vent 5 floors

CoolVent



- Ventilation and Air Flows

Open fume hoods: Energy Loss

Energy Efficient Ventilation Design for New Cancer Research Facility

Swedish Homes

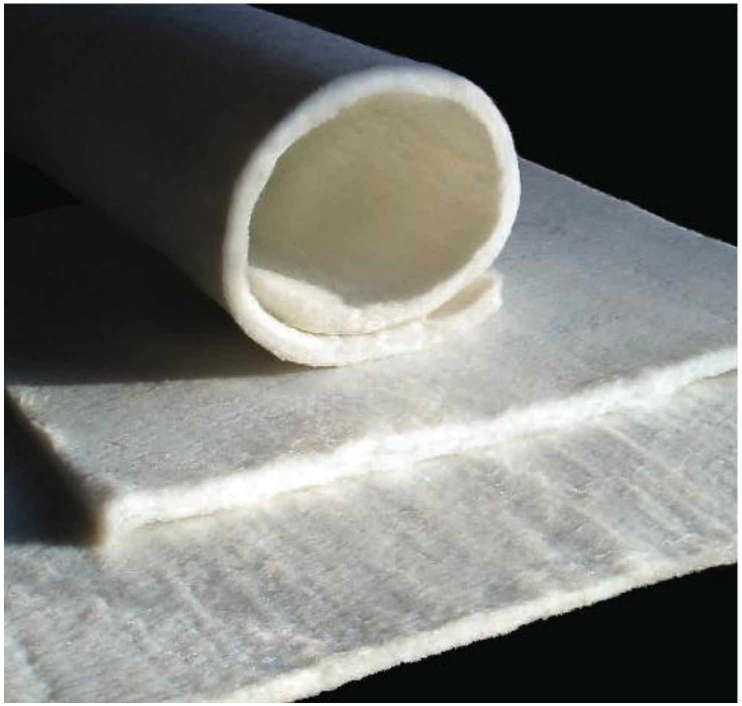
Comfortable

No Central Heating System!

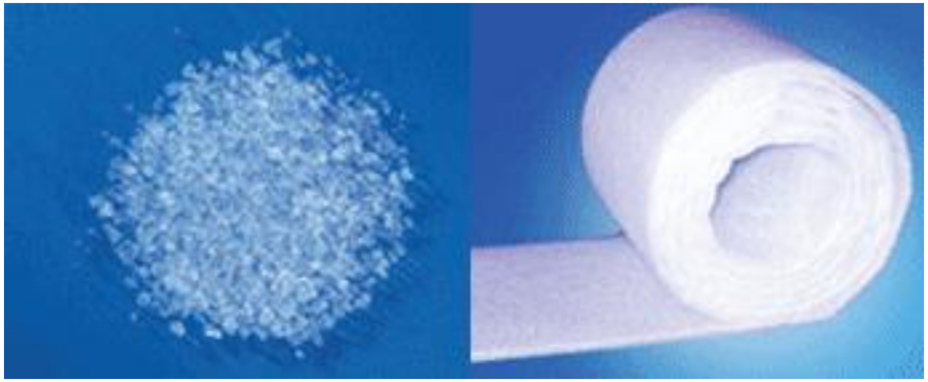
Aerogel insulation using nanotechnology

Aspen Aerogel

Commercially available aerogel for insulation purposes



Aspen Aerogel™ Spaceloft®



Cabot Nanogel® particles and Thermal Wrap™

- Granules or aerogel particles embedded in a fiber blanket
- Thermal properties: 14-20 mW/mK
- Our objective: practical aerogel insulation systems with improved performance

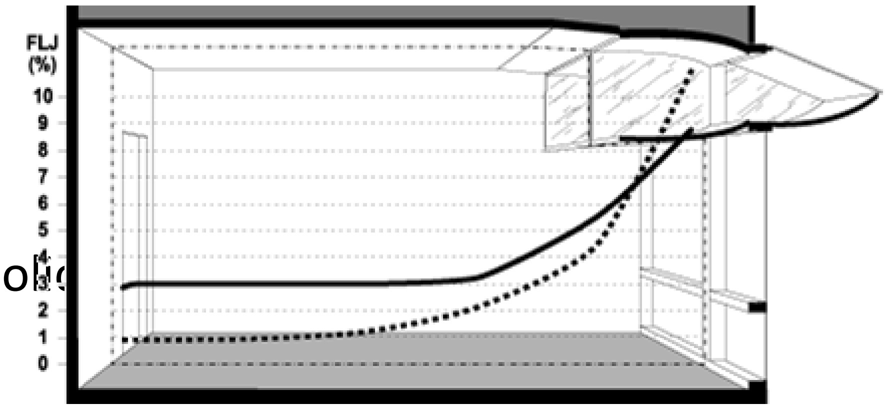
Straw Insulation

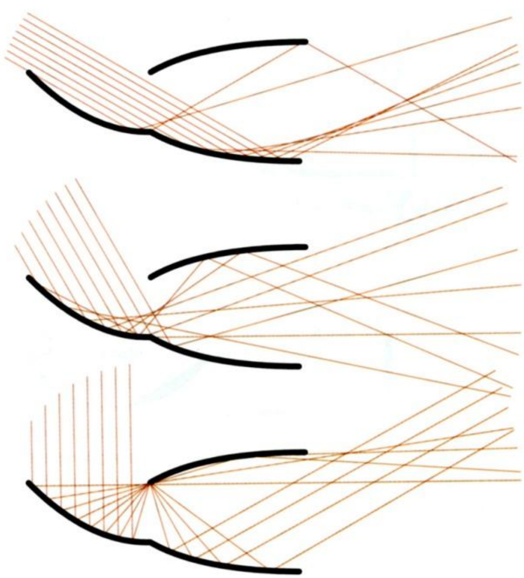
Use of Solar Energy

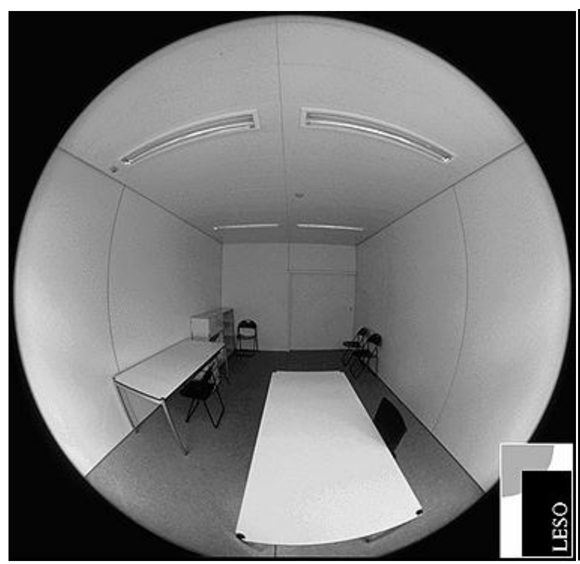
- Acceptable Interior Lighting Level :
  1/10 to 1/100 of exterior level
- Associated thermal load of solar less than that for artificial lighting
- How to control it?
- How to bring it deeper into interior?

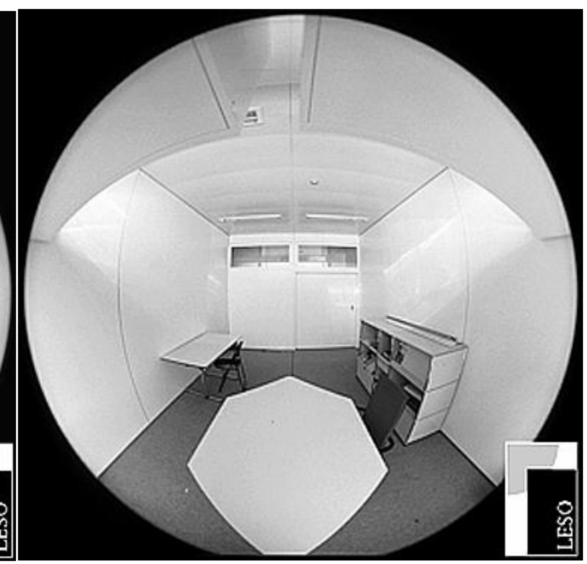
Enhancing daylight deeper in rooms

- Anidolics (based on non-imaging optics: research made at LESO-PB/EPFL)
  - Photos show 2 identical rooms at the same time, one equipped with an anidolic system, the other without









Full Scale Test in Tokyo of Window Unit

Building Condition Monitoring

Broken Buildings Waste Energy

- HVAC ≈ 50% of **Total** building energy use
- Faulty HVAC ≈ 5-30% of **Total** building energy use
- Simultaneous heating and cooling, extraneous HVAC operation, imbalanced flows ≈ 80% of “faults”
- Detecting, evaluating and diagnosing broken buildings is central to scalable energy efficiency

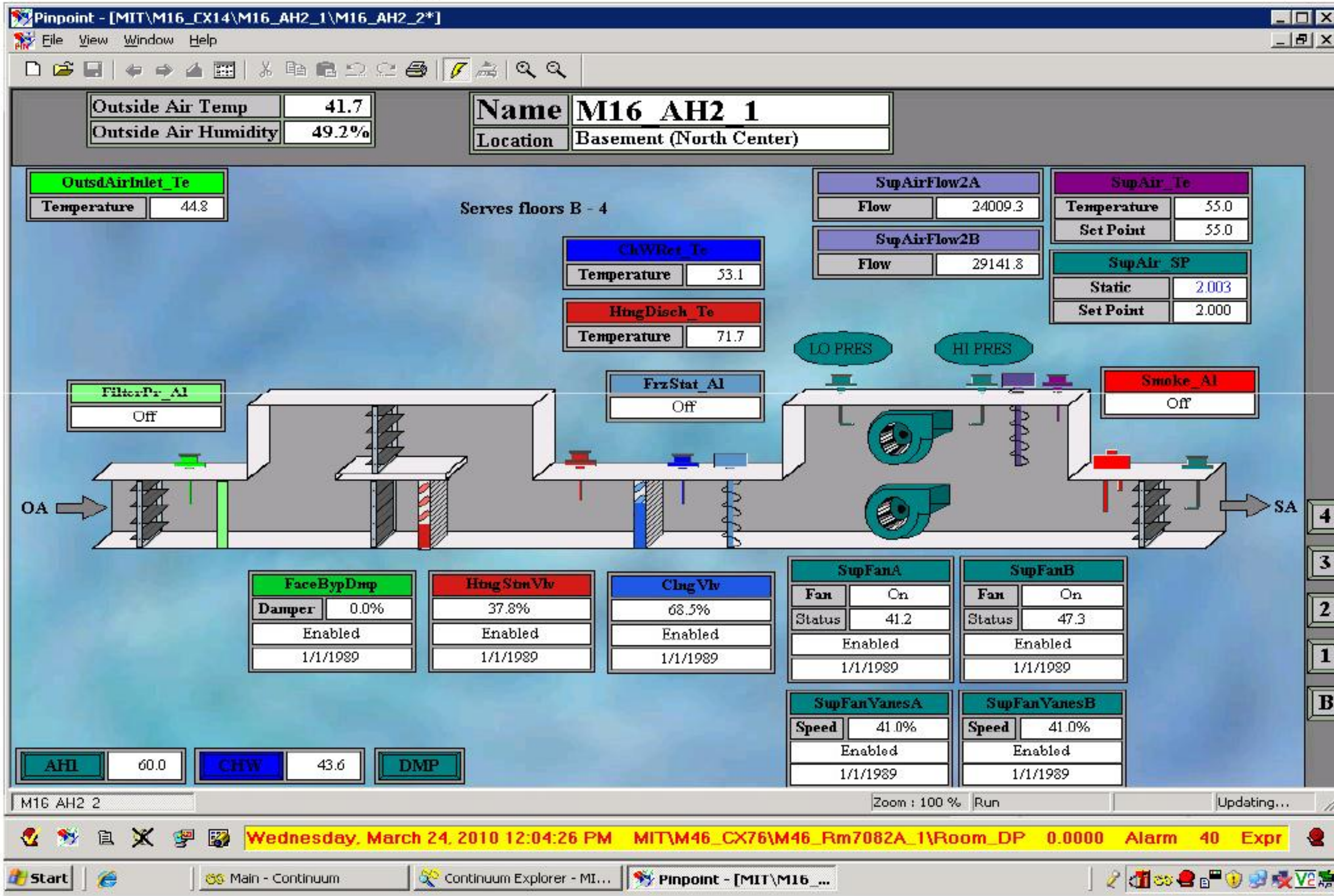
Fixing Buildings Is Very Hard

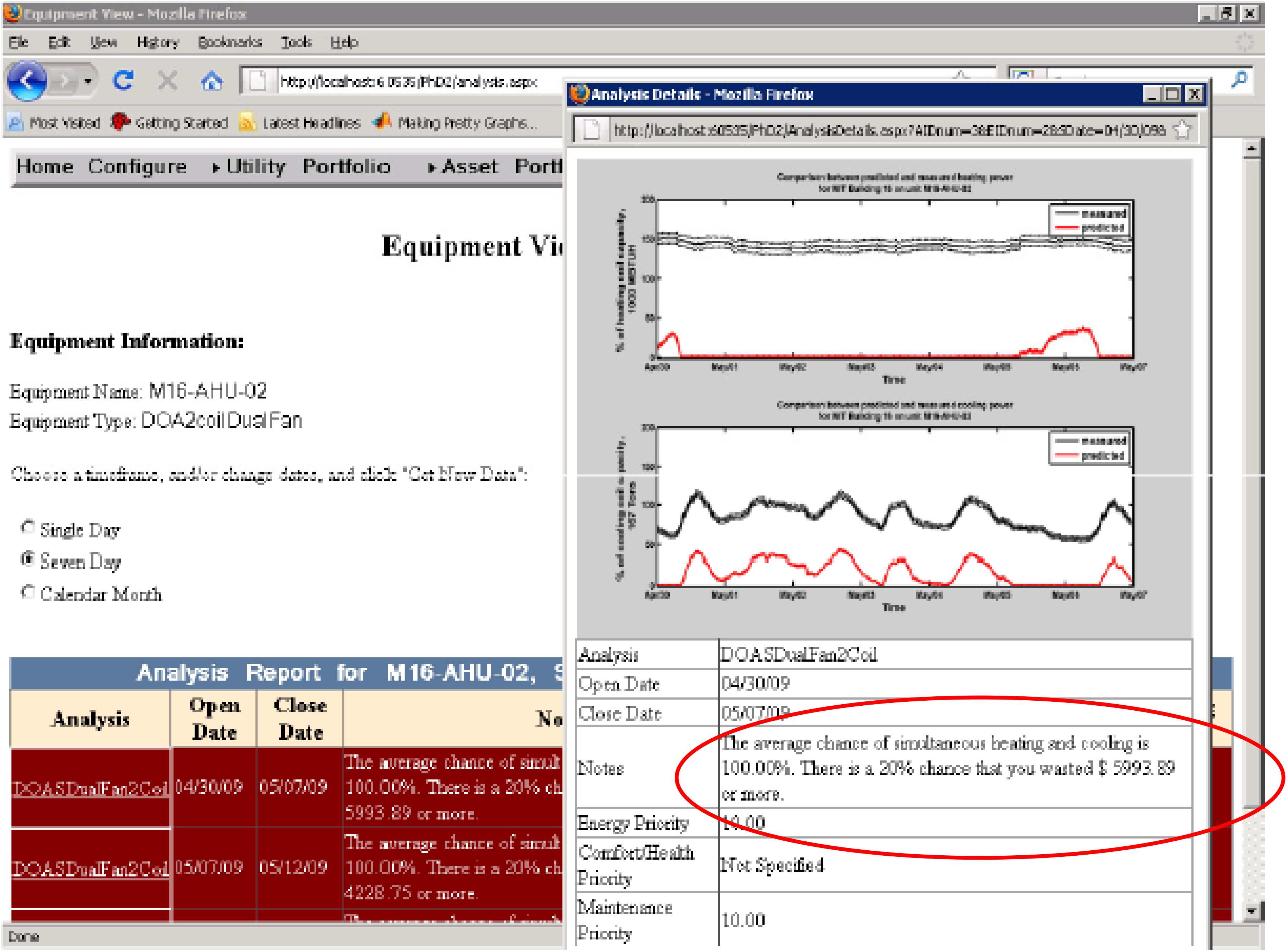
- Culture of fixing buildings is re-active, not pro-active
- Performance data is rarely collected, reviewed, or used for decisions; data is expensive ~ $1k per point
- Building documentation is usually poor; collecting system and equipment details is time consuming
- Risk-aversion and up-front labor costs control activities (~70% of data point cost is labor)

Thesis Focus on Automated Fault Detection and Evaluation

- Create a low-cost, easy-to-use tool to help fix lots of buildings, everywhere, quickly and consistently
- Help buildings saves money, reduces CO_2 emissions, improve comfort conditions and create jobs
- Combine theory and practice into a web-based, automated FDD&E software system

Testing M16 and M56 AHUs





Equipment View - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Most Visited Getting Started Latest Headlines Making Pretty Graphs...
Home Configure Utility Portfolio Asset Portf
Equipment Vi
Equipment Information:
Equipment Name: M16-AHU-02
Equipment Type: DOA2coil DualFan
Choose a timeframe, and/or change dates, and click "Get New Data":
Single Day
Seven Day
Calendar Month
Analysis Report for M16-AHU-02,
Analysis
Open Date
Close Date
No
DOASDualFan2Coil 04/30/09 05/07/09 The average chance of simult 100.00%. There is a 20% ch 5993.89 or more.
DOASDualFan2Coil 05/07/09 05/12/09 The average chance of simult 100.00%. There is a 20% ch 4228.75 or more.
Done
Analysis Details - Mozilla Firefox
measured
predicted
Time
measured
predicted
Time
Analysis DOASDualFan2Coil
Open Date 04/30/09
Close Date 05/07/09
Notes The average chance of simultaneous heating and cooling is 100.00%. There is a 20% chance that you wasted $ 5993.89 or more.
Energy Priority 10.00
Comfort/Health Priority Not Specified
Maintenance Priority 10.00

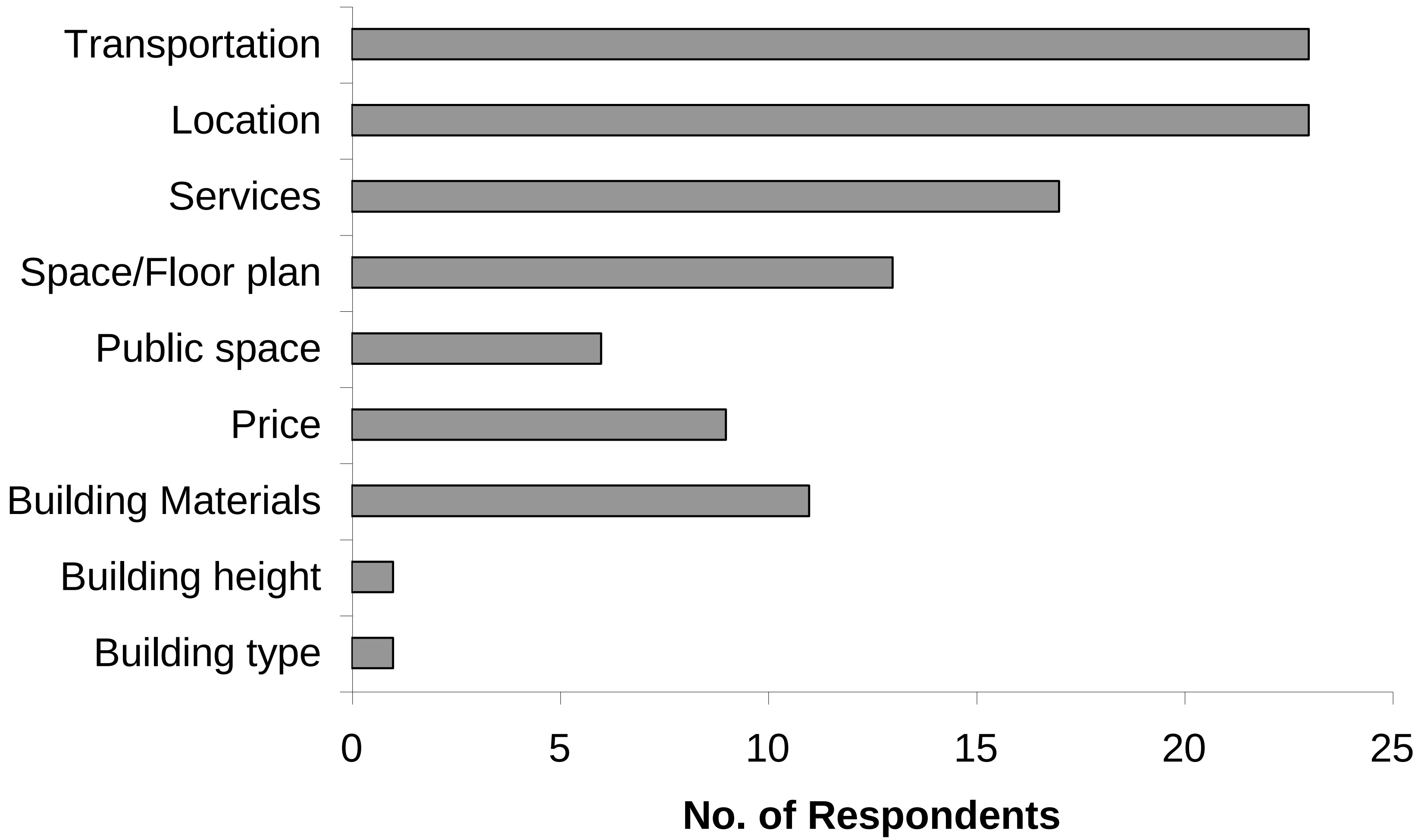
China
~ 10 M new residence units/year!

We conducted surveys with three groups of Chinese consumers:

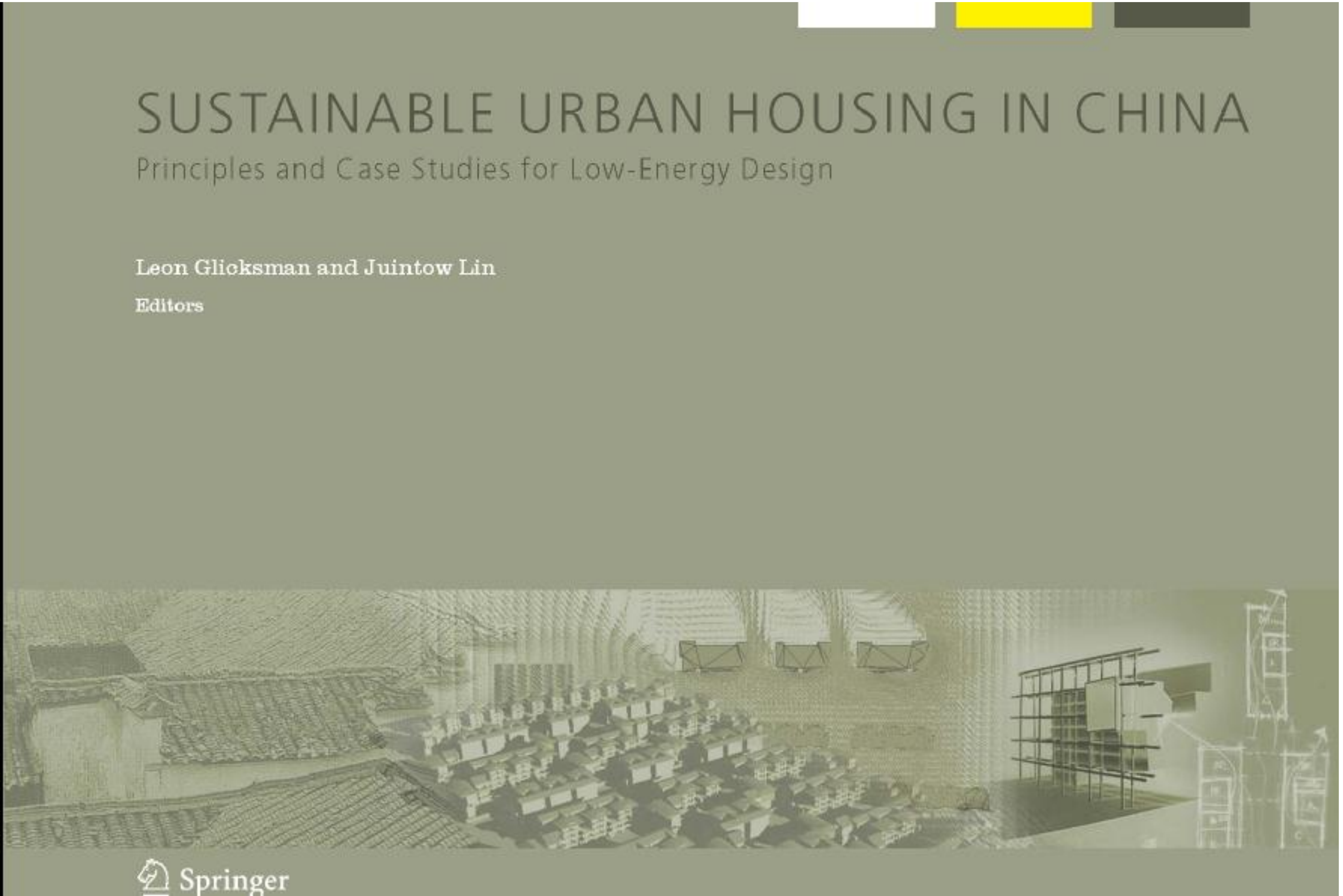
1. Visitors to the *Tian Hong* sales office in Beijing,
2. Other potential home-buyers in Beijing, and
3. Chinese nationals at MIT.

Tian Hong is a new "affordable" housing development in Beijing priced at 2600 RMB ($313) per sq. m.

Survey: Three Most Important Features of Home



Published Fall 2006




欢迎美国麻省理工学院建筑专家到访


WELCOME
EXPERTS