The Case For Sustainable Laboratories: First Steps at Harvard University

Jessica Woolliams, Coordinator
Longwood Green Campus Initiative
Harvard University
email: jwoollia@hsph.harvard.edu

www.greencampus.harvard.edu/

Sustainable Laboratories: First Steps at Harvard University

- ONE: The Case for Sustainable Laboratories
- TWO: Initial Efforts at Harvard
- THREE: Lab21 Questionnaire

ONE: Case For Sustainable Labs

First: Climate change is here

"There is no doubt the composition of the atmosphere is changing because of human activities, and today greenhouse gases are the largest human influence on global climate." (NSF 2003)

Second: Our labs are big contributors:

"… fume hoods are a major factor in making a typical laboratory four- to five-times more energy intensive than typical commercial buildings. A typical hood consumes 3.5-times more energy than an average house." (Bell, G., D. Sartor, and E. Mills 2003)

ONE: Case For Sustainable Labs

- Third: The benefits of this transition are enormous
- Recent studies show that minimal increases in upfront costs (2%) result in savings of 20% of total construction costs
- Example: “an initial investment of $100,000 to incorporate green features into a $5 million project would result in savings of $1 million in today’s dollars over the life of the building”

TWO: Initial Efforts at Harvard

Why are Universities Critical?

- 4,096 U.S. Colleges and Universities[1]
- 14.8 million students[1]
- $277 billion annual expenditures; 2.8% of the GDP[1]
- Higher education expenditures greater than the GDP of all but 25 countries in the world[2]

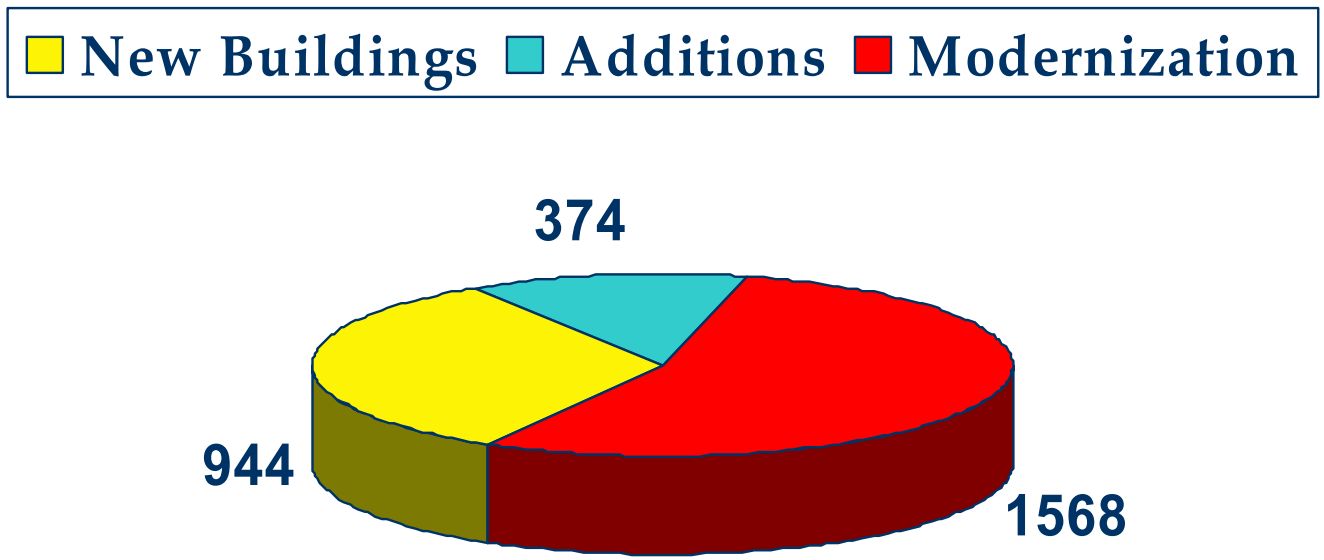
[1] *From: 2001 Digest of Education Statistics, US Dept. of Education.*

[2] *From: 2001 CIA World Factbook and Dowling, Mike., "Interactive Table of World Nations," available from http://www.mrdowling.com/800nations.html; Internet; updated Friday, June 29, 2001*

TWO: Initial Efforts at Harvard

Why are Universities Critical?

2,886 Capital Projects Completed, 2000

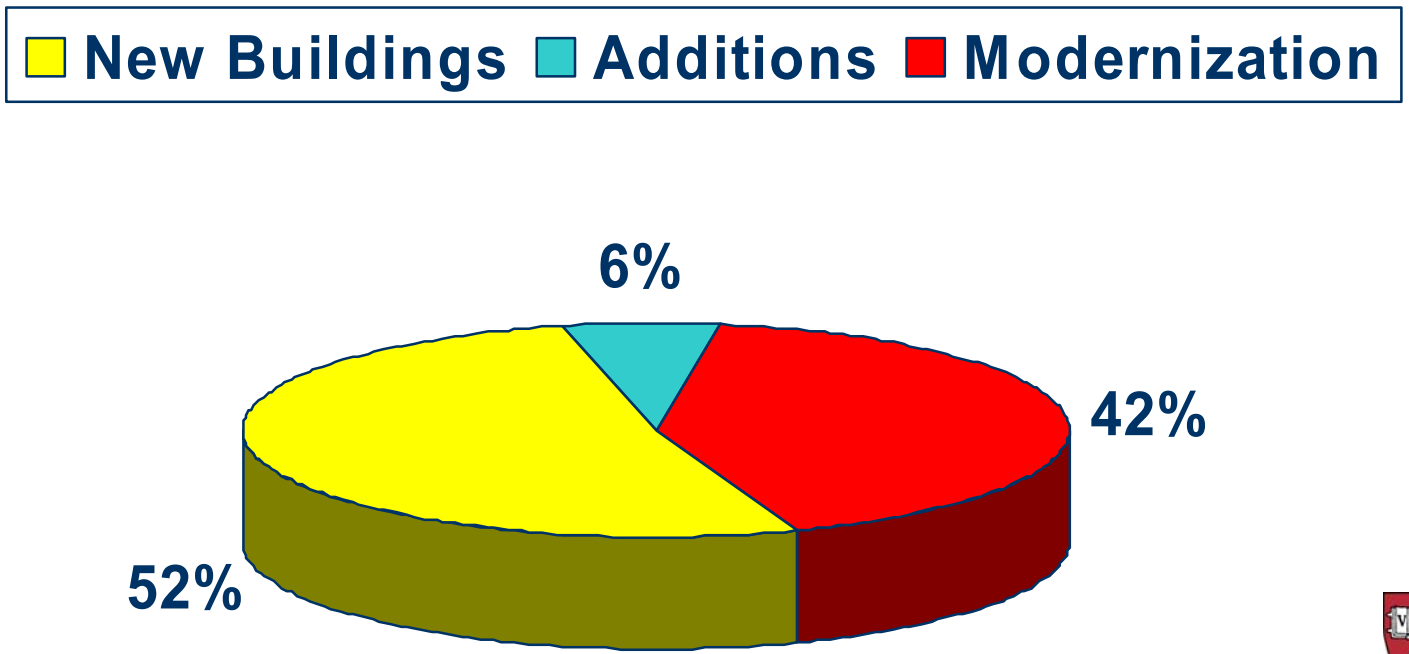


Source: American School and University's Official Education Construction Report, 2000.

TWO: Initial Efforts at Harvard

Why are Universities Critical?

$14.7 B Spent on Construction, 2000



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TWO: Initial Efforts at Harvard

Technical Background on University Labs

Laboratory Types at Harvard

- Chemistry
- Biochemistry
- Biological
- Biomedical
- Physics
- Geology
- Behavioral research

TWO: Initial Efforts at Harvard

Laboratory Environments May Contain…

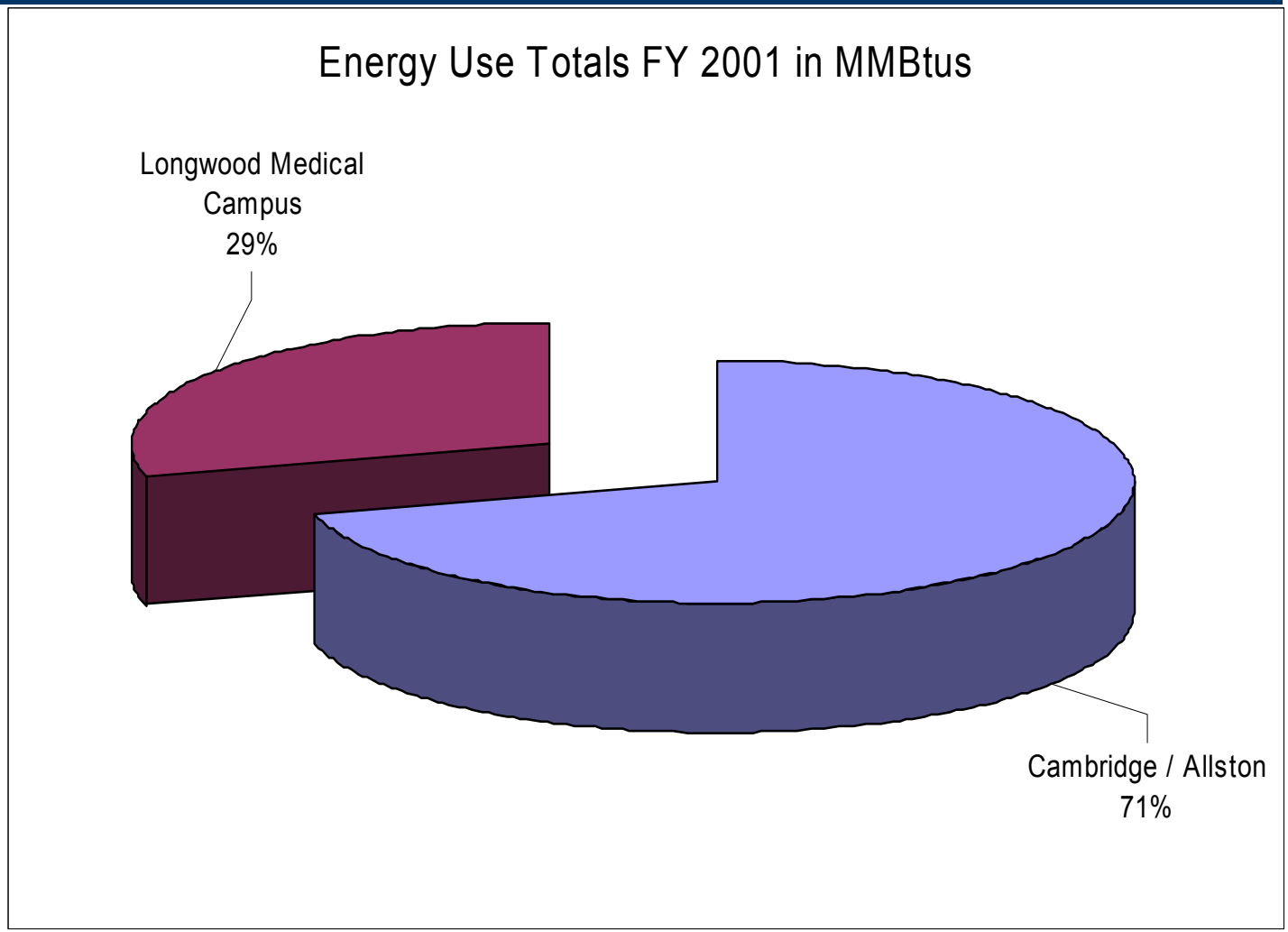
- Hundreds or thousands of chemicals
- Flammable Gases
- Compressed Gases
- Toxic Gases
- Flammable Liquids
- Biological Agents
- Radioactive materials
- Fume Hoods
- Biosafety Cabinets
- Centrifuges
- Autoclaves
- Vacuum Systems
- Research Animals
- Lasers
- Sophisticated Electrical Equipment
- Hazardous waste
- Infected animals
- ???

TWO: Initial Efforts at Harvard

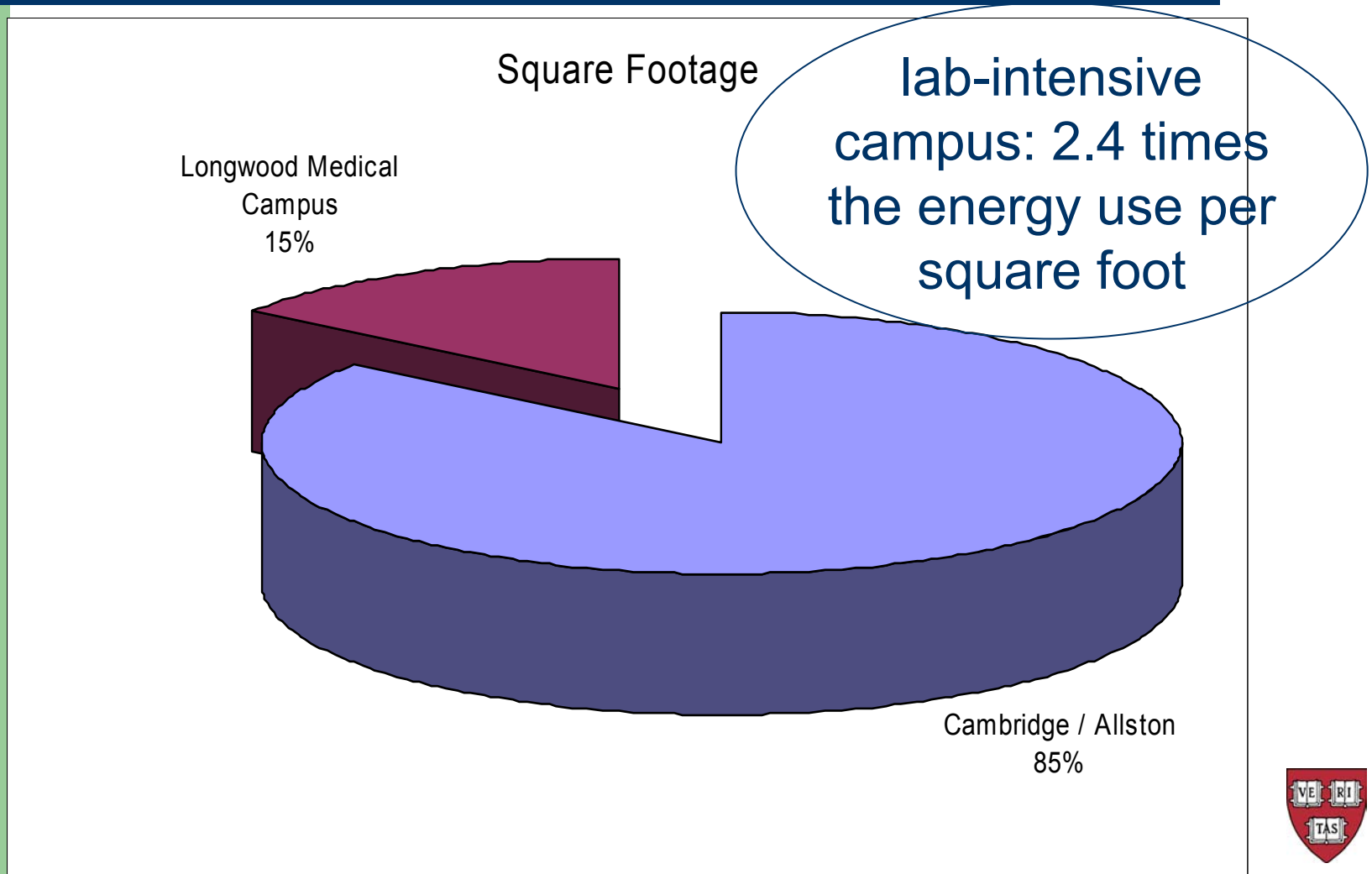
Types of Fume Hoods

- Constant Volume Fume Hoods
  - Conventional Constant Volume Fume Hood
  - Constant Volume Bypass Fume Hood
  - Auxiliary Air or “Make-Up” Fume Hoods
  - Low Flow Fume Hood
- Variable Volume Fume Hoods

TWO: Initial Efforts at Harvard



TWO: Initial Efforts at Harvard

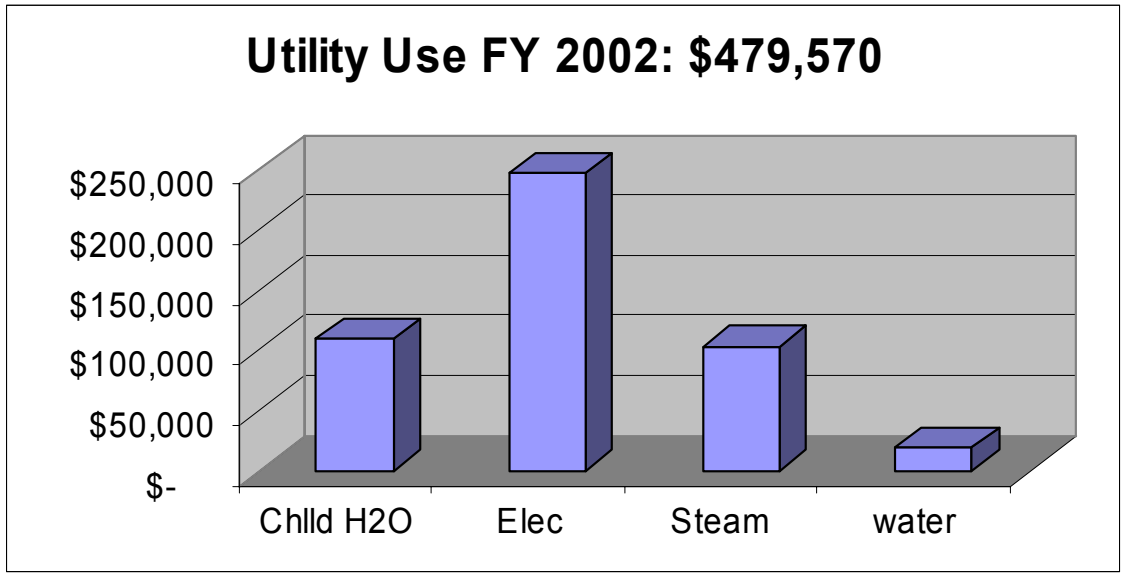


lab-intensive campus: 2.4 times the energy use per square foot

TWO: Initial Efforts at Harvard

Feasibility Study with Labs 21

- 68,000 sq ft: 52% Lab
- 6 floors + basement
- 26 fume hoods
- Built in 1969



Upgrade and Reduce Energy

- Constant Volume with Heat Recovery: $20,000/yr savings, 4.8 year payback
- Constant Volume with Usage Based Control: $18,500 /yr, 2.9 yr payback
- Constant Volume with Usage Based Control and Heat Recovery: $32,000 /yr, 4.7 yr pb
- Variable Air Volume: $33,500/yr, 3.3 yr pb
- Variable Air Volume with Heat Recovery: $48,000/yr, 4.25 yr pb
- Constant Volume with Low Flow Fume Hoods: $28,072, 7.85 yr pb

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- Variable Air Volume: $33,500/yr, 3.3 yr pb
- Variable Air Volume with Heat Recovery: $48,000/yr, 4.25 yr pb: 10% reduction in energy use
- Constant Volume with Low Flow Fume Hoods: $28,072, 7.85 yr pb

Important Discoveries

- Range of cost-effective opps identified:
  - Heat recovery, greater controls, VAV, low flow hoods, night set-backs.
- Unknown performance
  - faculty change-over, systemic lack of communication between faculty/researchers and facility managers, lack of ongoing building ventilation performance reviews
- Current codes and standards labyrinthine

Design Dilemma: Who's Stds to Follow?

Organizations with Recommendations for Air Changes per Hour (ACH):

- ASHRAE Applications Handbook
- NFPA 45, National Fire Protection Association
- OSHA 29 CFR-1910, Occupational Safety & Health Administration, US Dept of Labor
- Prudent Practices, National Research Council
- Industrial Ventilation, American Conference of Governmental Industrial Hygienists
- ANSI / AIHA Z9.5-2003, American National Standards Institute, American Industrial Hygiene Assn

Design Standards: ACH

ANSI / AIHA Z9.5-2003, American National Standards Institute, American Industrial Hygiene Assn:

"…air changes per hour is not the appropriate concept for designing contaminant control systems. Contaminants should be controlled at the source."

Design Standards: ACH

ANSI / AIHA Z9.5-2003, American National Standards Institute, American Industrial Hygiene Assn:

"…air changes per hour is not the appropriate concept for designing contaminant control systems. Contaminants should be controlled at the source."

Design Standards: Face Velocity

Organization	Citation	Face Velocity
ACGIH	Industrial Ventilation, 19th ed. p.5.24	60-100 fpm
ASHRAE	1999 ASHRAE Handbook 13.5	60-175[1]
ANSI/AIHA	ANSI/AIHA Z9.5 Sect 5.7	80-120 fpm
CALOSHA	CCR Title VIII Subchapter 7.5454.1	100 fpm[2]
NRC	Prudent Practices p.187	80-100 fpm
NFPA	NFPA 45 6-4.5 & A6-4.5	80-120 fpm[3]
NIOSH	Recommended Industrial Ventilation Guidelines p.166	100-150 fpm
NRC	NRC Guide 6.3	100 fpm[4]
OSHA	29 CFR 1910 Appendix A Sec. A.C.4.g	60-100 fpm
SEFA	SEFA 1.2:5.2	75-100 fpm

[1] 20%-50% of exterior disturbance velocities. 60-175 fpm if 300 fpm walk-by used to calculate.
[2] Minimum
[3] "Sufficient to prevent escape from hood; 80-120 fpm; 40 cfm/lin foot min"
[4] For hospital radioactives

Fume Hood Containment Test Standards

"… we can ask, does it make any difference which of the several standard protocols is followed? My answer is 'no,' inasmuch as none can define what the operational risks will be in service."

Dr. Melvin First, Harvard School of Public Health

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Dr. Melvin First, Harvard School of Public Health

Best Practices: LEED

Labs 21 develop Environmental Performance Criteria, and among the strategies:

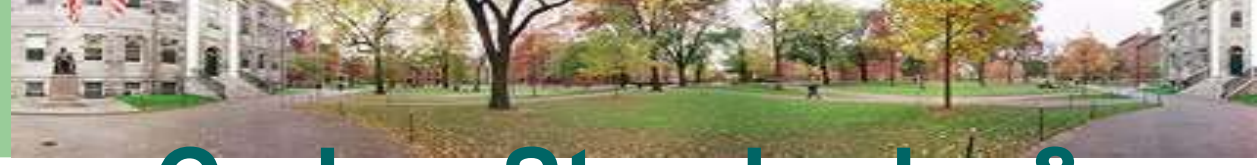
- “Use high performance low-flow fume hoods.”
- “Minimize outside air to 1 cubic foot per minute per square foot (cfm/sf) or less.”
- “Reduce unoccupied outside airflow during unoccupied periods.”

Best Practices: LEED

Labs 21 develop Environmental Performance Criteria, and among the strategies:

- Use high performance low-flow fume hoods.
- Minimize outside air to 1 cubic foot per minute per square foot (cfm/sf) or less.
- Reduce unoccupied outside airflow during unoccupied periods.

- **We need to "define the operational risks"**
- **Need for research**



Research on Codes, Standards, & Energy Efficiency in Laboratories

- Labs 21: internship position
- Student intern research:
  - national survey of architects, engineers and facility managers
  - Labs 21 group identified a national need: understanding how codes and standards impact energy efficiency

Advisory Group

Labs 21 Phil Wirdzek Environmental Protection Agency	Harvard Green Campus Initiative Dr. John Spengler, Co-Chair	University Steering Group Dr. John Spengler Harvard University Faculty, Facilities
Geoffrey C. Bell Energy Engineer Lawrence Berkeley National Laboratory	Danny Beaudoin Manager of Operations Harvard School of Public Health	Massachusetts Institute of Technology EH&S Director Facilities and Engineering
Paul Mathew, Ph.D Energy Engineer Lawrence Berkeley National Laboratory	Leith Sharp, Director HGCI	Tufts University EH&S, Facilities
Itzhak Maor, Ph.D., P.E. Director of Engineering PWI Energy	Jessica Woolliams Medical Area Coordinator HGCI	Northeastern University EH&S Director
Chris Benjamin Environmental Analyst Eastern Research Group Labs21 Media Outlet	Matt Lloyd, Intern HGCI	University of Massachusetts Amherst Greening Campus Rep

The Questionnaire: Intent

Three questions:

1) *In what ways do current codes and standards either hinder or help energy efficient laboratory design?*
2) *Do current codes and standards fail to provide enough guidance on the issues of health and safety, energy efficiency, and the relationship between the two?*
3) *What is the scope and magnitude of the problem?*

Understanding the Relationship Between Codes, Standards, and Energy Efficiency in Laboratories

Matt Lloyd, AEA
Longwood Green Campus Initiative
Harvard School of Public Health
Boston, MA 02215
email: mlloyd@hsph.harvard.edu

EPA United States Environmental Protection Agency

www.epa.gov/labs21century

www.greencampus.harvard.edu/

The Questionnaire

- Identifying the Target Audience:
  1) Labs21 “case study” design team members (n=6)
  2) A pool of A&E participants with laboratory design experience (n=19)
  3) Facilities Managers (n=6)

Nearly 4 centuries of experience with energy efficiency!!!

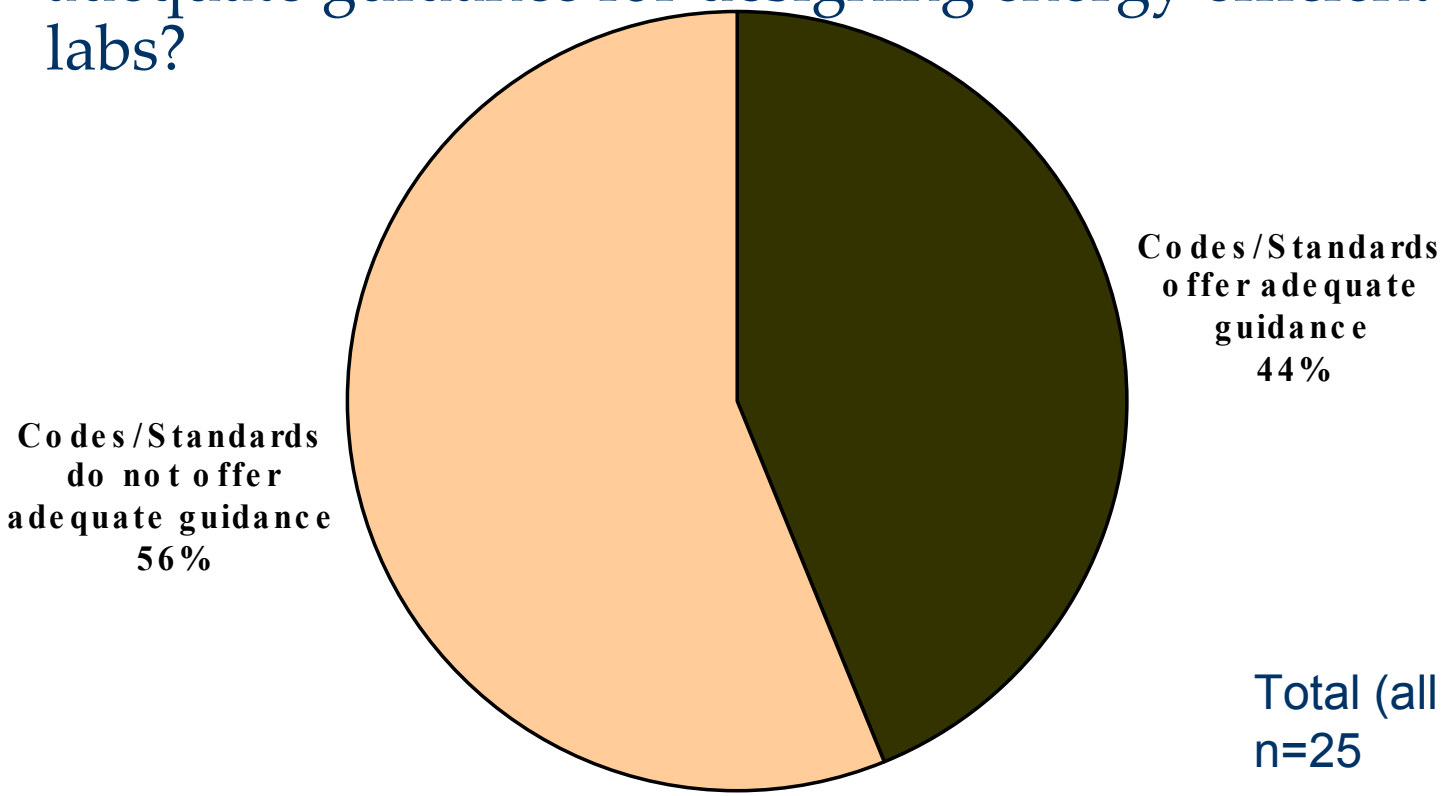
The Questionnaire: Intent

- An exploratory effort to identify contradictions and/or issues within the framework of the current codes and standards for laboratory ventilation and energy efficiency.

- Over a 90% response rate to questionnaire

Applicability of Energy Codes/Standards

- Do you feel that these codes and standards offer adequate guidance for designing energy efficient labs?



Total (all groups): n=25

Applicability of Energy Codes/Standards

- For those that answered **No**, what are the issues:
  - Codes not designed to address labs
  - **Inadequate methodology for determining air flow / safety requirements**
  - Inconsistent standards for lab ventilation
  - **Different lab types deserve consideration**
  - **Fan energy limits/ restrictive heat recovery in ASHRAE 90.1**
  - Codes do not address lab design holistically
  - Safety and use of chemical fume hoods

Applicability of Energy Standards: ASHRAE 90.1

- Using the ECB method for lab compliance:
  - **Case Studies group: 83% used ECB**
  - **A&E group: 21% used ECB**
    - Experience with ECB:
      - Labor intensive calculations
      - Better suited for commercial buildings

L21 Environmental Performance Criteria

Technologies and Strategies:

- Use of low-flow fume hoods
- Use of VAV fume hoods
- Energy (latent or sensible) recovery
- Use of computer simulations to ID effective efficiency measures
- Quantification of energy performance as compared to a baseline bldg.
- Expansion of unoccupied temperature dead band by resetting zone temperature based on occupancy
- Incorporating diversity into design
- Cooling system with at least 2 cooling loops (different temps.)
- Design for high part-load heating and cooling efficiency
- Reduction of outside airflow during unoccupied periods
- In mixed lab settings, use dedicated HVAC for admin. Areas

L21 Environmental Performance Criteria

Technologies and strategies Labs21 “case study” design team members employed:

More often:

- Incorporating diversity into design
- Use of VAV fume hoods
- Energy recovery (latent or sensible)
- Reduction of outside airflow
- Design for high part-load heating and cooling efficiency
- Dedicated HVAC for admin. areas in mixed lab settings
- Quantification of energy performance as compared to a baseline bldg.
- Use of computer simulations to ID effective efficiency measures

Less often:

- Use of low flow fume hoods
- Expansion of temperature dead bands based on occupancy
- Cooling system with at least 2 cooling loops (different temps.)

L21 Environmental Performance Criteria

Technologies and strategies general A&E group employed:

More often:

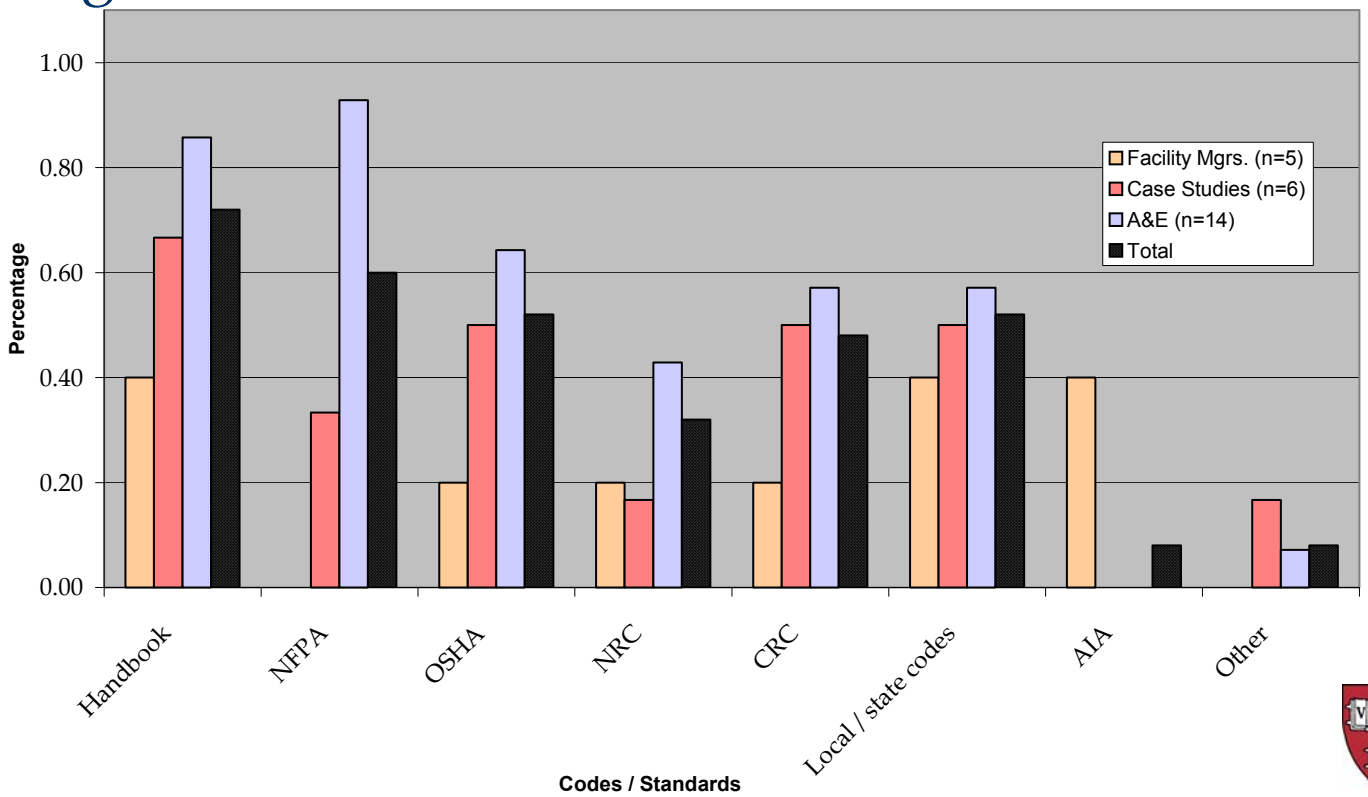
- Incorporating diversity into design
- Use of VAV fume hoods
- Reduction of outside airflow
- Dedicated HVAC for admin. areas in mixed lab settings

Less often:

- Use of low flow fume hoods
- Expansion of temperature dead bands based on occupancy
- Cooling system with at least 2 cooling loops (different temps.)
- Energy recovery (latent or sensible)
- Design for high part-load heating and cooling efficiency
- Quantification of energy performance as compared to a baseline bldg.
- Use of computer simulations to ID effective efficiency measures

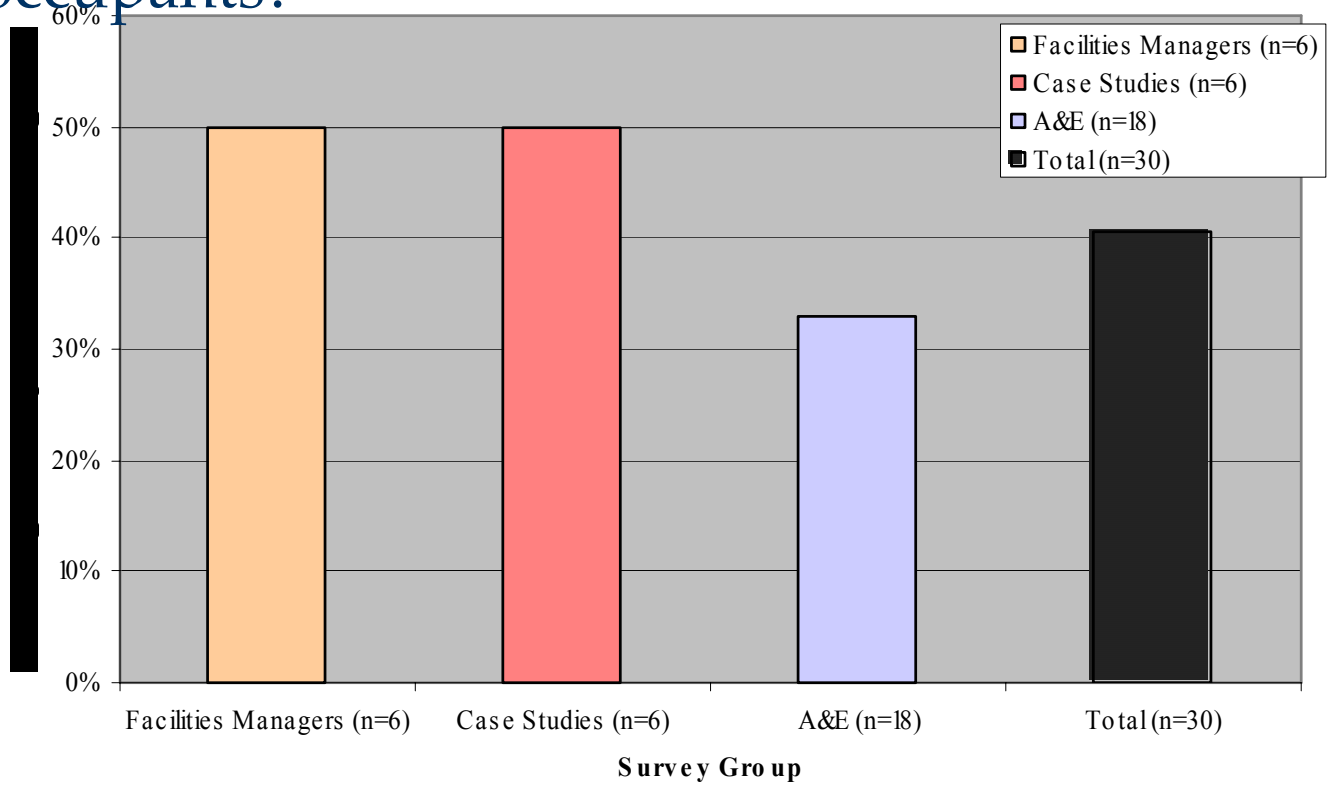
General Lab Ventilation

- If your firm use ACH to calculate ventilation rates, what code(s) / standard(s) do you reference in setting air change rate?



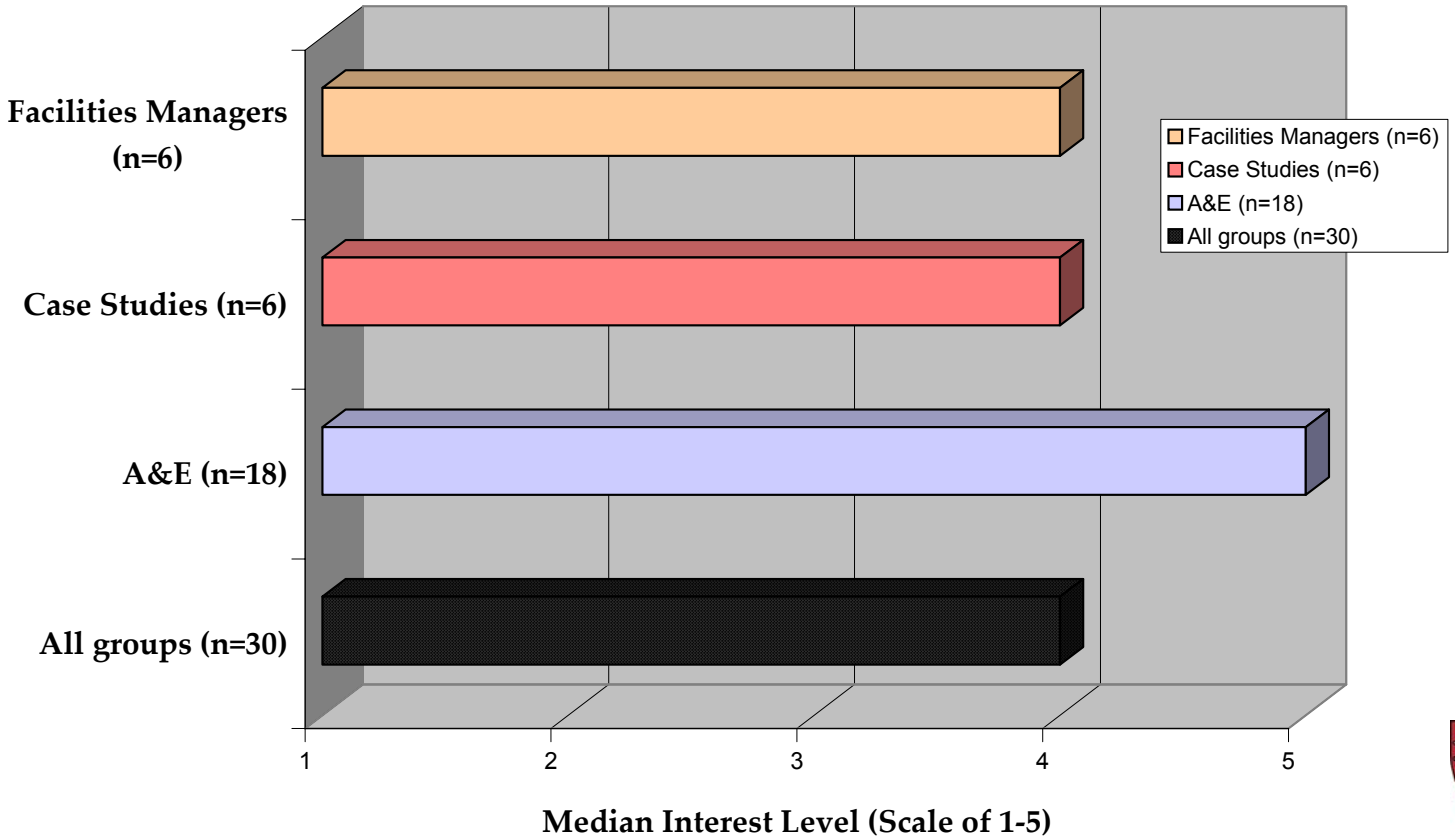
General Lab Ventilation

- In your opinion, are the standards from part b adequate to ensure the long-term safety of laboratory occupants?



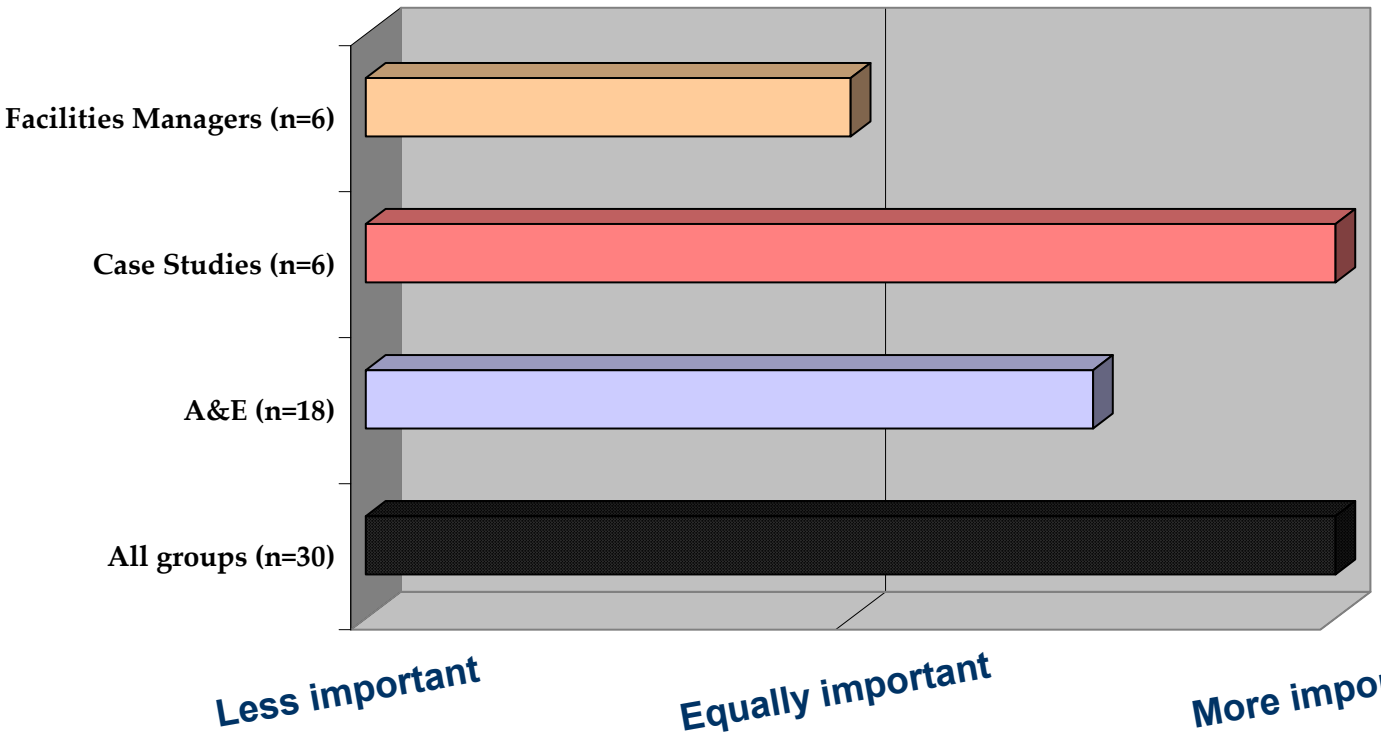
General Lab Ventilation

- On scale of one to five, indicate your interest in additional research quantifying the correlation between laboratory ventilation and human health risks.



Laboratory Air Distribution and Diffusion

- Do you believe the location of the fume hoods in relation to air supply diffusers and pedestrian traffic is _____ for human health and safety than the number of air changes per hour in a laboratory?

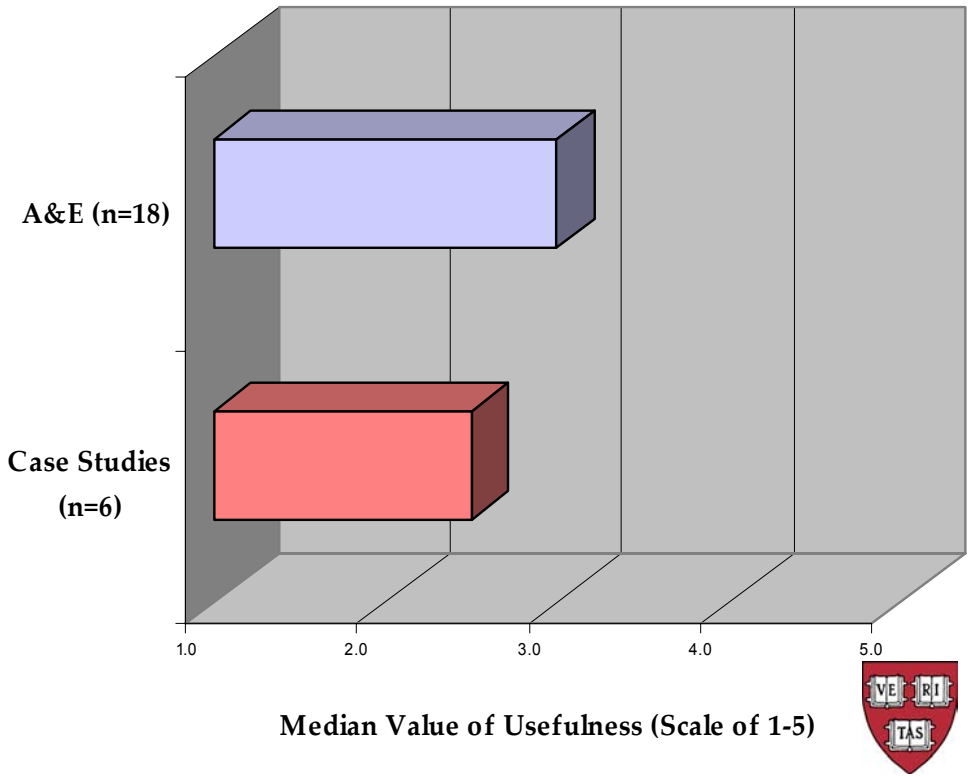


Laboratory Air Distribution and Diffusion

- Do you utilize CFD as a computational tool for predicting lab air distribution?

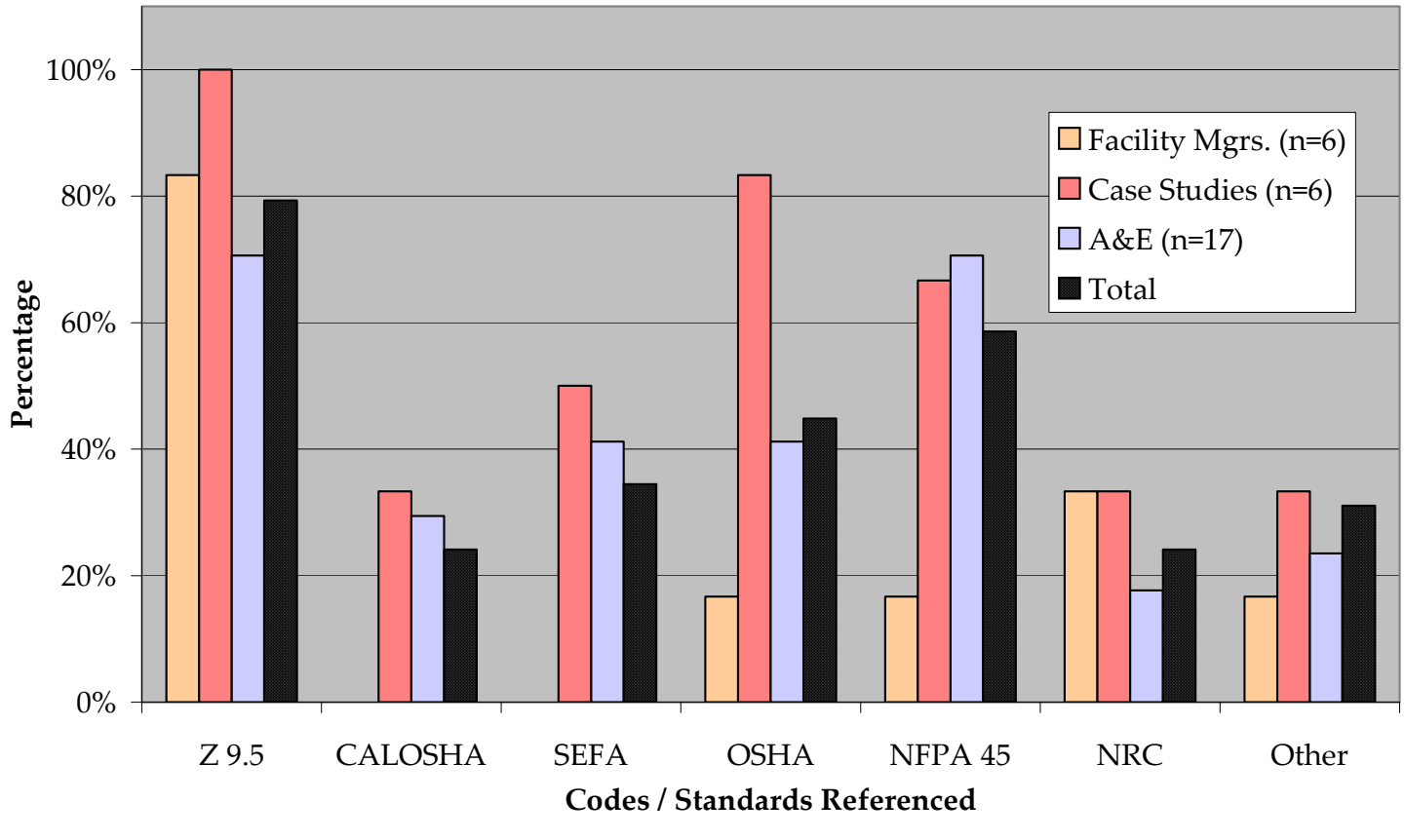
Survey group:	Use CFD as a computational tool:
Case Studies	60%
General A&E audience	40%

- On scale of one to five (1=lowest, 5=highest), rate the usefulness of CFD for the design of safe and energy efficient laboratories.



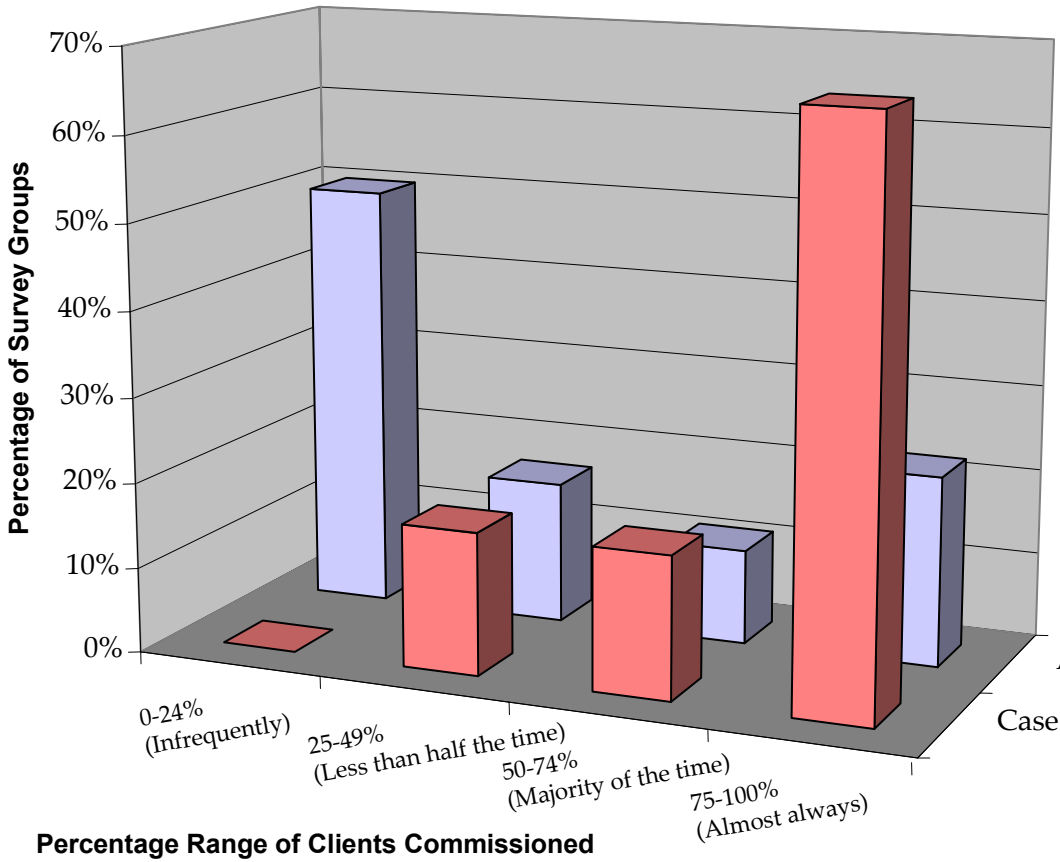
Fume Hoods

- What specific codes and standards do you reference to select face velocity…that you use as your criteria for fume hoods?



Testing

- Estimate the percentage of clients that your firm provides building commissioning for beyond traditional TAB protocol?



Operation

- What are one or two common problems you have seen emerge over the operating lifetime of labs that lead to reduced performance?

1. Poor preventative maintenance
2. System upgrades
3. Fume hood misuse
4. Inappropriate user modifications

Summary of Issues Raised

- There is concern that codes and standards may not offer adequate guidance for energy efficiency
- Many energy efficient technologies and practices are not at saturation point
- Maintenance issues play a role beyond design – into the long term bldg. operation
- There is concern that current codes and standards may not be adequate to ensure safety of lab occupants
- There is interest in additional research quantifying the correlation between lab ventilation and health risks

Discussion

- If a research center existed, what deficiencies/clarifications to current codes and standards would you like to see addressed?
  - Identifying energy consumption reduction options without sacrificing occupant safety
  - Safety of low flow fume hoods
  - Common ventilation standards that address laboratories
  - Improved techniques for estimating energy options
  - Clarification of hazardous exhaust system options