Practical Design Approaches for Efficient Cleanroom Fan Systems

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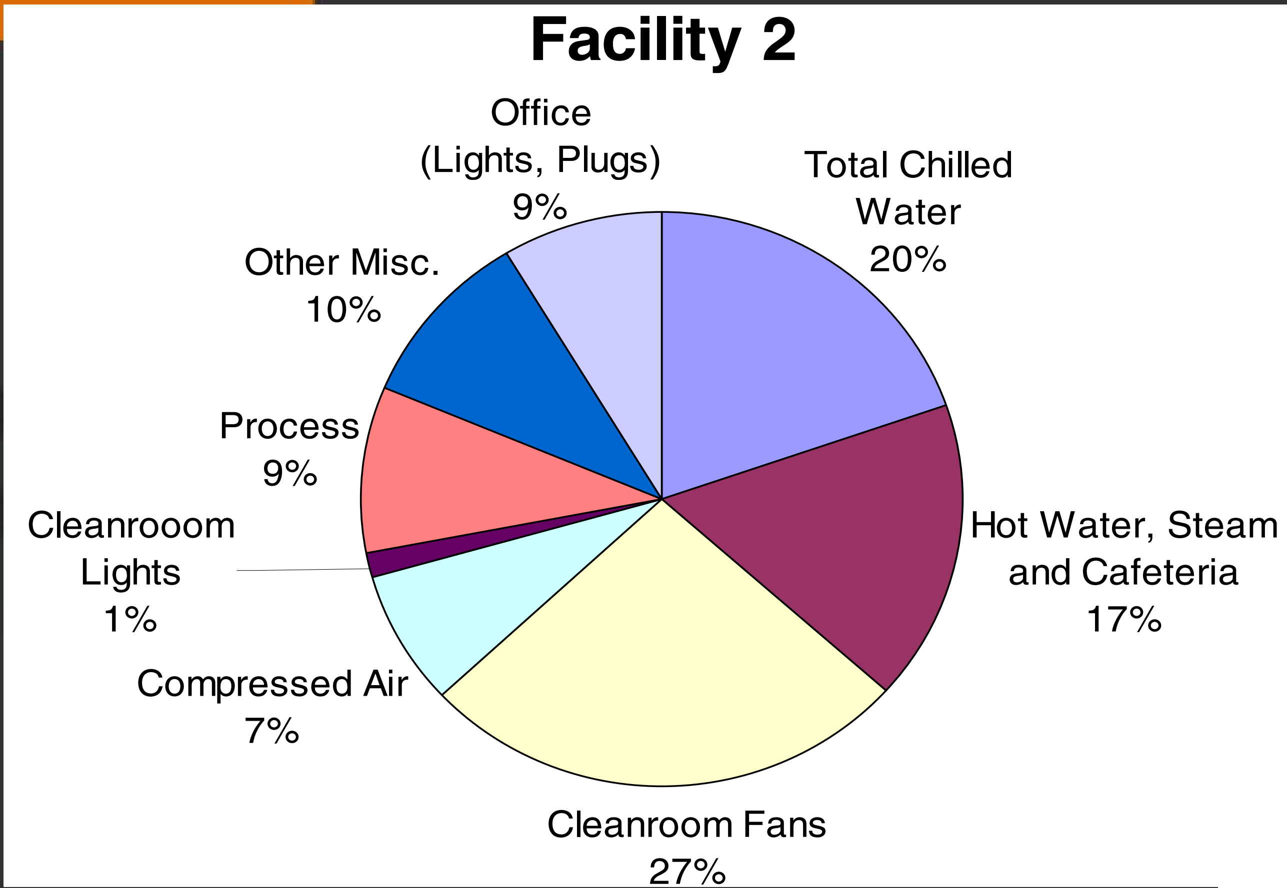
Overview

- LBNL Benchmarking Results
  - Cleanroom Energy Use
  - Fan System Metrics
- Practical Approaches
  - Obvious opportunities
  - Less Obvious opportunities
- Fan Filter Units

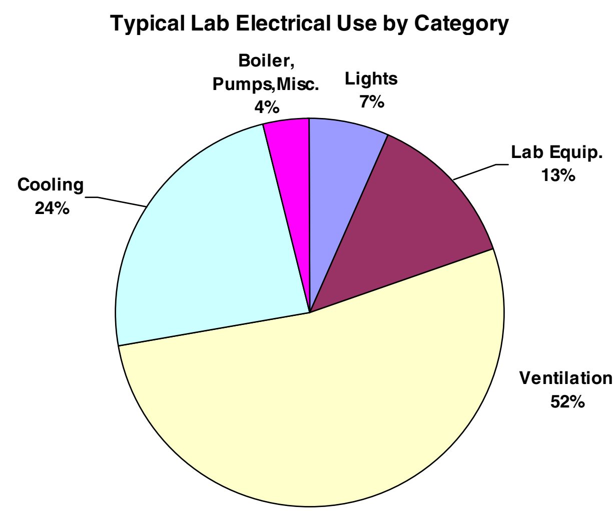
Lawrence Berkeley National Laboratory Cleanroom Benchmarking

- Close to 20 cleanroom facilities benchmarked
- Electronics, Biotech, Research
- Contacts – Bill Tschudi and Dale Sartor
- http://ateam.lbl.gov/cleanroom/

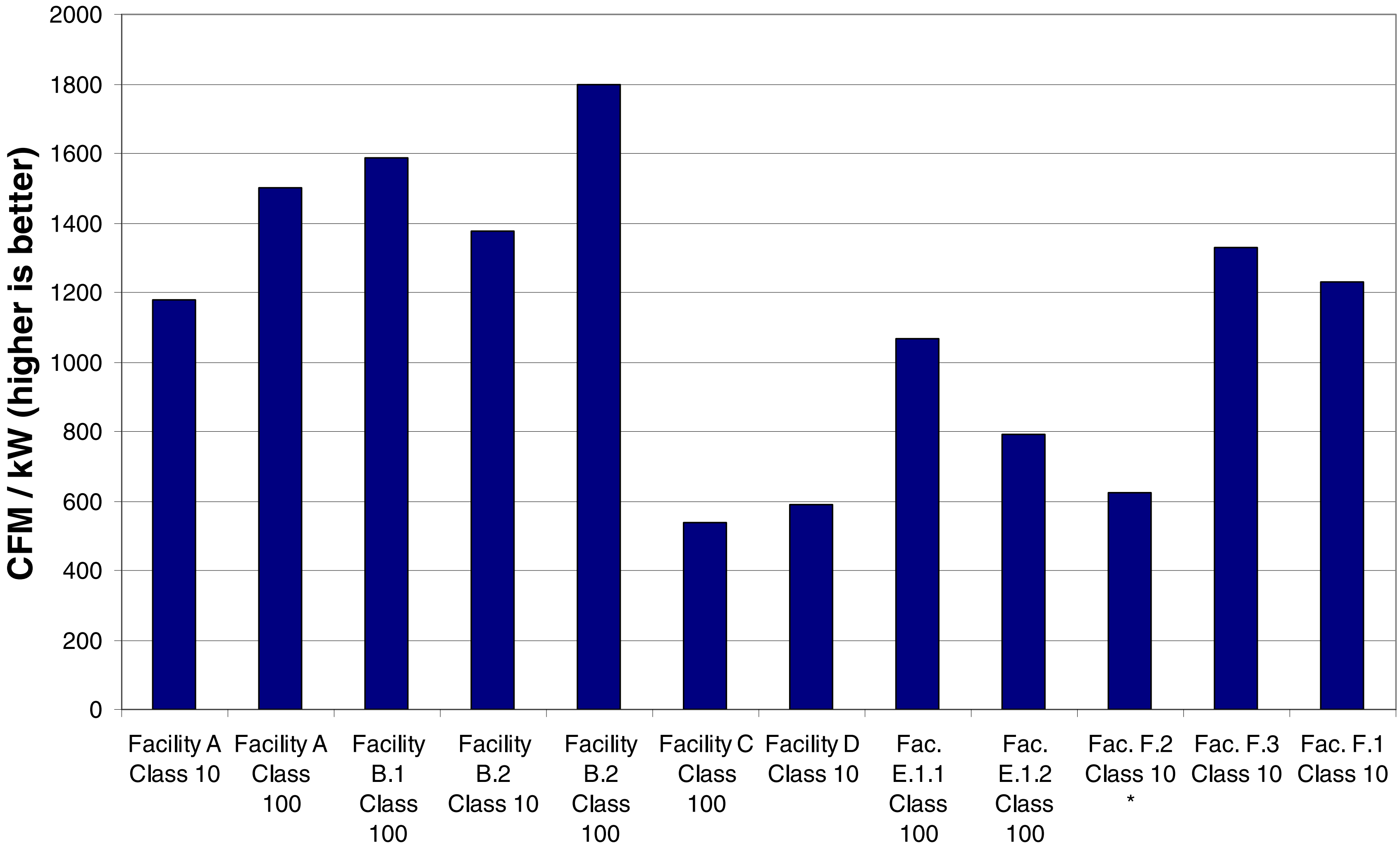
LBNL Cleanroom Benchmarking Data



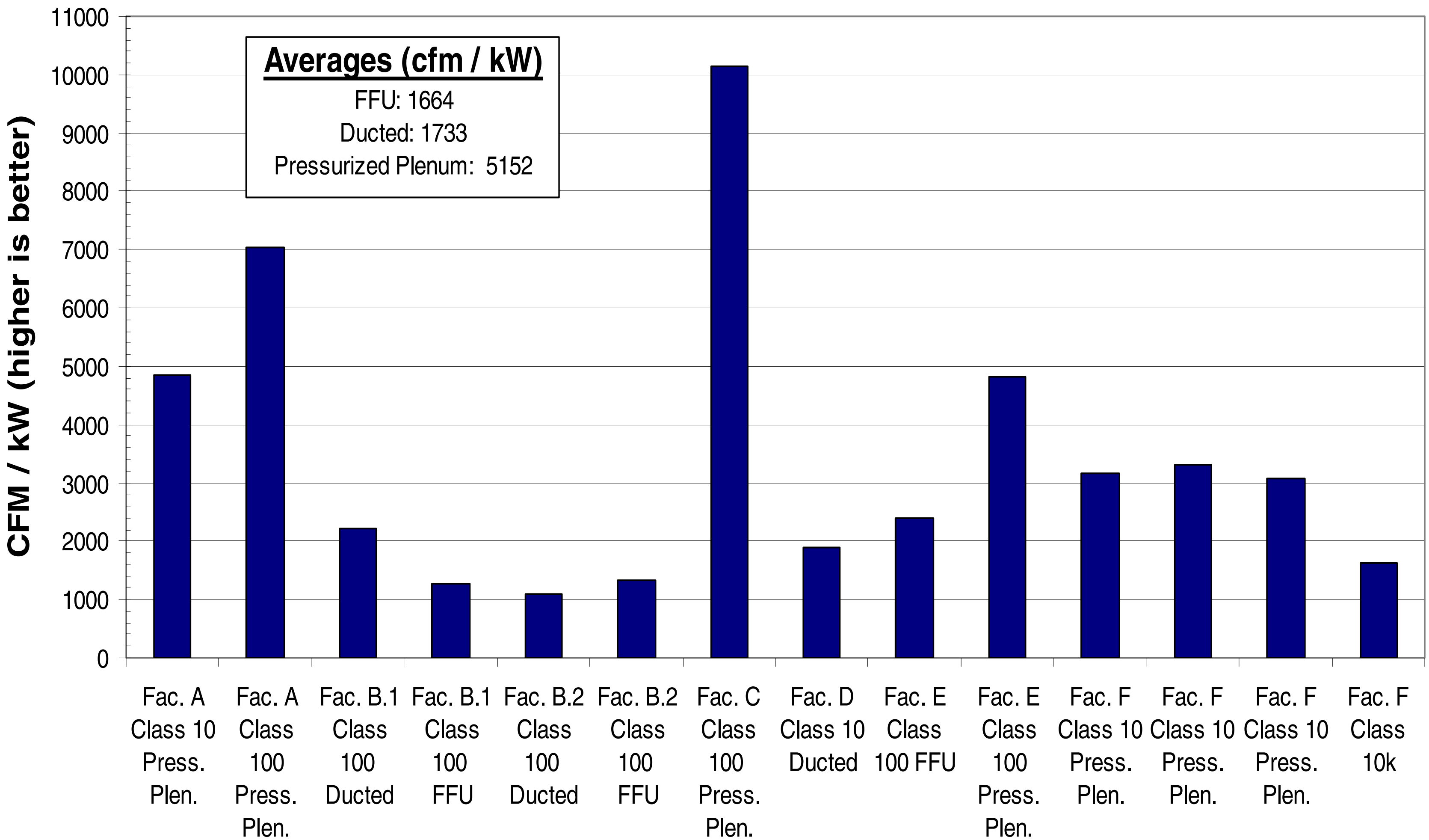
Fan Energy consists of Make-up and Recirculation Requirements



Make-up Air Performance Comparison



Recirculation Air Performance Comparison

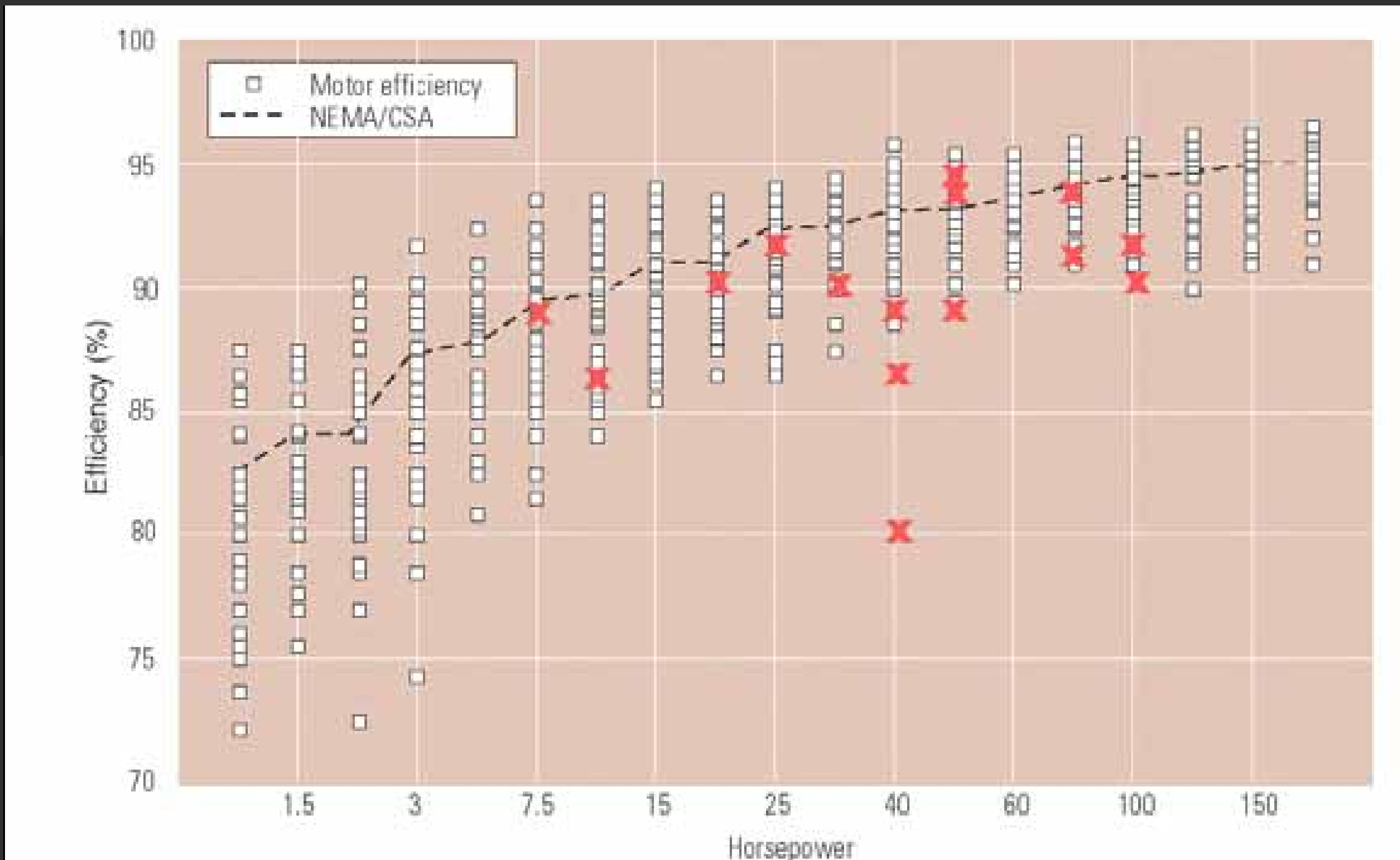


Strategies for Lowering Fan System Energy Use

- The Basics:
  - $$\text{Fan Power} = \frac{\text{CFM} \times \text{Pressure Drop (in inches)}}{6345 \times \text{Fan Eff} \times \text{Motor Eff}}$$

The Obvious Strategies

- Use Premium Efficiency Motors
  - Motor master software
- Select the fans for high efficiency
  - Typical fan efficiency 60% to 70%
  - Best Practice > 75%
- Use VFDs



Motor efficiency
NEMA/CSA
Efficiency (%)
100
95
90
85
80
75
70
1.5
3
7.5
15
25
40
60
100
150
Horsepower

The Less Obvious Strategies
Most of the Savings Are Here

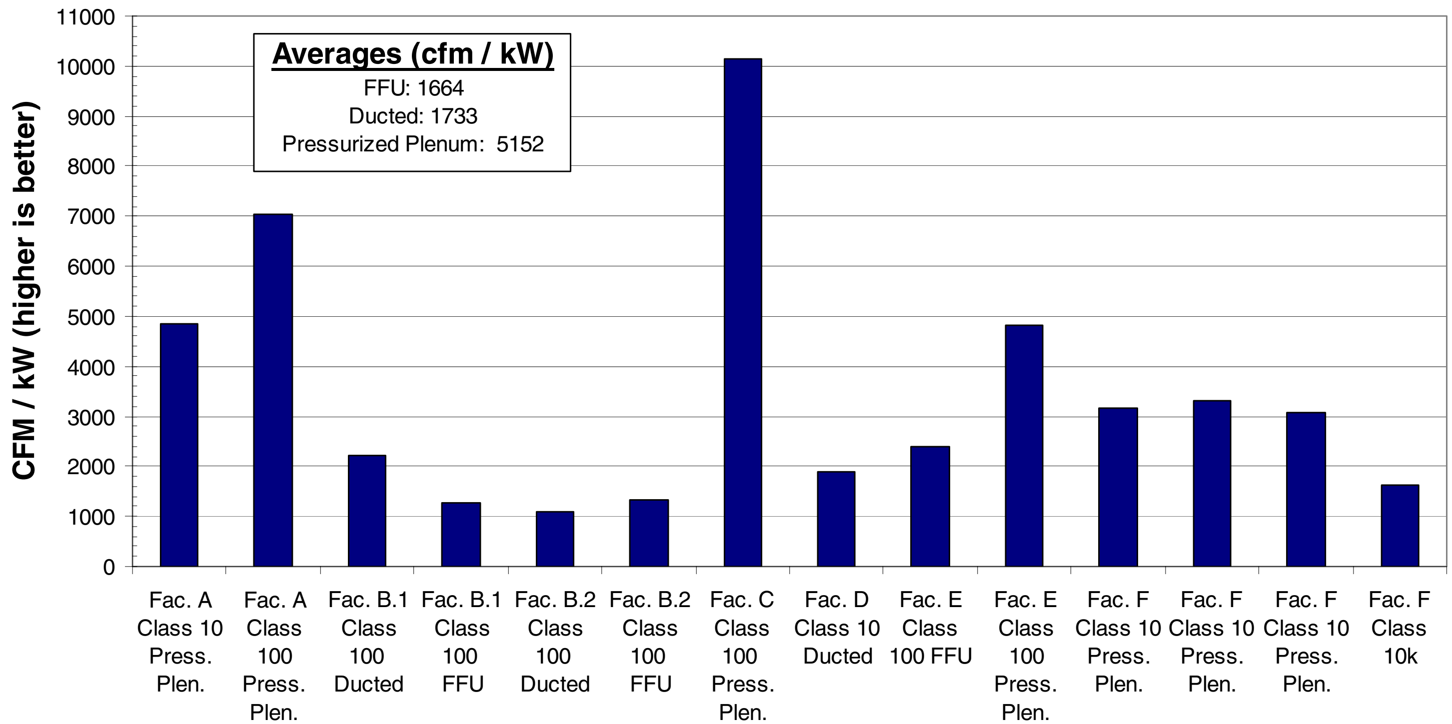
- Lower pressure drop
  - Selection of system
  - Duct layout and sizing
  - Low face velocity Air Handlers
- Lower air flow
  - Air change rates
  - Exhaust Optimization
  - Demand Controlled Filtration

Lower Pressure Drop

- $$\text{Fan Power} = \frac{\text{CFM} \times \text{Pressure Drop (in inches)}}{6345 \times \text{Fan Eff} \times \text{Motor Eff}}$$

System Type Selection

- Recirculation Air Handling Systems in Cleanrooms
  - Pressurized Plenum
  - Ducted Hepa
  - Fan Filter Units



What is the cost impact?

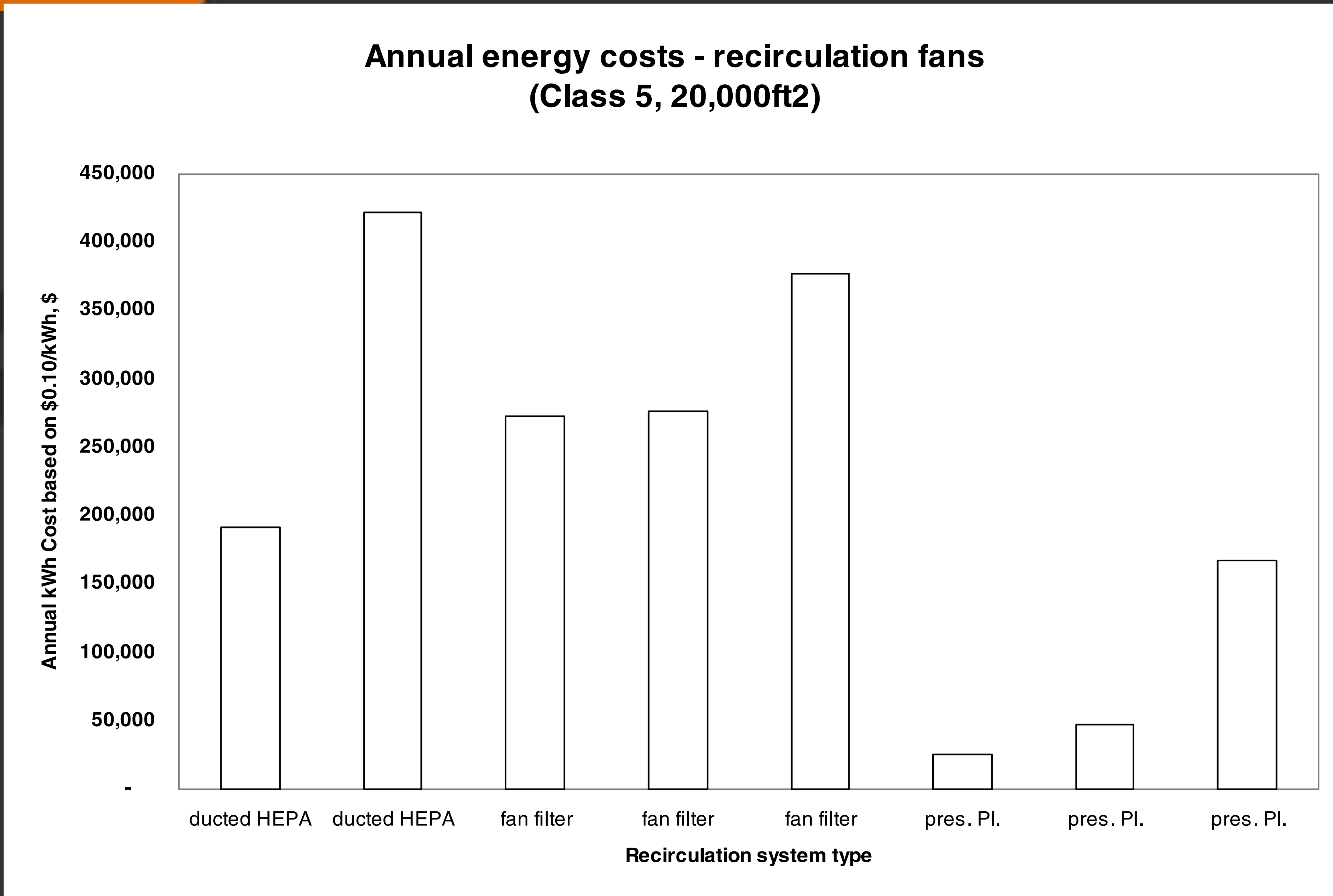
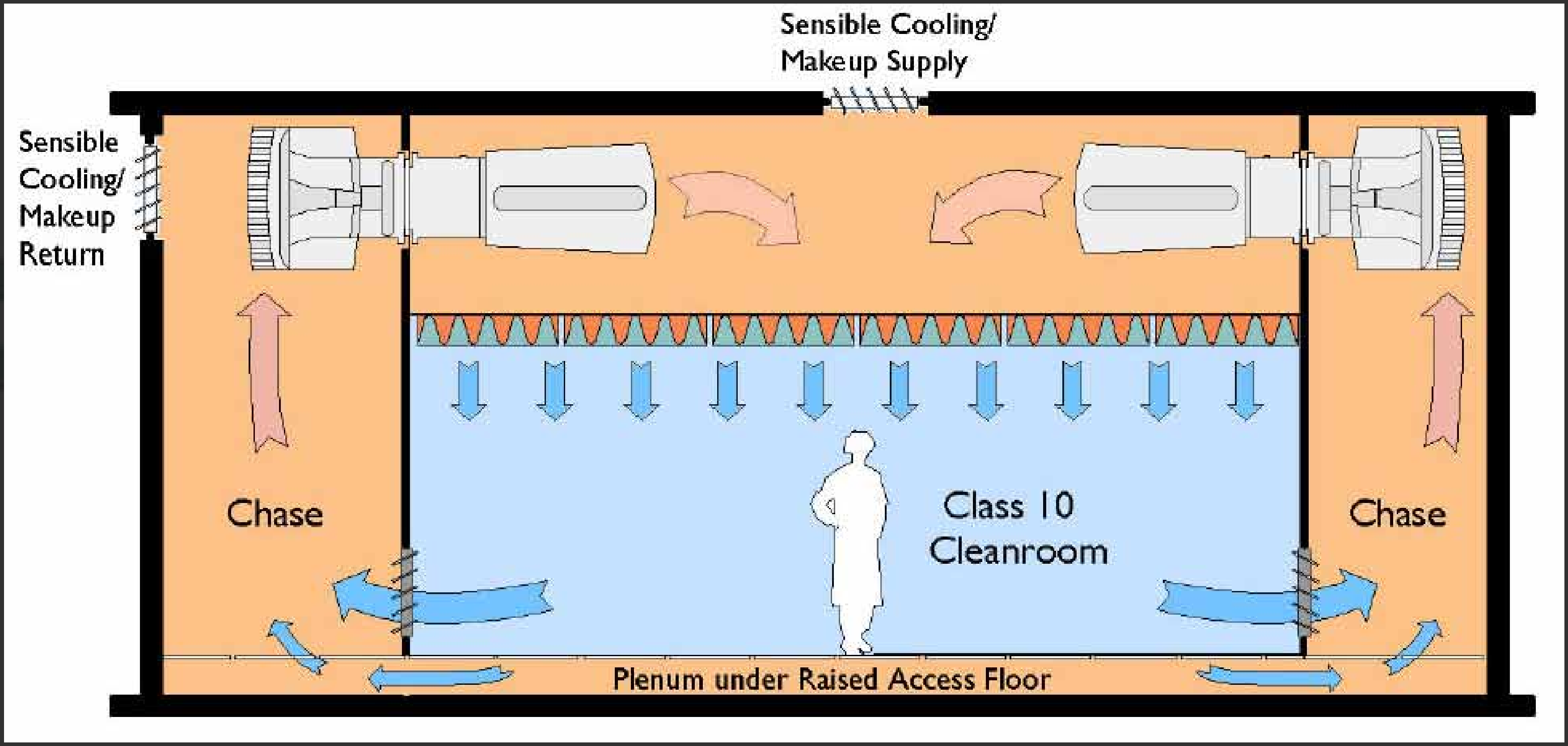


Image courtesy of LBNL – Bill Tschudi

Rumsey Engineers, Inc.

Ducted HEPA

Pressurized Plenum



Duct Layout and Sizing

$$\text{Pressure drop} \propto \frac{1}{\text{duct dia}^{5.1}}$$

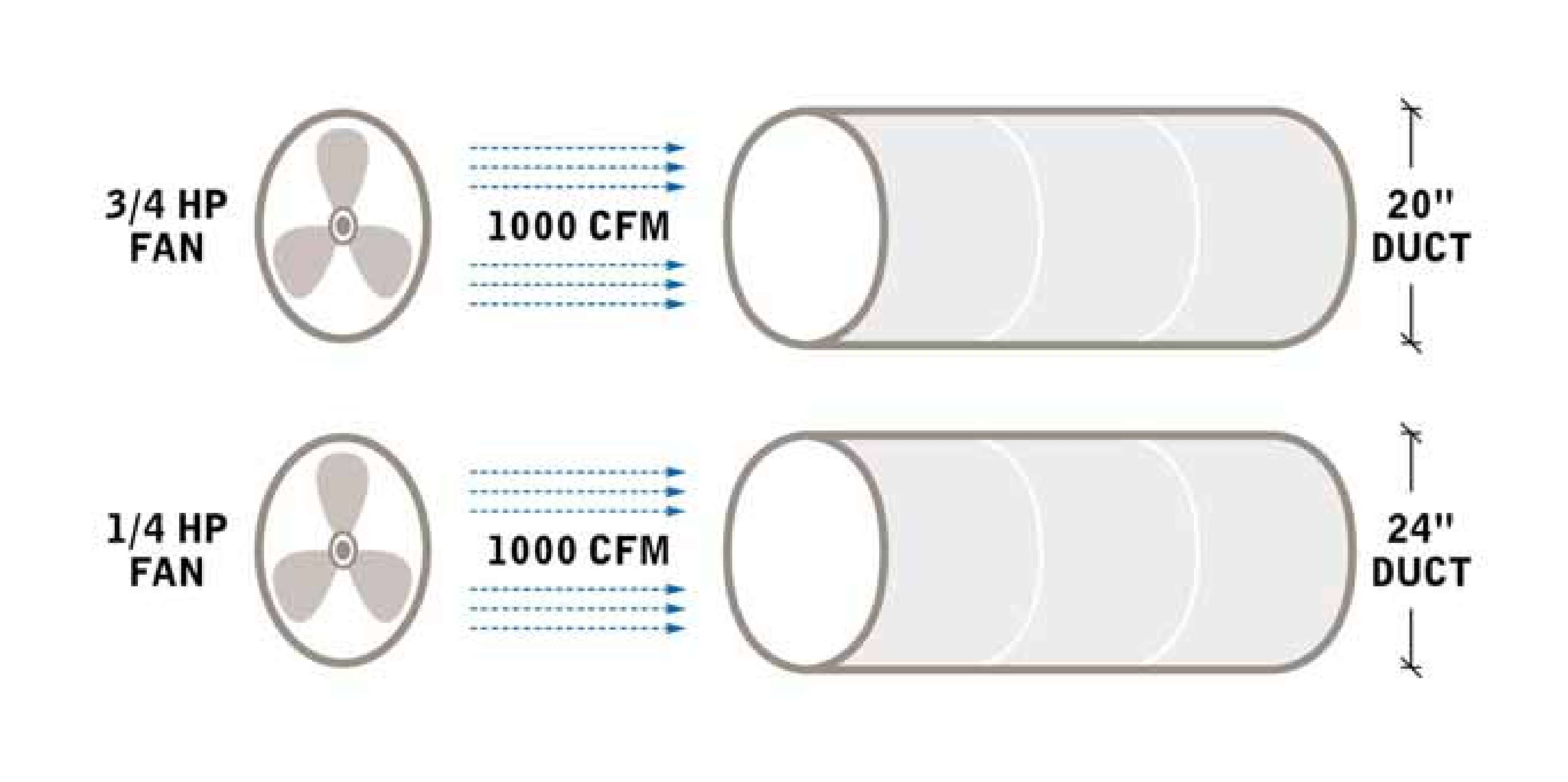
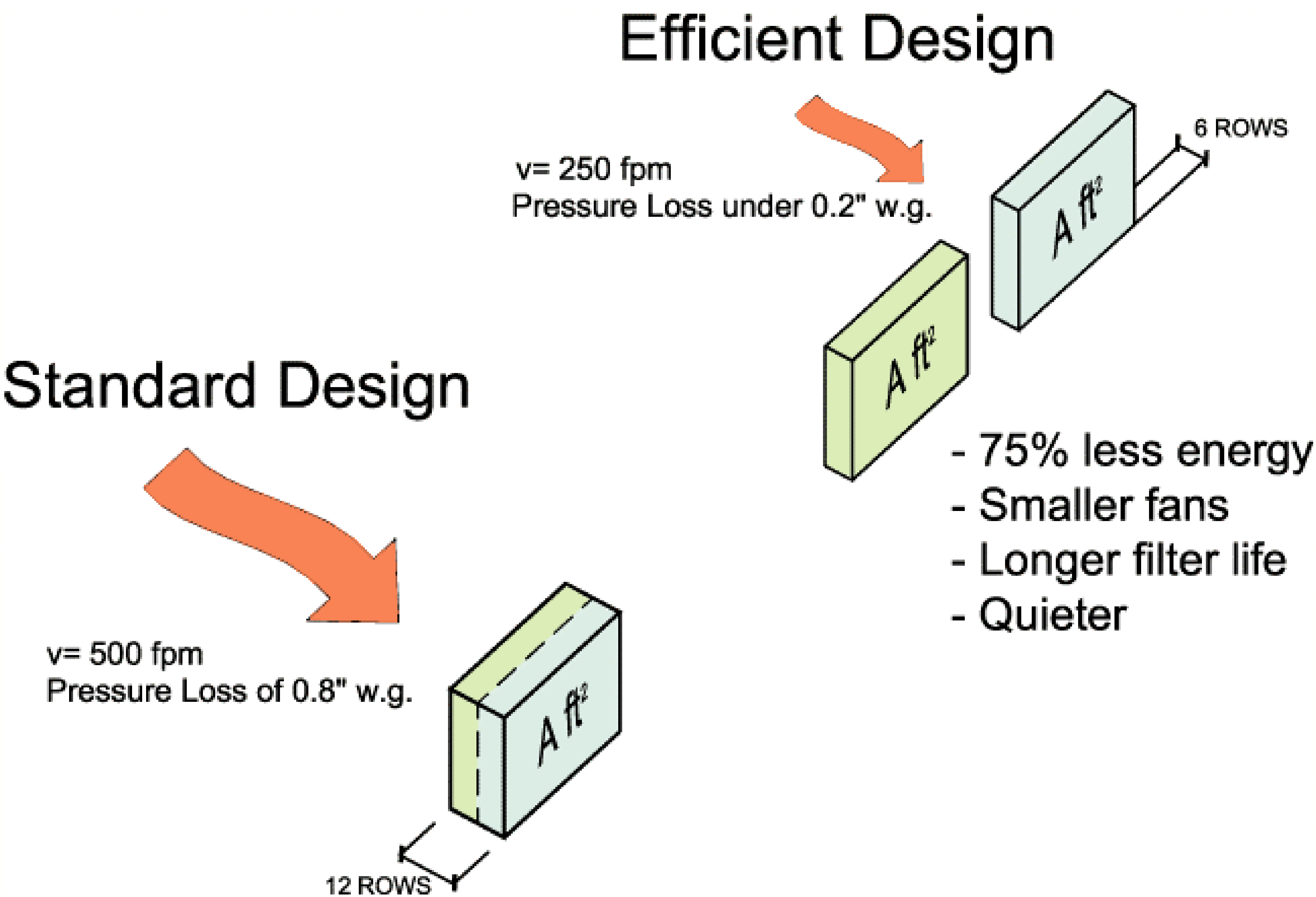


Image Courtesy of EHDD Architects

Low Face Velocity Air Handlers

Pressure drop α velocity^2


Efficient Design
v= 250 fpm
Pressure Loss under 0.2" w.g.
6 ROWS
A ft²
A ft²
- 75% less energy
- Smaller fans
- Longer filter life
- Quieter
Standard Design
v= 500 fpm
Pressure Loss of 0.8" w.g.
A ft²
12 ROWS

Low Face Velocity Example
43,500 CFM Make-up air handler

$$\text{Face Velocity} = \frac{\text{Unit CFM}}{\text{Coil or Filter Face Area}}$$

Coil Sizes for 43,000 CFM Air Handler

500 fpm 87 sf 9.3' square	425 fpm 102 sf 10.1' square	350 fpm 124 sf 11.1' square	300 fpm 145 sf 12' square

Courtesy of Greg Owen, Jacobs Engineering

Cost Impacts of Low Face Velocity Air Handlers

Component	Cost Impact
Larger Casing	→ Increase Capital Cost
Larger Coils	→ Increase Capital Cost
Increased Filter Count	→ Constant Life Cycle Cost
Smaller Fan Motors	→ Decreased Capital Cost
Reduced Infrastructure	→ Decreased Capital Cost

Fan Motor Sizing Impacts

Face Velocity	RPM	Brake Hp
500 FPM	801	65.0
425 FPM	757	55.6
350 FPM	709	46.0
300 FPM	687	41.8

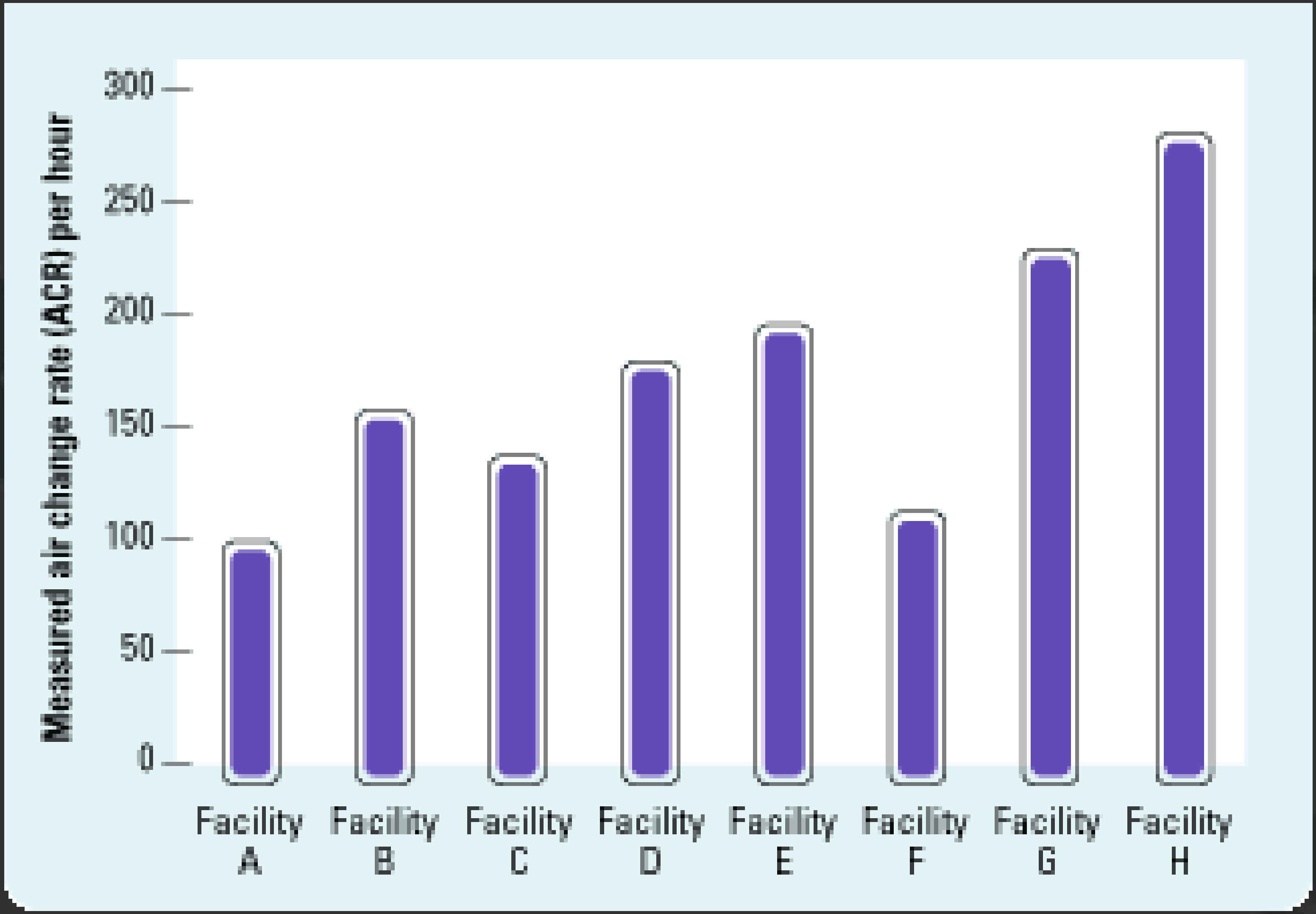
Cost Comparison Results

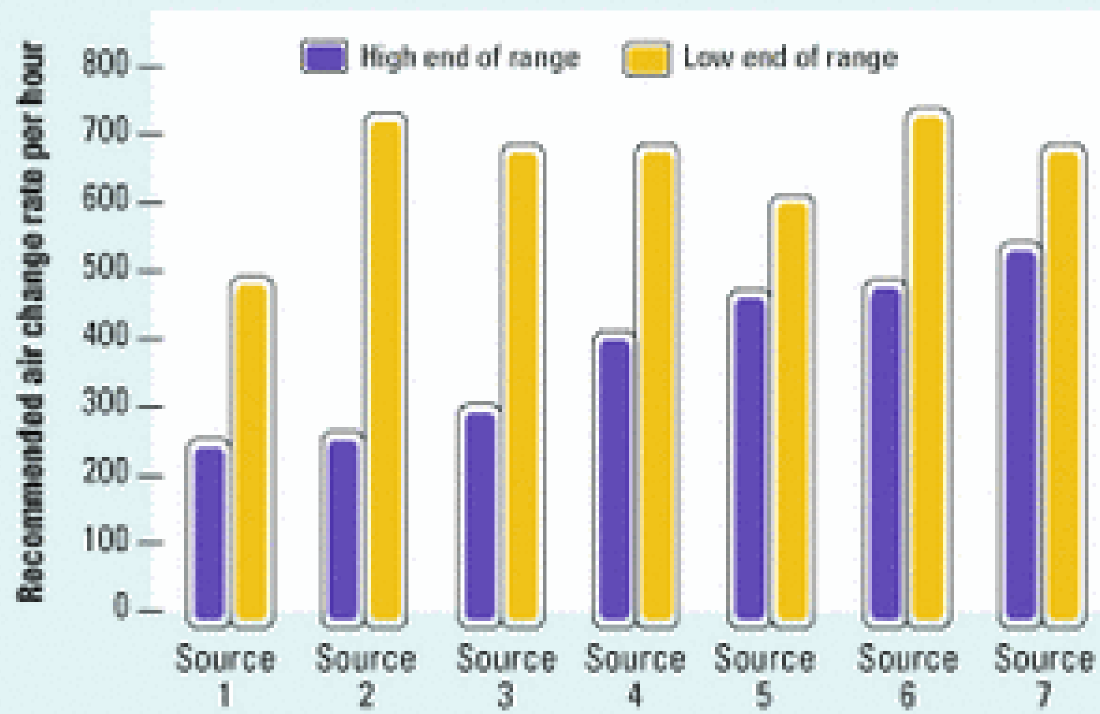
500 FPM	Base Cost
425 FPM	+$4,820
350 FPM	-$1,610
300 FPM	+$9,450

Lower Air Flow

$$\text{Fan Power} = \frac{\text{CFM} \times \text{Pressure Drop (in inches)}}{6345 \times \text{Fan Eff} \times \text{Motor Eff}}$$

Comparison of ISO Class 5 Cleanrooms (LBNL Benchmarking Data)

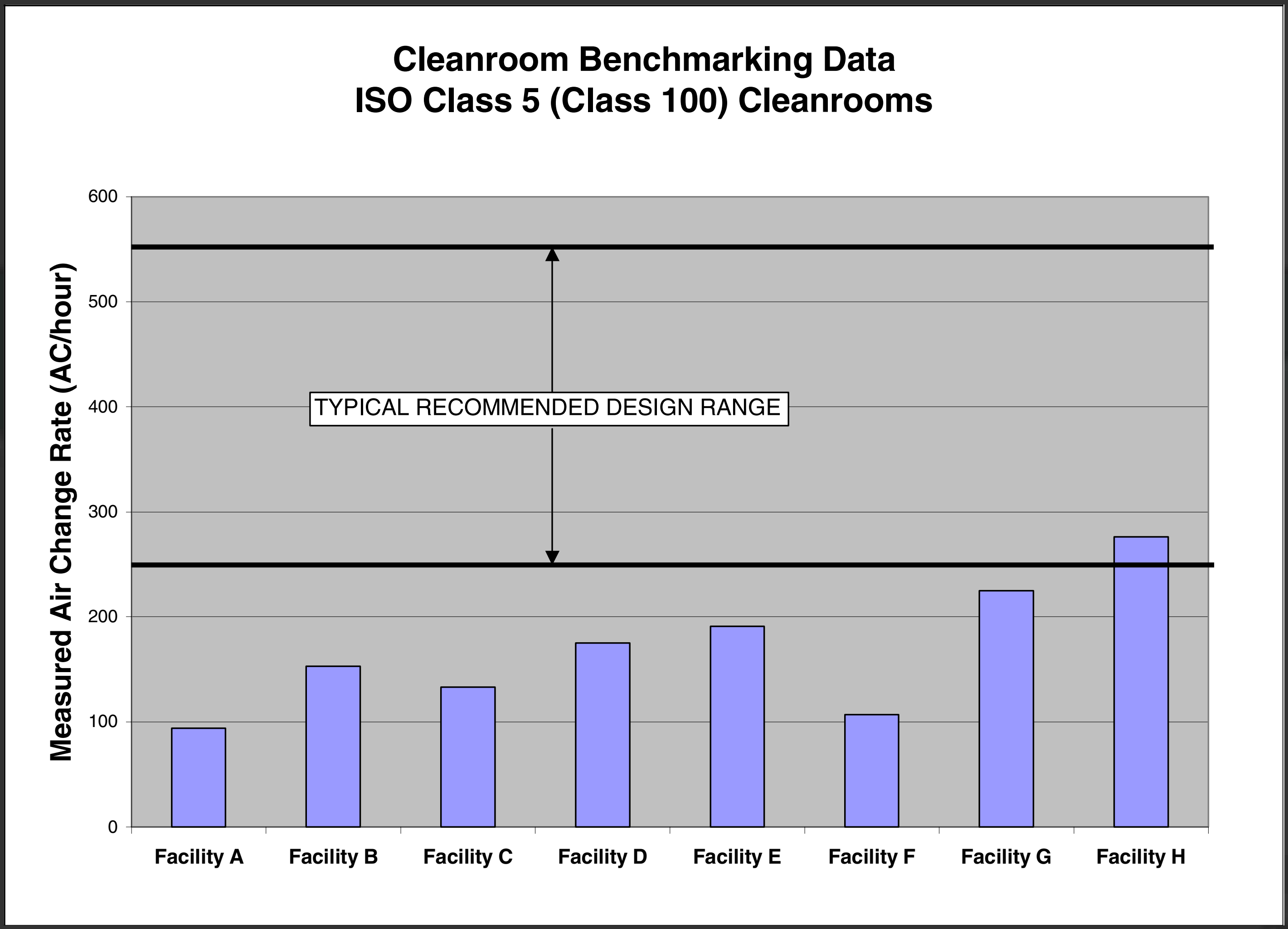




Sources:

1. Institute of Environmental Sciences and Technology (IEST; Rolling Meadows, Ill.) Recommended Practice (RP) CC012.1
2. Raymond Schneider, Practical Cleanroom Design
3. Cleanrooms equipment supplier
4. Faulkner, Fisk and Walton, "Energy Management in Semiconductor Cleanrooms"
5. California-based designer and cleanrooms instructor
6. Federal Standard 209B (outdated)
7. National Environment Balancing Bureau, "Procedural Standards for Certified Testing of Cleanrooms," 1996

Compare Recommendations to Actual Practice



Results of Recent Exhaust Optimization

Ion Implant Tool - 1,612 to 1,232 scfm

Wet Bench - 574 to 254 scfm

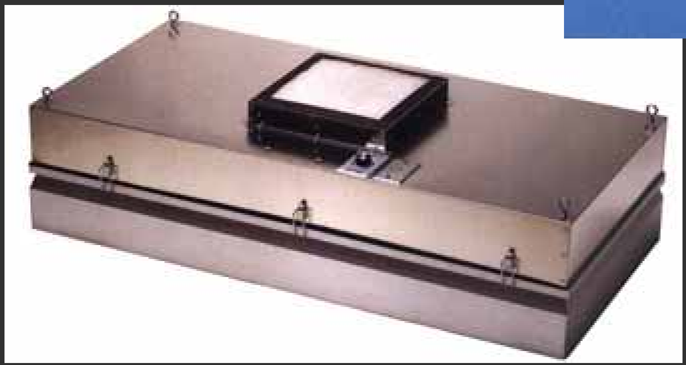
Vertical Furnace - 628 to 474 scfm

Courtesy of Northwest Energy Efficiency Alliance Website (www.nwalliance.org)

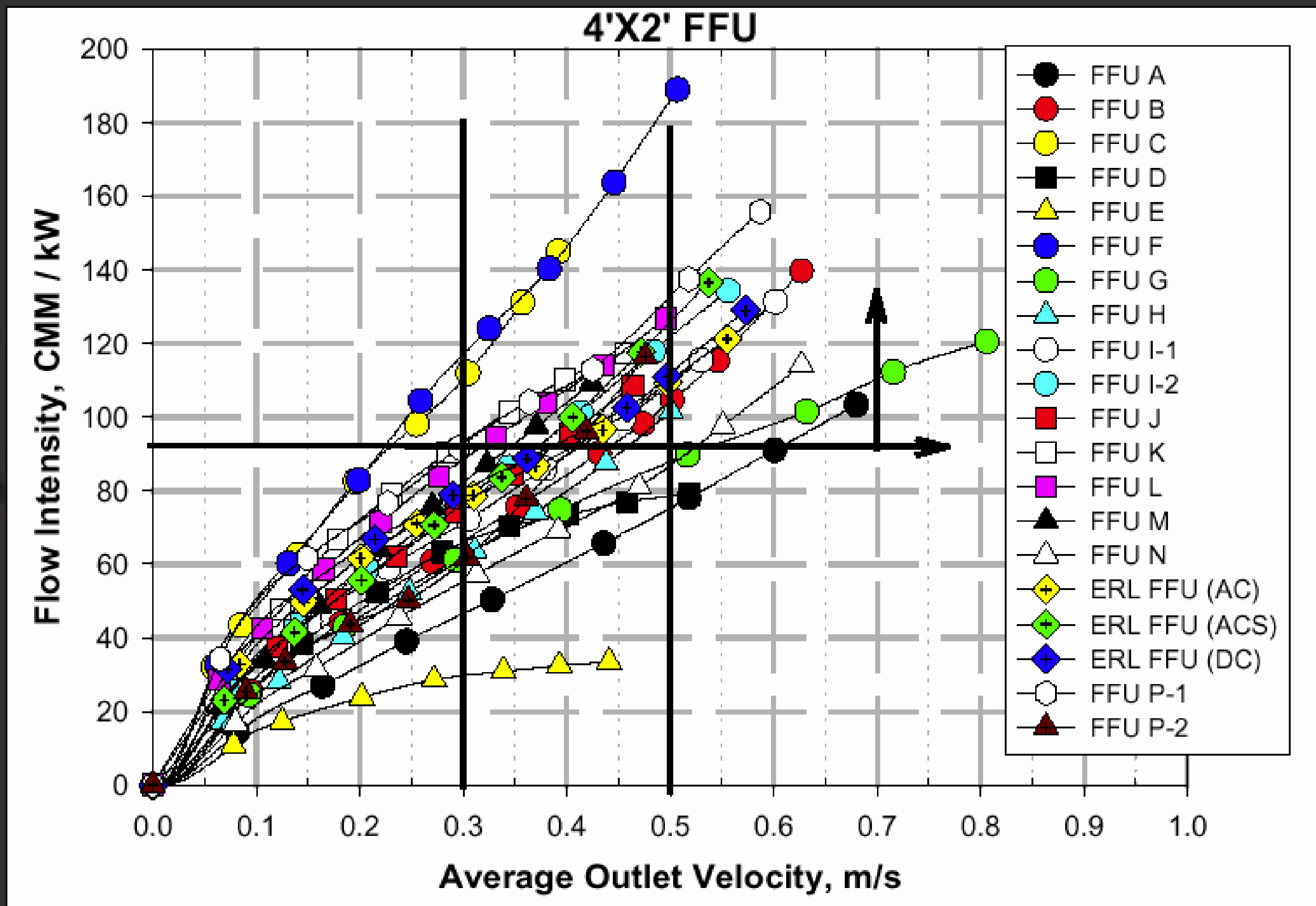
Demand Controlled Filtration

Fan Filter Units

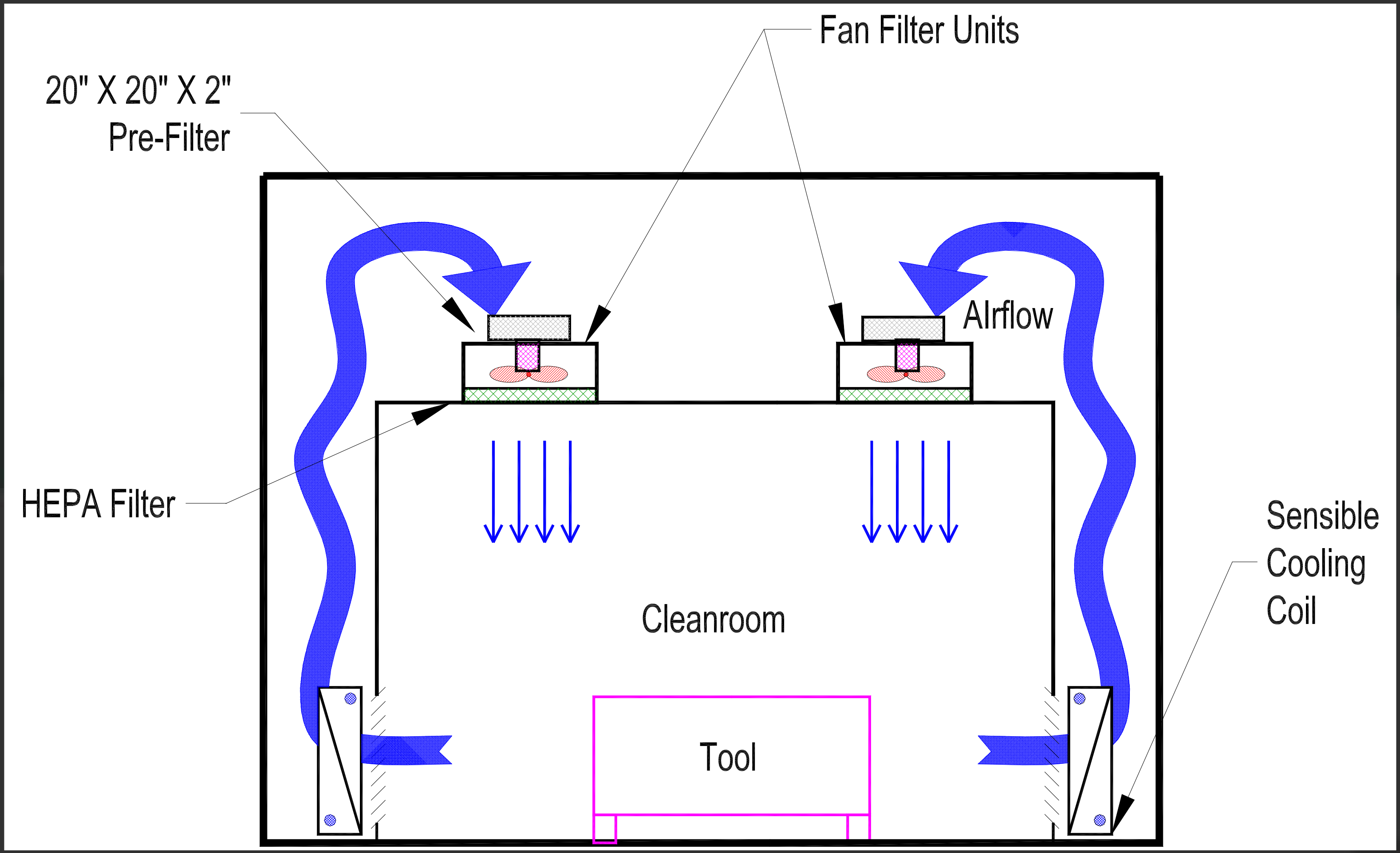
Fan Filter Units



Taiwanese Performance Comparison of FFUs



Efficient FFU Design Minimizes System Pressure Drop



How to Select an Efficient FFU?

- To compare FFU energy performance, provide manufacturers with:
  - The airflow – define the method of measurement, hood or velgrid at set distance from filter with a defined assumed active filter area (6.5 sq. ft. or less for a 2'x4')
  - The filter requirement (HEPA, ULPA, "nines")
  - External system pressure drop – this is crucial!
- Require a written specification of the FFU's power consumption at above criteria

- Coming Soon – FFU Efficiency Testing Standard from LBNL

Conclusion

- Use Efficient fans and Motors
- Lower pressure drop
  - Selection of system
  - Duct layout and sizing
  - Low face velocity Air Handlers
- Lower air flow
  - Air change rates
  - Exhaust Optimization
  - Demand Controlled Filtration
- FFU Systems
  - Not all FFUs are created equal…
- The largest and most cost effective efficiency strategies are not the most obvious ones

THANK YOU!

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