



# Implementing Wind Responsive VAV Exhaust Systems at NREL's Energy Systems Integration Facility: A Four-Year Follow-Up

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# Learning Objectives

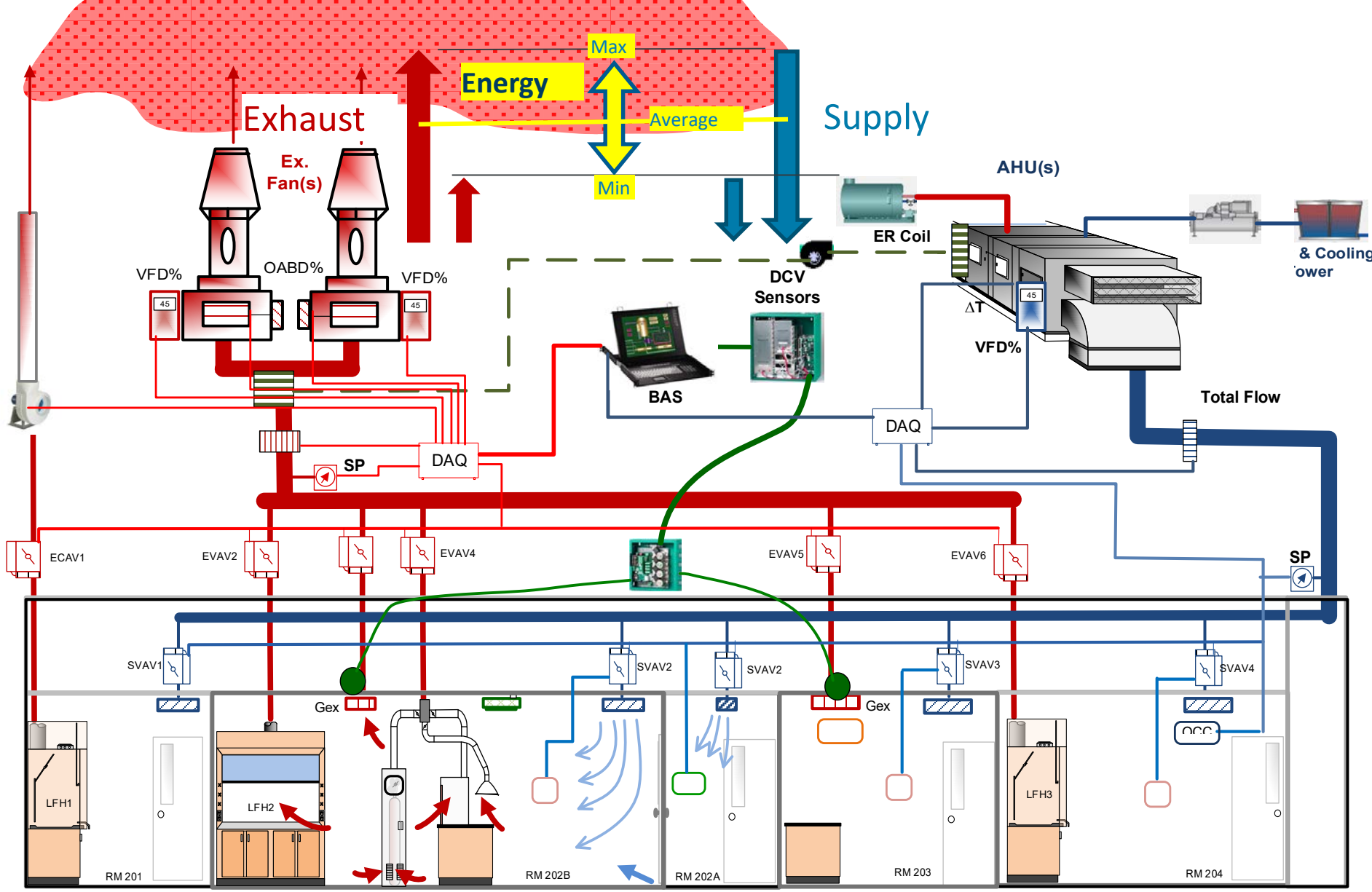
- Just because a building went through a thorough commissioning process before occupancy doesn't necessarily mean that it is operating properly post-occupancy.
- Things change over time; A thorough investigation into the current HVAC operation is warranted to ensure safe and efficient operation.
- When properly employed, a wind responsive VAV exhaust system can provide significant energy savings while maintaining a safe working environment.
- What to look for when evaluating the current operation of a VAV laboratory exhaust system to determine whether or not it is functioning properly.

# Key Elements of a Smart Lab

| Key Element                                   | Approaches to Overcome Barriers   |
|---|---|
| Optimized ventilation and exhaust systems     | Partner with industrial hygiene to determine lowest safe ventilation rate for each lab space and exhaust stack discharge velocity |
| Optimized fume hoods                          | Partner with EHS/IH and lab staff to determine fume hood number, size, and containment requirements                               |
| Continuous commissioning                      | Use building control system and tools to optimize lab mechanical systems operations   |
| Energy-efficient lighting                     | Implement energy-efficient lighting technologies and controls   |
| Variable air volume                           | Upgrade constant air volume systems to variable air volume  |
| Minimized system fan energy                   | Minimized system pressure drops and set duct static pressure to lowest adequate level   |
| Lab staff is engaged in sustainable practices | Provide sustainable best practices to lab staff   |

<https://betterbuildingssolutioncenter.energy.gov/accelerators/smart-labs>

# Smart Labs Ventilation System – Flow & Energy



Courtesy of ECT

# NREL Energy Systems Integration Facility Lab, Data Center, and Office



DATA CENTER

HIGH BAY  
LABORATORIES

OFFICE

# Performance Targets

**Data Center: PUE 1.06, ERE 0.9**

**Office: 26.7 kBtu/sf/yr**

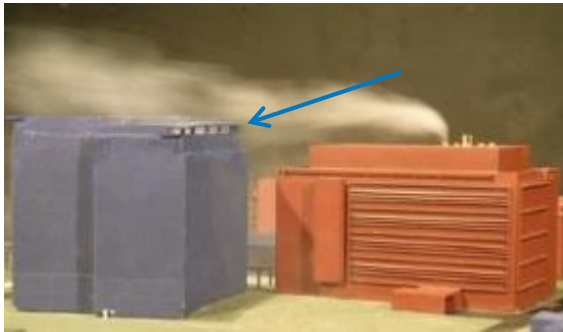
**Lab: 30% less than ASHRAE 90.1-2007**

- Actual: Low flow CFH set to 100 FPM vs NREL standard of lowest FPM that provides containment using ASHRAE 110 tests
- Ventilation rates occupied/unoccupied of 6 ACH/4 ACH (1/ 0.66 CFM/ sq. ft.) per NREL standards but construction did not install occupancy sensors. Need to install push button overrides to bring room out of scheduled unoccupied mode.
- Wind responsive exhaust controls installed, programmed but not operational. Now operational.



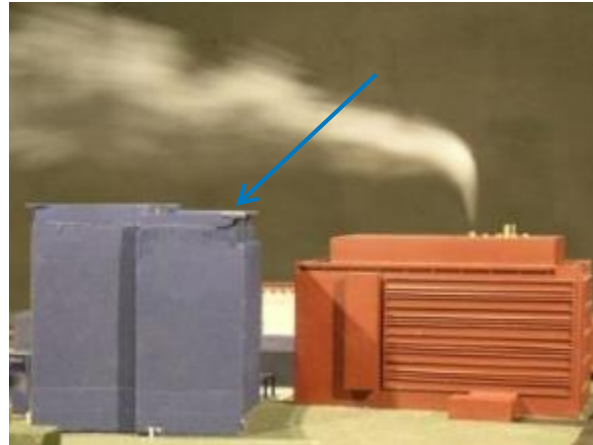
# Performance-Based Design

Adverse Air Quality



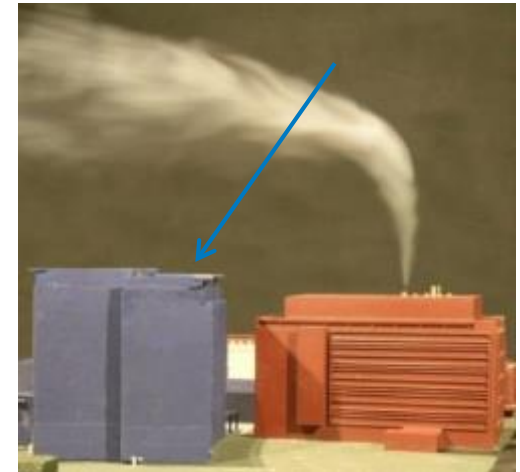
Low flow and low energy under-designed specifications.

“SAFE AND ENERGY EFFICIENT”



Optimum balance between energy and air quality.

Wasted Energy Potential

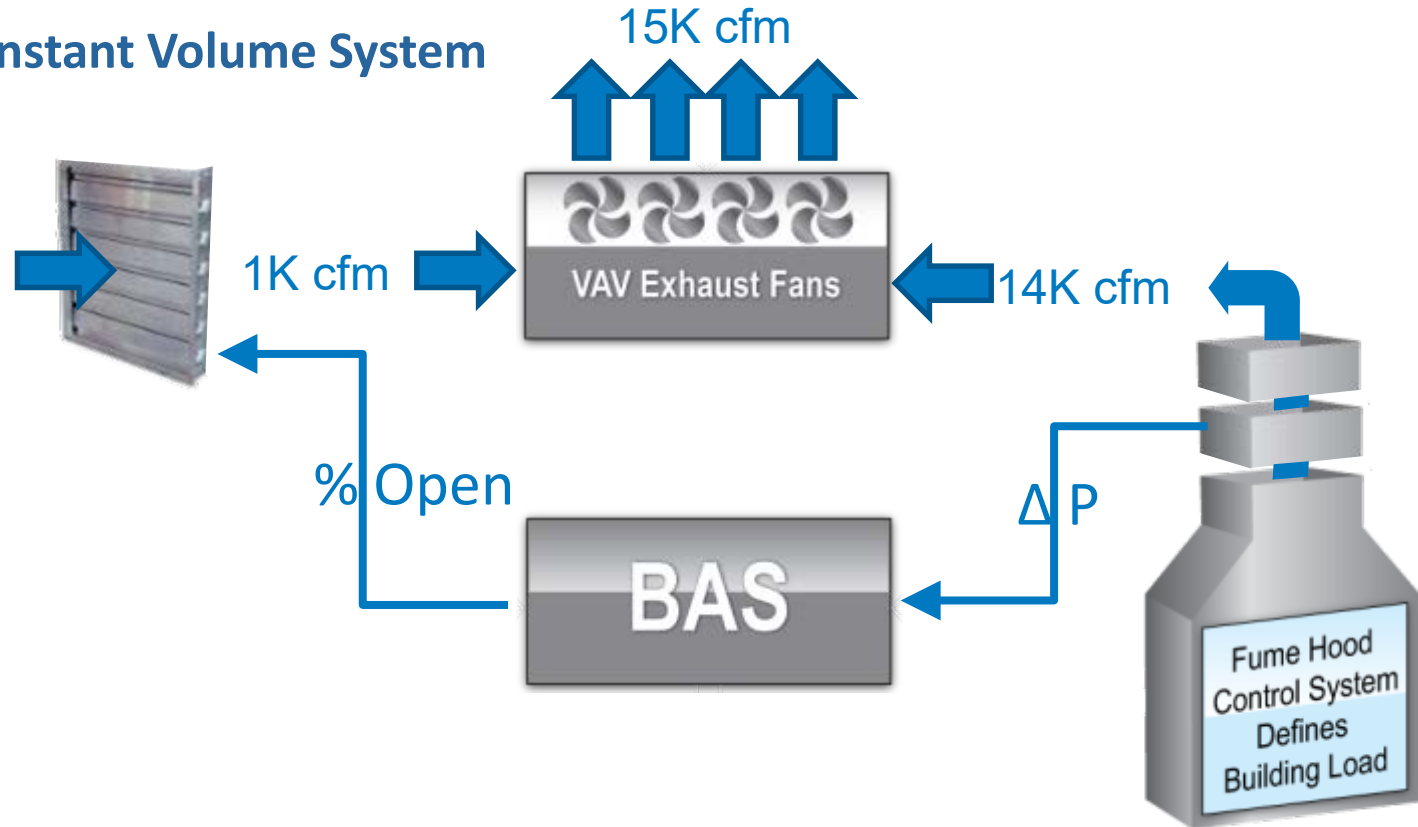


High flow and high energy. Typical manufacturer specifications.

# Energy vs. Air Quality

## Energy-Efficient Design

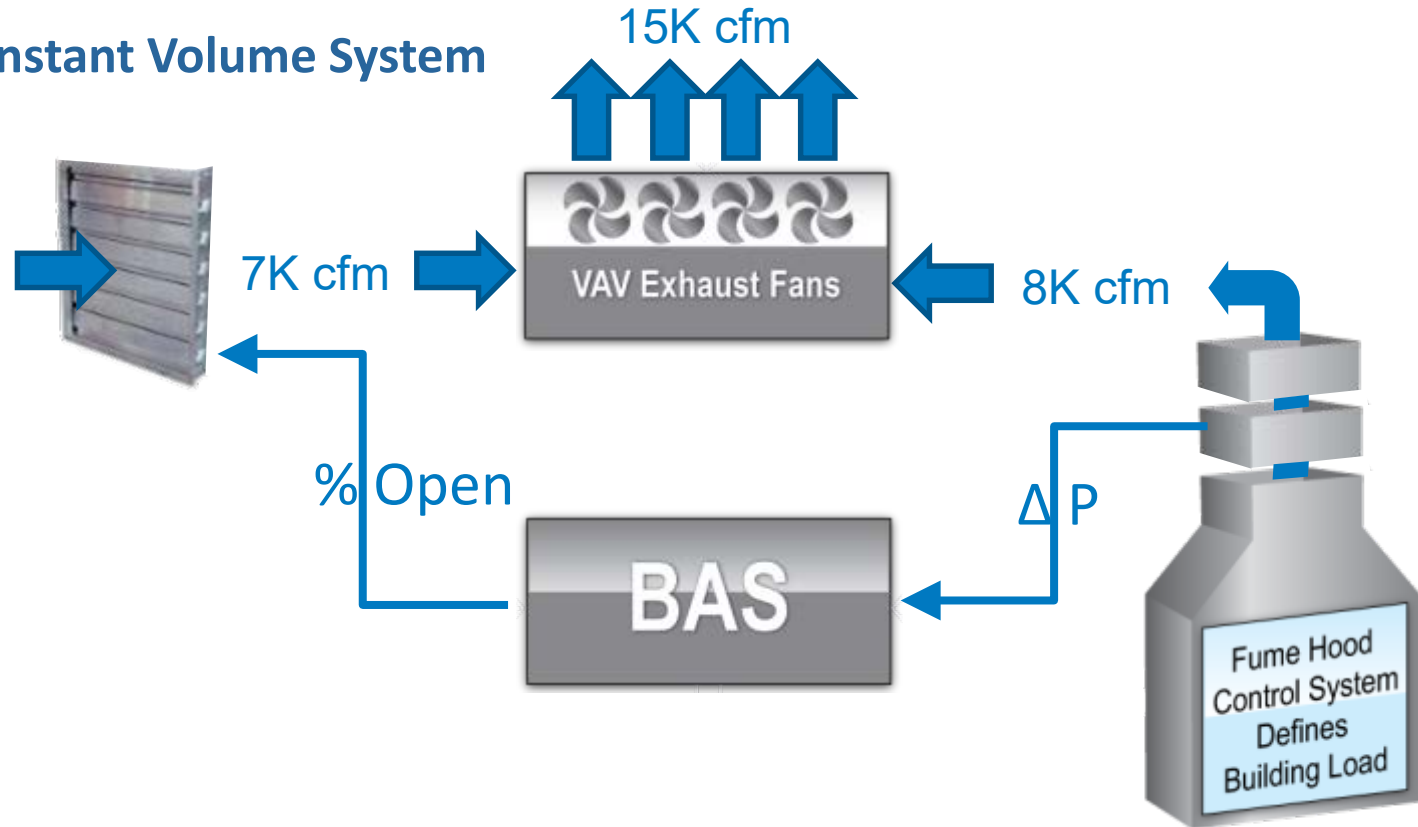
Traditional Constant Volume System  
Max Load



# Energy vs. Air Quality

## Energy-Efficient Design

Traditional Constant Volume System  
Min Load

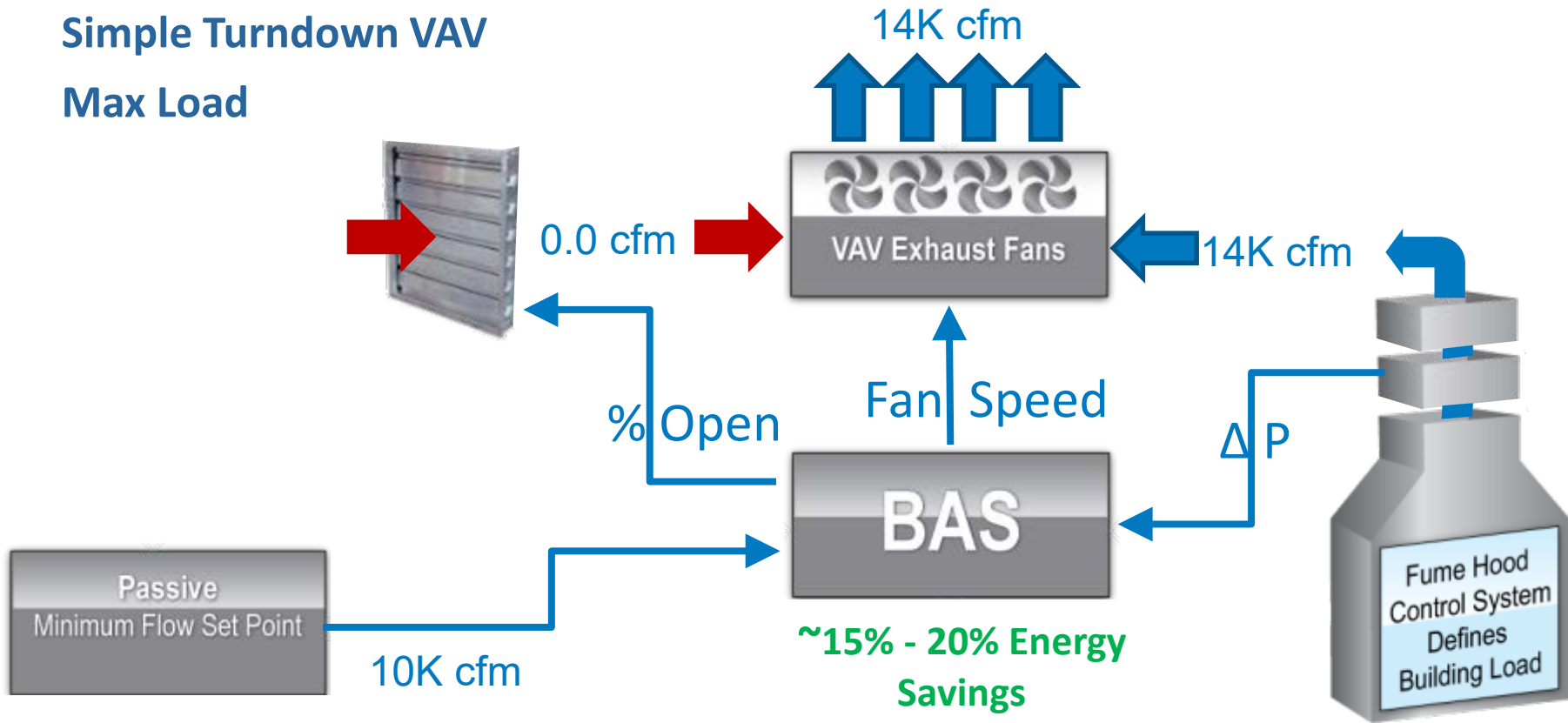


# Energy vs. Air Quality

## Energy-Efficient Design

Simple Turndown VAV

Max Load

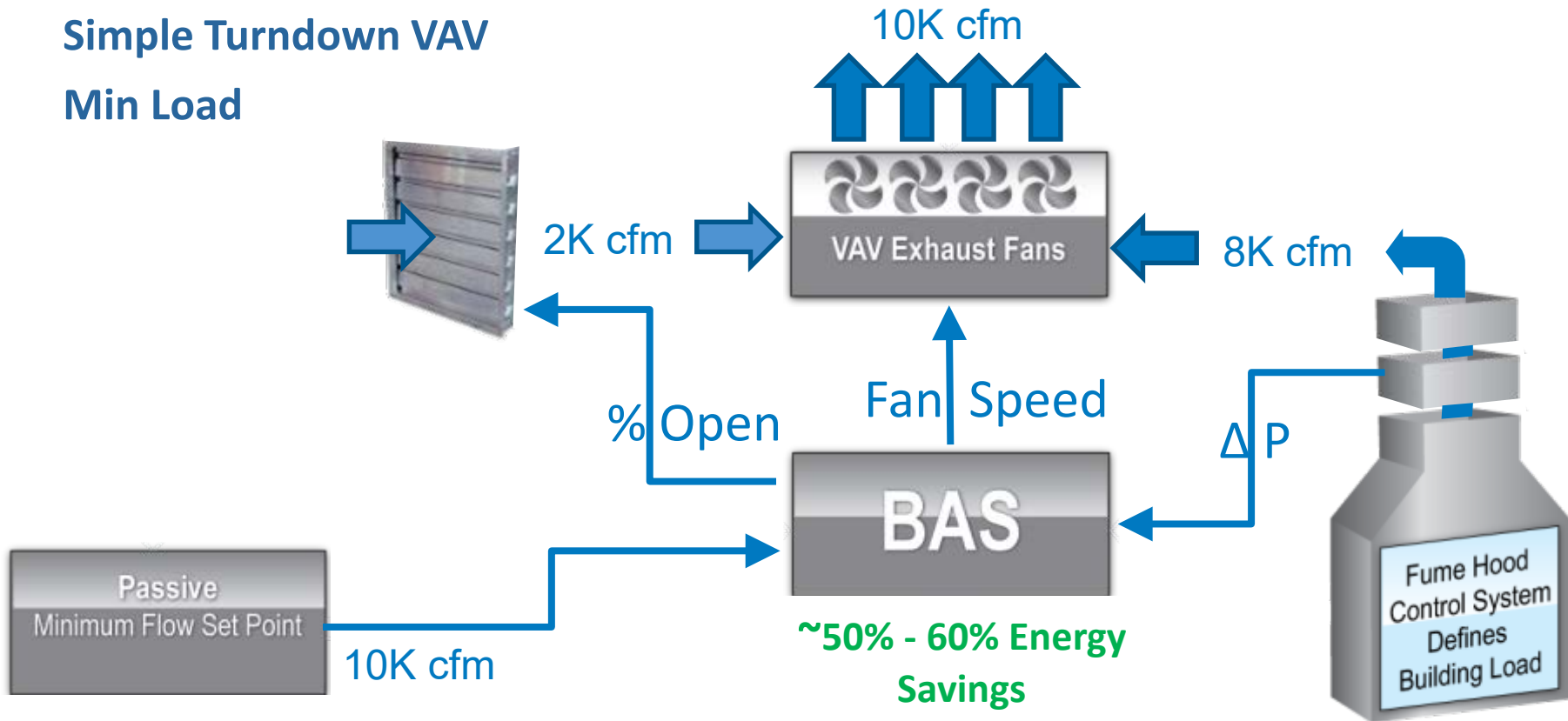


# Energy vs. Air Quality

## Energy-Efficient Design

Simple Turndown VAV

Min Load



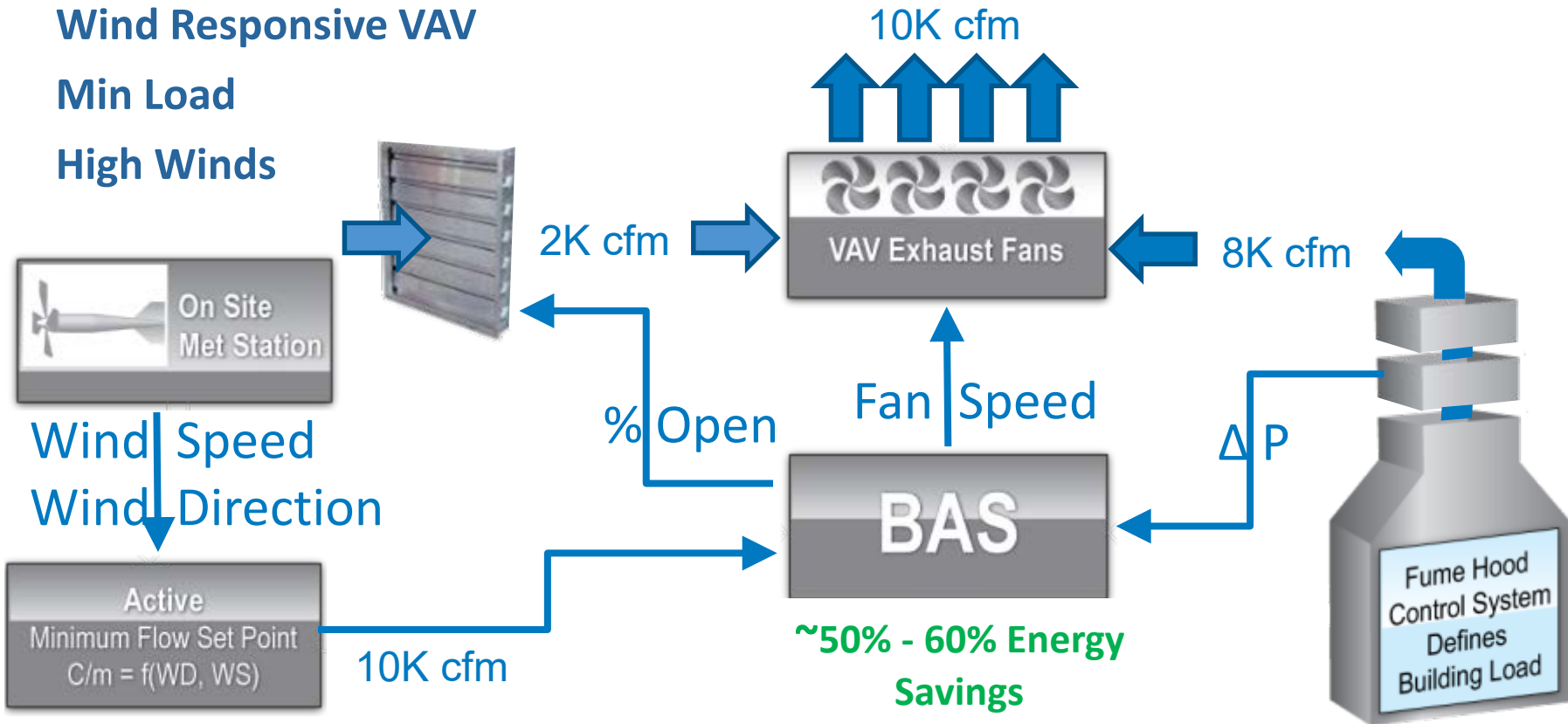
# Energy vs. Air Quality

## Energy-Efficient Design

Wind Responsive VAV

Min Load

High Winds



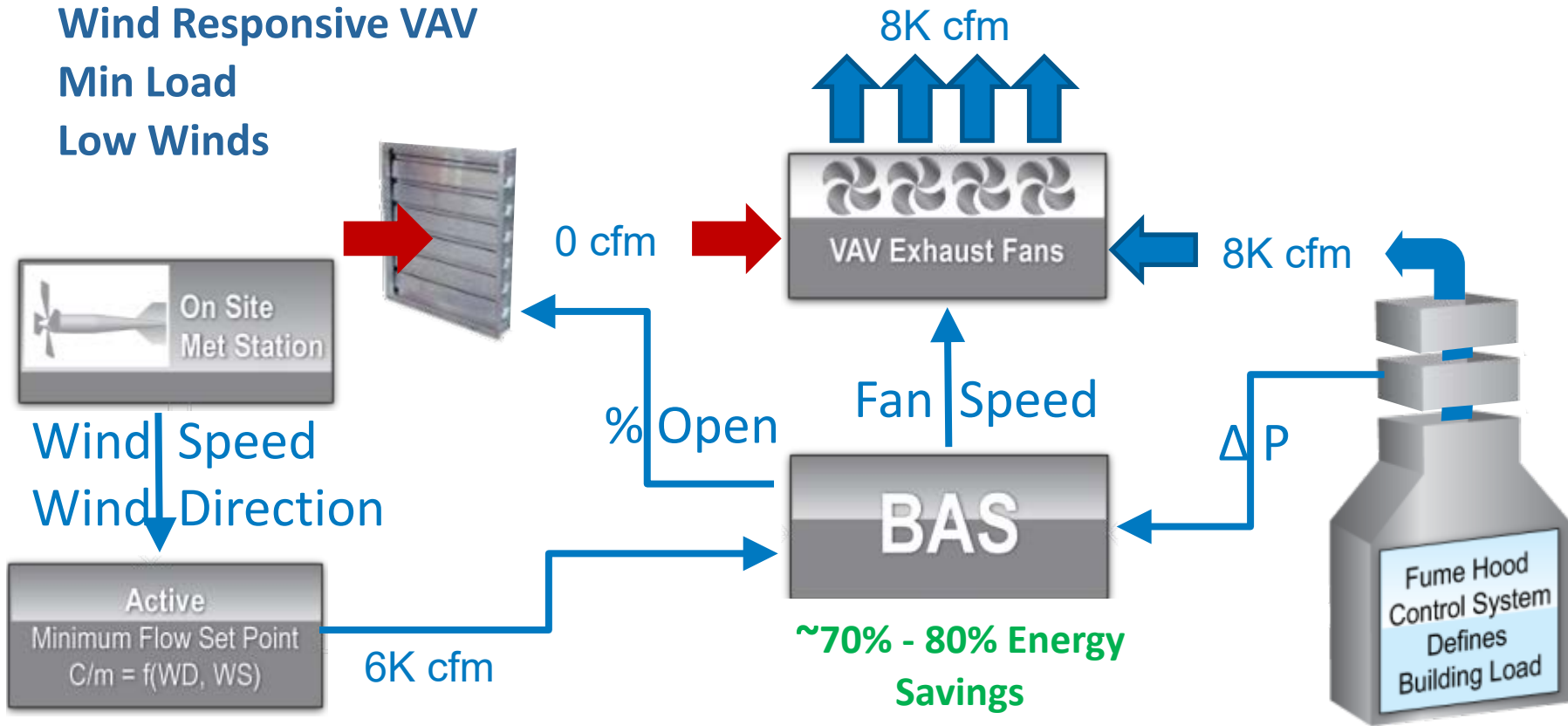
# Energy vs. Air Quality

## Energy-Efficient Design

### Wind Responsive VAV

Min Load

Low Winds



# Case Study

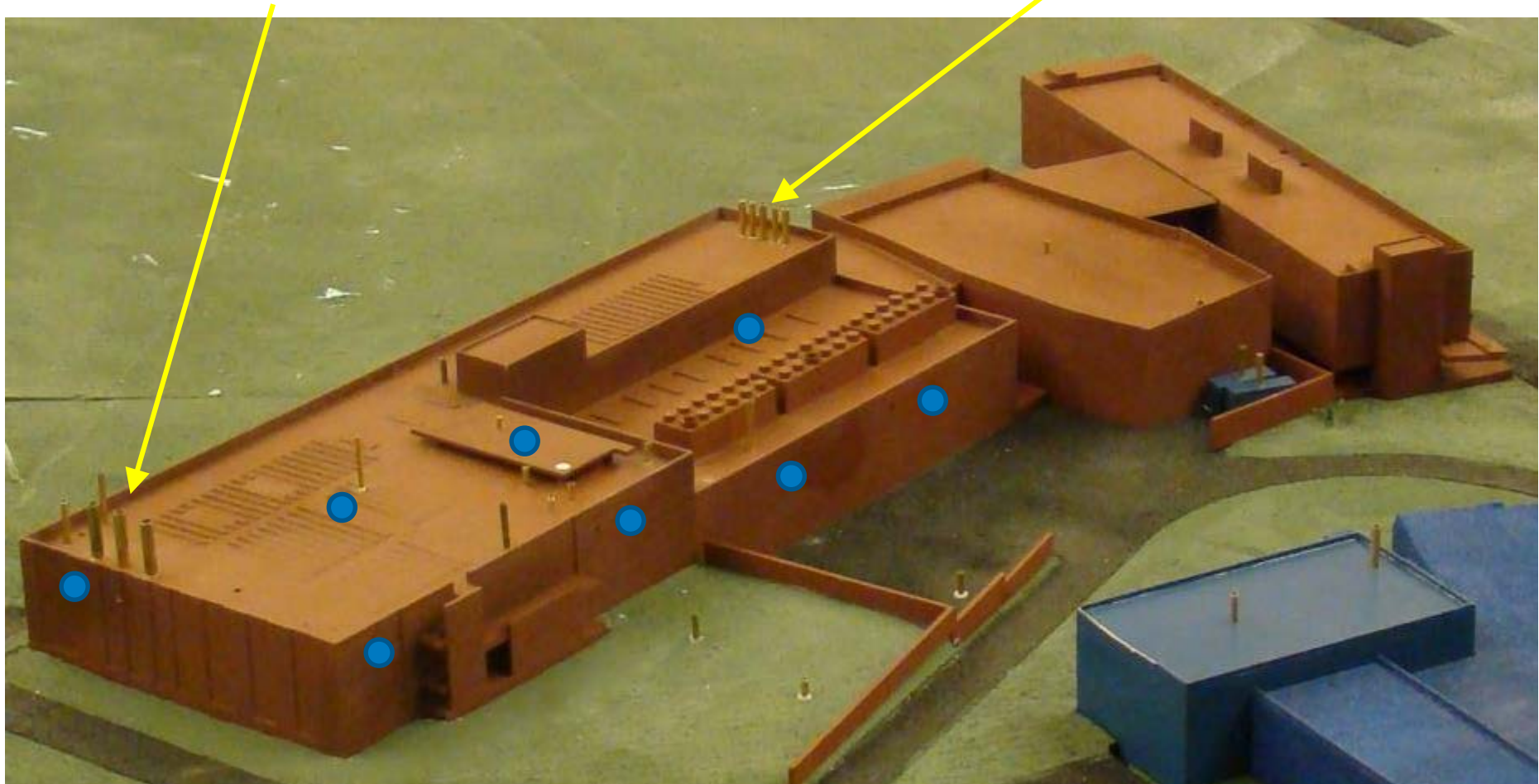
## NREL ESIF



# Case Study

- Level 3 Exhaust (LEF-4,-5,-6)
  - 15,000 cfm; 30 HP

- Level 2 Exhaust (LEF-1,-2,-3)
  - 13,000 cfm; 25 HP

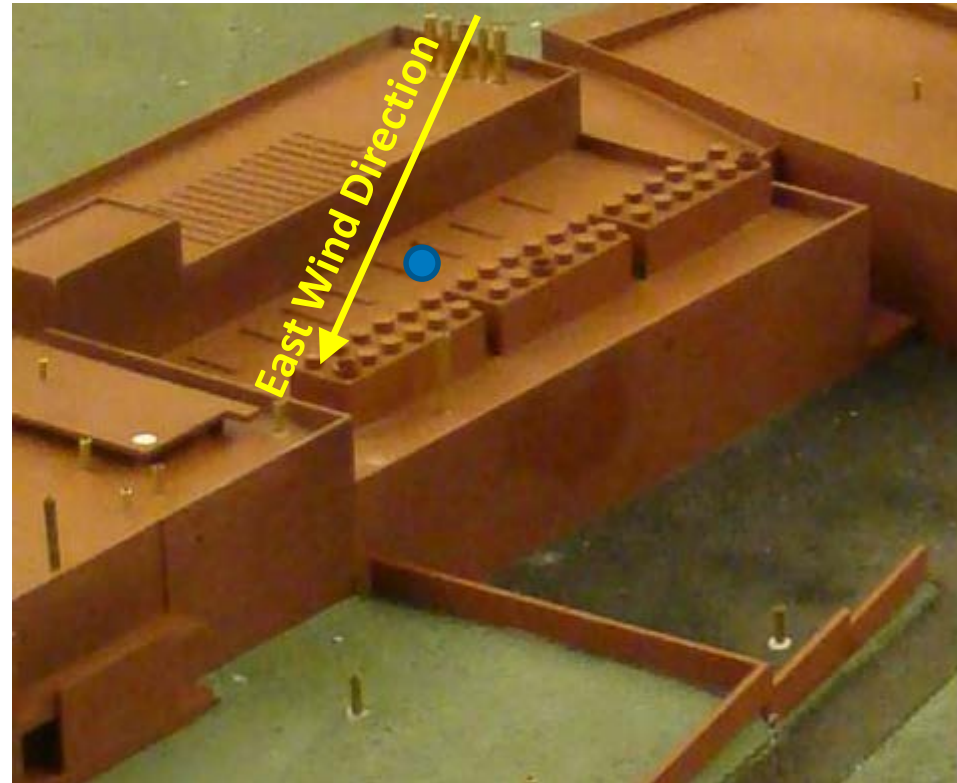


# Case Study

## LEF-1, -2, -3

### Simple Turndown VAV

- Maximum concentrations met design criteria for certain wind speeds and wind directions.
- Little or no turndown available – need the maximum volume flow rate under ESE wind conditions.
- **No Energy Savings Available w/ Simple VAV System**

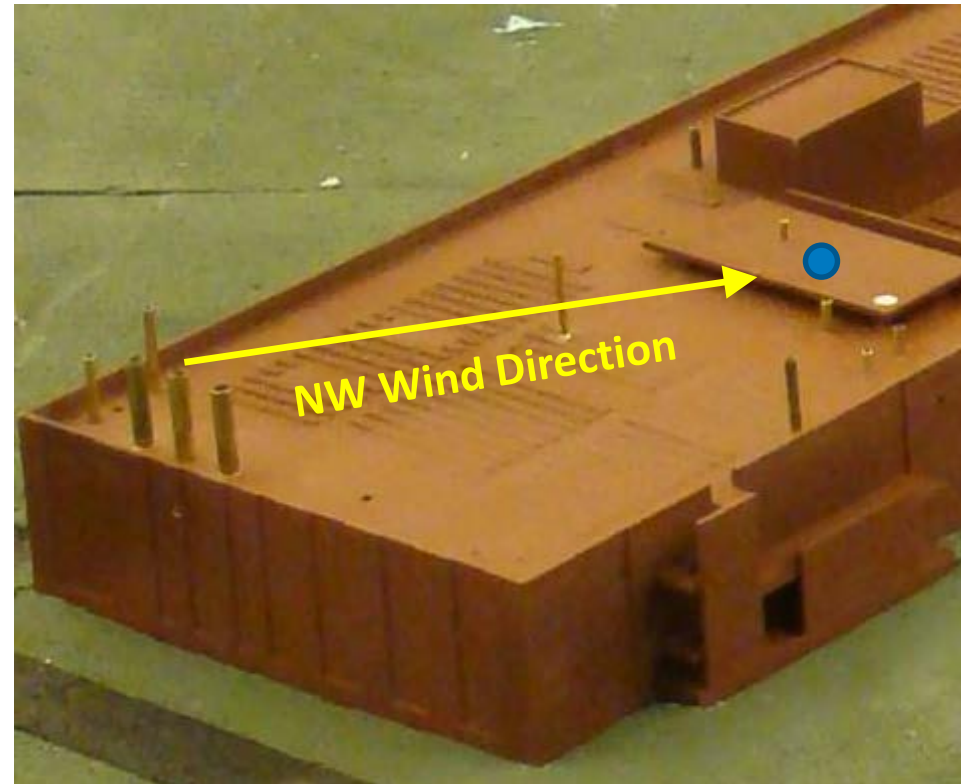


# Case Study

## LEF-4, -5, -6

### Simple Turndown VAV

- Maximum concentrations 20% less than design criteria for worst-case wind speed and wind direction.
- **Some Energy Savings Available w/ Simple VAV System**



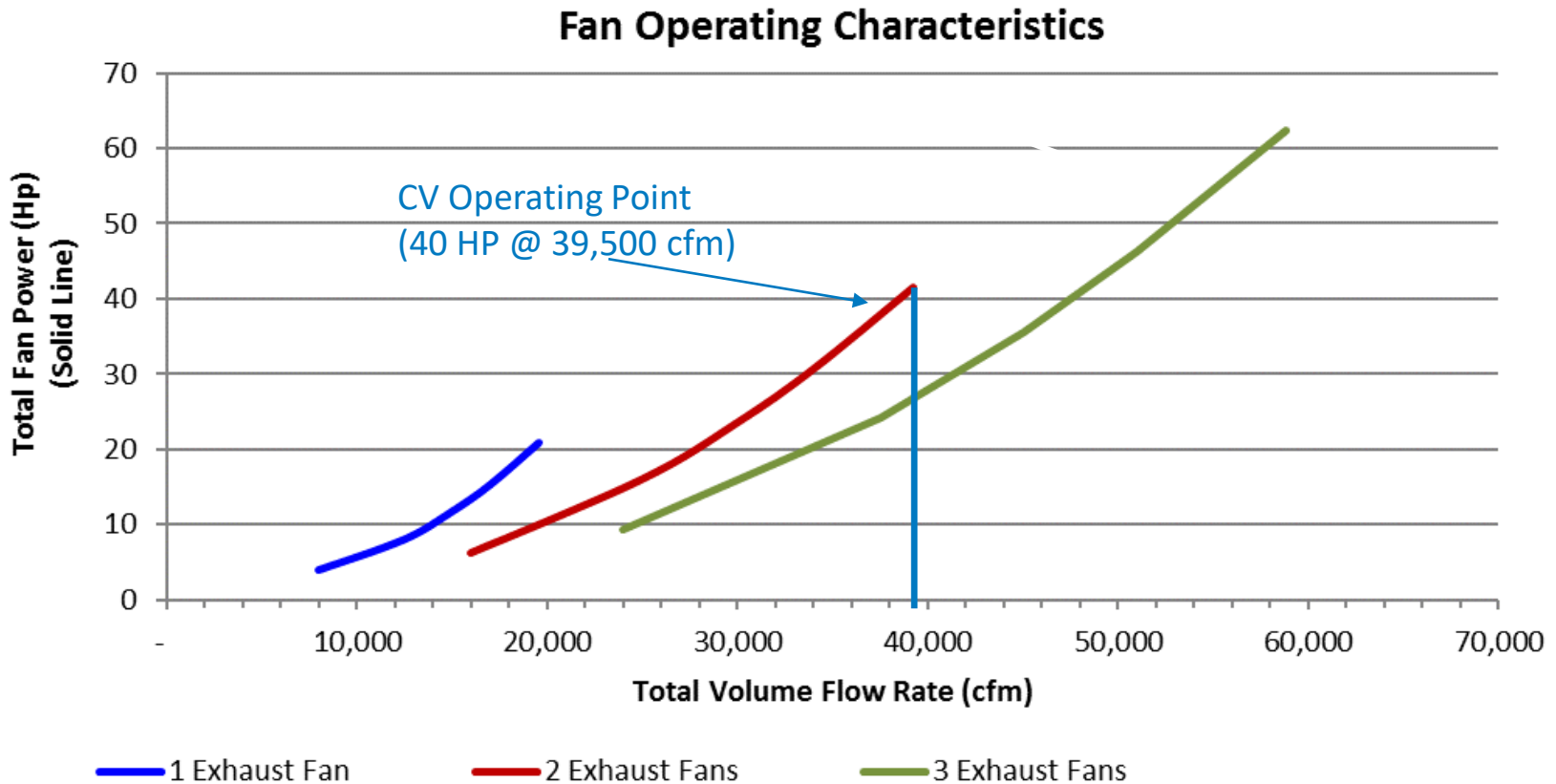
# Case Study

## LEF-1, -2, -3

| Wind Direction |     | Anemometer Wind Speed * |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|----------------|-----|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Min            | Max | < 1                     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  |
| 350            | 10  | 41%                     | 40% | 38% | 36% | 33% | 31% | 28% | 26% | 25% | 24% | 23% | 22% | 22% | 23% | 23% |
| 10             | 30  | 41%                     | 33% | 30% | 27% | 24% | 22% | 20% | 18% | 18% | 17% | 17% | 18% | 18% | 18% | 19% |
| 30             | 50  | 41%                     | 22% | 22% | 21% | 21% | 20% | 20% | 19% | 18% | 18% | 17% | 17% | 17% | 17% | 17% |
| 50             | 70  | 41%                     | 31% | 48% | 59% | 67% | 70% | 71% | 70% | 67% | 63% | 58% | 52% | 47% | 41% | 36% |
| 70             | 90  | 41%                     | 38% | 56% | 70% | 81% | 88% | 92% | 93% | 92% | 89% | 84% | 78% | 72% | 65% | 58% |
| 90             | 110 | 41%                     | 39% | 54% | 67% | 77% | 84% | 89% | 91% | 91% | 89% | 86% | 81% | 74% | 68% | 61% |
| 110            | 130 | 41%                     | 34% | 48% | 58% | 65% | 70% | 72% | 73% | 73% | 71% | 69% | 66% | 62% | 59% | 55% |
| 130            | 150 | 41%                     | 32% | 42% | 49% | 54% | 56% | 57% | 56% | 55% | 52% | 49% | 46% | 43% | 40% | 36% |
| 150            | 170 | 41%                     | 25% | 41% | 51% | 56% | 58% | 57% | 55% | 51% | 47% | 42% | 37% | 33% | 30% | 27% |
| 170            | 190 | 41%                     | 21% | 19% | 17% | 16% | 15% | 15% | 14% | 14% | 14% | 13% | 13% | 13% | 13% | 13% |
| 190            | 210 | 41%                     | 21% | 21% | 20% | 19% | 18% | 18% | 17% | 16% | 15% | 14% | 14% | 13% | 13% | 13% |
| 210            | 230 | 41%                     | 22% | 21% | 20% | 19% | 19% | 18% | 17% | 16% | 16% | 15% | 14% | 14% | 14% | 13% |
| 230            | 250 | 41%                     | 11% | 10% | 9%  | 8%  | 8%  | 7%  | 7%  | 7%  | 7%  | 6%  | 6%  | 6%  | 6%  | 6%  |
| 250            | 270 | 41%                     | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  |
| 270            | 290 | 41%                     | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  |
| 290            | 310 | 41%                     | 3%  | 3%  | 3%  | 2%  | 2%  | 1%  | 1%  | 1%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  |
| 310            | 330 | 41%                     | 33% | 32% | 30% | 28% | 26% | 24% | 22% | 21% | 20% | 19% | 18% | 18% | 17% | 17% |
| 330            | 350 | 41%                     | 41% | 40% | 38% | 36% | 34% | 33% | 31% | 29% | 27% | 26% | 25% | 24% | 23% | 23% |

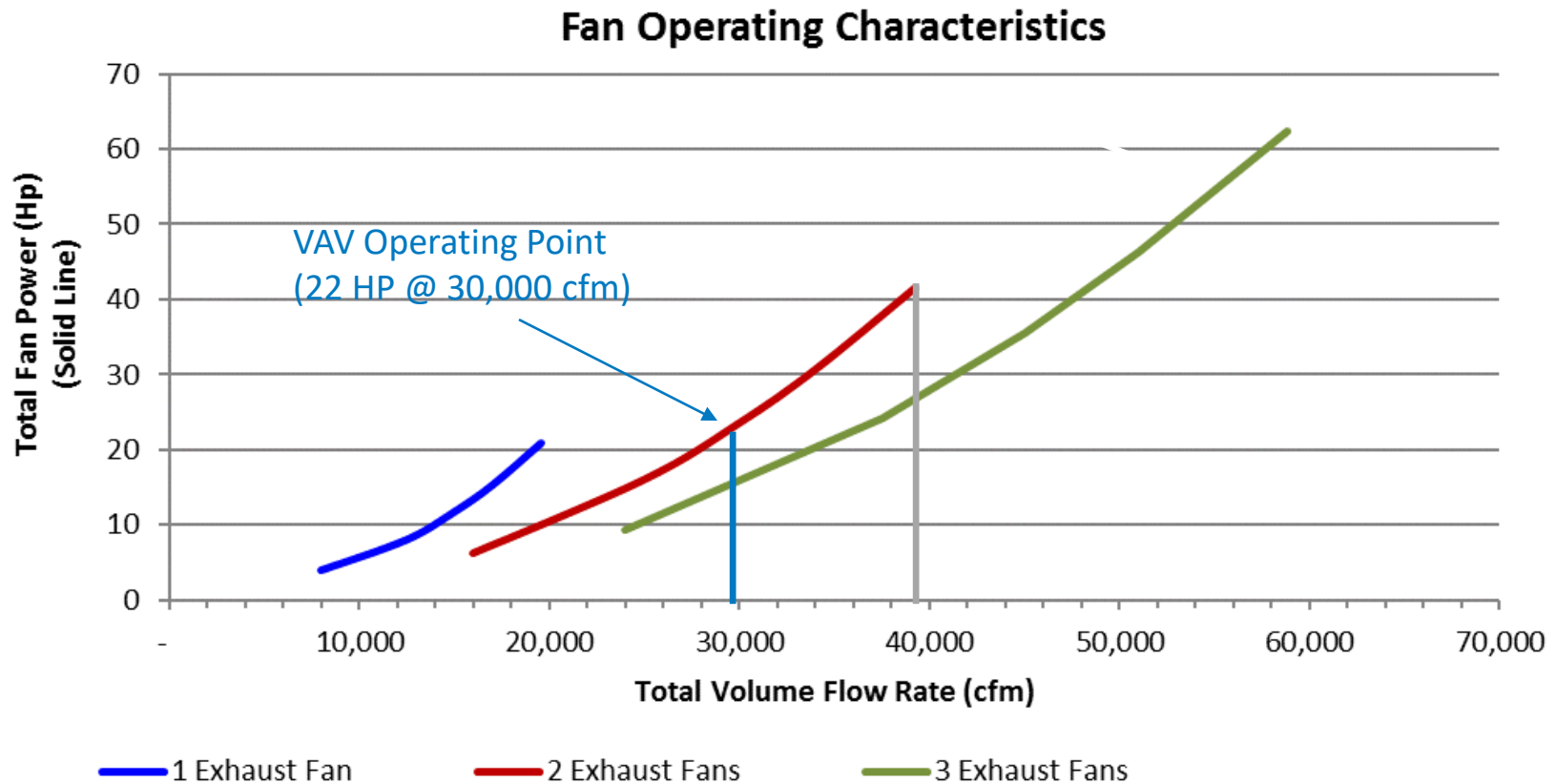
# Case Study

## LEF-1; -2; -3 – CAV Operation



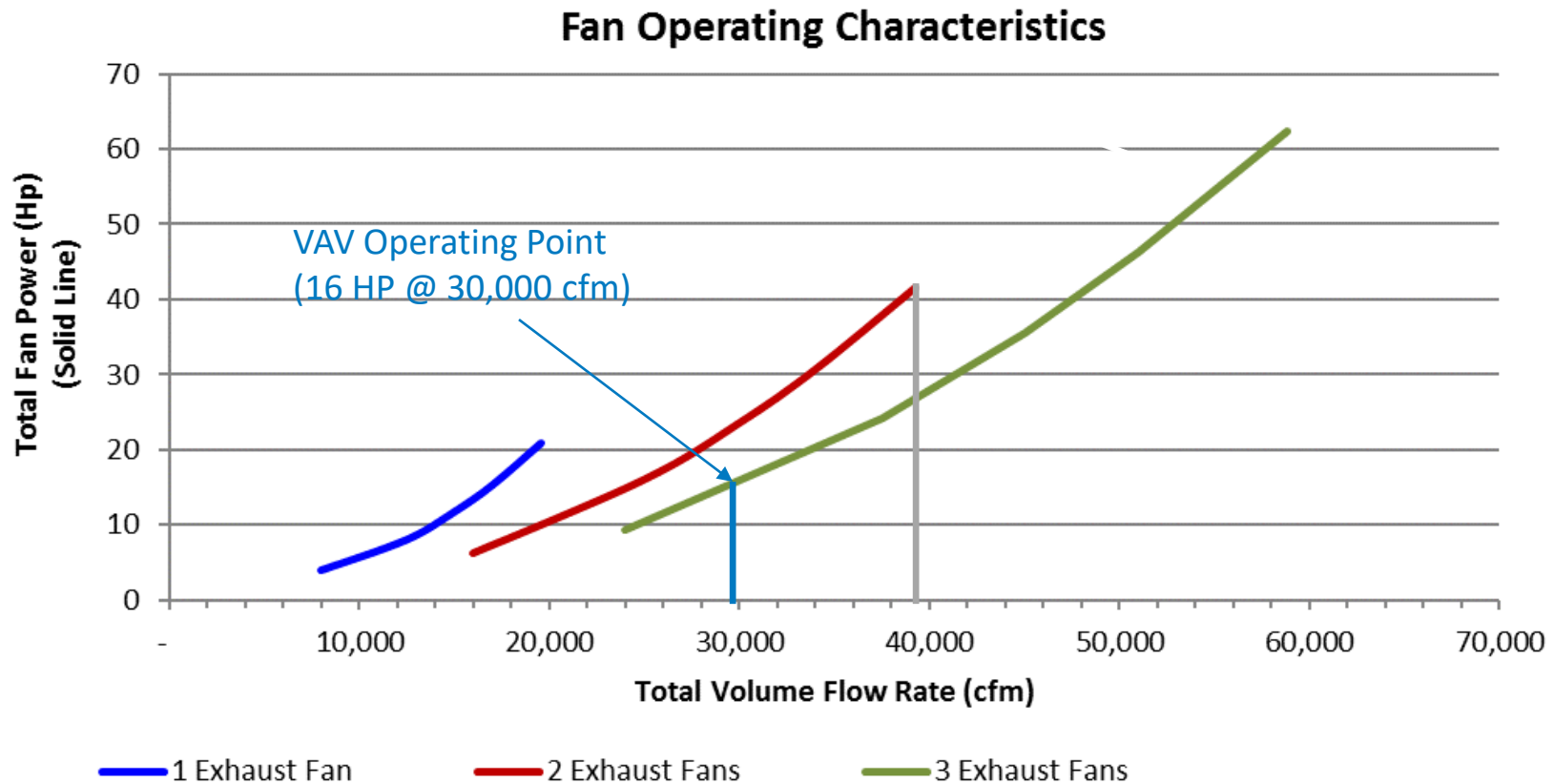
# Case Study

## LEF-1; -2; -3 – VAV Operation – 2 of 3 Fans Operating (Current)



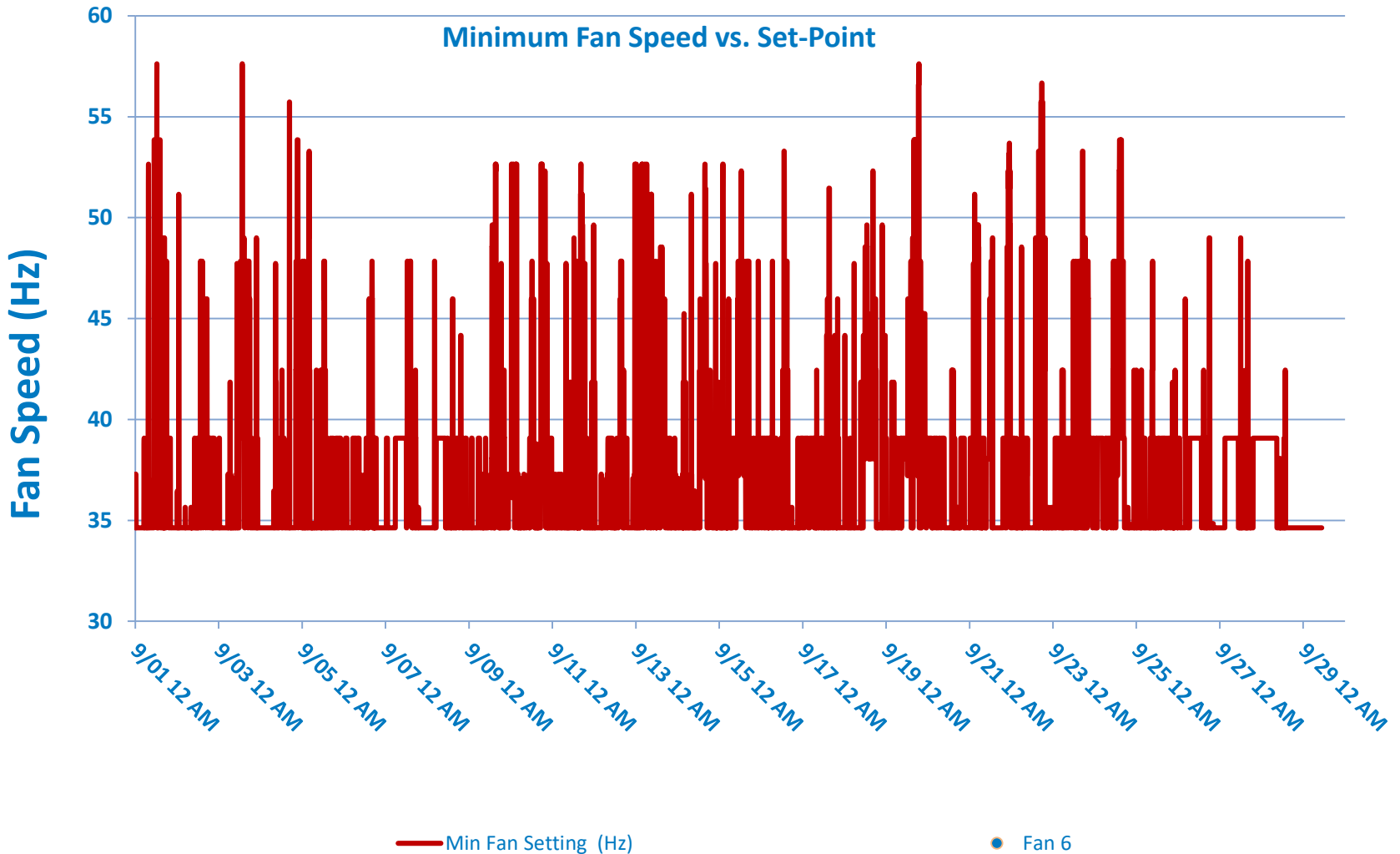
# Case Study

## LEF-1; -2; -3 – VAV Operation – 3 of 3 Fans Operating



# Case Study

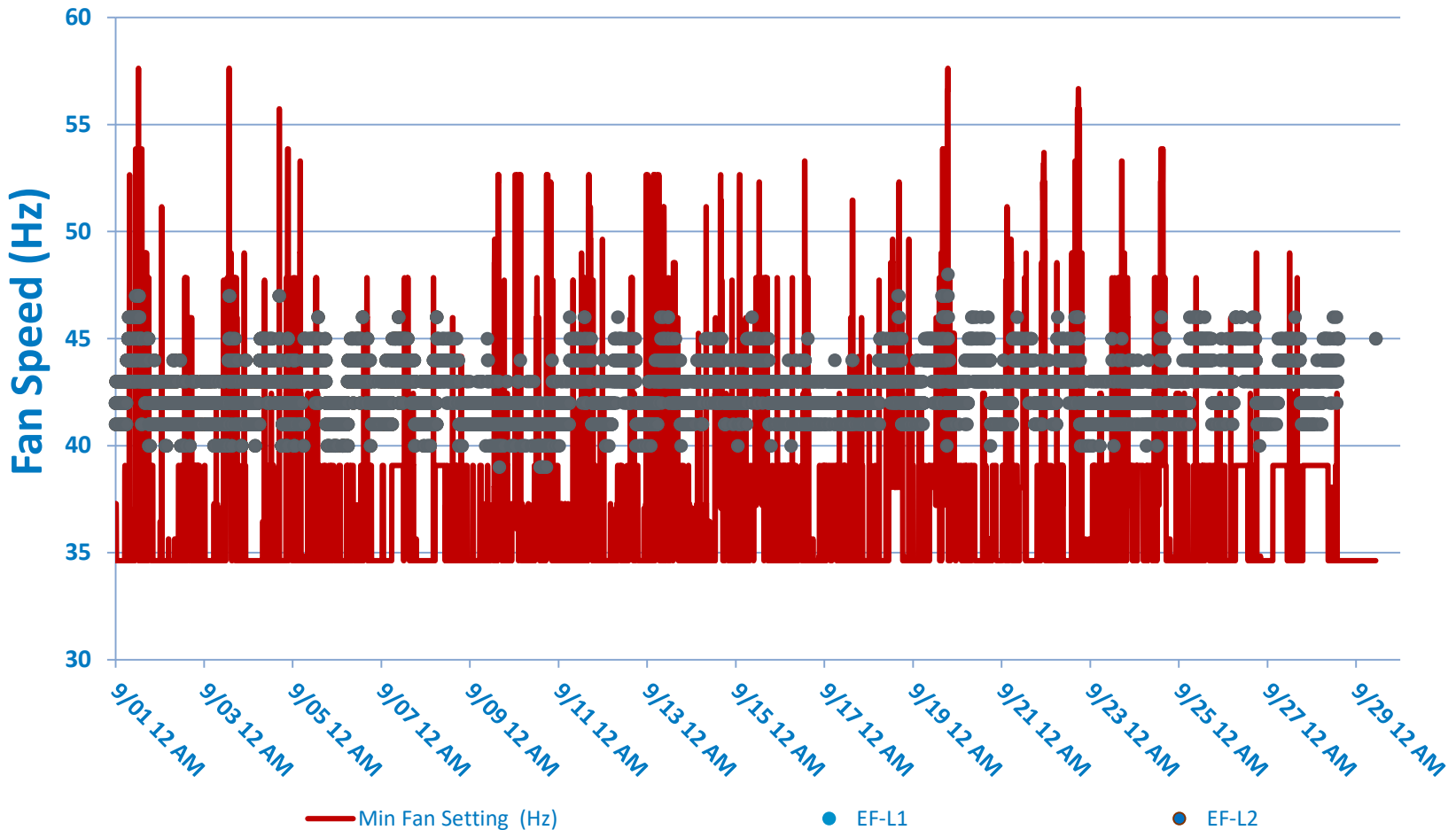
## LEF-1; -2; -3 – VAV Operation (Current)



# Case Study

## LEF-1; -2; -3 – VAV Operation (Current)

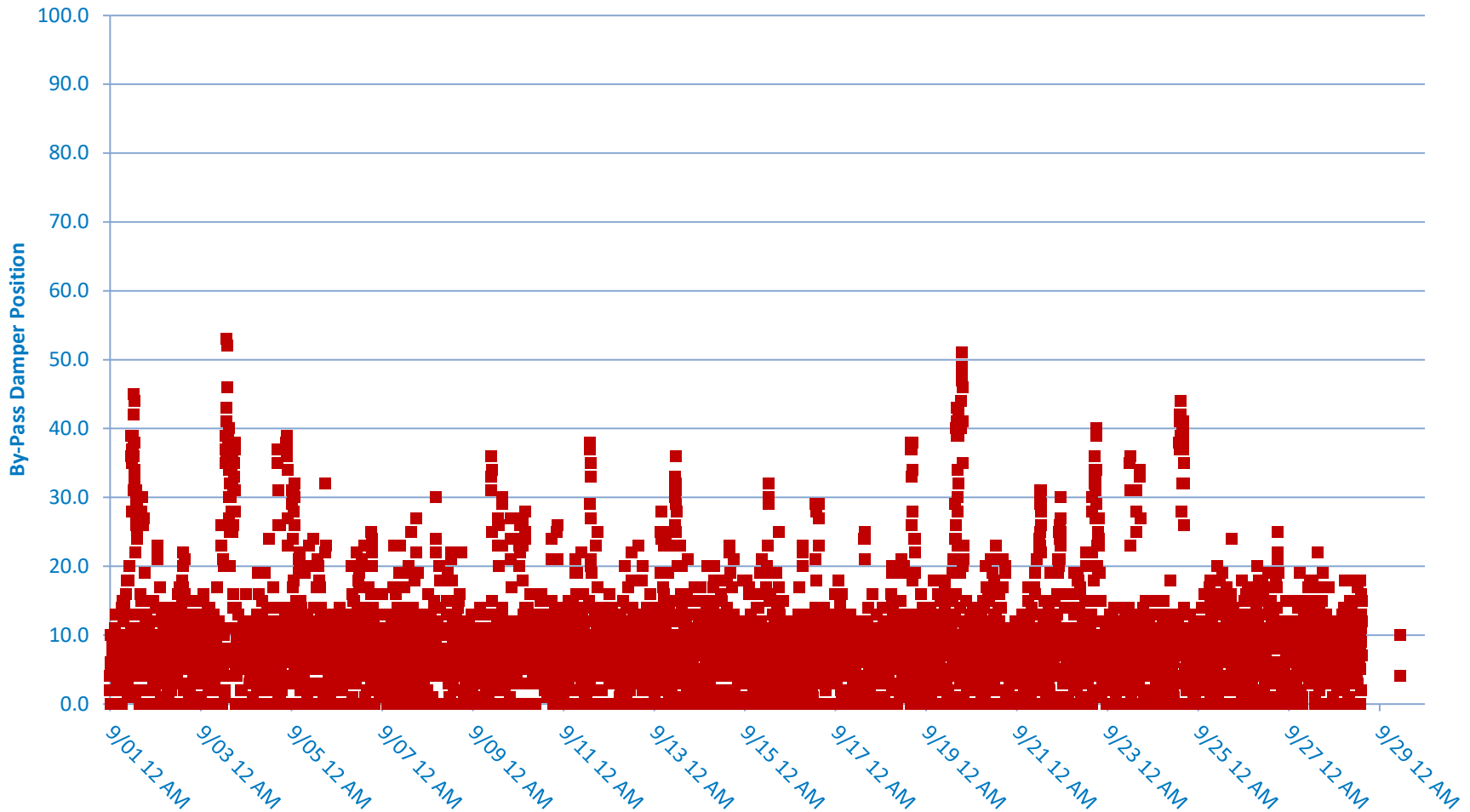
Minimum Fan Speed vs. Set-Point



# Case Study

## LEF-1; -2; -3 – VAV Operation (Current)

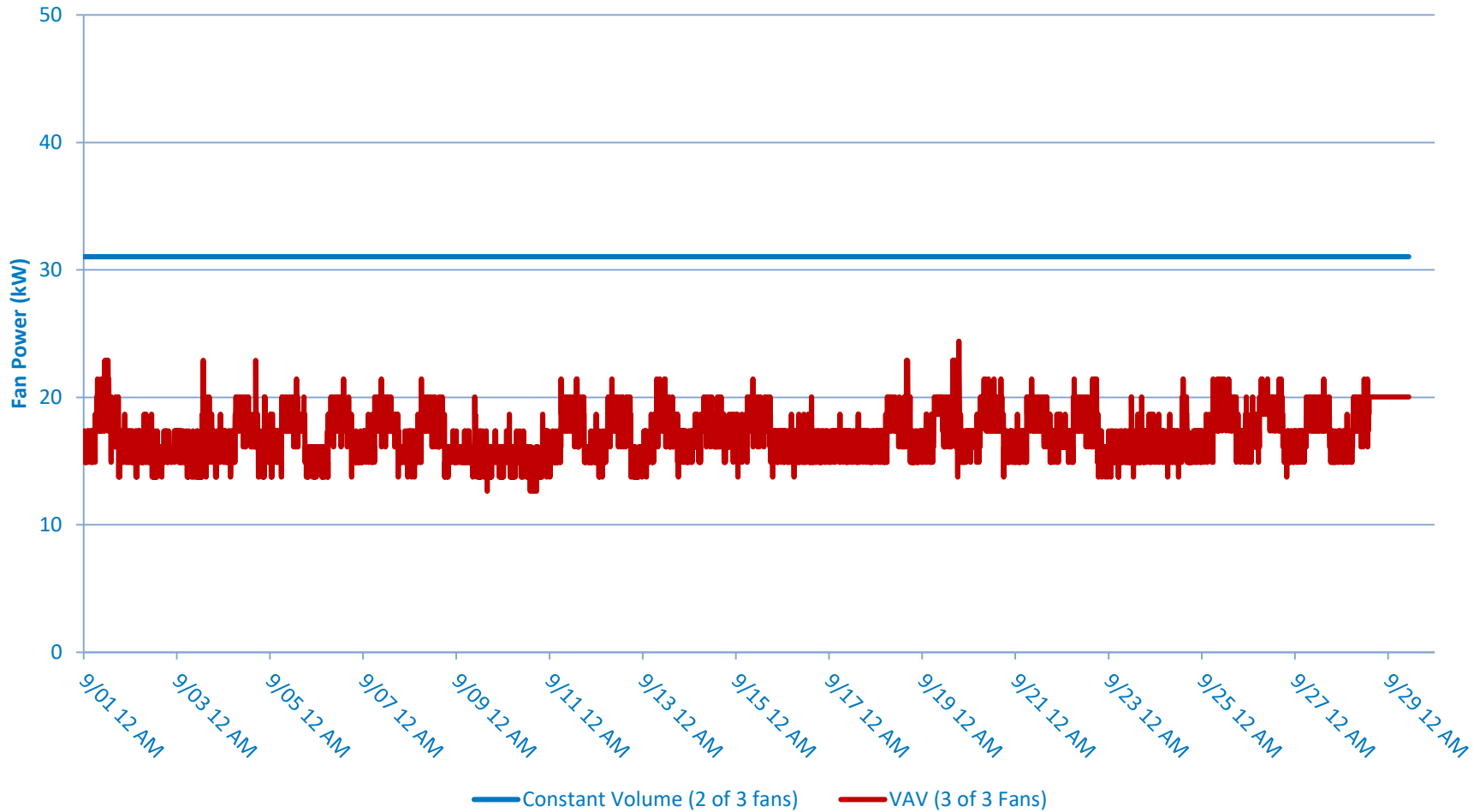
By-Pass Damper Position



# Case Study

## LEF-1; -2; -3 – VAV Operation (Current)

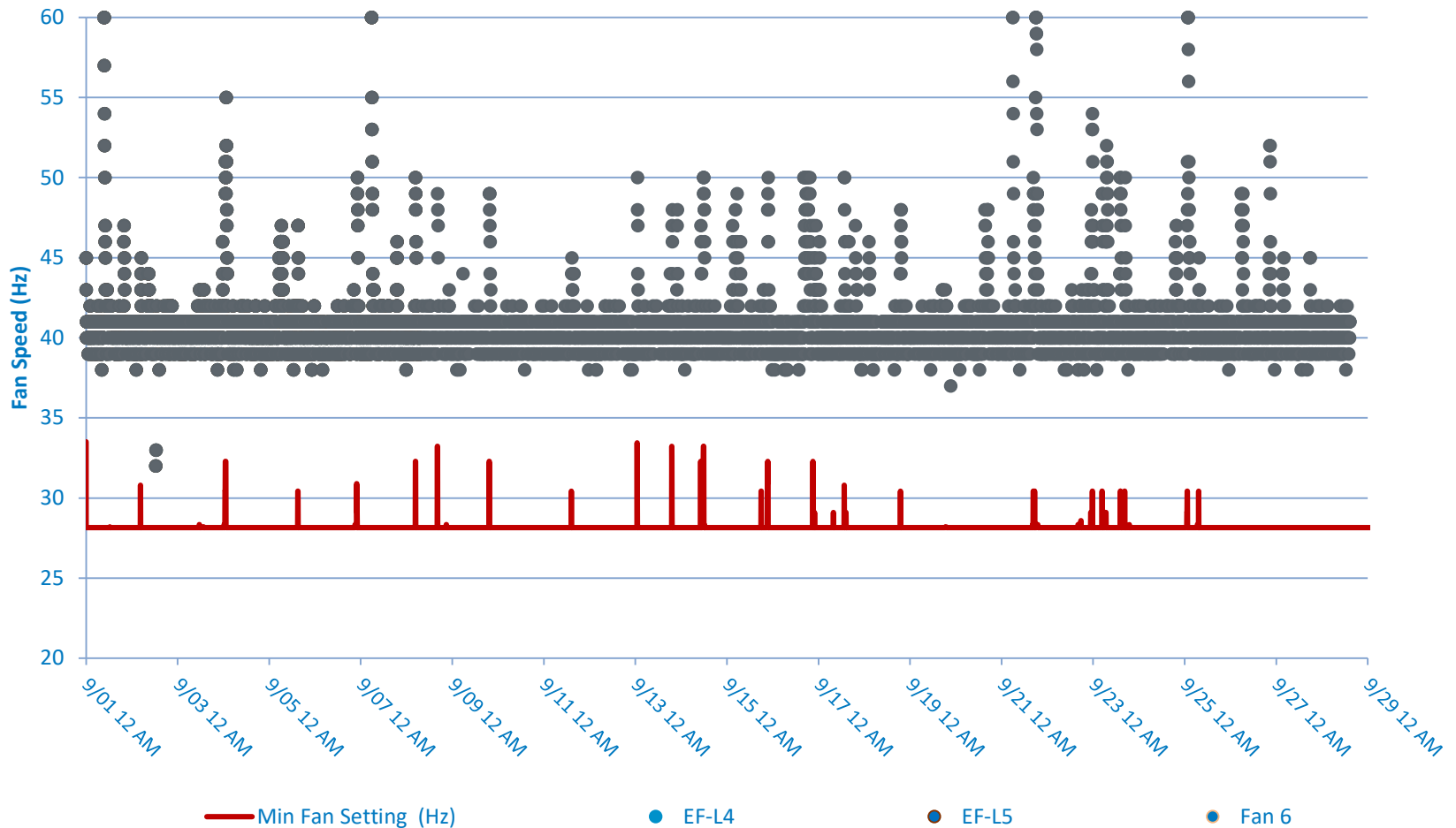
Laboratory Exhaust Fan Power Consumption



# Case Study

## LEF-4; -5; -6 – VAV Operation (Current)

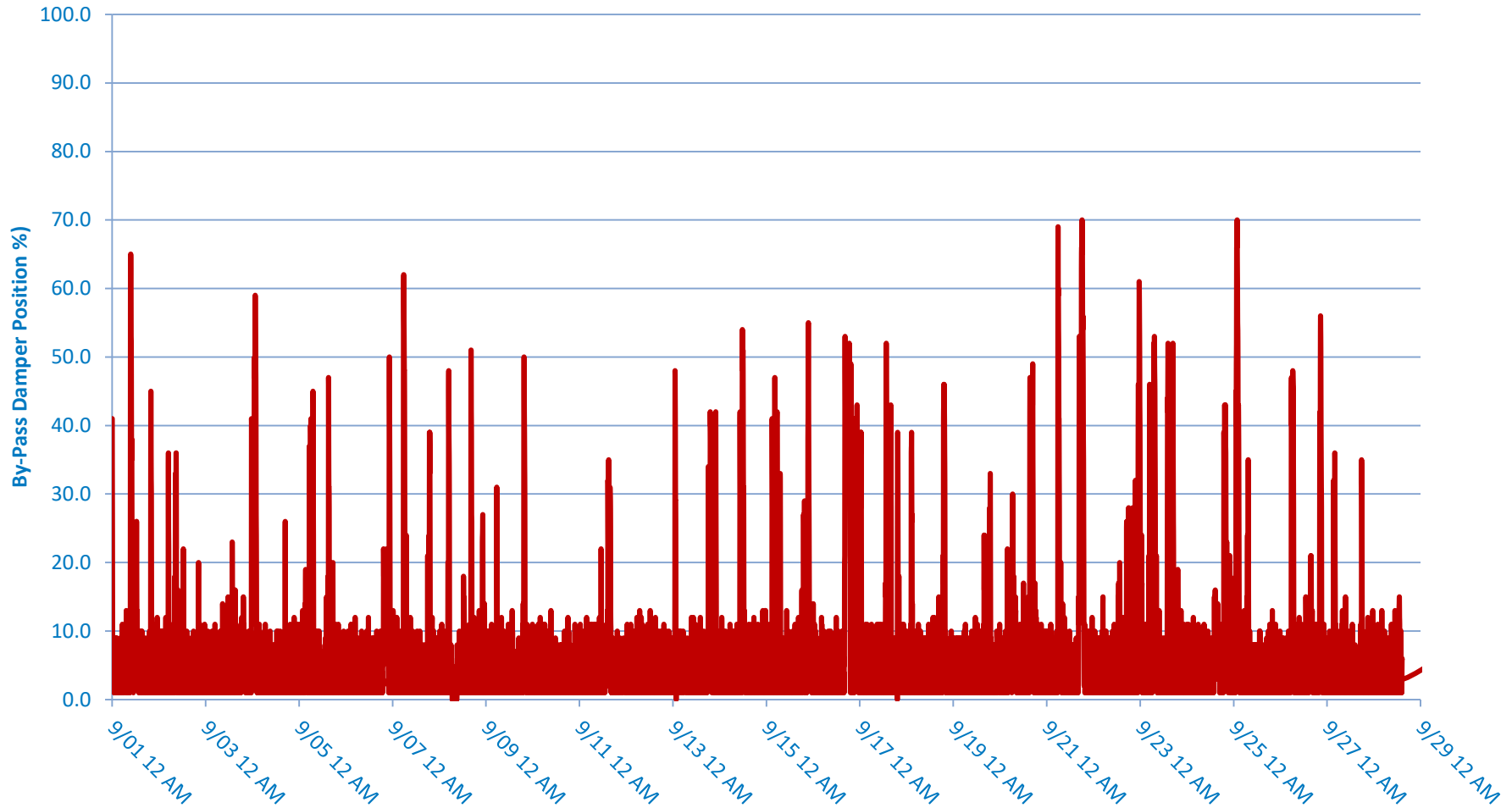
Minimum Fan Speed vs. Set-Point



# Case Study

## LEF-4; -5; -6 – VAV Operation (Current)

By-Pass Damper Position





# Case Study

## Energy Savings

|                 | LEF-1; -2; -3 | LEF-4; -5; -6 |
|-----------------|---------------|---------------|
| Constant Volume | 272 MW hr/yr  | 555 MW hr/yr  |

# Case Study

## Energy Savings

|                     | LEF-1; -2; -3 | LEF-4; -5; -6 | Energy Savings |
|---------------------|---------------|---------------|----------------|
| Constant Volume     | 272 MW hrs/yr | 555 MW hr/yr  | (-)            |
| Simple Turndown VAV | 272 MW hrs/yr | 132 MW hr/yr  | 423 MW hr/yr   |

# Case Study

## Energy Savings

|                                | LEF-1; -2; -3 | LEF-4; -5; -6 | Energy Savings |
|--------------------------------|---------------|---------------|----------------|
| Constant Volume                | 272 MW hrs/yr | 555 MW hr/yr  | (-)            |
| Simple Turndown VAV            | 272 MW hrs/yr | 132 MW hr/yr  | 423 MW hr/yr   |
| Wind Responsive VAV<br>Current | 148 MW hrs/yr | 267 MW hr/yr  | 412 MW hr/yr   |

# Case Study

## Energy Savings

|                     | LEF-1; -2; -3 | LEF-4; -5; -6 | Energy Savings |
|---------------------|---------------|---------------|----------------|
| Constant Volume     | 272 MW hrs/yr | 555 MW hr/yr  | (-)            |
| Simple Turndown VAV | 272 MW hrs/yr | 132 MW hr/yr  | 423 MW hr/yr   |
| Wind Responsive VAV |               |               |                |
| Current             | 148 MW hrs/yr | 267 MW hr/yr  | 412 MW hr/yr   |
| Optimized           | 92 MW hrs/yr  | 132 MW hr/yr  | 603 MW hr/yr   |

# Questions?

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AIR QUALITY CONSULTANTS

# Thank you!

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