Residential HVAC Filtration
Energy and airflow impacts

Brent Stephens, Ph.D.
Department of Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
brent@iit.edu
www.built-envi.com

Built Environment Research @ IIT

Advancing energy, environmental, and sustainability research within the built environment

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Energy/airflow impacts of filtration

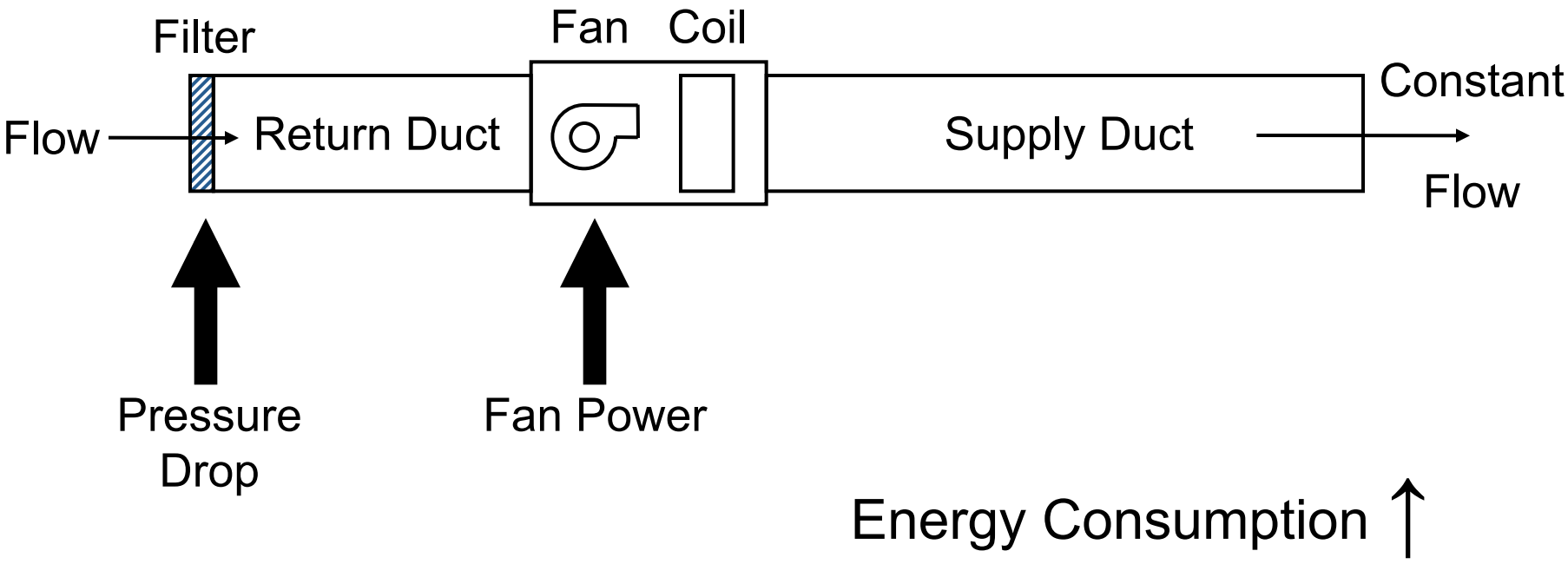
- 2007-2010 ASHRAE RP-1299: Energy impacts of filtration in residential and light-commercial buildings
  - PI: Jeff Siegel
  - Generally minimal energy and airflow impacts of 1-inch MERV 11-12 filters relative to MERV <5 and MERV 6-8

    Stephens et al., 2010 *HVAC&R Research*; Stephens et al., 2010 *ASHRAE Transactions*

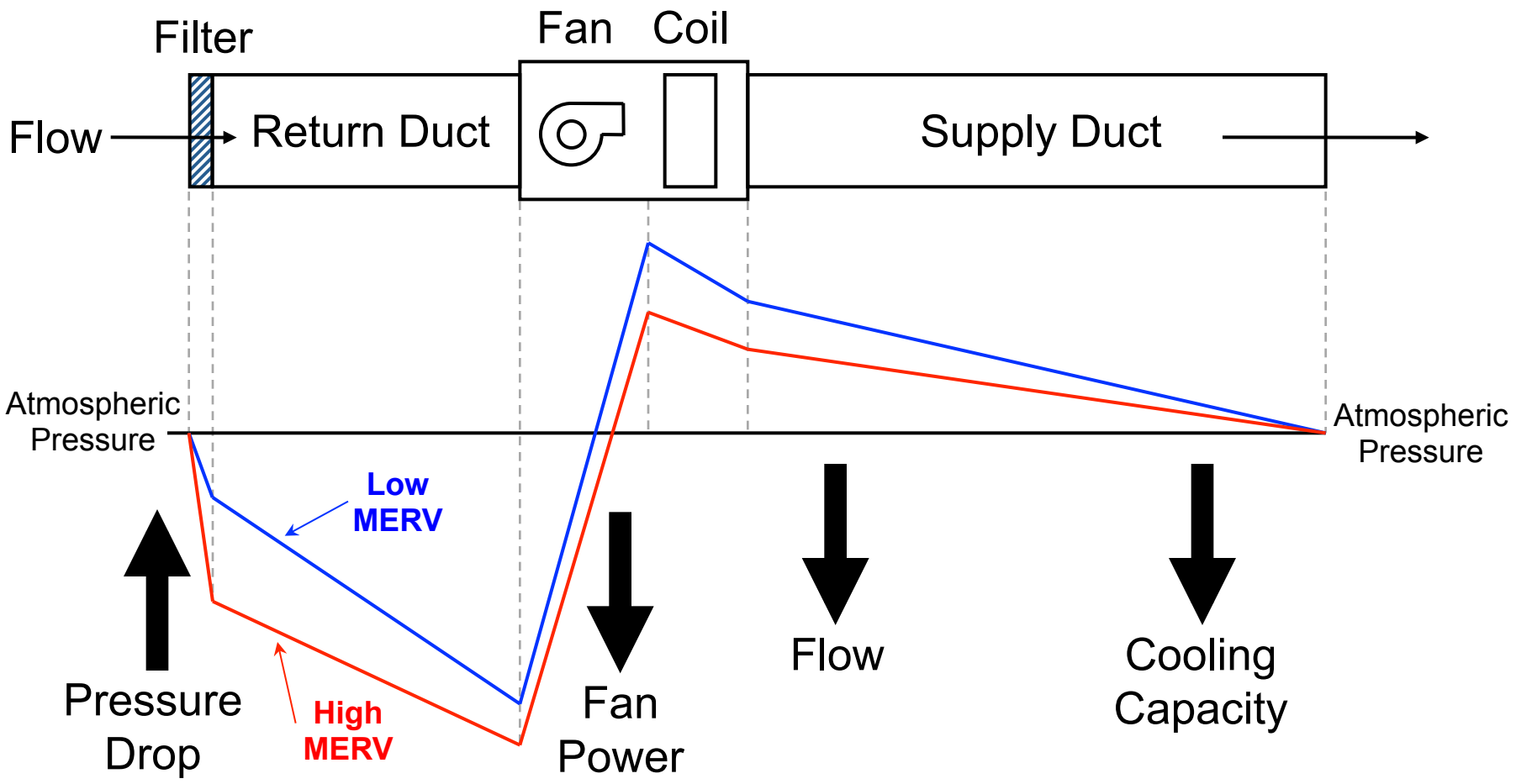
- June 2012 San Antonio 62.2 IAQ subcommittee meeting
  - Mark Jackson presented on my behalf:
    - Ultrafine particle (UFP) removal by filters in a test house
    - $PM_{2.5}$ removal by filters in a test house
  - Not mentioned much (if at all):
    - Pressure drop and airflow impacts

Energy consequences of filters

- In systems with variable speed fans (e.g., ECM/BPM):



Residential (PSC) systems



ASHRAE RP-1299

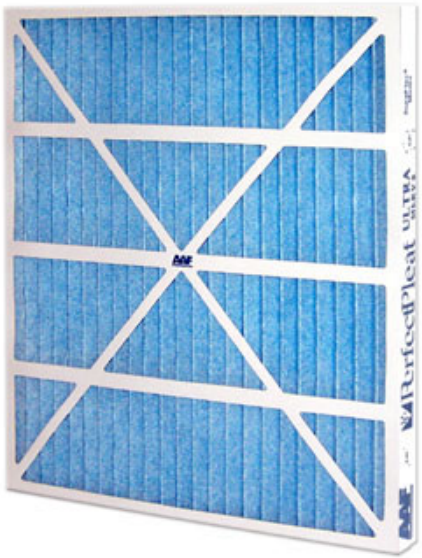
Energy implications of filters in residential and light-commercial buildings

ASHRAE RP-1299: Experimental investigation

- 3 rated filter efficiencies
  - Low (MERV <4)
  - Medium (MERV 6-8)
  - High (MERV 11-12)
- Occupied field sites
  - 8 residential & 9 light-commercial systems
  - 1 visit per month for a year (~270 total visits)
  - Influenced by climate and occupant behavior
- Unoccupied test house
  - 2 systems continuously monitored for 6 months
  - Controlled thermostats
  - Binned analysis isolates climate and occupant impacts

Filter examples

Low-MERV
(MERV 1 - 4)

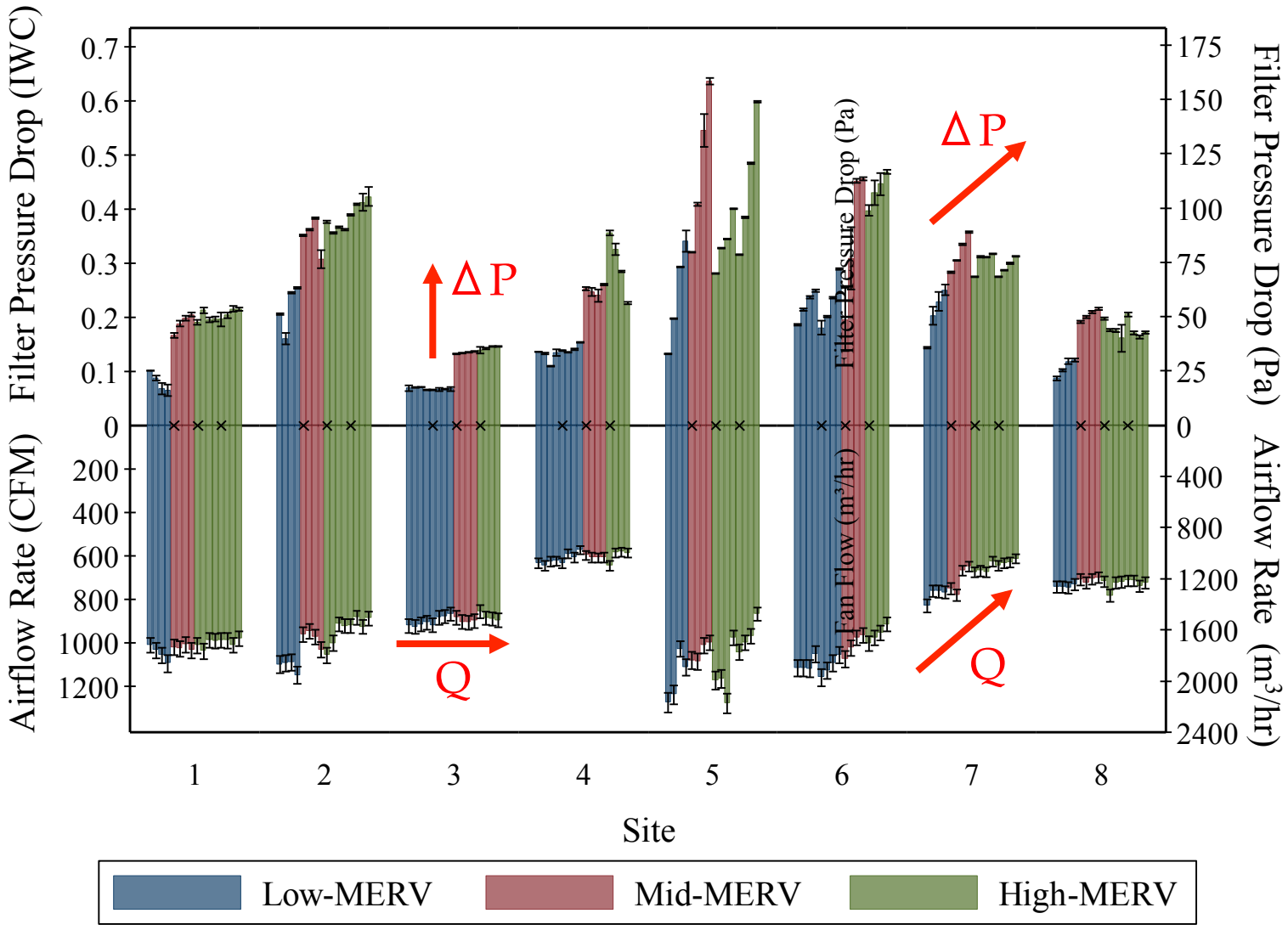


Mid-MERV
(MERV 5 - 8)

High-MERV
(MERV 9 - 12)

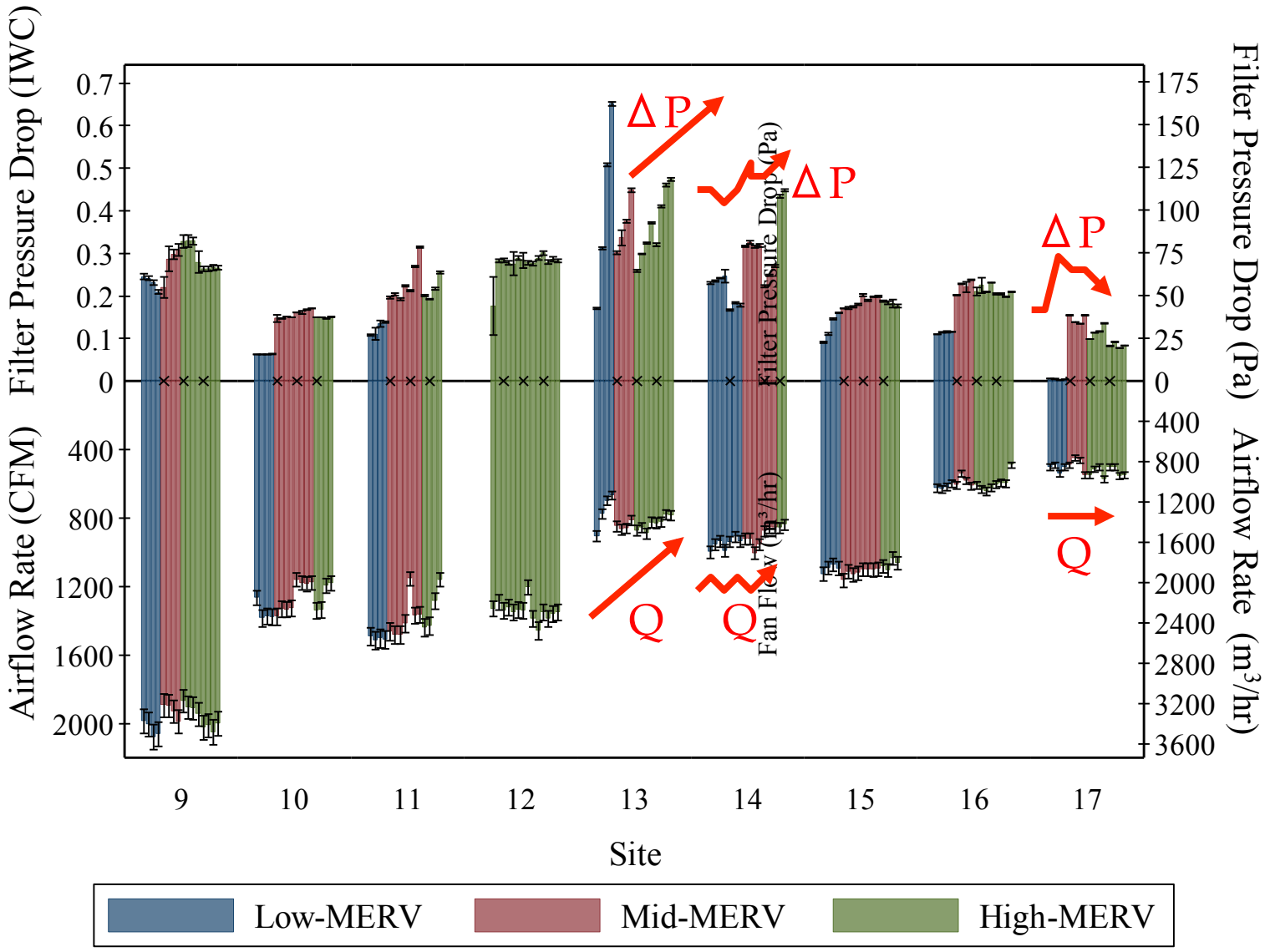
Stephens et al., 2010 *ASHRAE Transactions*

Residential field results: Filter pressure drop and airflow



Stephens et al., 2010 *ASHRAE Transactions*

Commercial field results: Filter pressure drop and airflow



Stephens et al., 2010 *ASHRAE Transactions*

FILTER LIFESPANS

Using data from ASHRAE RP-1299

Filter lifespan data from RP-1299

- We left each filter installed for ~90 days
  - Occupied residential and light-commercial environments

- Out of 64 filter installations:
  - Filters loaded enough within 90 days…
  - To increase pressure drop enough…
  - To decrease airflow rates 10% or more…
    - In only 11 installations (17%)
      - 2 times with a MERV <5
      - 5 times with MERV 6-8
      - 4 times with MERV 11-12

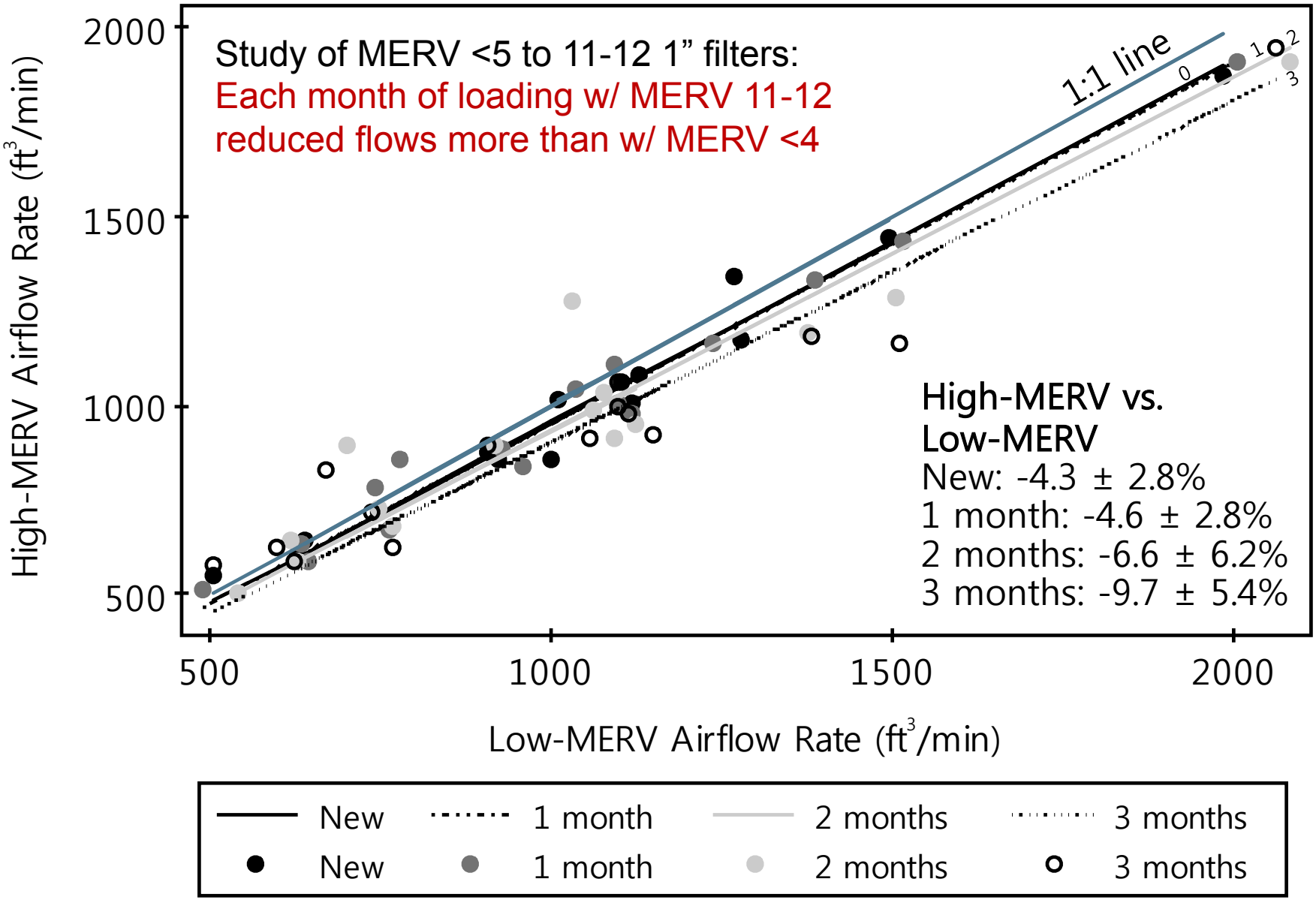
Stephens et al., 2011 *Building and Environment*

Filter lifespan data from RP-1299

- One question I've received:
  - Don't higher MERV, higher pressure drop filters load more quickly than lower MERV, lower pressure drop filters?

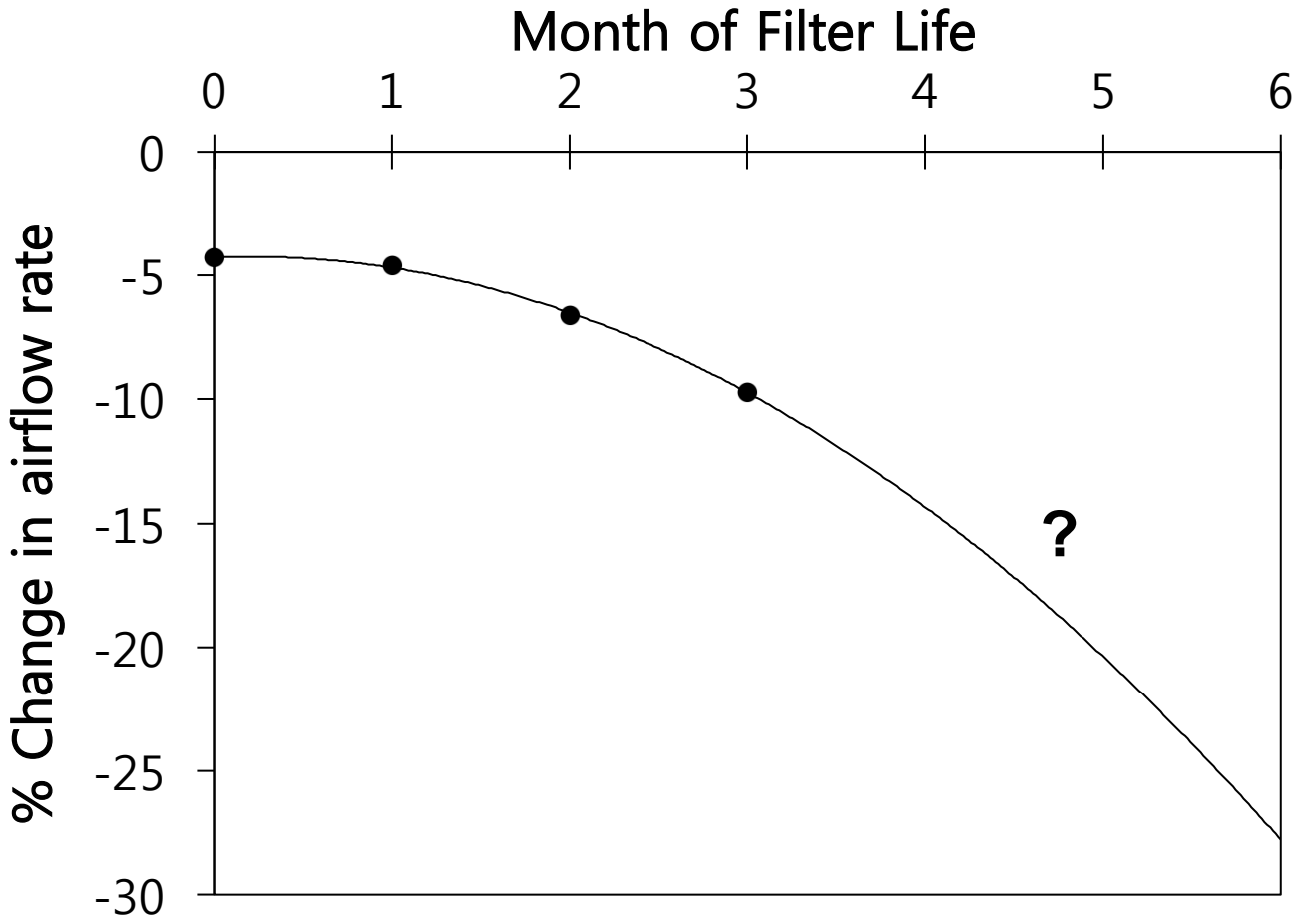
- Answer from our data:
  - Quite possibly…

Airflow changes w/ loading: High-MERV vs. Low-MERV



Data from Stephens et al., **2010** *ASHRAE RP-1299*

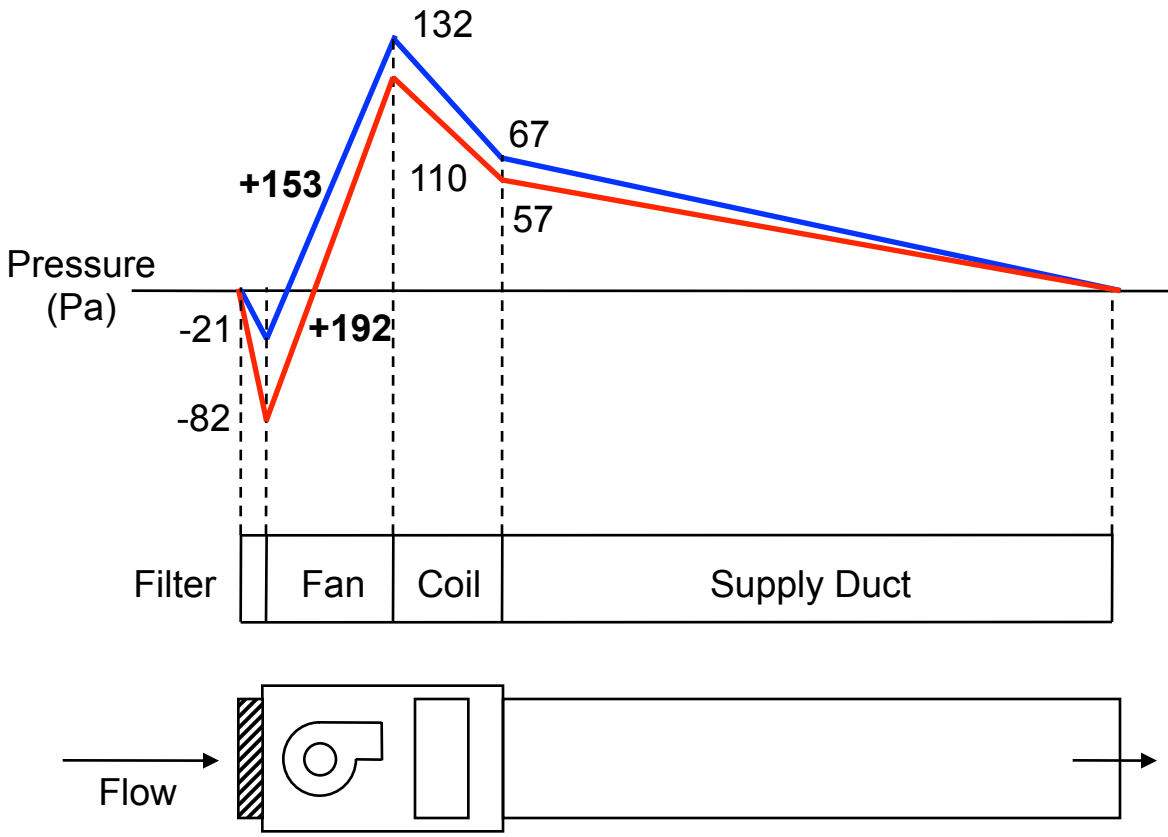
Trends between low-MERV and higher-MERV w/ loading



TEST HOUSE RESULTS

ASHRAE RP-1299

Test house results: Binned T/RH analysis



High-MERV vs.
Low-MERV
(Average Change)

- Filter ΔP ↑ 4x
- Flow ↓ 9%
- Fan Power ↑ 3%
- Outdoor Unit Power ↓ 0.5%
- Total Power ↑ 0.1%
- Total Capacity ↓ 4%

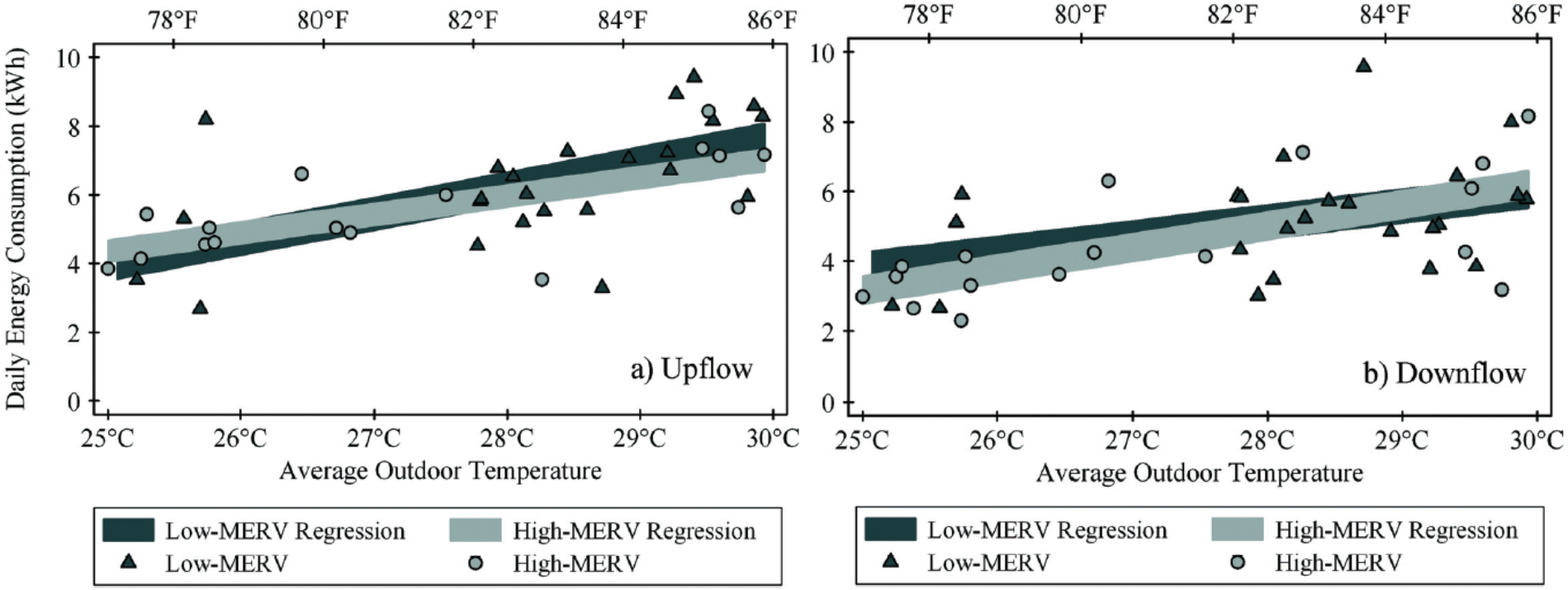
$$cap_{tot} = Q_{fan}\rho(C\Delta T + \Delta Wh_{fg})$$

Airflow ↓ 9%
ΔT across coil ↑ 6%
ΔW across coil ↑ 5%
Total Capacity ↓ 4%

Stephens et al., 2010 *HVAC&R Research*

Test house results

Daily energy consumption versus outdoor air temperature



Test House System #1

Test House System #2

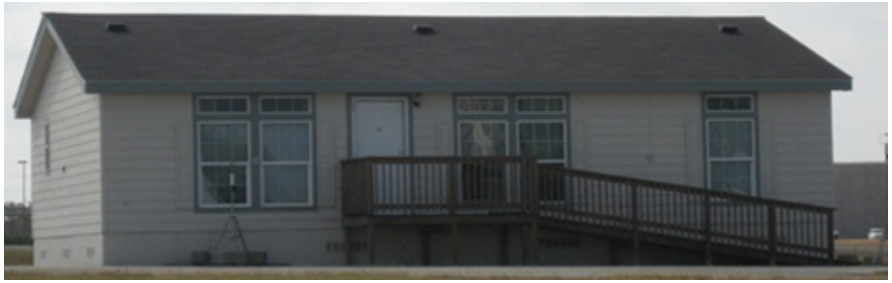
No measured differences in energy consumption with the low and higher pressure drop filters installed

Stephens et al., 2010 *HVAC&R Research*

MORE DATA ON PRESSURE AND FLOW W/ 1-INCH AND 5-INCH FILTERS

From UT Test House (PSC blower)

Filters from previous slide



1-inch depth

5-inch depth

MERV 4

MERV 6

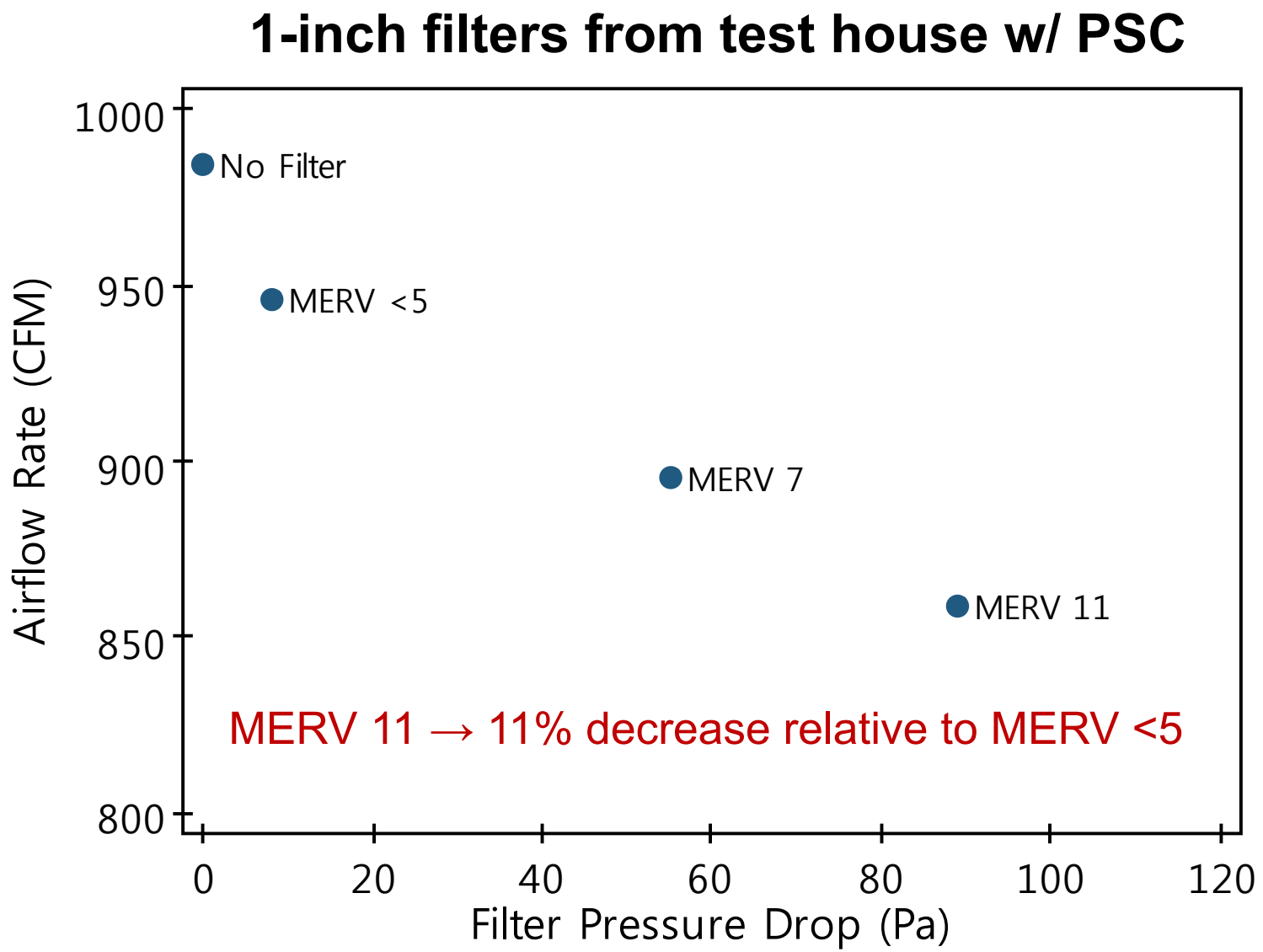
MERV 11

MERV 10

MERV 13

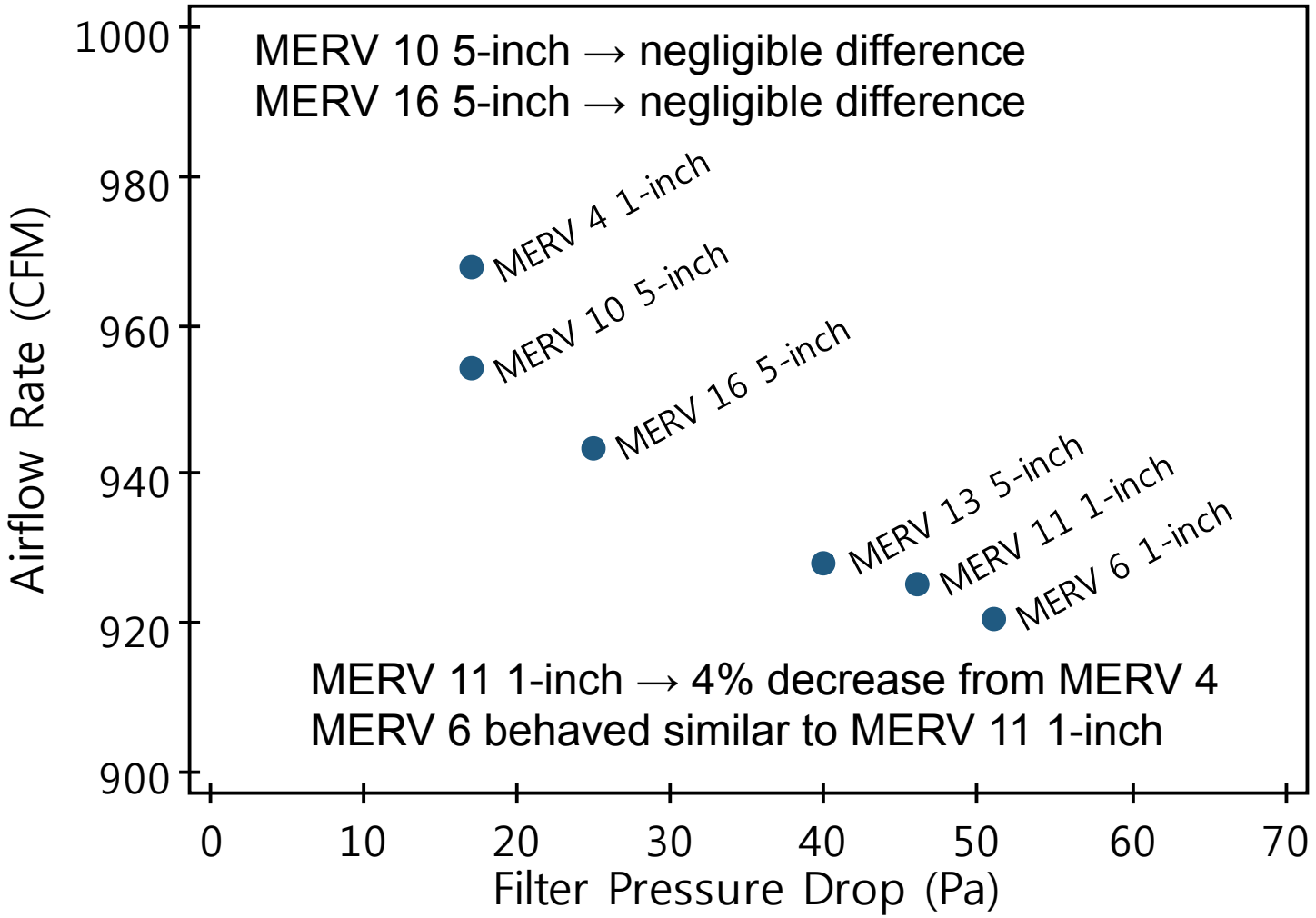
MERV 16

More data on pressure and flow (new filters)



More data on pressure and flow (new filters)

Three 1” filters and three 5” filters in test house w/ PSC blower:

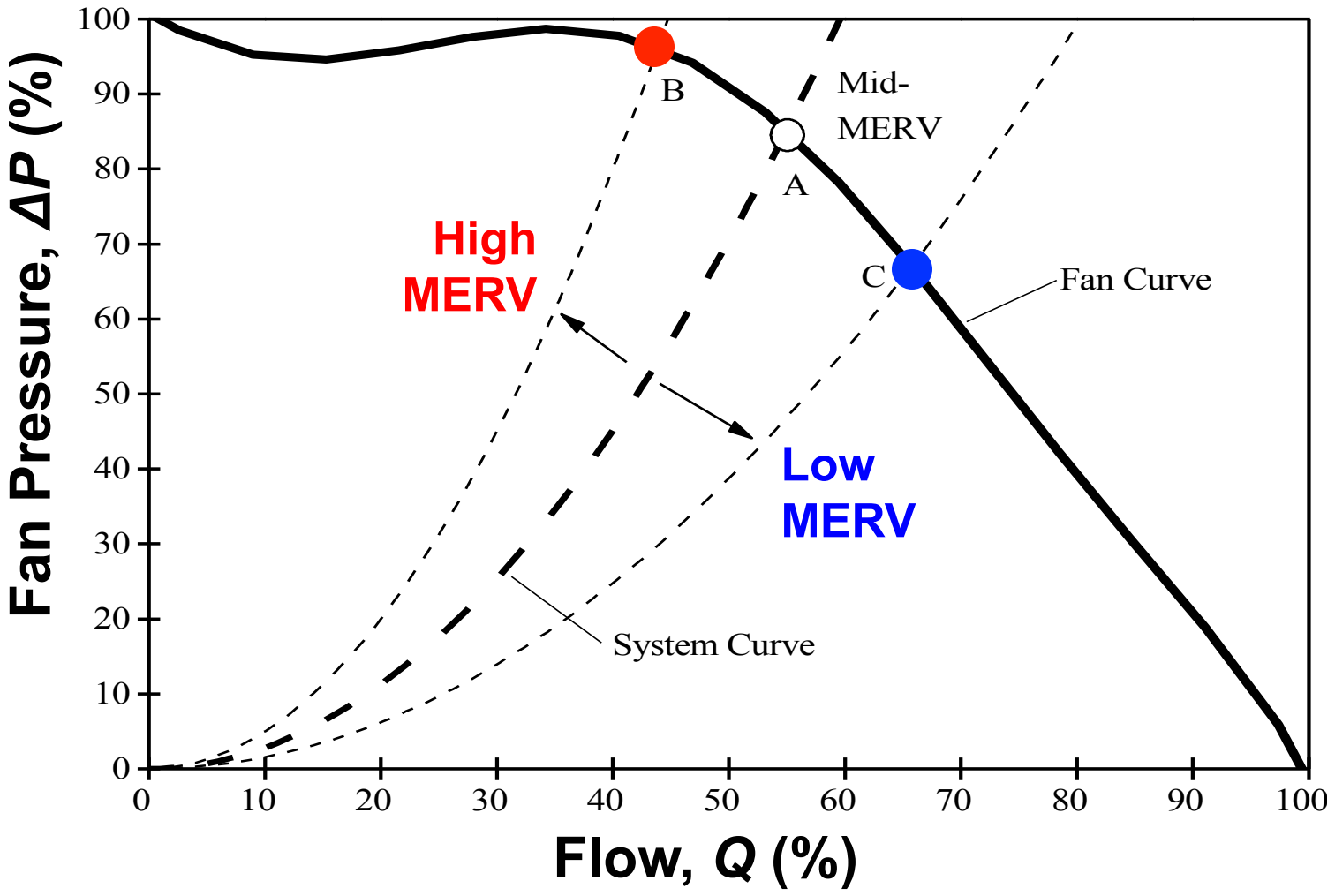


Summary

- Energy and airflow impacts of MERV 11-12 1-inch filters do not appear to be substantial over typical 90 day lifetime in most homes with PSC blowers
- Higher MERV 1-inch filters may indeed load more quickly than lower MERV 1-inch filters
- Some make/models of MERV 13+ filters with 5-inch depths appear to achieve very low pressure drop and high removal efficiency
  - No data on rate of dust loading and flow changes in time
- Question/comments
  - brent@iit.edu

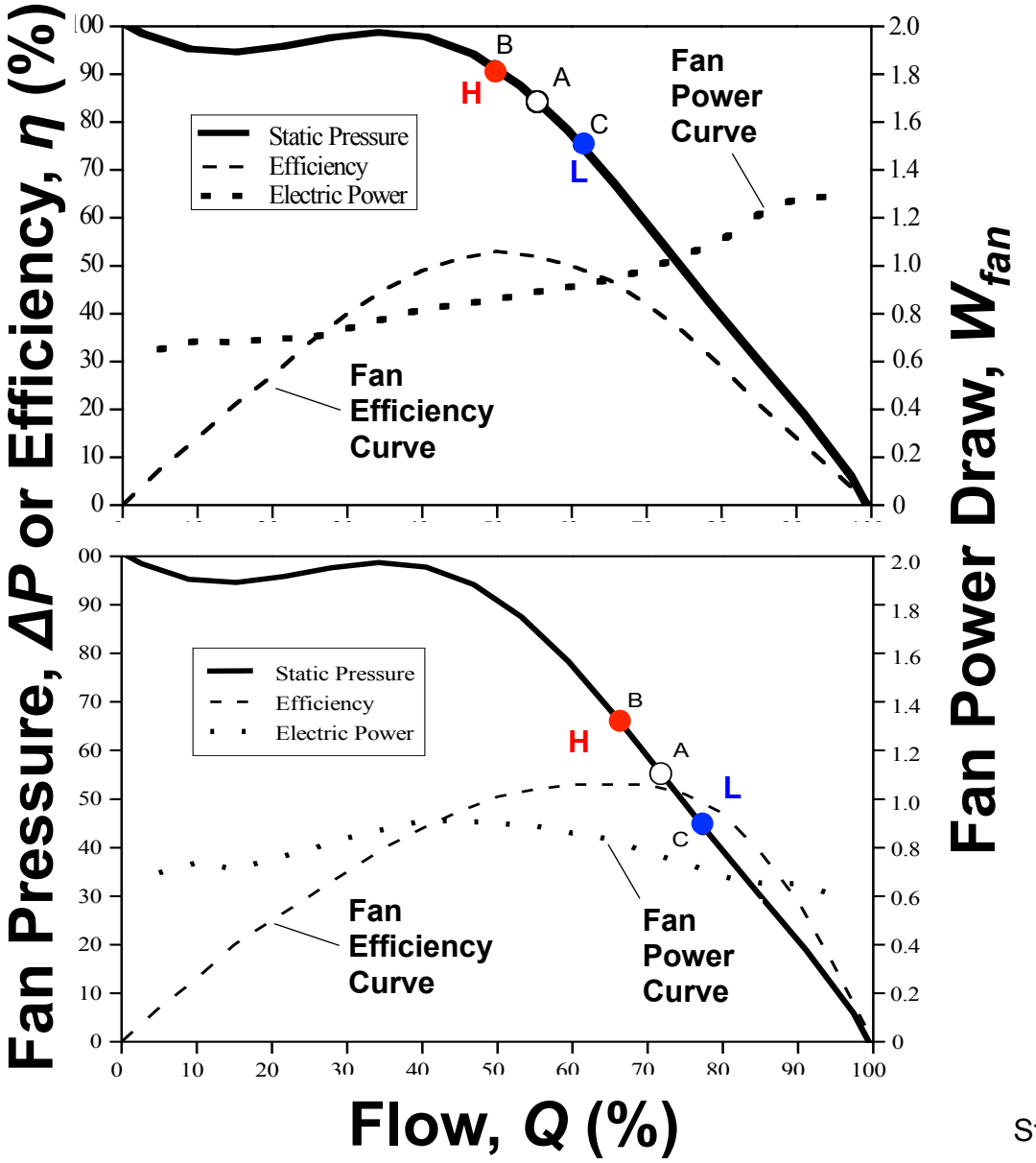
Extra slides

Fan and system curve interactions



Stephens et al., 2010 *HVAC&R Research*

Fan power draw impacts

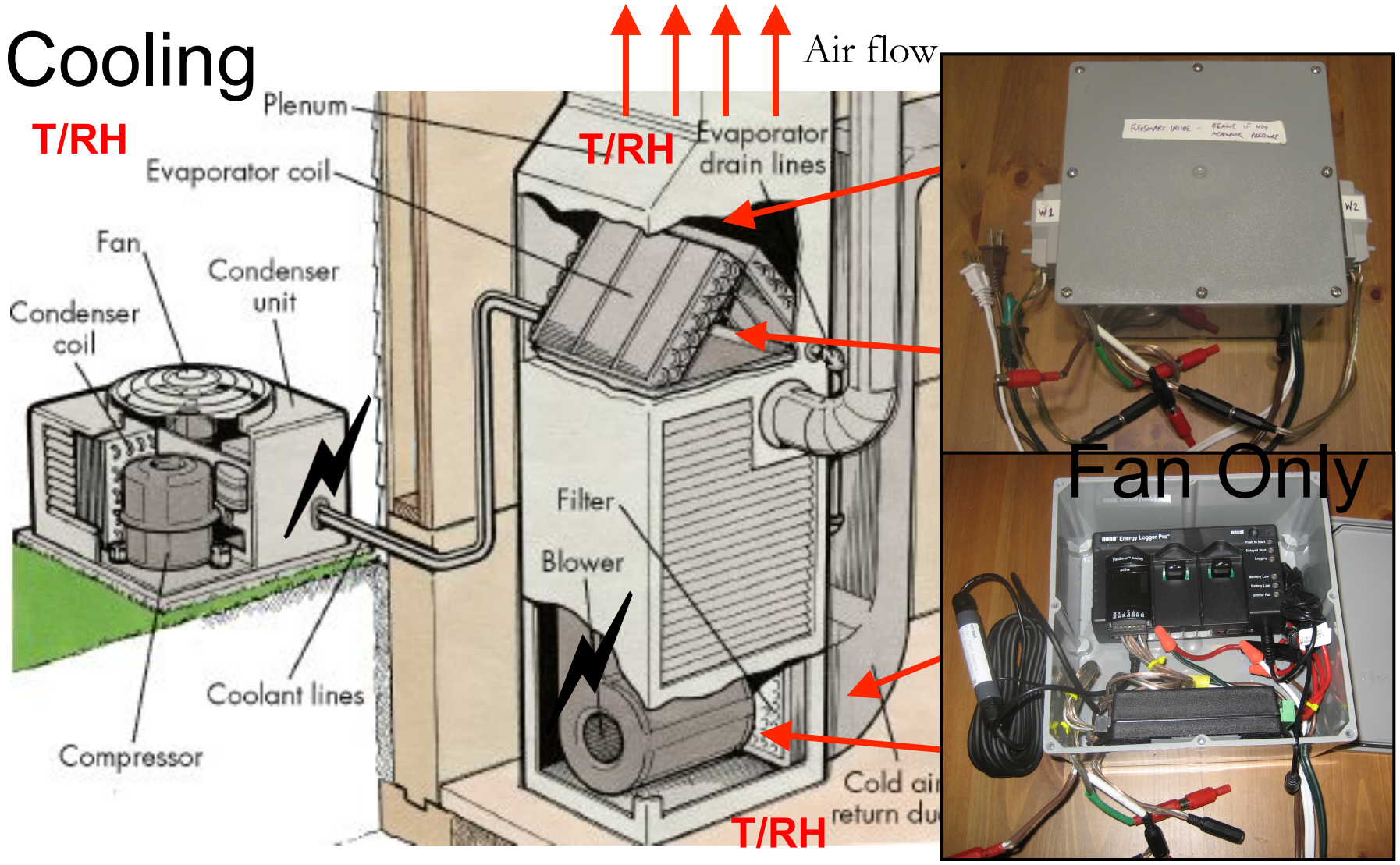


$$W_{fan} = \frac{Q\Delta P_{total}}{\eta_{elec}}$$

Power draw may increase or decrease in response to higher pressure (and lower flow for PSC blowers) depending on type of fan

Stephens et al., 2010 *HVAC&R Research*

Field measurements



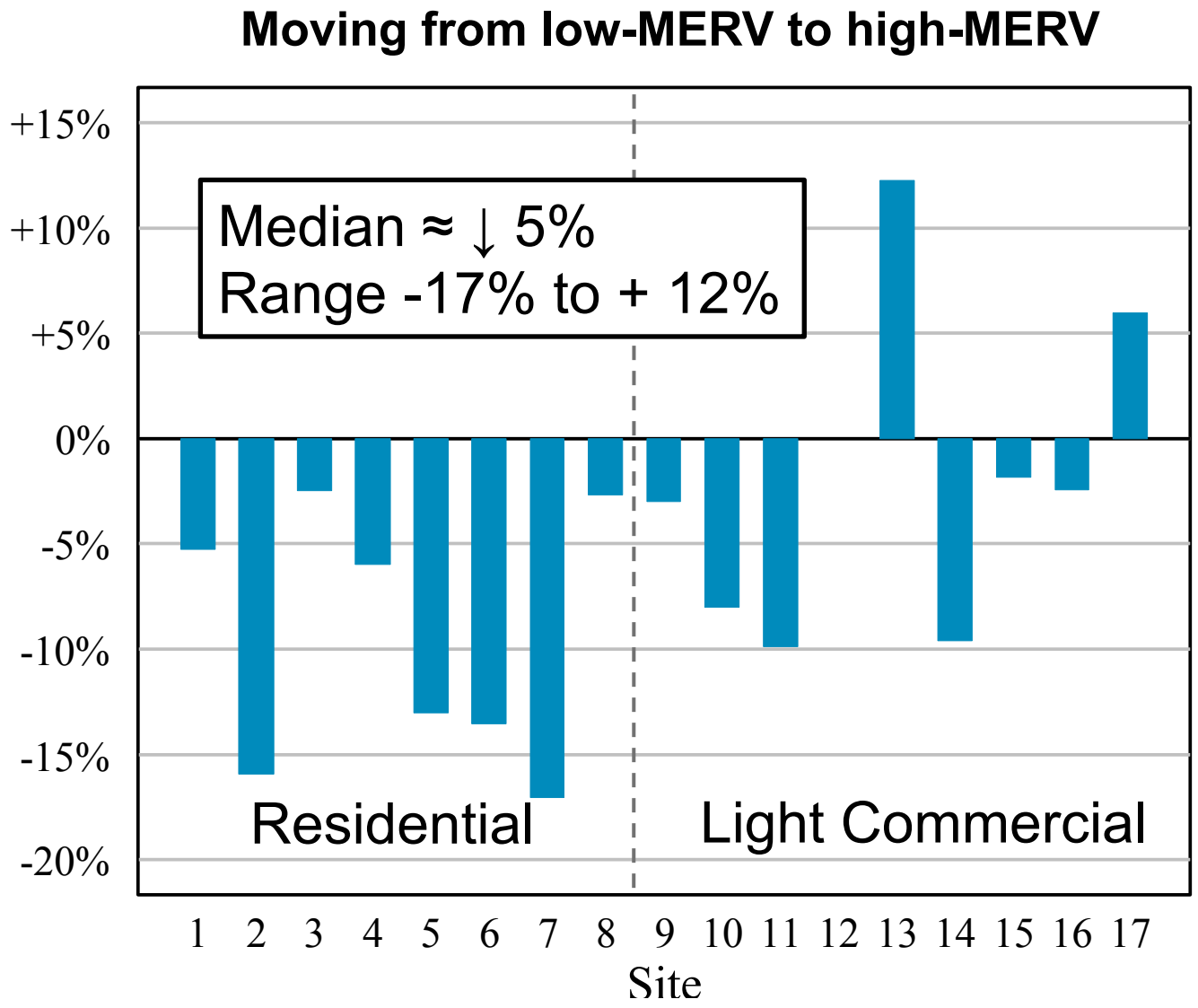
Source: http://static.howstuffworks.com/gif/how-to-troubleshoot-a-central-air-conditioning-system-1.jpg

Test house measurements

- Unoccupied manufactured home at PRC (UT)
- 2 systems continually monitored at 10-second intervals
- Controlled thermostats

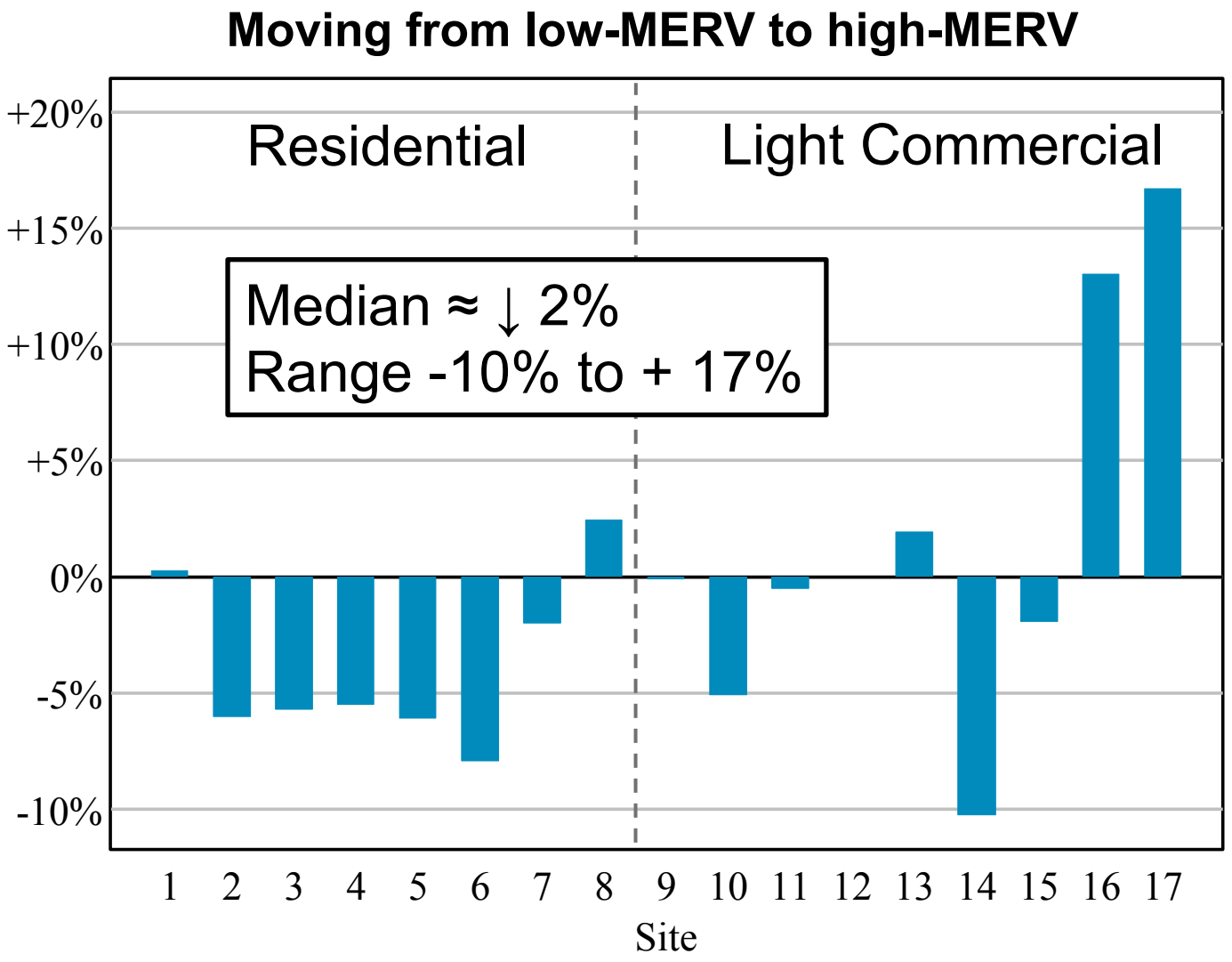
Stephens et al., 2010 *ASHRAE HVAC&R Research*

Median changes in **airflow rates**



Stephens et al., 2010 *ASHRAE Transactions*

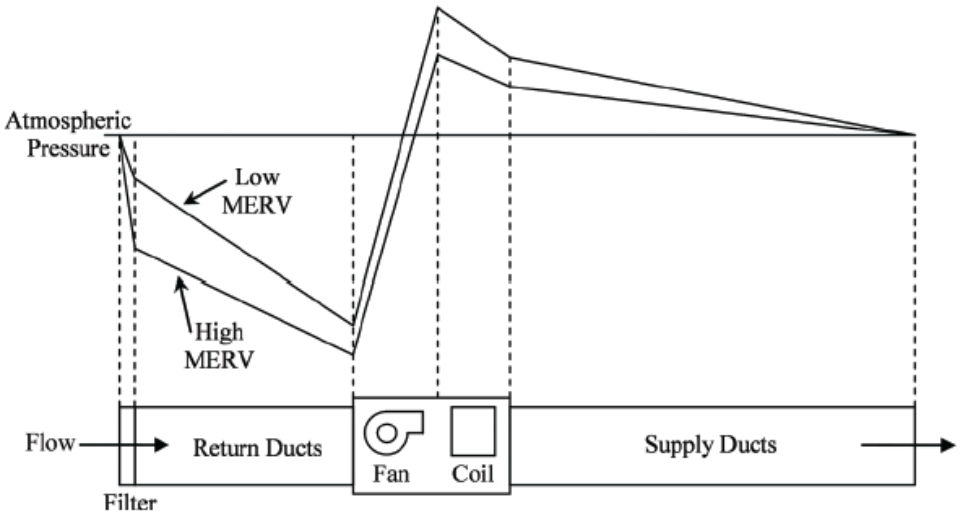
Median change in **fan power draw**

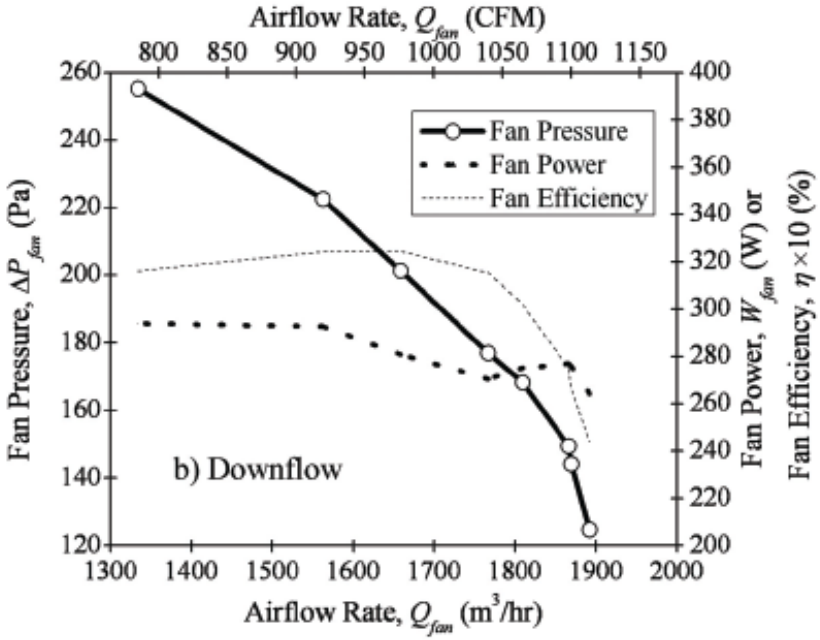


Stephens et al., 2010 *ASHRAE Transactions*

Whole new can of worms

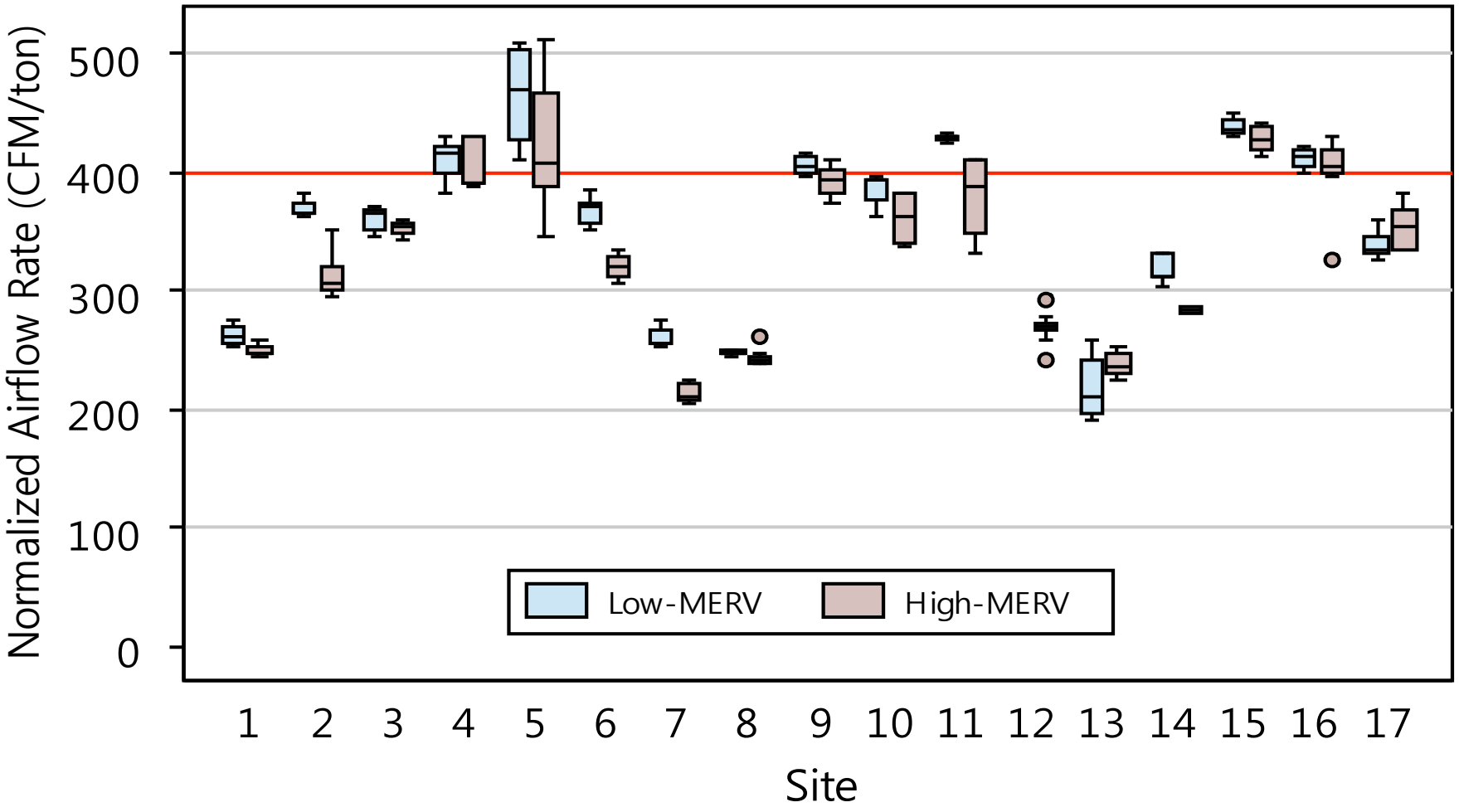
- Relationships between:
  - Filter efficiency
  - Filter pressure drop
  - Airflow rates
  - Fan power draw
  - System runtime
  - Energy consumption



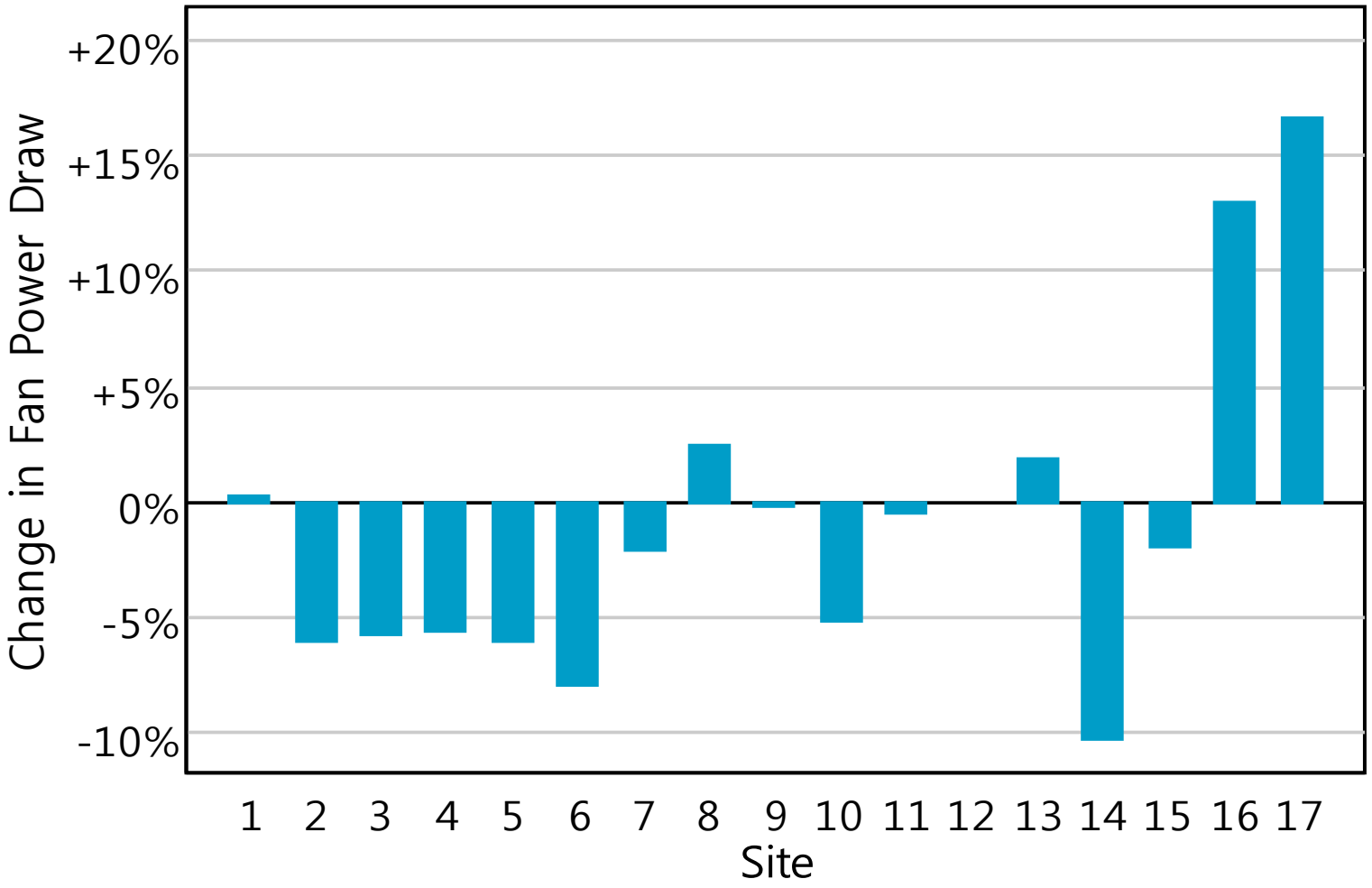


Stephens et al., *HVAC&R Research* **2010** 16(3), 273-294 and ASHRAE Research Project RP-1299

Low-MERV to high-MERV



From low-MERV to higher-MERV



Range of energy consequences

Average Change in Daily Energy Consumption

Moving from low-MERV to high-MERV