

# **BUILDINGENERGY BOSTON**

---

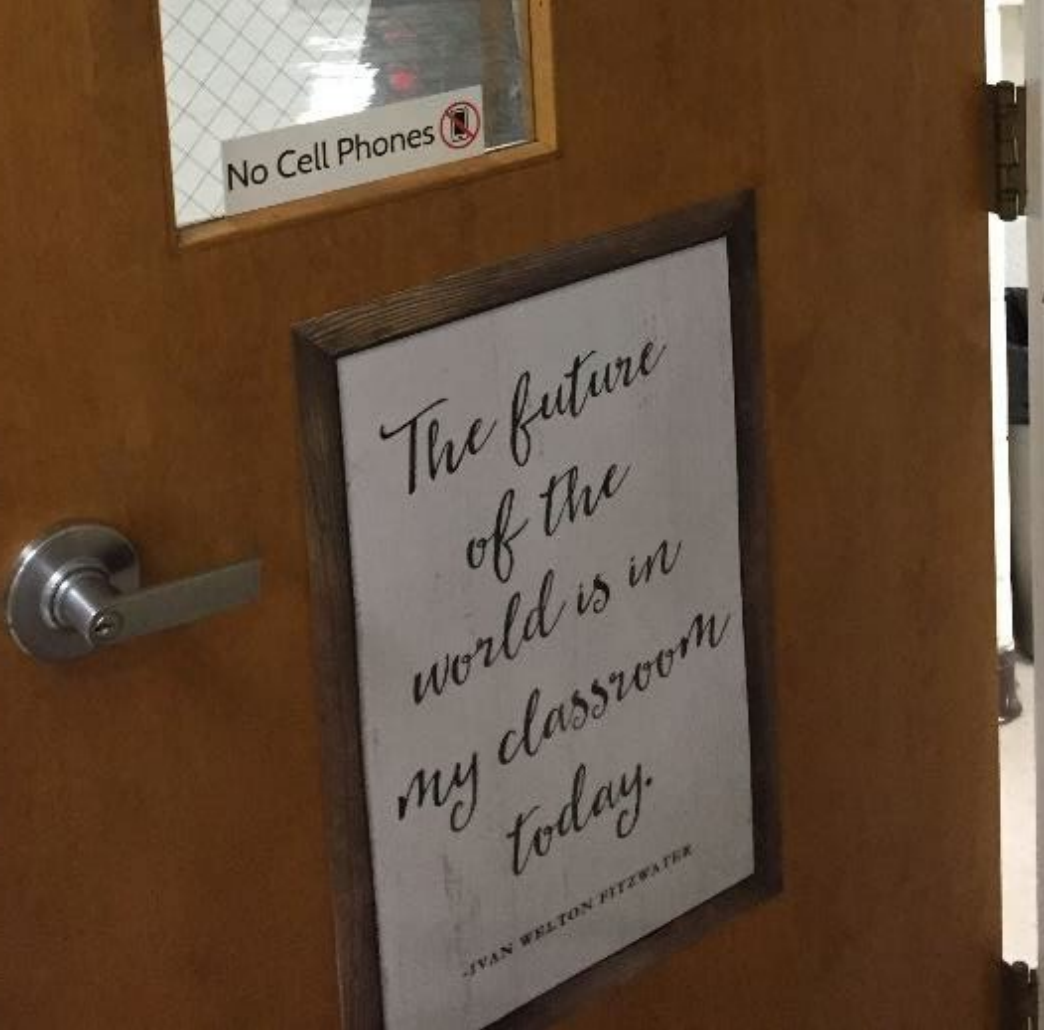
## **Creating Healthy, Decarbonized Classrooms**

**Ty Newell (Build Equinox)**

**Curated by Marc Rosenbaum**

---

**Northeast Sustainable Energy Association (NESEA)**  
**March 29, 2023**



# Creating Healthy Decarbonized Classrooms

Ty Newell, PhD, PE

Build Equinox

Urbana, IL 61802

[www.buildequinox.com](http://www.buildequinox.com)



SOLUTIONS FOR A **HEALTHY,**  
**COMFORTABLE,** AND  
**SUSTAINABLE LIFESTYLE**



**March 28 & 29, 2023**

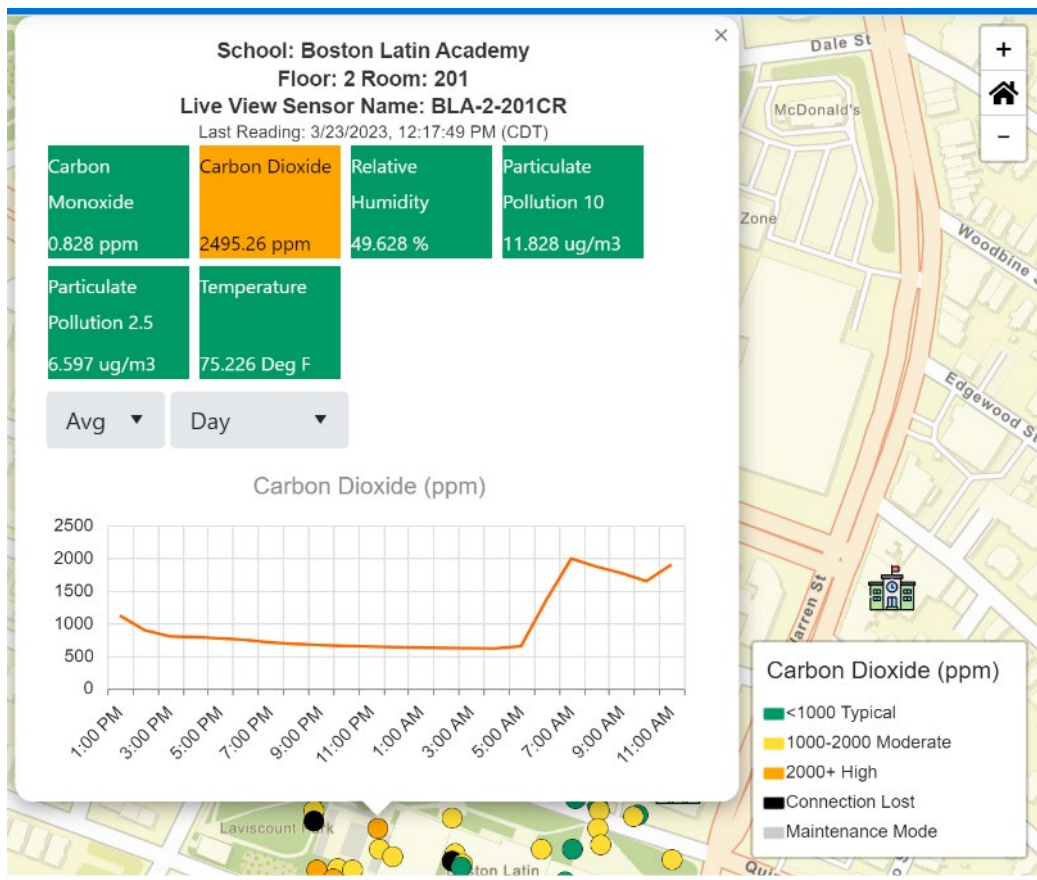
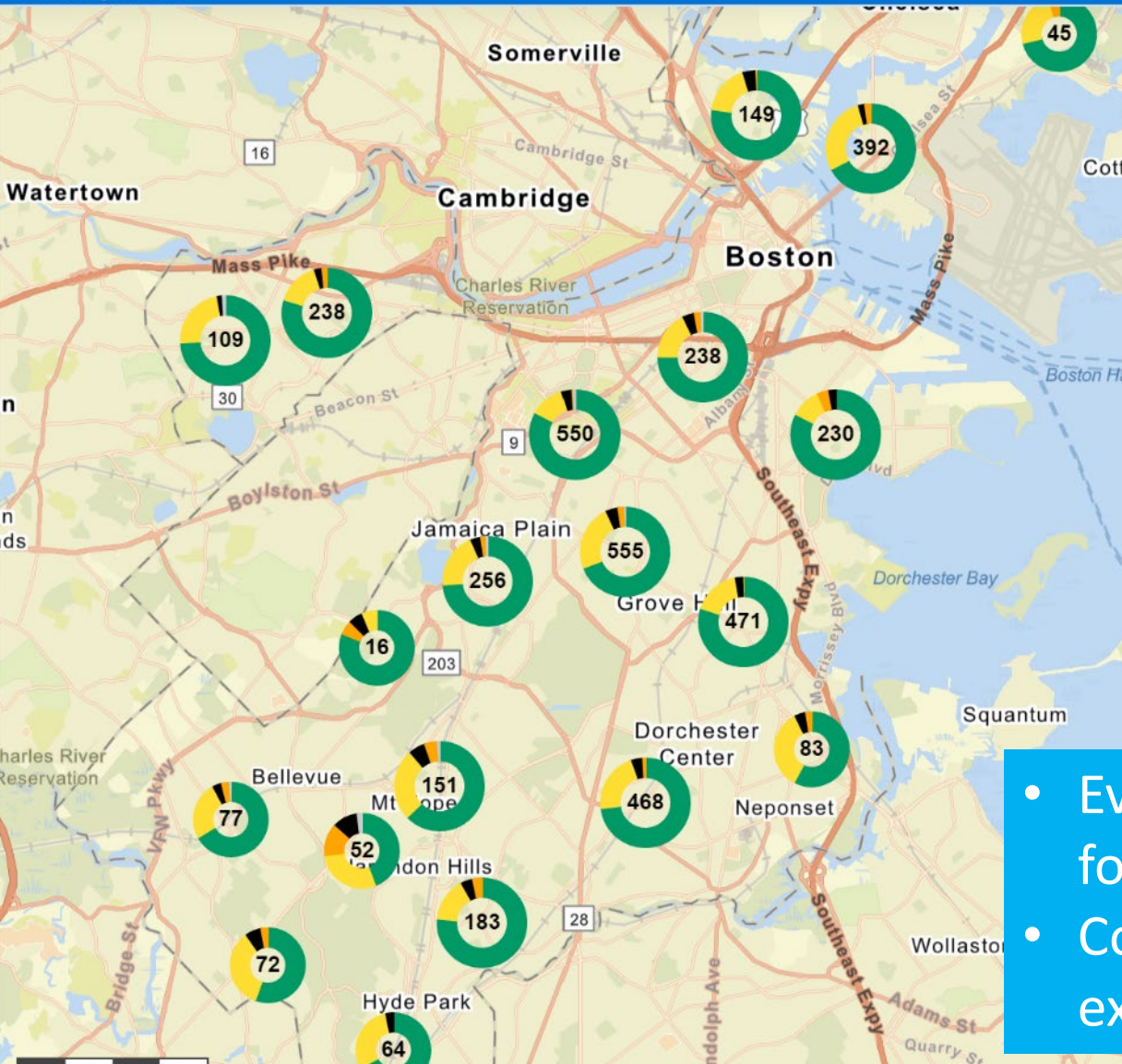


Georgetown-Ridge Farm IL junior high school

# Kudos to Boston Public Schools!

## SGS Live View Boston Public Schools Indoor Air Quality

Powered by TerraBase



- Every indoor space should have IAQ data available for occupants to view anytime, anywhere
- Cost for degradation of health and productivity far exceed the cost to monitor IAQ

# Newell – Broken Record on Sustainability, Health & Comfort



**2017 NESEA**

About | Contact

CONFERENCES PROGRAMS MEMBERSHIP COMMUNITY EVENTS DO

Home » Conferences » New IAQ Metrics to Avoid Being Stupid, Sick, and Tired

## New IAQ Metrics to Avoid Being Stupid, Sick, and Tired

Our poorly ventilated homes and buildings are making us stupid, sick, and tired—at a cost that is staggering. Improvement of today’s ventilation standards can increase human productivity with a value that is more than 100

**Our Homes and Buildings are making us**

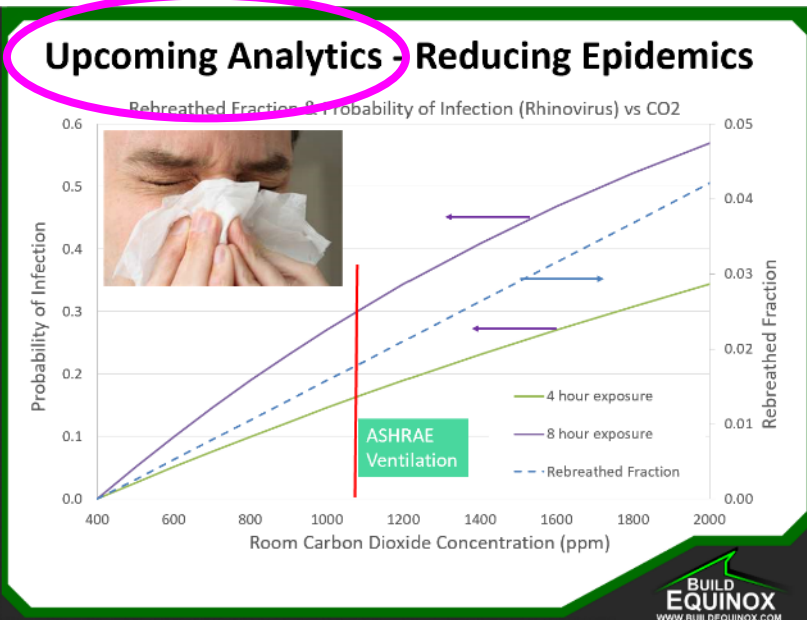
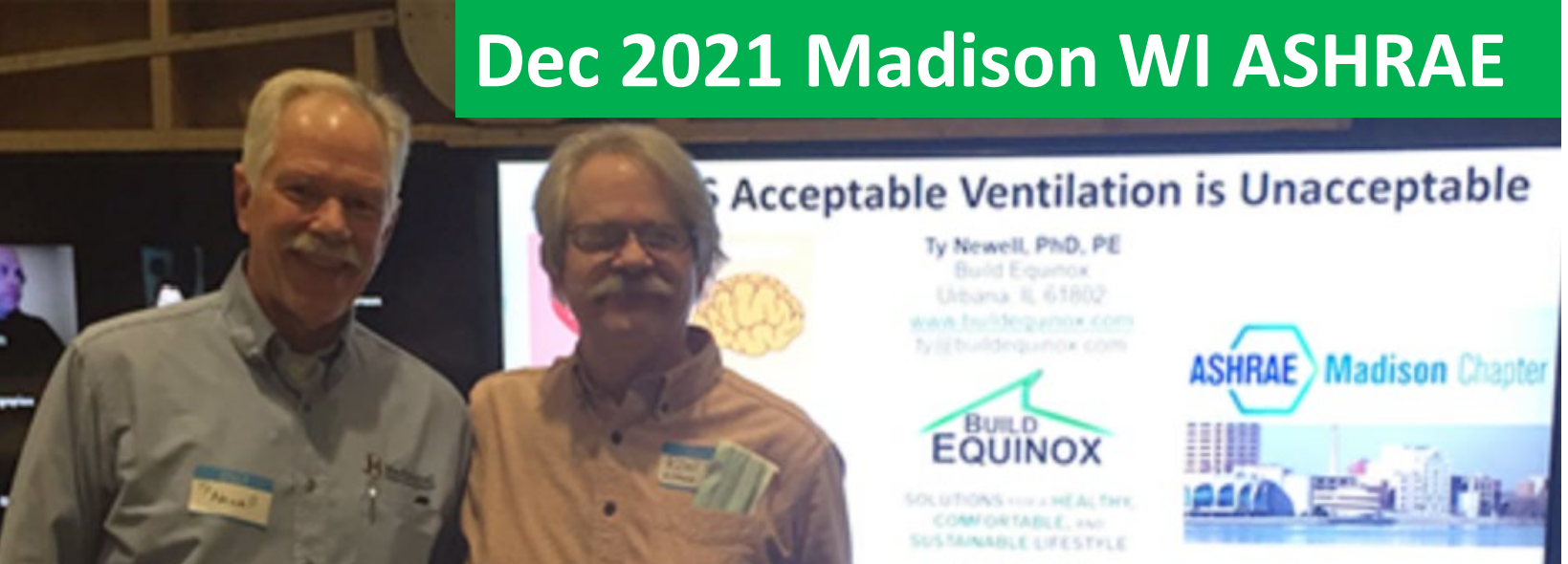
**Stupid**

**Sick**

The cost of being stupid, sick and tired is staggering....

**and, Tired**

## Dec 2021 Madison WI ASHRAE



# Don't Sacrifice Humans to "Save" Energy

"The purpose of a building is to keep people healthy, comfortable and secure; not to *save* energy"

William Bahnfleth, Prof Arch Engr, Penn State Univ; ASHRAE President Emeritus

## Featured Article

Filters are More Important (and Expensive) than Energy!



**100% Solar Powered Business!**



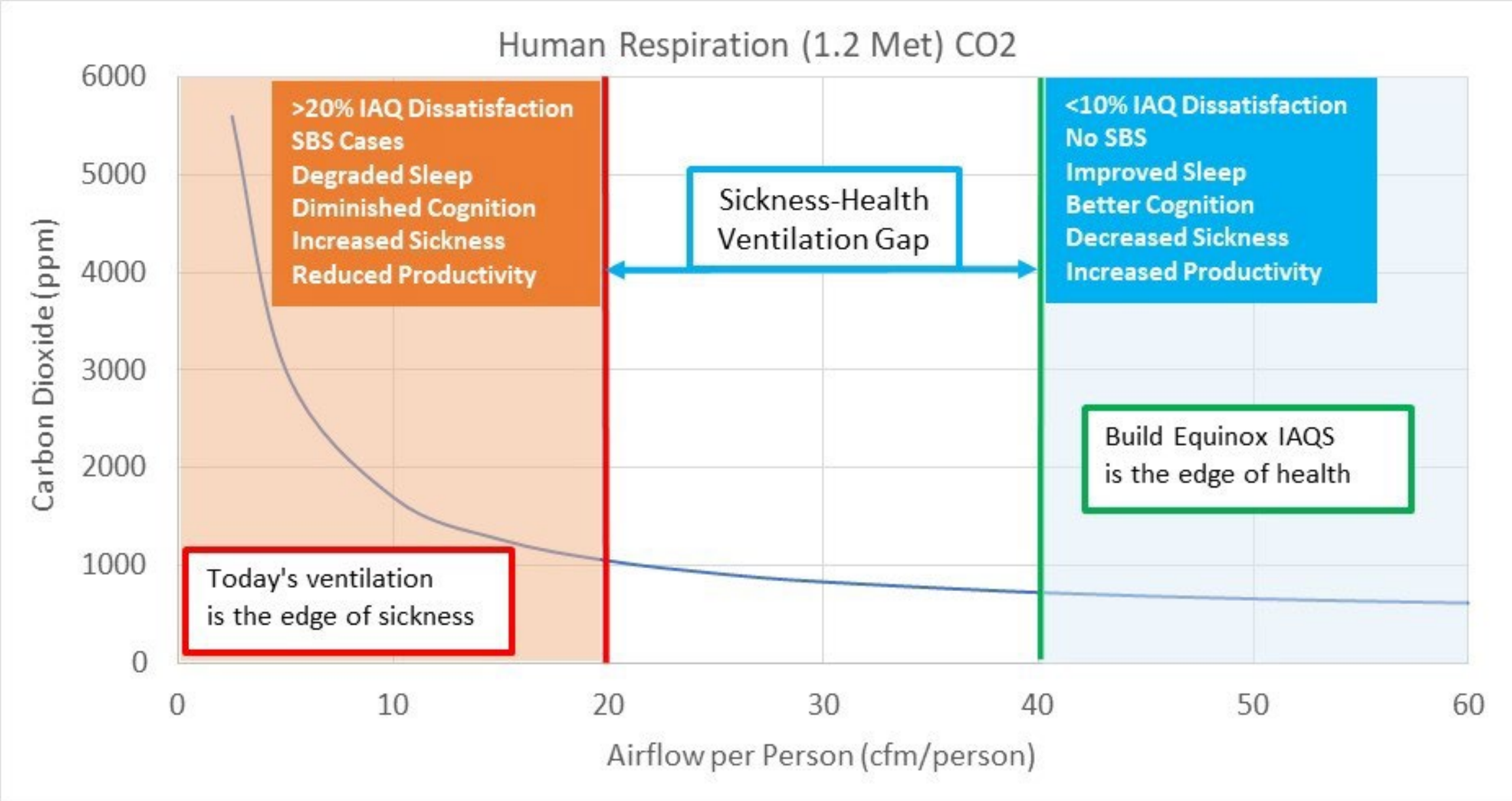
Don't get us wrong. Energy is really important. That's why we transformed our [4500sqft business facility to net zero operation](#).

But air filters are really, really important! Your health depends on good filters. Ironically, filters transition from a health benefit to a

Too many project focus on energy, leaving IAQ as a checkbox following today's inadequate ventilation standards

The cost of healthy air is less than 1 ½ cents per hour per person more in harsh climates without energy recovery .... but energy recovery is justified on its own

# Today's Ventilation Standards "Edge of Sickness"



# 2006 ASHRAE Journal Article on School Ventilation

## Northeast Ohio schools leading state in new COVID-19 cases: See the Top 20

Updated: Mar. 07, 2023, 11:52 a.m. | Published: Jan. 06, 2022, 3:56 p.m.

Alexis Oatman; Cleveland.com



ASHRAE Technology award winning school designed ranks number 4 on Ohio list for most Covid cases



May 2006 ASHRAE Journal

Standard 62 IAQ Procedure

## Reduced Outdoor Air For Auditorium

By Peter F. Johnson, Member ASHRAE

If you don't use the air purification option in the IAQ Procedure in ANSI/ASHRAE Standard 62.1-2004, *Ventilation for Acceptable Indoor Air Quality*, you may miss out on a non-traditional but cost-effective design that reduces heating, cooling loads, duct

able Indoor Air Quality, IAQ procedure that combined the use of gas-phase cleaning and high-efficiency particulate filters for reduced OA. For greatest savings, an energy recovery unit (wheel) was added for energy recovery of the exhaust air.

This project was designed as an architectural showcase. It is a one-story insulated brick building with a built-in

### Ventilation Rate Procedure vs. IAQ Procedure

Original Plan per Ventilation Procedure

Designed in 1999, three air-handling units required a total of 15,000 cfm (7079 L/s) outside air with 30% DS filters (MERV 5).

### Optimized per IAQ Procedure

With the use of bipolar ionization and 80% DS filters (MERV 11), the outside air is reduced to 7,500 cfm (3540 L/s). Enthalpy wheel energy recovery systems were added to save additional energy.

# Classroom Pollution & IAQ



## We understand people pollution

- $\sim 0.03\text{kg/h}$  CO<sub>2</sub> per person, Met=1
  - Sleep = 0.7 Met
  - Strenuous Activity = 7 Met
  - Typical Activity  $\sim 1.3$  Met
- $\sim 6.3\text{mg/h}$  VOC per person
  - Breath  $\sim 2.5\text{mg/h}$ -person
  - Ozone, temperature, personal care products, hygiene, and more impact human VOCs
  - 3<sup>rd</sup> hand smokers impact IAQ dissatisfaction  $\sim 20$ -25 times of a clean clothed, recently washed, non-smoker
- Human particulate generation
  - $\sim 100,000\#/\text{min}$  (sitting still) to more than  $1,000,000\#/\text{min}$  with physical activity
  - Newell  $> 7,000,000\#/\text{min}$ 
    - Hygiene?
    - Genetics?
    - Age?
- You can average humans, but there is no average person!



# Build Equinox Healthy IAQ Standard

<b>CO<sub>2</sub></b> <b>&lt; 800ppm</b> Carbon Dioxide	<b>PM<sub>10</sub></b> <b>&lt; 10 µg/m<sup>3</sup></b> Total Mass of All Particulates 10µm and Smaller
<b>VOCs</b> <b>&lt; 125 ppb</b> Volatile Organic Compounds	<b>PC<sub>0.3</sub></b> <b>&lt; 40,000 #/L</b> Total Count of All Particulates 0.3µm and Greater
<b>CO</b> <b>&lt; 9 ppm</b> Carbon Monoxide	<b>Rn</b> <b>&lt; 4 pCi/L</b> Radon

**Human-centric IAQ Standard**  
Today's ACH and ASHRAE 62.1/62.2 are "building centric"

Each term is measurable and controlled in practical manners

- Reduce sick days ~40%
- Improve cognition capability (eg, focus, creativity, decision making, information organization) ~10%
- Improve sleep with increased next day productivity
- Reduce indoor air quality dissatisfaction by 50% (25% to 12%)
  
- \$50 vent energy/yr-person
- \$500 sick day savings/yr-person
- \$5000 productivity gain/yr-person



**Health**

Reduce Illnesses

**Cognition**

Live Up to Your Potential

**Sleep Quality**

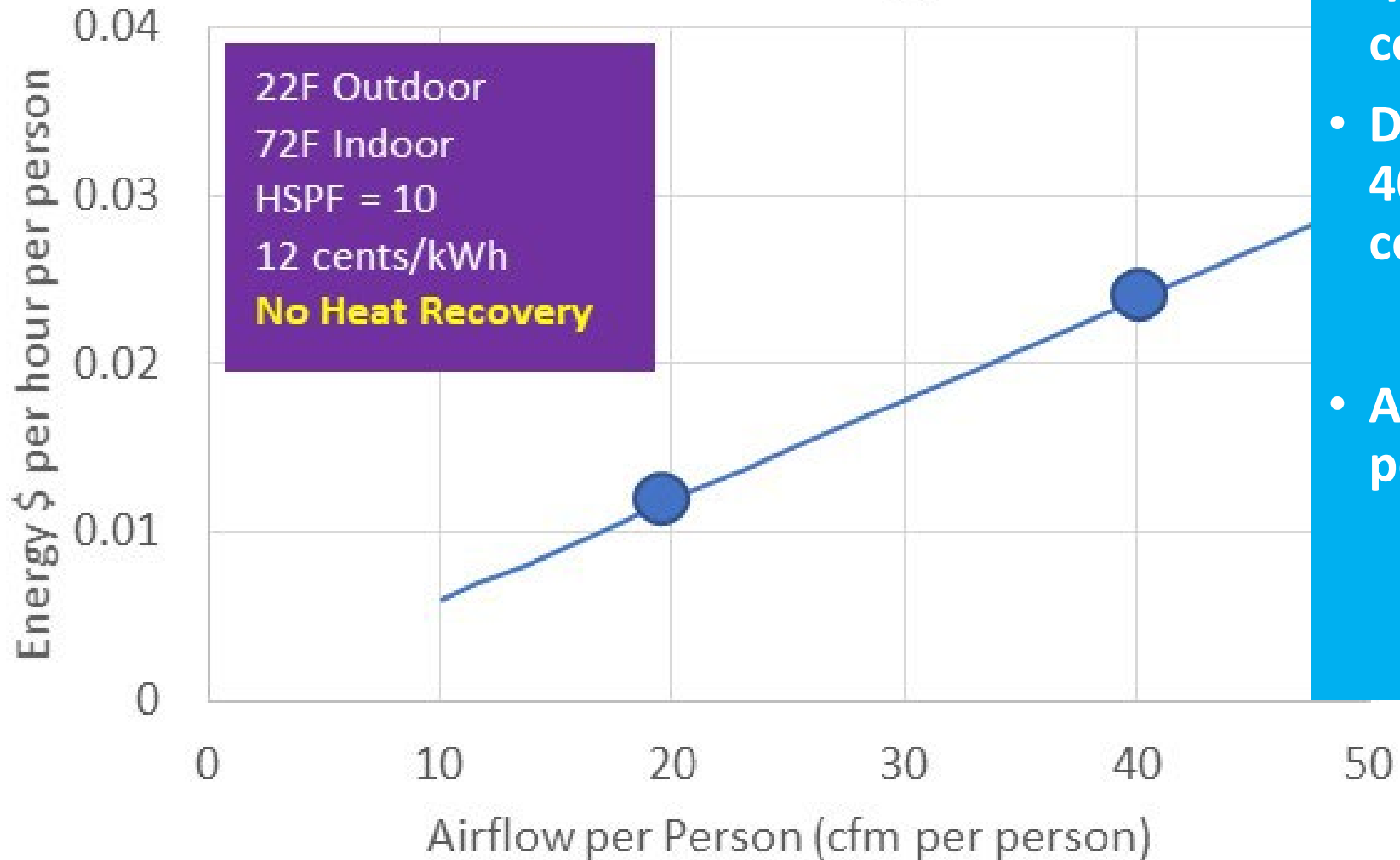
Rest More Effectively

**Productivity**

Get More Done

# What If Fresh Air is Increased to 40cfm/person?

Ventilation Energy Cost

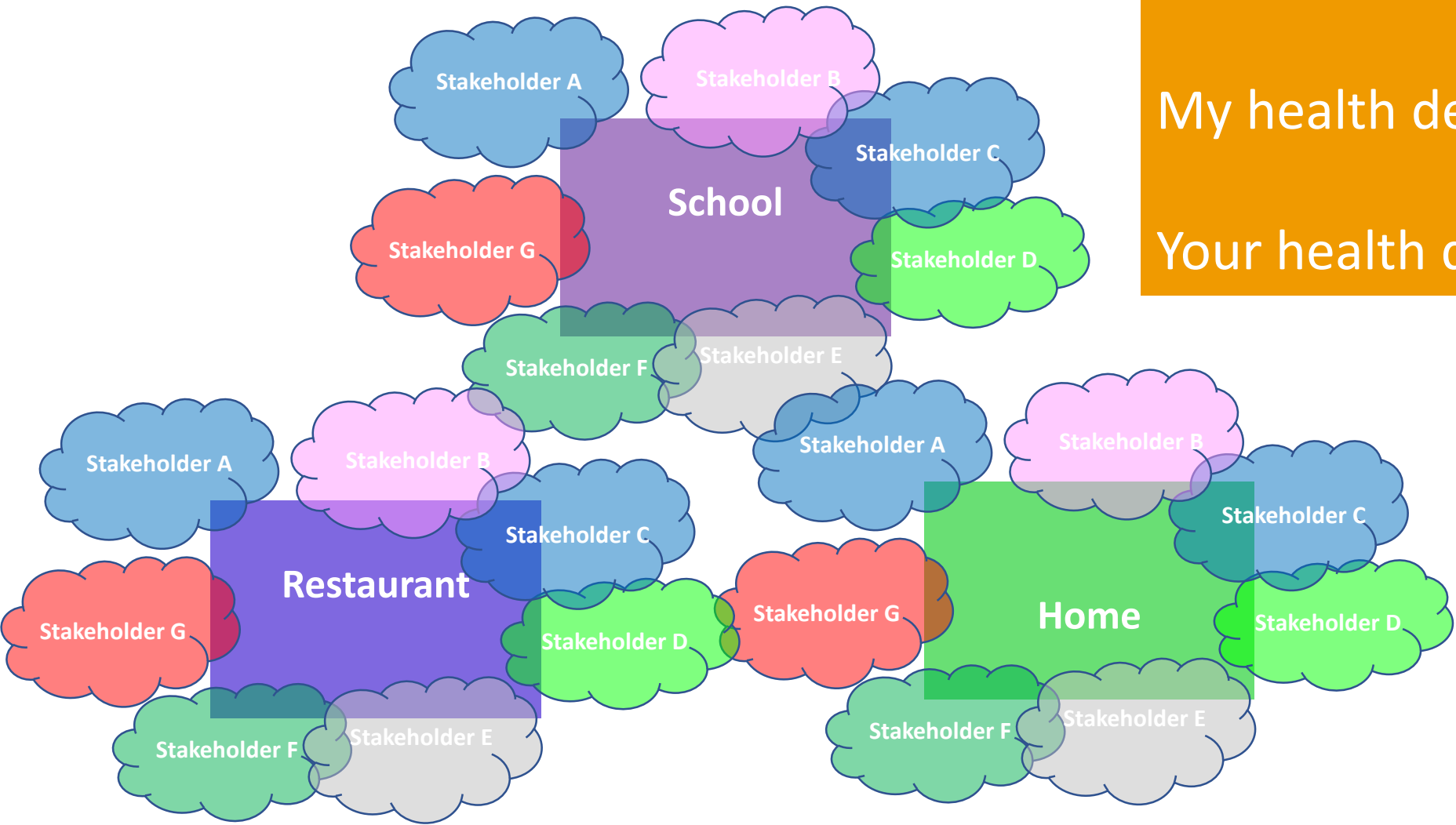


**and, no heat is recovered??**

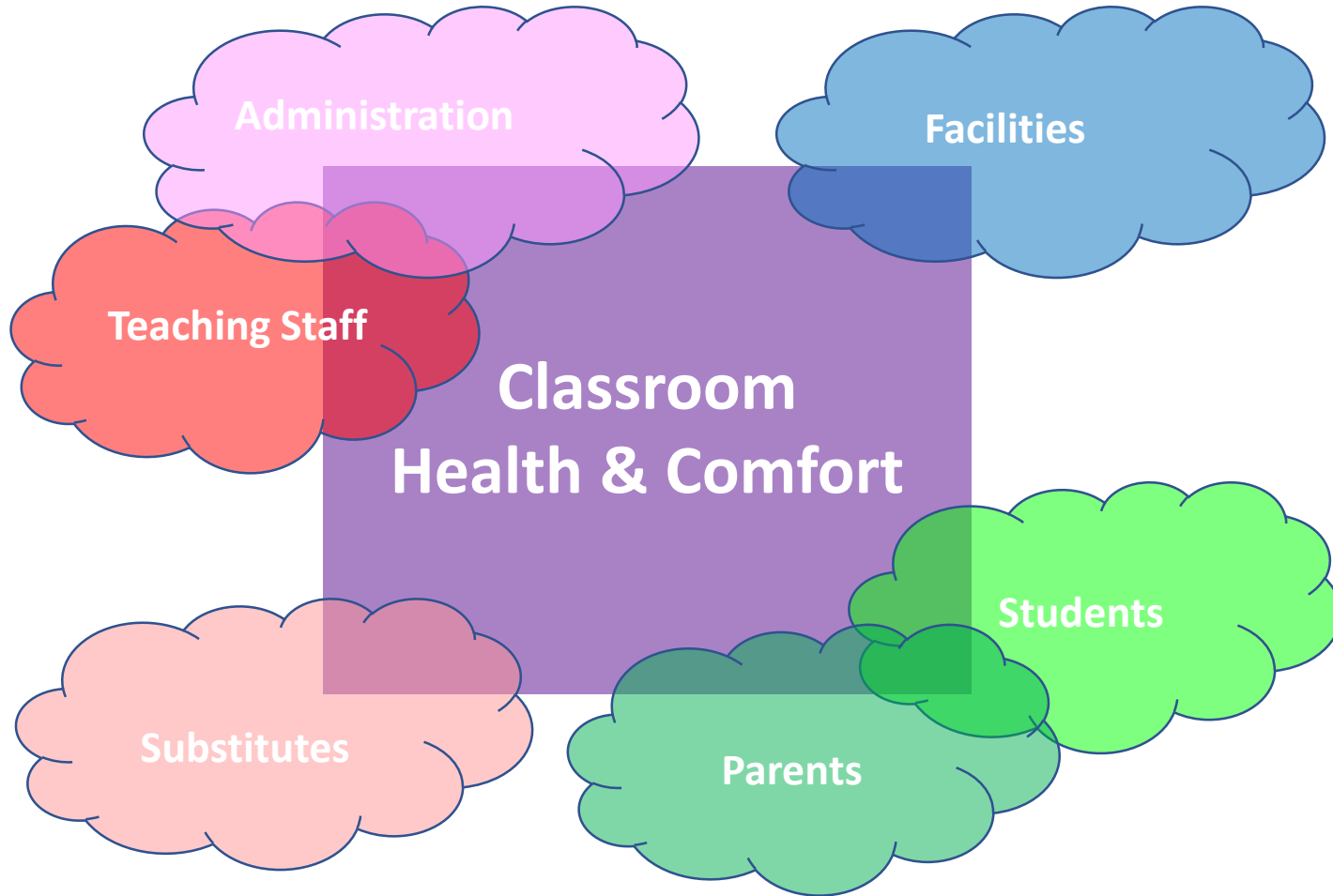
- “Acceptable” ventilation would cost 1 cent per hour per person
- Doubling ventilation to 40cfm/person would cost 2.5 cents per hour per person
- Are you worth an extra 1.5 cents per hour?
  - ...Yes, you are!

# 7 degrees of All Stakeholders – We're in this Together

All stakeholders are connected  
My health depends on you.  
Your health depends on me!



# Healthy Classrooms – Who Should be Involved?



Responsibility for creating safe, comfortable and energy efficient schools should involve all stakeholders.

Administration, teachers, students, parents, facility managers, substitute teachers .... want healthy, comfortable schools.

# Classroom Covid - 20 Students, 1 Teacher

- from Build Equinox IAQ Calculator – FREE!

(download from BE February 2021 newsletter)

## • Standard Conditions

- 420 minute exposure
- 1 Infectious
- 1200ppm CO<sub>2</sub>
  - 20cfm/person
  - MERV 8 filters
- 800ppm CO<sub>2</sub>
  - 40cfm/person
  - MERV 13 filters
- Masking

		Immunity		
		0%	50%	75%
MERV 8 filter	Infect Probability %	44	44	44
20cfm/person	Infection Multiplier	8.9	4.9	2.9
800ppm CO <sub>2</sub>	Infect Probability %	25	25	25
40cfm/person	Infection Multiplier	5.1	2.8	1.7
MERV 13 filter	Infect Probability %	14	14	14
40cfm/person	Infection Multiplier	2.9	1.6	0.9
50% Mask Use	Infect Probability %	12	12	12
20% Mask Eff	Infection Multiplier	2.4	1.3	0.8
80% Mask Use	Infect Probability %	2	2	2
80% Mask Eff	Infection Multiplier	0.4	0.2	0.1

# Georgetown-Ridge Farm Junior High School

- 200 students in junior high school
- Rural with 75% free and reduced lunch
- 25,000sqft with multiple additions
  - Original school gutted and converted into gymnasium; two classroom wings
  - Cafeteria, library
  - Addition for locker rooms, music rooms, and special activity areas
  - Administration, nurse, counseling, special needs offices



# Air Quality Improvement in Older Classrooms



## Current state

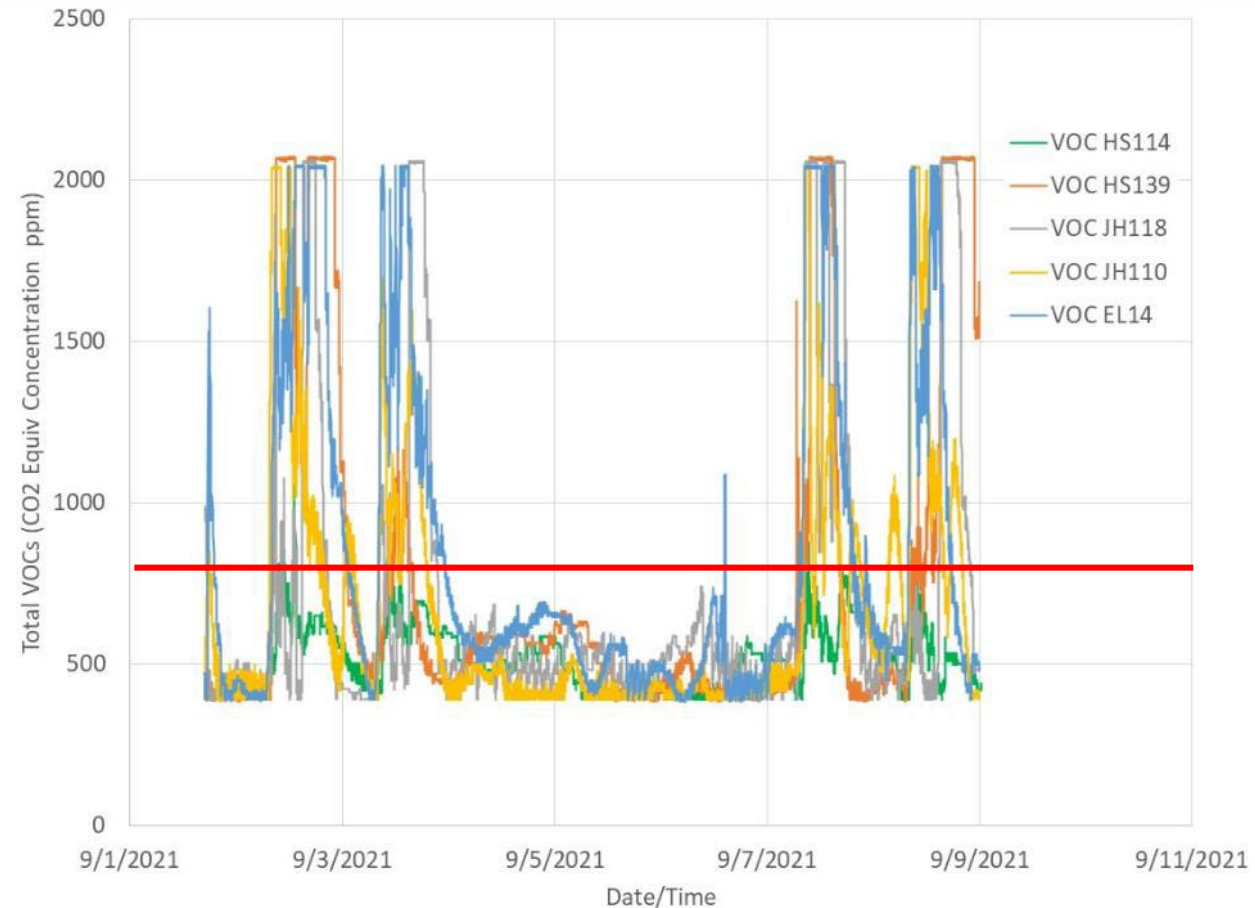
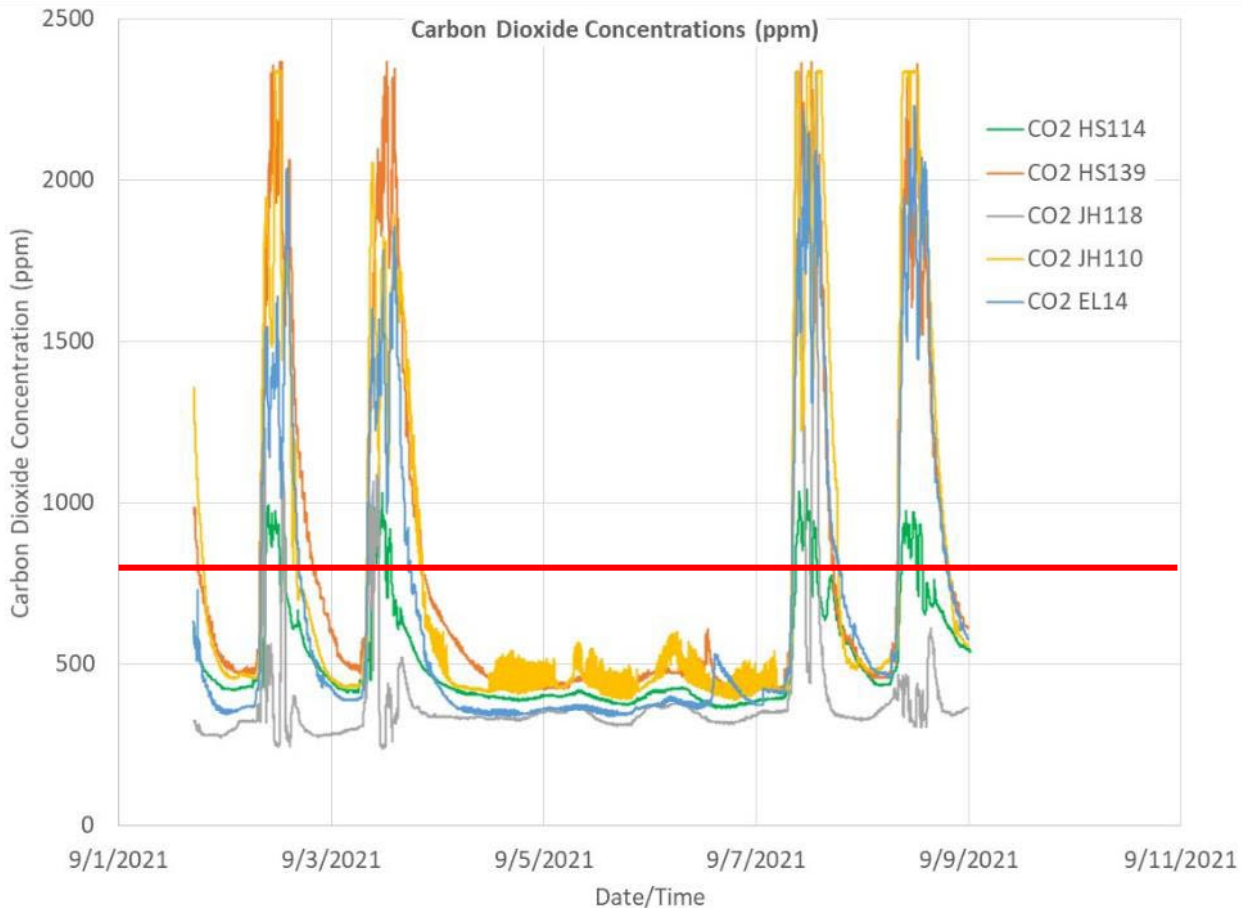
- No ventilation!
- Natural gas hot water radiators
- Inadequate window AC
- Window walls (upper half of exterior wall covered and insulated) with reduced windows
- **Electrical**
  - Original incandescents were three 20amp breakers
  - Each circuit with LEDs draws 2amps
  - Window AC 20amp breaker

## Concerns

- Covid
- Disinfectant spraying
  - Papers wet in the morning

How can a classroom in an older school be improved without a large capital project and without shutting facility down?

# Carbon Dioxide & VOC Trends (1 week data)



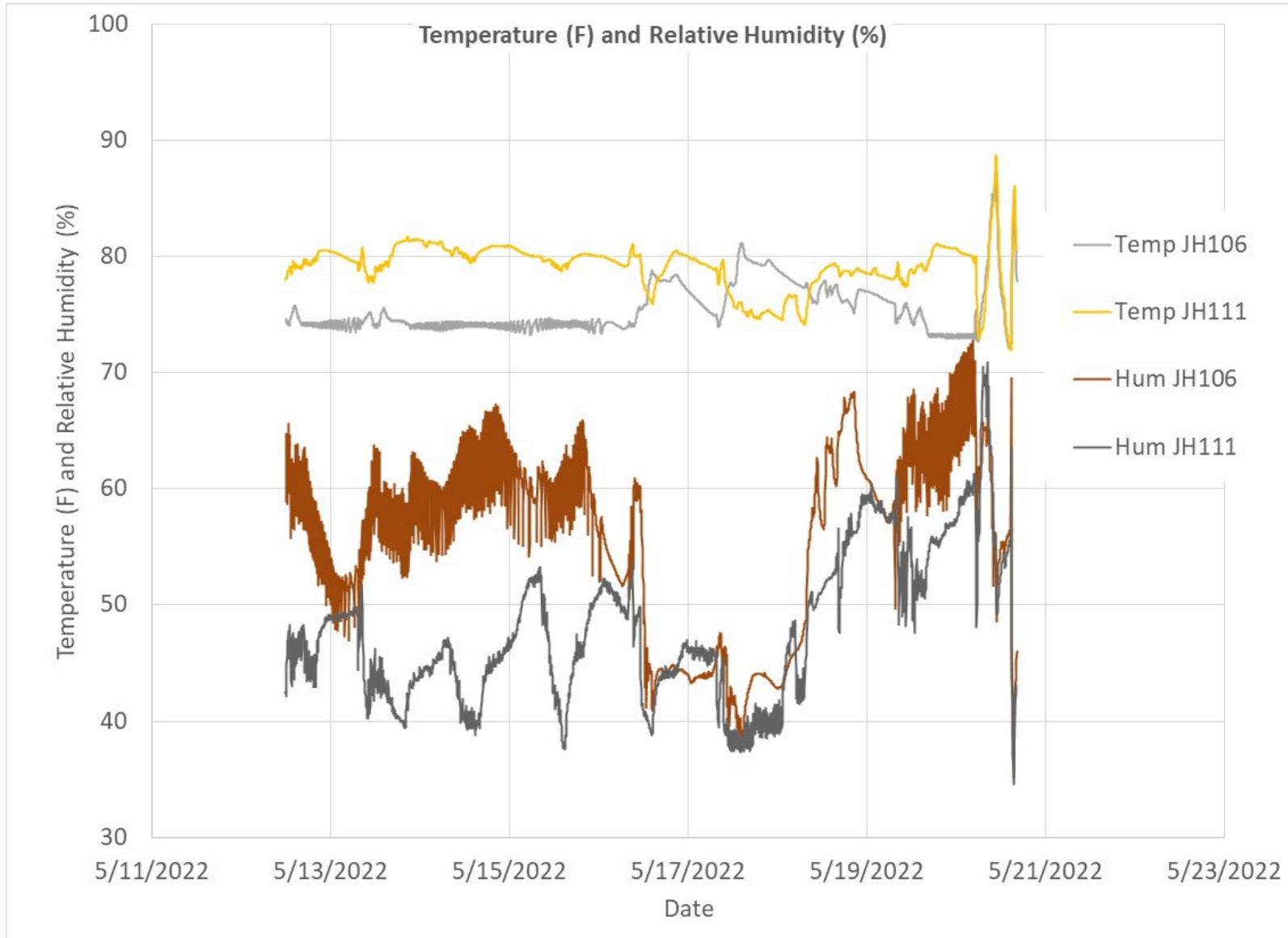
**Carbon Dioxide (<800ppm)**

**30-40cfm/person fresh air**

**VOCs (<125ppb)**



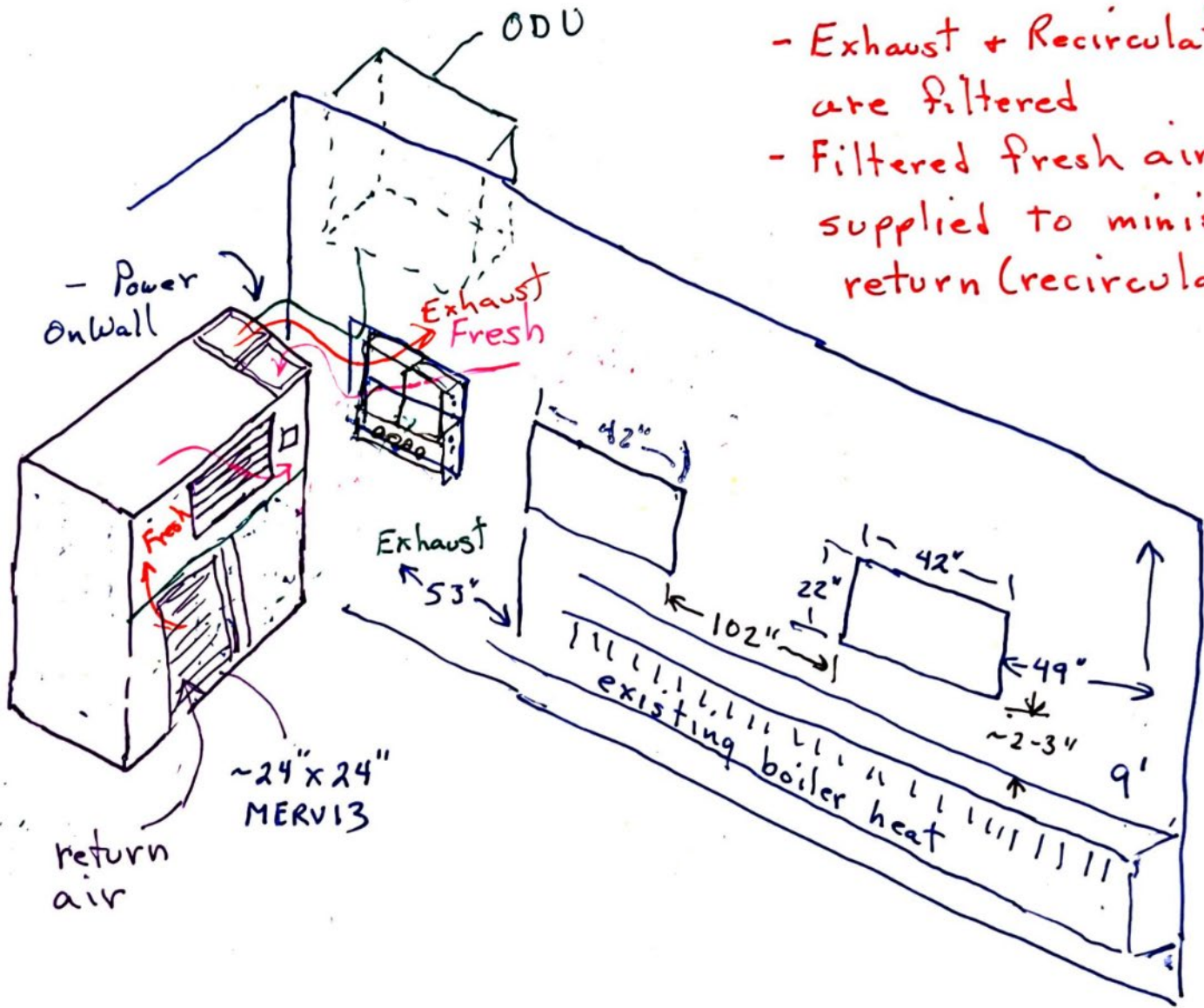
# Comfort – Junior High School (south and north side rooms)



- 1% productivity drop per 1F outside of one's comfort range
- Increasing rate of productivity drop the further from comfort range
- Similar impact for humidity

How to Improve and How Much?

# Unitized Concept for IAQ and Electrifying Older Classroom



- Exhaust + Recirculated are filtered
- Filtered fresh air is supplied to minisplit return (recirculated)

# Unitized Concept for IAQ and Electrifying Older Classroom

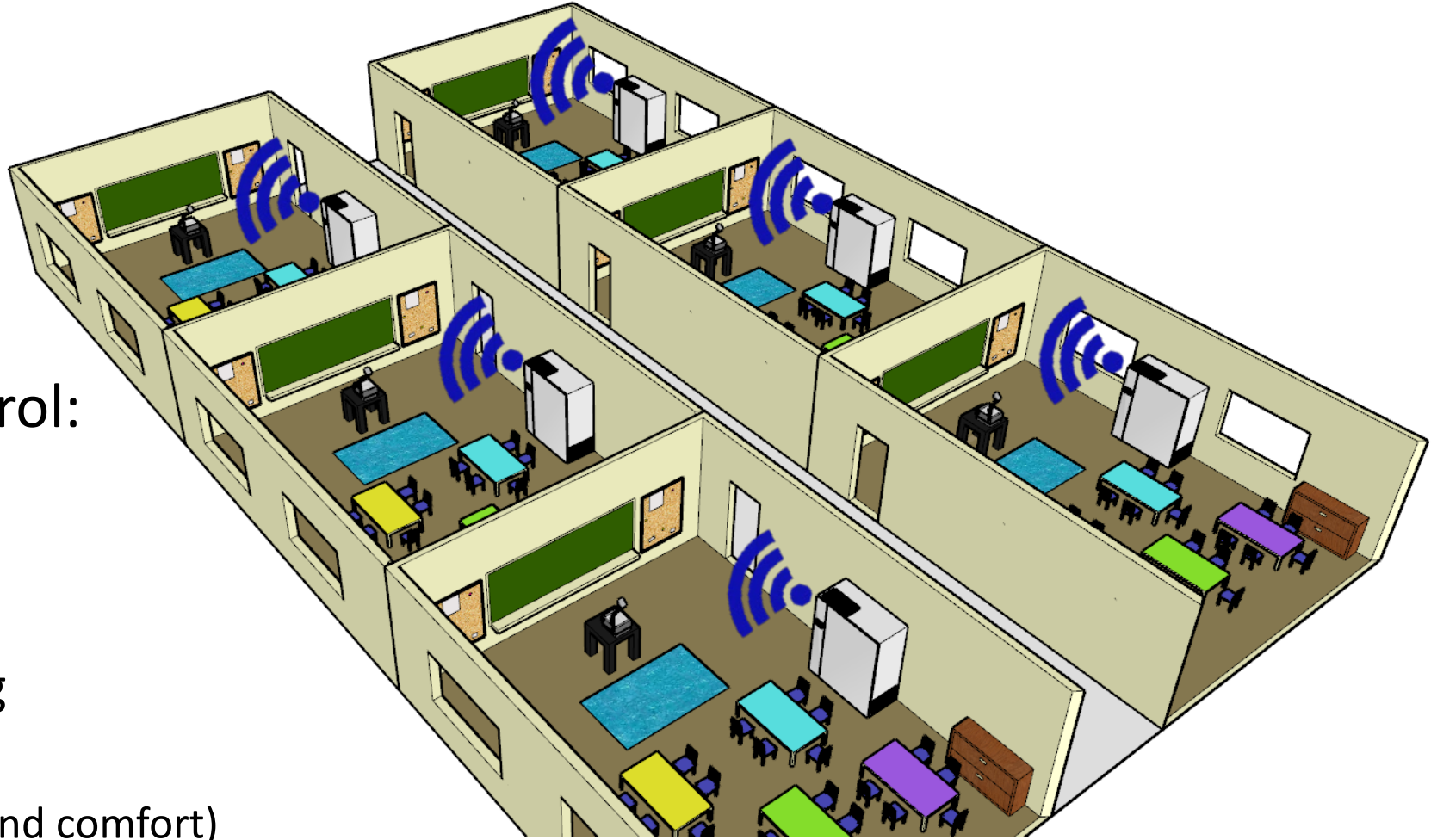
Unitized smart ventilation and comfort conditioning system



## Multiple Goals

- Avoid classroom shutdown
- Unit < doorway size
- Room-by-room “rolling” installation
- Installation labor from local community
  - HVAC installer skill
  - Maximize funds spent within school community
  - Flexibility in installation scheduling
- Increase facility maintenance efficiency
- Eliminate classroom disinfectant spraying
- Online classroom monitoring & control
- Compare absenteeism and staff sick days to previous years
- Investigate IAQ effects on health (reduced, wheeze, headache, asthma triggers, etc)

# Administration & Facilities Management

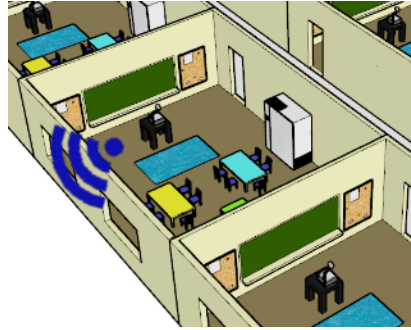


- Dashboard Monitor & Control:
  - Online support
  - Replacement scheduling
    - Filters, UV lamps, etc.
  - Diagnostics/Troubleshooting
- Classroom:
  - IAQ (CO<sub>2</sub>, VOC, Particulates and comfort)
  - Sensor status (occupancy, window/door status)

# Administration & Facilities Management



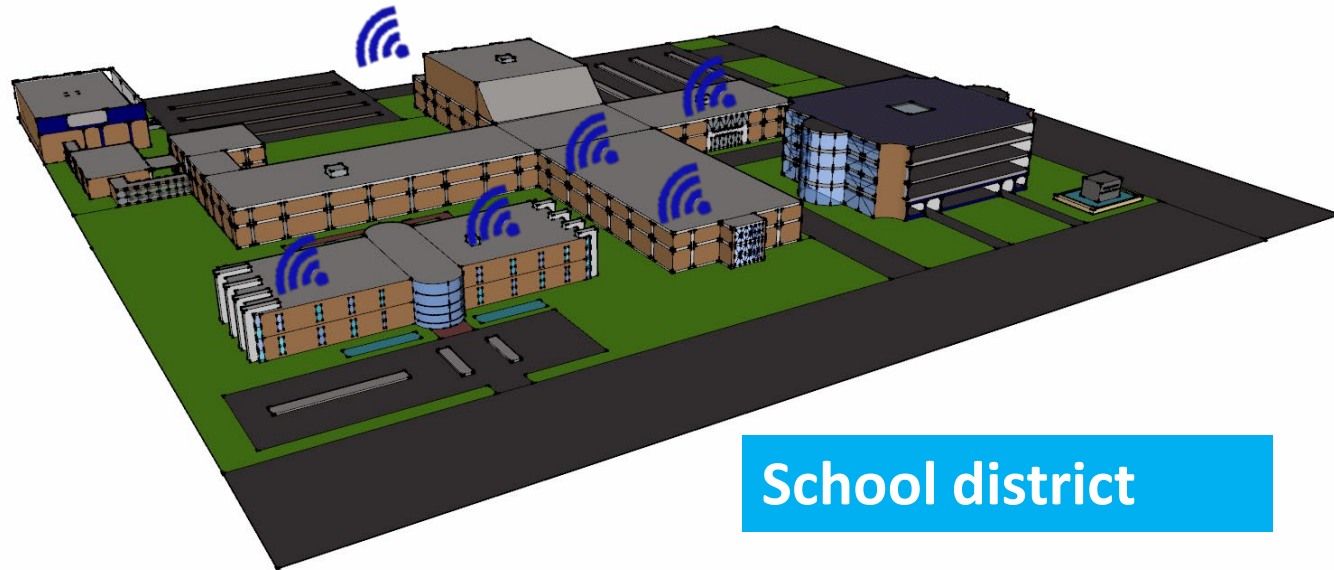
Classroom



School building

- Dashboard Monitor & Control:

- Classroom operation & status
  - Teacher
- Building operation & status
  - Principal's Staff
- District operation & status
  - Superintendent's Staff



School district



# Classroom Energy Analysis

## Inputs

- ~750sqft/classroom (20students\*30sqft/student + 150sqft for Teacher)
- 750sqft roof = R12
- 250sqft exterior wall; R9
- 25sqft double glazed window
- 180 day school year; 10 hours/day (20% occupied, 80% unoccupied)
- 840cfm fresh air ventilation (40cfm/person)
  - 60-80%sensible; 40-60% latent recoveries



# Classroom Energy Outputs



Zero Energy Residence  
Optimization software  
Free-to-use, online software  
[Buildequinox.com/zeros](http://Buildequinox.com/zeros)

## Outputs

- Occupied electrical energy = 4000kWh/y (20% of year)
- Unoccupied electrical energy = 3000kWh/y (80% of year)
- Annual electrical energy usage = 7000kWh/y
- Winter Design Day (-10F) = 30,000Btu/h (occupied); 12,000Btu/h (unoccupied)
- Summer Design Day (104F) = 20,000Btu/h (sensible, occ); 12,000Btu/h (latent, occ)
- = 12,000Btu/h (sensible, unocc); 800Btu/h (latent, unocc)
- Optional: net zero classroom: 6000W solar PV = 7200kWh annual energy
  - Use for training and developing local installers
  - ~500sqft PV array (less than class area)

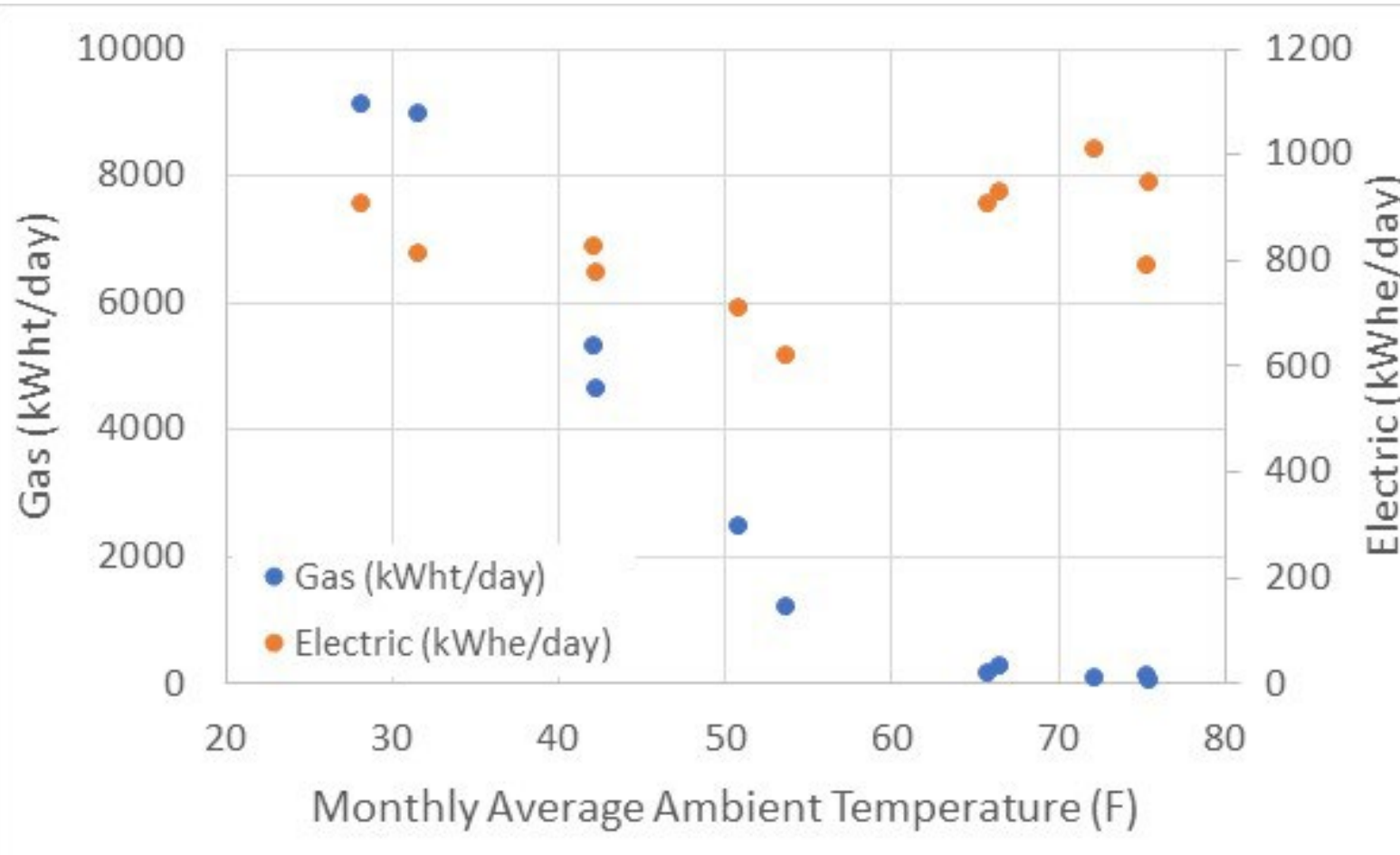
# Classroom Capital & Energy Cost

## Fresh Air and Comfort Conditioning System Cost

- Fresh air and comfort conditioning unit = \$25K
- Installation cost = \$5K (in house) up to \$15K (contract)
- Total Cost \$30K-40K; \$30-40/sqft (~\$50-60/sqft for central system installation)
- \$30,000/10 years/180days per year/21people per class =
- **80cents per day per person** for better health and decarbonized classroom
  
- Option: net zero classroom:
  - Annual utility cost = \$840/y (\$0.12/kWh and increasing!; 7000kWh/classroom)
  - 6000W solar PV = \$18,000 (\$3/W in our area)
    - ~\$9000 net cost (30% solar tax credit for tax-exempt; 20% Solar Renewable Energy Credits in Illinois)
    - 10 year payback

# Ultimate Goal – Overall School IAQ & Energy

## January 2022- December 2022 Utility Data

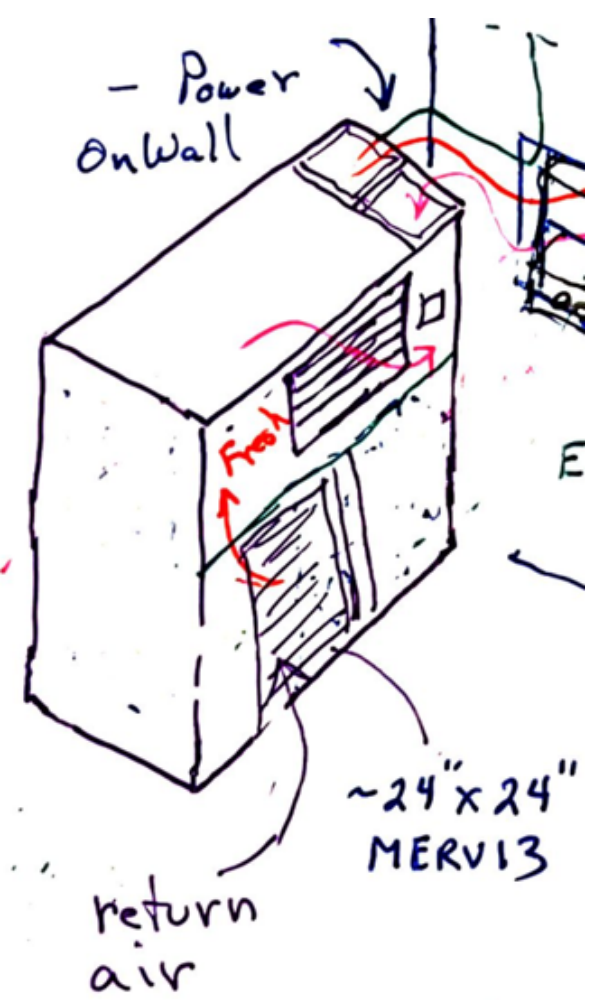


Junior High School = 25,000sqft

### Energy Usage 2022

- Gas = 43,180 therms (1260MWht)
- Elec = 305MWhe
- EUI = 213kBtu/sqft
- Gas use = 250tons/y carbon dioxide
- Current utility = \$51K/y and increasing
- Conversion of gas heating and elimination of current window AC units to heat pump comfort conditioning = 471MWhe
- EUI = 64
- Add 200kW solar PV = 240MWhe reduced
- EUI = 9
- Annual energy savings ~\$29K/y
- AE incentive \$5/sqft (Federal rebate) for 50% ASHRAE 90.1 reference case
  - \$75K AE for decarbonization, improved IAQ & energy savings

# Concept to Production Reality



# Health, Comfort & Sustainability in Classrooms

- Older classrooms can simultaneously and economically be converted into healthy, comfortable and sustainable environments
- Unitized concept reduces classroom disruption and can be installed by local community HVAC installers, increasing money spent by a community within the community
- Improved classroom IAQ will reduce sick days, improve productivity and improve classroom performance

Thank you!