Human Centric Metrics for Improving Health, Comfort, and Productivity

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BUILD EQUINOX

SOLUTIONS FOR A HEALTHY, COMFORTABLE, AND SUSTAINABLE LIFESTYLE

Mission

Develop solutions for healthy, comfortable and sustainable lifestyles ….learning to live on our daily allowance of solar energy.

"How do we live on a piece of land without spoiling it?"
Aldo Leopold

phius con
NEW YORK 2021

October 2021

“Why can't we be smart enough to say let's have balanced ventilation, provide mixing and distribution and ventilate according to need. We have the technology to be able to measure stuff. John, not only CO_2, we're able to measure volatile organic compounds, VOCs in particulates come on baby, if I can have 14,000 songs on my iPhone, why can't I measure VOCs in particulates, baby.”

Joseph Lstiburek and John Straube

ASHRAE Podcast 4 “There’s No Such Thing as a Free Thermodynamic Lunch”

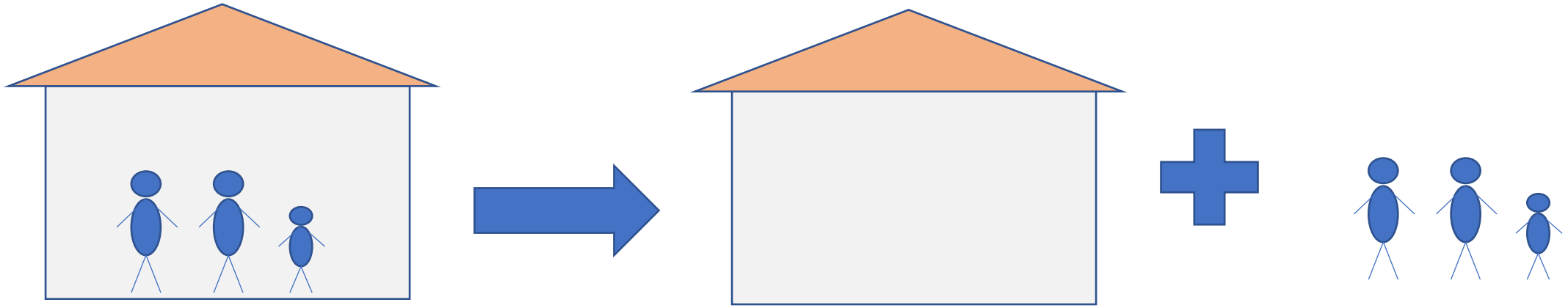
Human Centric Design

Preventilation

We are smart enough!

What Makes You, YOU? …. A Lot!!

We Should Separate Building and Human Needs



Today's "Building Centric" ventilation promotes building energy above human needs, and is making us stupid, sick and tired

<u>ASHRAE 62.2-2019</u>
7.5cfm x (1+Bed) + 0.03cfm/ft^2 x Area
- EPA Indoor airPlus
- PHIUS
- USGBC

<u>PHI</u>
0.3 ACH or 18cfm/person

Energy efficient building

-Don't ignore building design impact on health, comfort and productivity

- FLLW "organic" architecture principals (VOC free material construction)

"Human Centric" smart ventilation adjusts with occupancy and occupant activities

- 800ppm CO_2 standard
- Increased productivity
- Fewer sick days
- Reduced IAQ & comfort dissatisfaction
- More $$$$ than energy$

Human Centric IAQ & Comfort

Human Centric IAQ & Comfort requires:

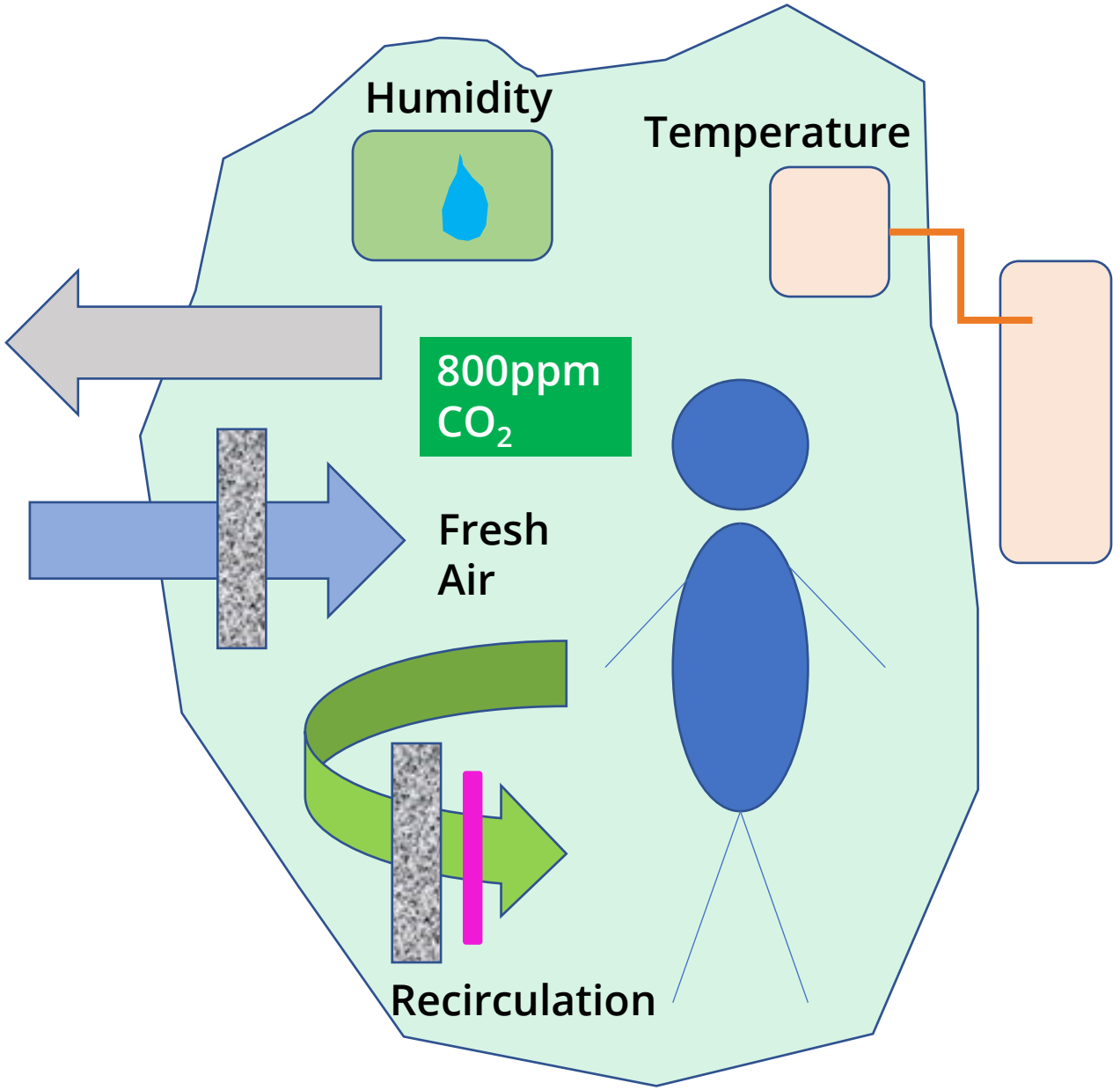
- Fresh, filtered air
- Recirculated, filtered and sanitized air
- Humidity control
- Temperature control

Controlled by occupant preferences!!

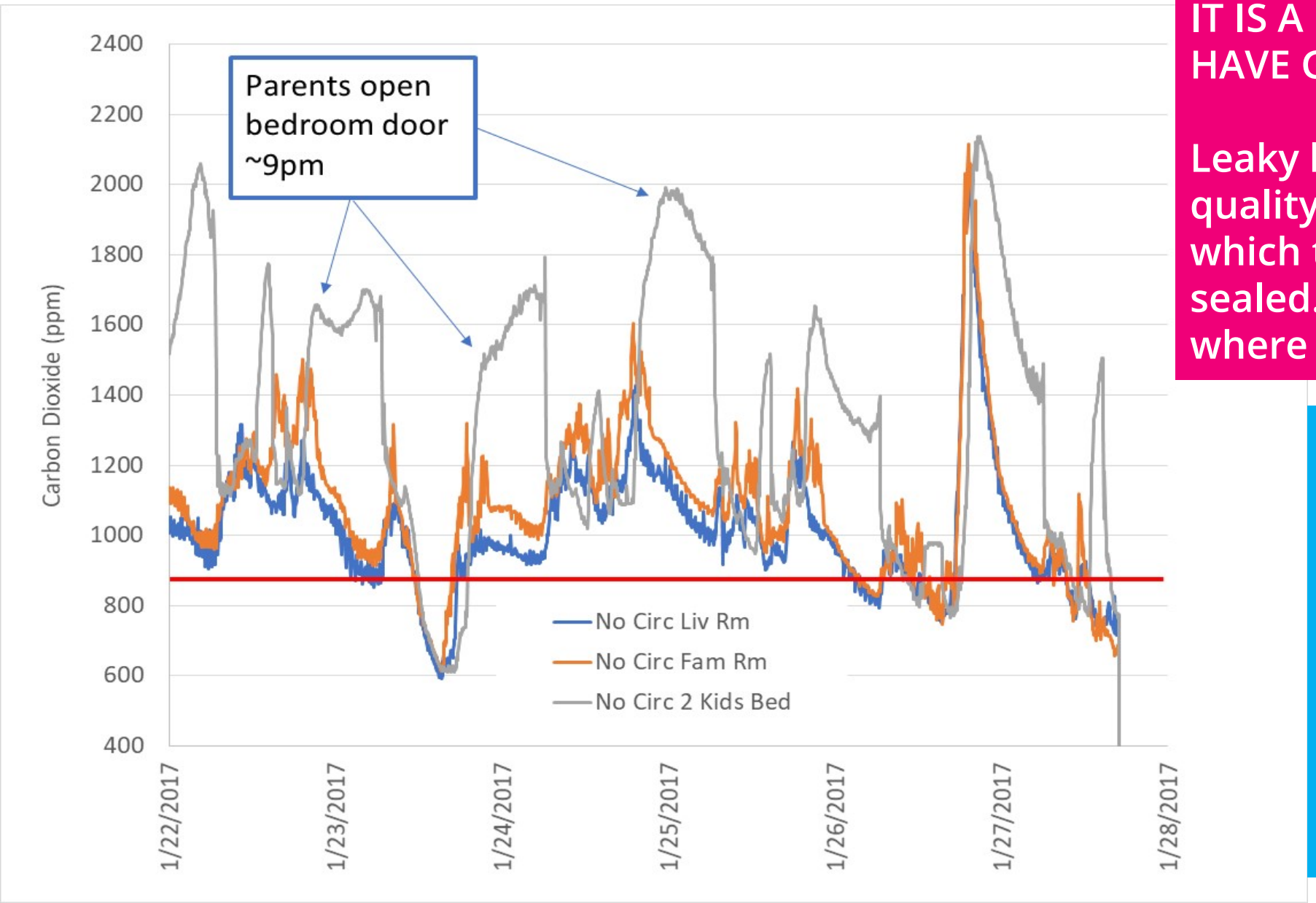
Human centric controlled indoor environments follow a person wherever they go, and into every building they enter.

All homes with human centric design need 1 ton of heating/cooling capacity!
- And 2 tons are more efficient than 1 ton!!

Occupants regularly change indoor temperature regardless of outdoor weather!!



1800ft² Home – "Leaky Home" Myth



IT IS A MYTH THAT LEAKY HOMES HAVE GOOD AIR QUALITY

Leaky homes often have poor air quality, especially in bedrooms which tend to be well-sealed….where people live and where leaks exist are different

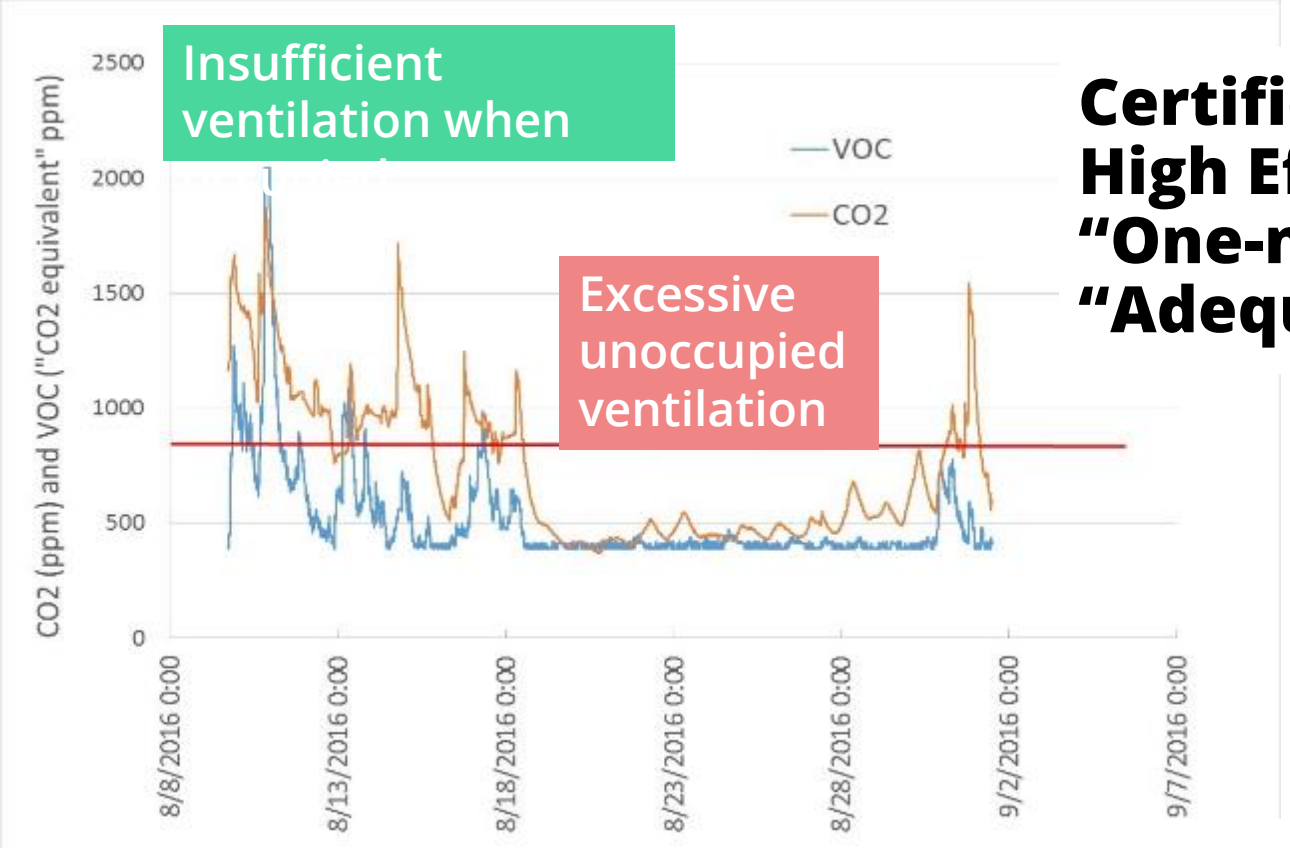
- 2 Adults & 3 Kids
- 3 Bedrooms
- 1950s construction
- Radiant Heating

- IAQ control more complex than comfort control

Today's Ventilation Standards: Too Little, Too Much, But Never Enough

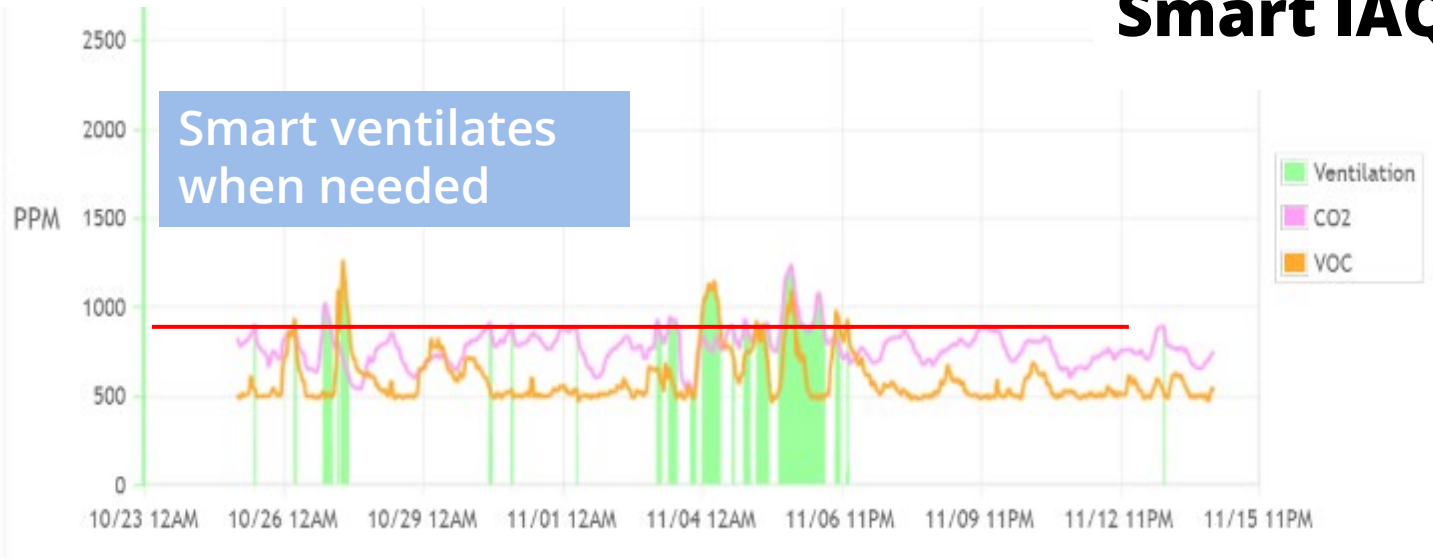
- Small homes and apartments are underventilated
  - 1000ft^2, 2 bedroom apartment with 4 occupants
  - ASHRAE 62.2-2013-2019 = 52.5cfm (13cfm/person)
- Large homes with few occupants are overventilated
  - 4000ft^2, 4 bedroom home with 2 occupants
  - ASHRAE 62.2-2013-2019 = 158cfm (79cfm/person)
  - But, underventilated in occupied areas!!

- Ventilation should emphasize people, not buildings
  - Why no difference between sleeping and exercising occupants?
  - Why no difference between all electric and gas (cooking) homes?
  - Why no difference when occupied versus unoccupied?



Certified Passive House
High Efficiency HRV
"One-n-Done", No Recirculation
"Adequate" IAQ ventilation

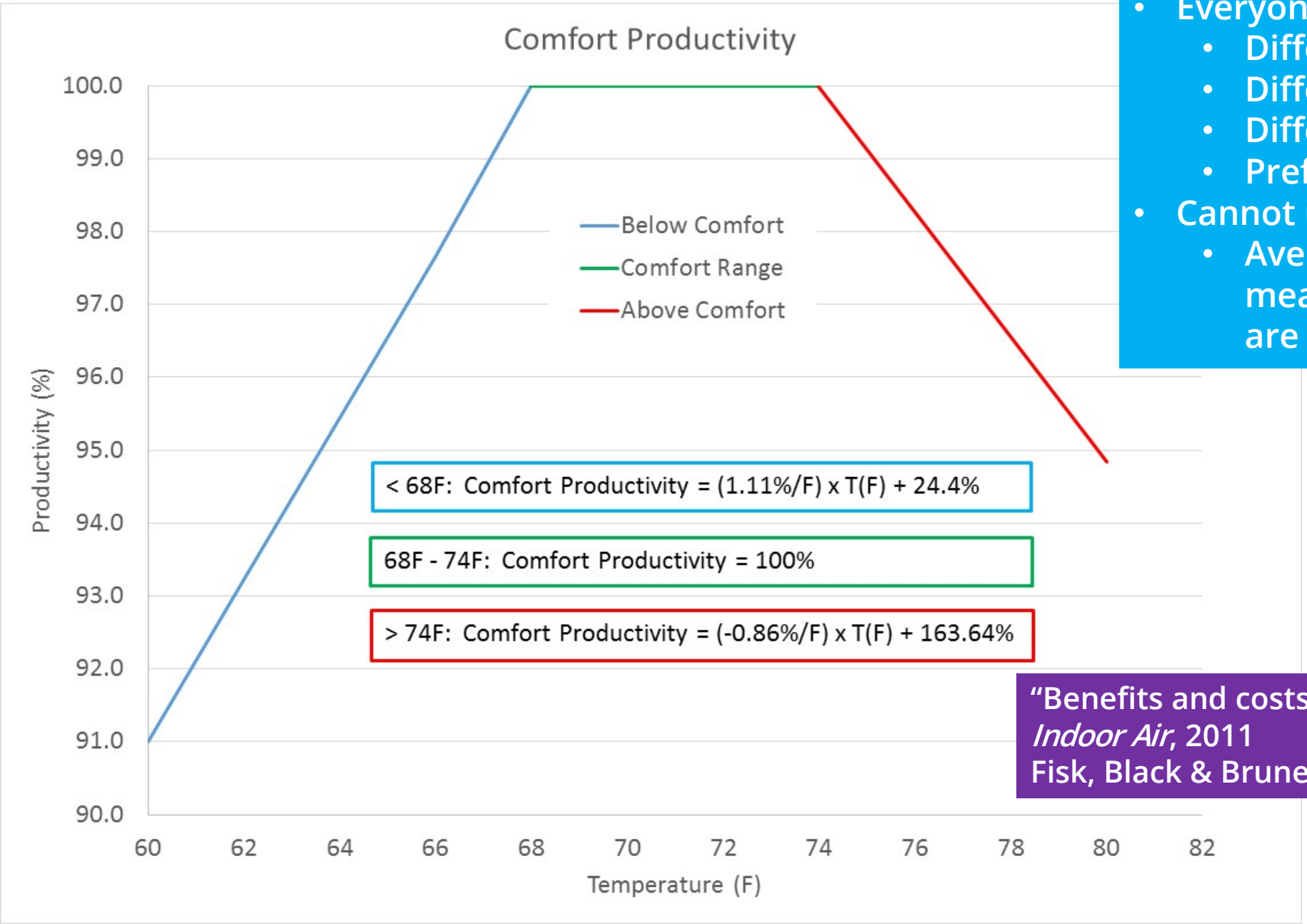
"Adequate" Ventilation vs Smart Ventilation



Smart IAQ ventilation

- Human centric ventilation delivers air when and where needed
- When fresh air not needed, smart ventilation recirculates indoor air through filters and air purification (UV)
- Recirculation uses fresh air "stored" in unoccupied rooms

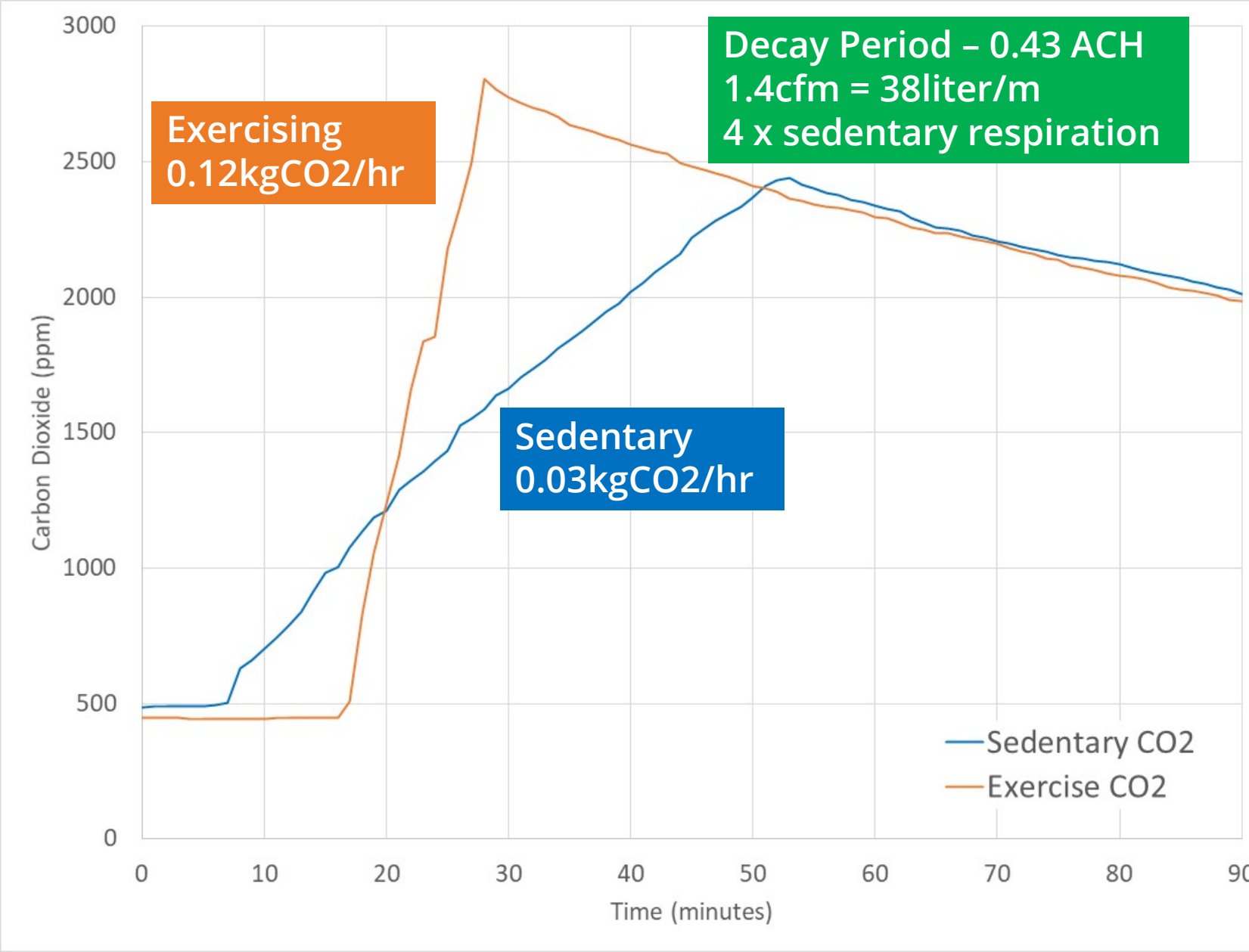
Comfort & Productivity



- Every % drop in comfort is expensive!!
  - $50k/year = $500 loss for 1% drop
- Everyone's comfort is different
  - Different metabolism
  - Different activity levels
  - Different clothing
  - Preferences change every day!
- Cannot use average
  - Average comfort temperature means half are too cold and half are too warm

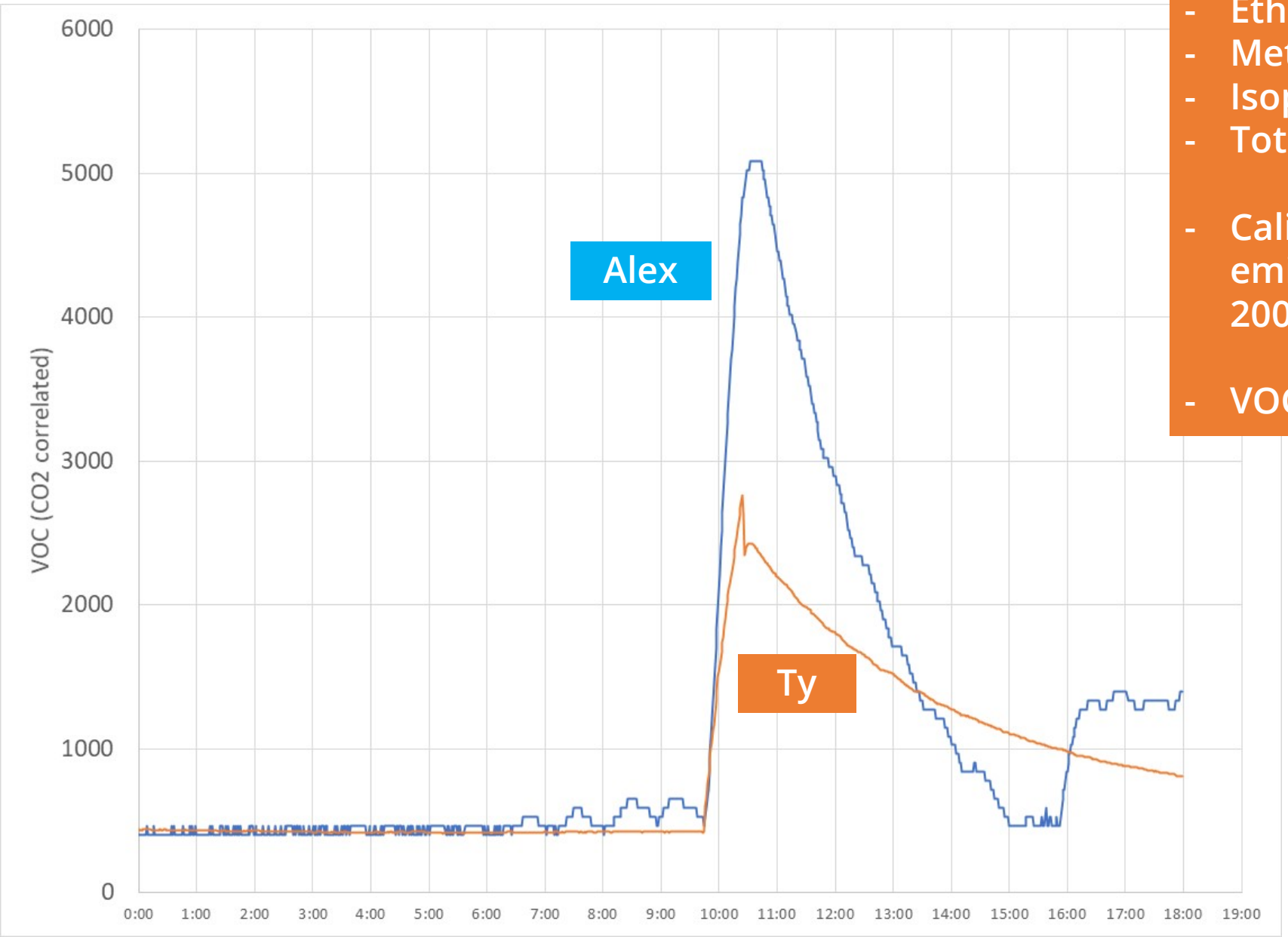
"Benefits and costs of improved IEQ in U.S. offices"
Indoor Air, 2011
Fisk, Black & Bruner

Ty Self-Pollutes for Science



Increased metabolism (exercising) requires 3 to 4 times fresh air flow per person as sedentary

VOCs – Ty versus Alex



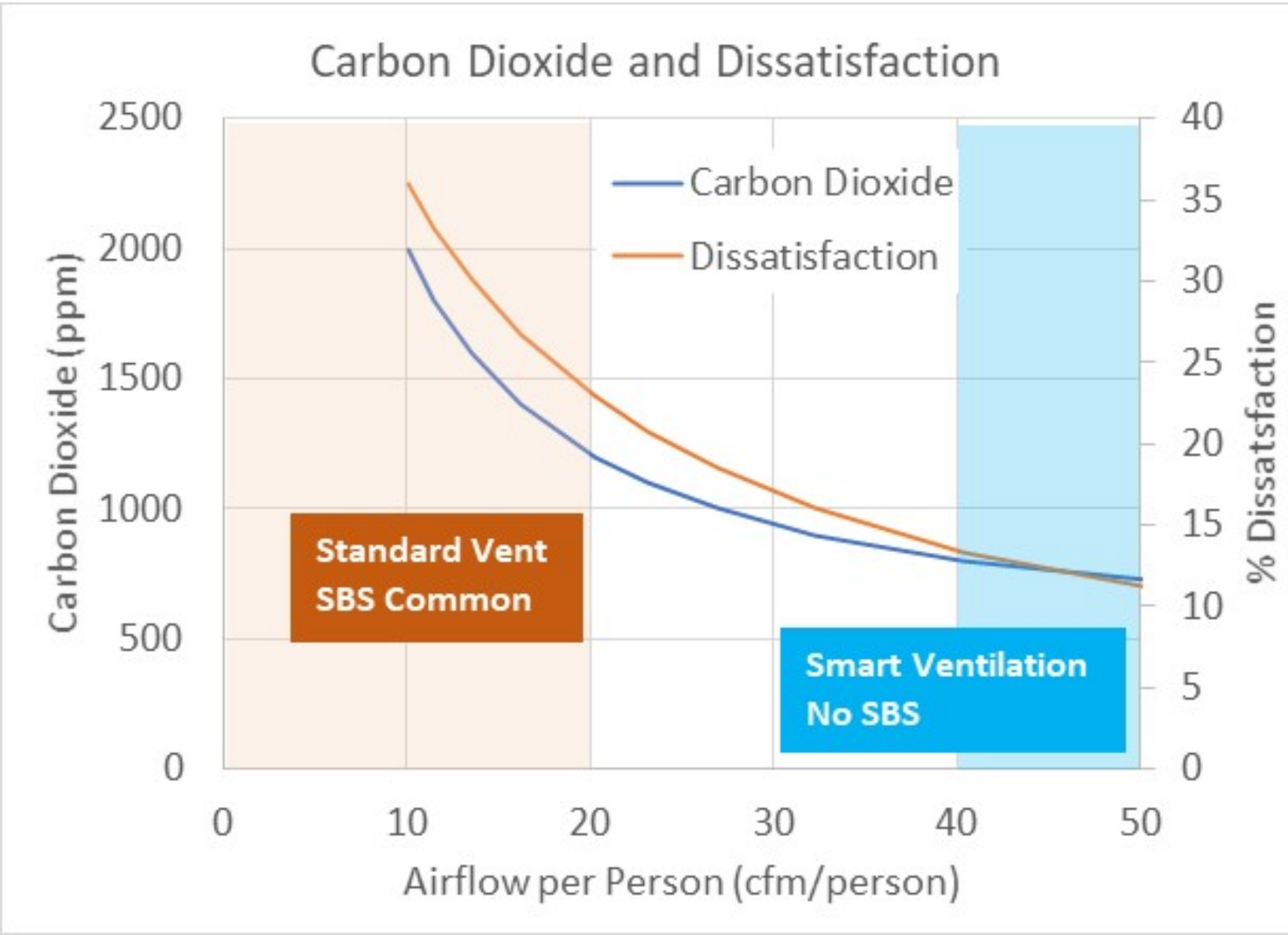
Human VOC output consist mostly of

- Isoprene
- Acetone
- Ethanol
- Methanol
- Isopropanol
- Total VOC ~2400µg/hour

- California allowed formaldehyde emissions from walls/floor/ceiling for 2000sqft house ~2400µg/hour

- VOCs additive to human output

800ppm CO2 for Health & Productivity

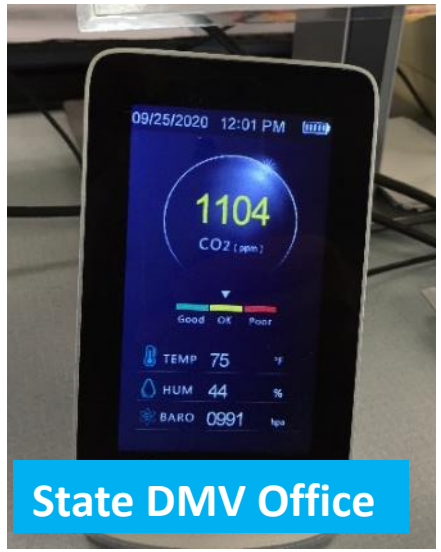


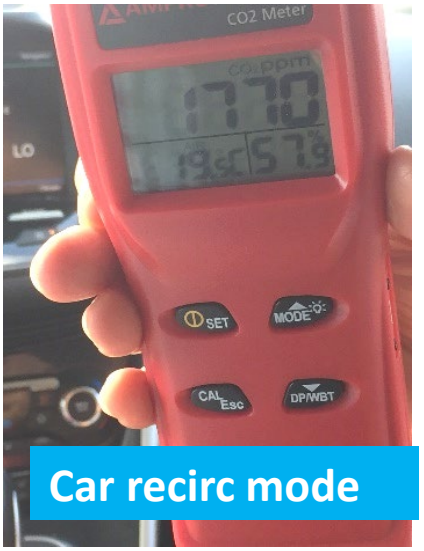
- CO2 and IAQ Dissatisfaction are related
- <20cfm per person
  - >20-25% dissatisfaction
  - Sleep degraded
  - SBS common
- 40cfm per person
  - 10-12% IAQ dissatisfaction
  - 5cents/hour (40% reduction) sick day savings
  - Up to 50cents/hour (10%) productivity increase

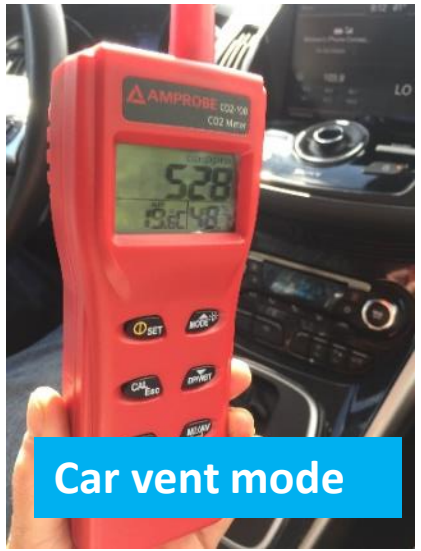
Poor IAQ Everywhere! 34,000 People, 215 Buildings

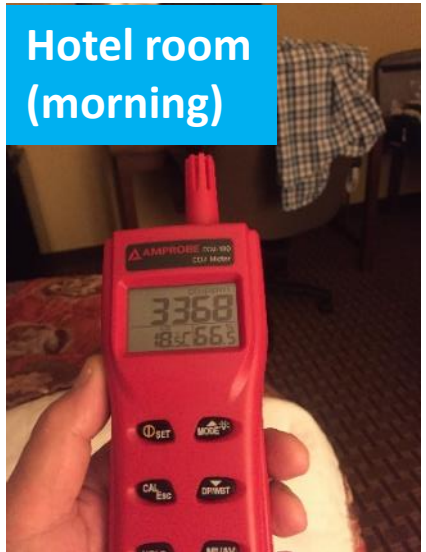
80% Buildings have > 20% IAQ & Comfort Dissatisfaction

"Air Quality and Thermal Comfort in Office Buildings: Results of a Large Indoor Environmental Quality Survey", Proceedings of Healthy Buildings 2006, Lisbon,Vol. III, 393-397, Univ of California Berkeley Center for the Build Environment









Carbon Dioxide - Gateway to Safe Air

Remember 1 thing.....
800ppm (parts per million)

- ~$200 for one
- Check your home, businesses, school rooms, and all spaces

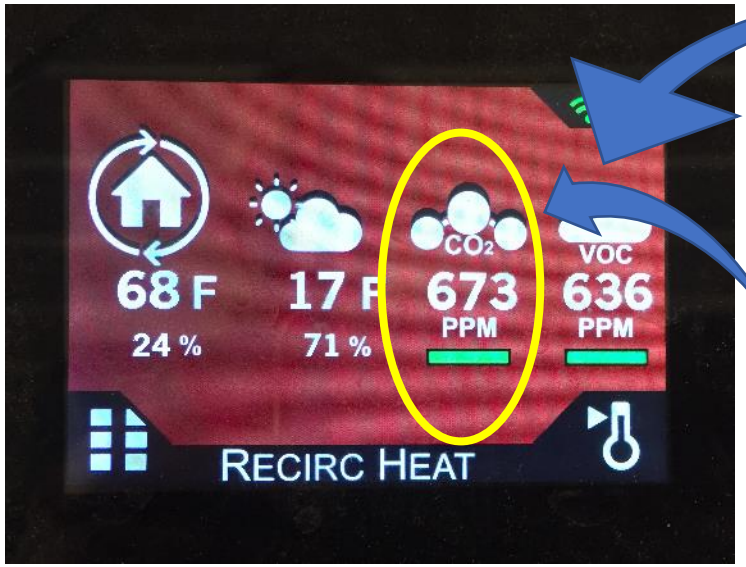
"Badly constructed houses do for the healthy what badly constructed hospitals do for the sick. Once insure that the air in a house is stagnant, and sickness is certain to follow."

Florence Nightingale, 1859
Notes on Nursing

CO2 (ppm)	Airflow/person (cfm)	
400 (ambient)	infinite	
500	160	
600	80	
800	40	
1200	20	ASHRAE
2000	10	Range
3600	5	

Activity	Met
Sleeping	0.7
Seated, quiet	1.0
Standing, relaxed	1.2
Walking about	1.7
Cooking	1.8
House Cleaning	2.0-3.4
Exercise	3.0-4.0
Heavy exertion	7.0-9.0

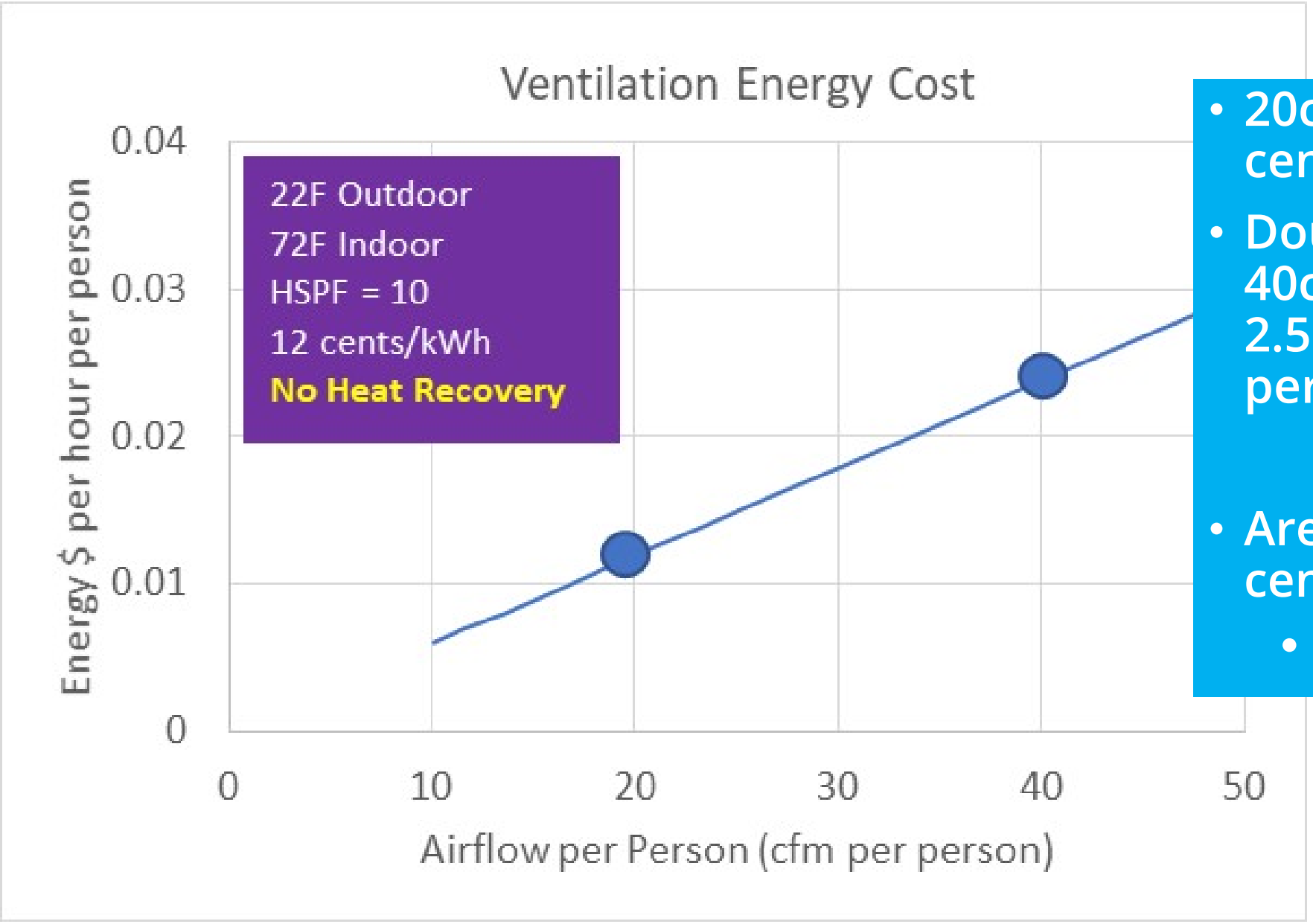
Every Space Should Measure CO_2 (VOCs, Part, & ?)



Automated fresh air integrated into every ventilation system

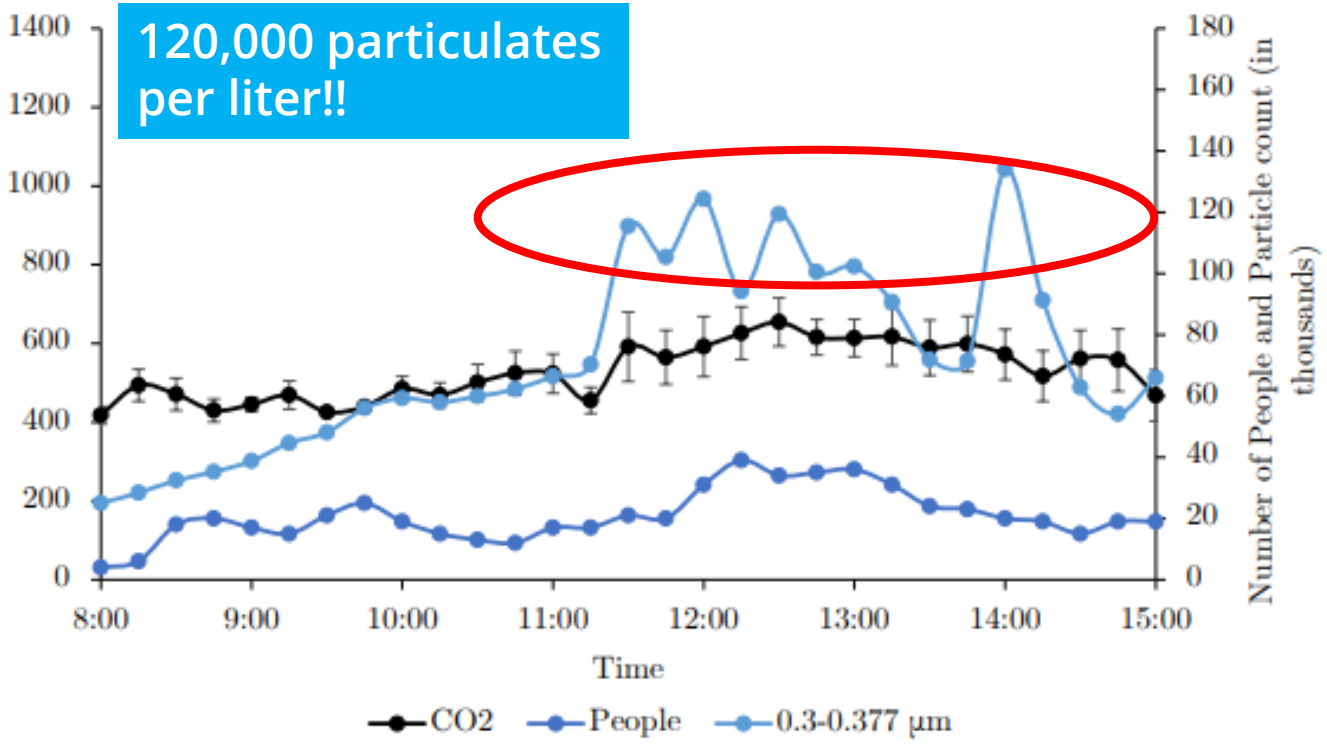
Wireless
Battery-free
-CO_2
-Temperature
-Humidity

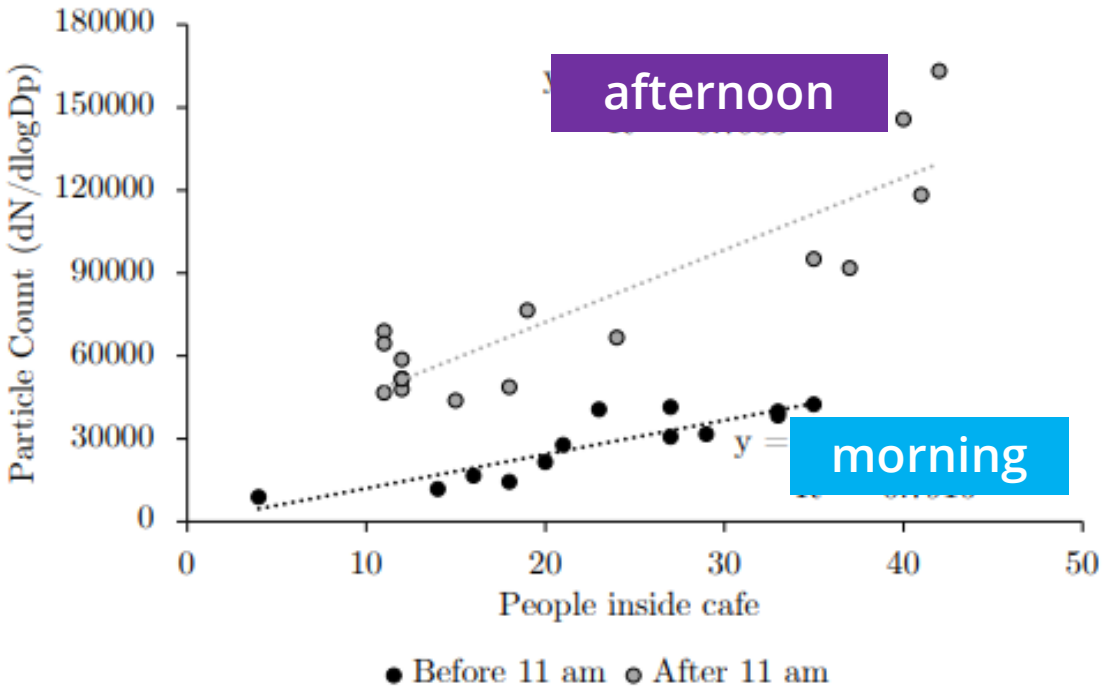
20cfm to 40cfm/person $ Cost – without energy recovery



- 20cfm/person 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!

Submicron (0.3-0.374μ) Particulates & People





Most indoor particulates are generated indoors! ~5000 part/liter outdoor ambient vs >100,000 part/liter indoors!

Data from Urbana Illinois café with excellent fresh air flow (CO_2 < 800ppm) and filtration (MERV12 filter)

University of Illinois Environmental Engineering study; August-September 2021 (Verma & Nguyen research

Submicron particulates (<0.6μ) correlate with occupancy and occupant activity … large particulates (>1μ) do not

37,000 particulates 0.3μ diameter fit in one 10μ particulate!

High MERV filters work!

Preventilation – where we are going

Alexa, what's my IAQ?
Alexa, increase room temperature 2 degrees

Alexa time stamp log

332	09/10/2021, 08:1	blood pressure 114 over 78 and pulse 64
333	09/10/2021, 08:1	second blood pressure 109 over 72 and pulse 59
334	09/10/2021, 08:1	3rd blood pressure 105 over 69 and pulse 61
335	09/11/2021, 08:0	weight 180.2 lbs
336	09/11/2021, 08:0	pedaled 30 minutes for 106 calories
337	09/11/2021, 09:5	blood pressure 120 over 68 and pulse 61
338	09/12/2021, 02:1	weight 183.2 lbs
339	09/12/2021, 02:1	had lunch N2 beers at Riggs brewery yesterday
340	09/12/2021, 02:1	blood pressure 116 over 70 and pulse 59
341	09/13/2021, 07:5	weight 180.4 lbs
342	09/13/2021, 07:5	mowed lawn yesterday
343	09/13/2021, 07:5	solved rubiks 3 minutes and 15 seconds messed
344	09/13/2021, 08:0	pedaled 31 minutes for 109 calories

There are reasons

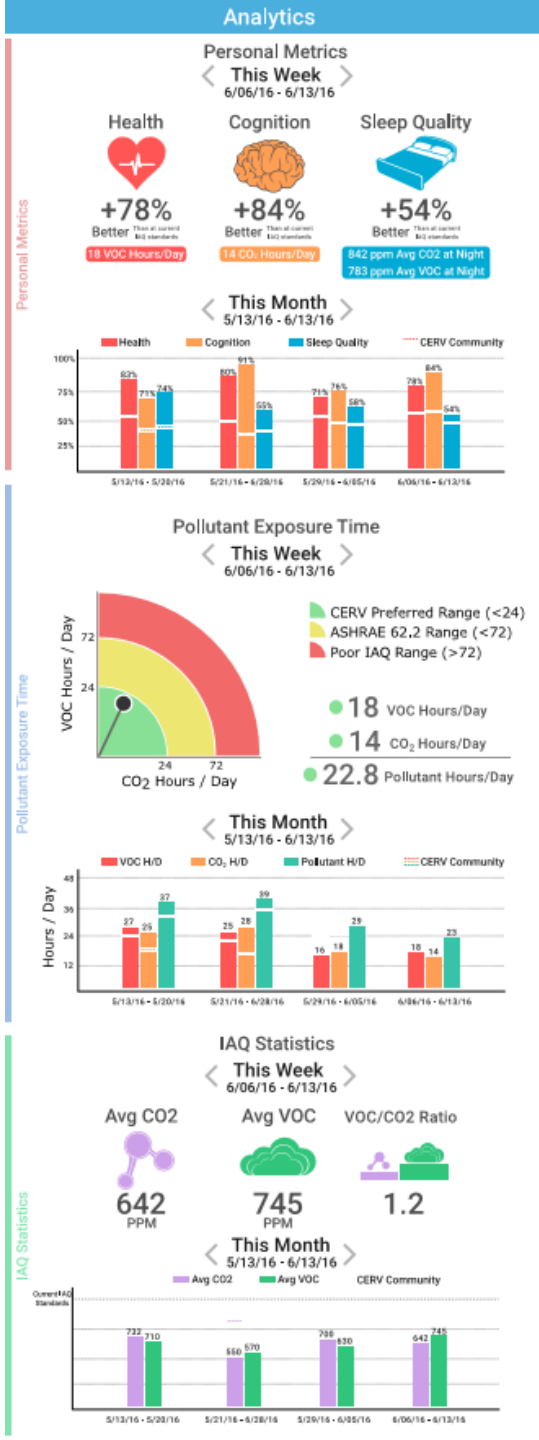
- why we don't feel well
- why we don't sleep
- why we can't concentrate
- why we get sick.

Some reasons are beyond our control, but many are within our control.

Today's technologies can help us figure it out.

My data can help me, and help you.

Our data can help all of us, individually and collectively.



Human Centric Conclusions

- Managing IAQ and comfort are important for
  - Health
  - Well-being
  - Productivity
- Today's ventilation standards are building centric
  - Excess wasted ventilation
  - Occupied spaces unventilated with poor IAQ
- Human centric IAQ and Comfort
  - More energy efficient and better IAQ
  - Use CO_2 (800ppm) as primary standard; VOCs & Particulate important
  - Recirculation is essential! Utilizes fresh air in unoccupied areas, controls particulates
  - Value of reduced sick days, improved IAQ satisfaction, and increased productivity much more valuable than energy cost to improve IAQ and comfort

THANK YOU!

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Urbana IL

Background info

Fresh Air is Wasted with Today's Ventilation Systems

- Human centric ventilation automatically maintains 800ppm CO2 (40cfm/person) = 70cfm
  - 2.6 people, 16 hours/day average US home occupancy
    - 200cfm smart ventilation airflow
      - 35% fresh air vent time (8 hours)
      - 65% filtered recirculated air (16 hours)
      - Recirculation filters house particulates and distributes fresh air from unoccupied rooms

- ASHRAE 62.2-2019 = 30cfm (people) + 60cfm (building) = 90cfm constant, one-and-done
  - Average US home is 2000sqft with 3 bedrooms and 2.6 occupants
    - 25% wasted ventilation compared to Human centric ventilation
    - No filtered recirculation air requirement
    - Even with excess ventilation, occupied rooms polluted!
      - 90cfm divided among 6rooms = 15cfm/room; unhealthy for a single person

It's getting worse:

- Average new US home is 2700sqft with 4 bedrooms and 2.6 occupants = 119cfm
  - 70% wasted fresh air
  - And occupied rooms are still polluted

With Human centric ventilation, every hour you spend outside reduces your house ventilation needs by 6%!

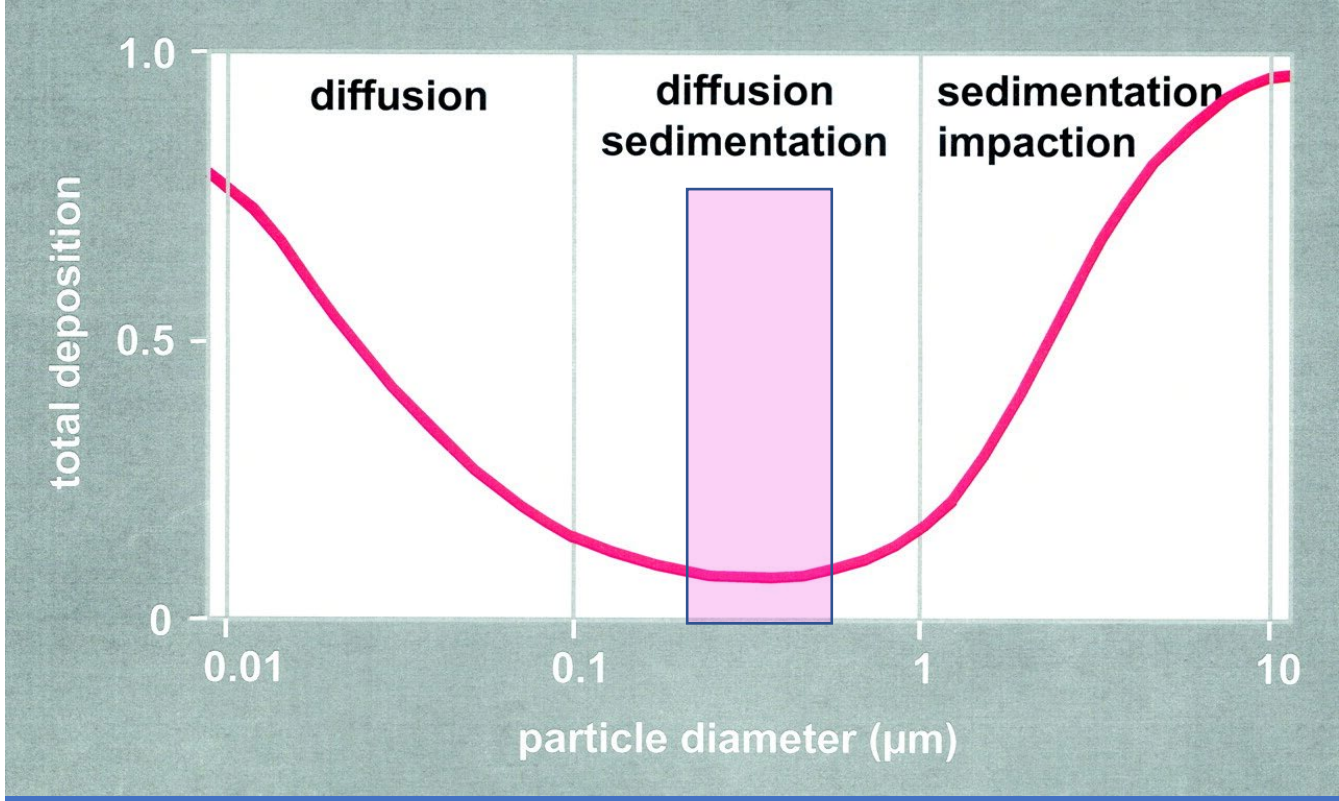
Airborne Pandemics

Respiratory (breathing) produces 10 aerosol droplets per cc in “high shedders” in clean air (80,000 per minute for 8 liter/minute breathing)

We are immersed in a sea of submicron particulates in the indoor environment, inhaling millions of 0.3µ particulates per breath (eg, 100,000part/cc = 800,000,000 inhaled per minute of 0.3µ particulates!)

Alveoli (air sacs) are considered primary virus infection multiplication regions. Alveoli ~250µ diameter

If I was a 0.1µ virion, I would try to hitch a ride on a 0.3µ particulate because most 0.3µ particulates penetrate deeply into the alveoli region without deposition



Total deposition of unit-density spheres in the human respiratory tract inhaled orally at rest.

Proc Am Thorac Soc,
https://www.atsjournals.org/doi/abs/10.1513/pats.200409-046TA

Published in: Joachim Heyder; *Proc Am Thorac Soc* 2004 1315-320.

- ~300,000,000 alveoli (air sacs) in human lungs
- Type I & II alveoli cells infected with SARS-CoV-2 produce ~1000 virions over 10hour eclipse period
- 10^{11} (~300 cells per alveoli) Type I & II cells

eLife Science Forum 2020; “SARS-CoV-2 by the Numbers”

HVAC Cost – Commercial Institutional

UIUC Mechanical Engineering Building Addition and Renovation

Urbana/Champaign, IL

GSF: 100,466

33,000ft² new building and 65,000ft² renovation project currently under construction at the University of Illinois

New HVAC mechanicals = $55 per ft²

Renovation HVAC mechanicals = $49 per ft²

Building IAQ follows ASHRAE 62.1

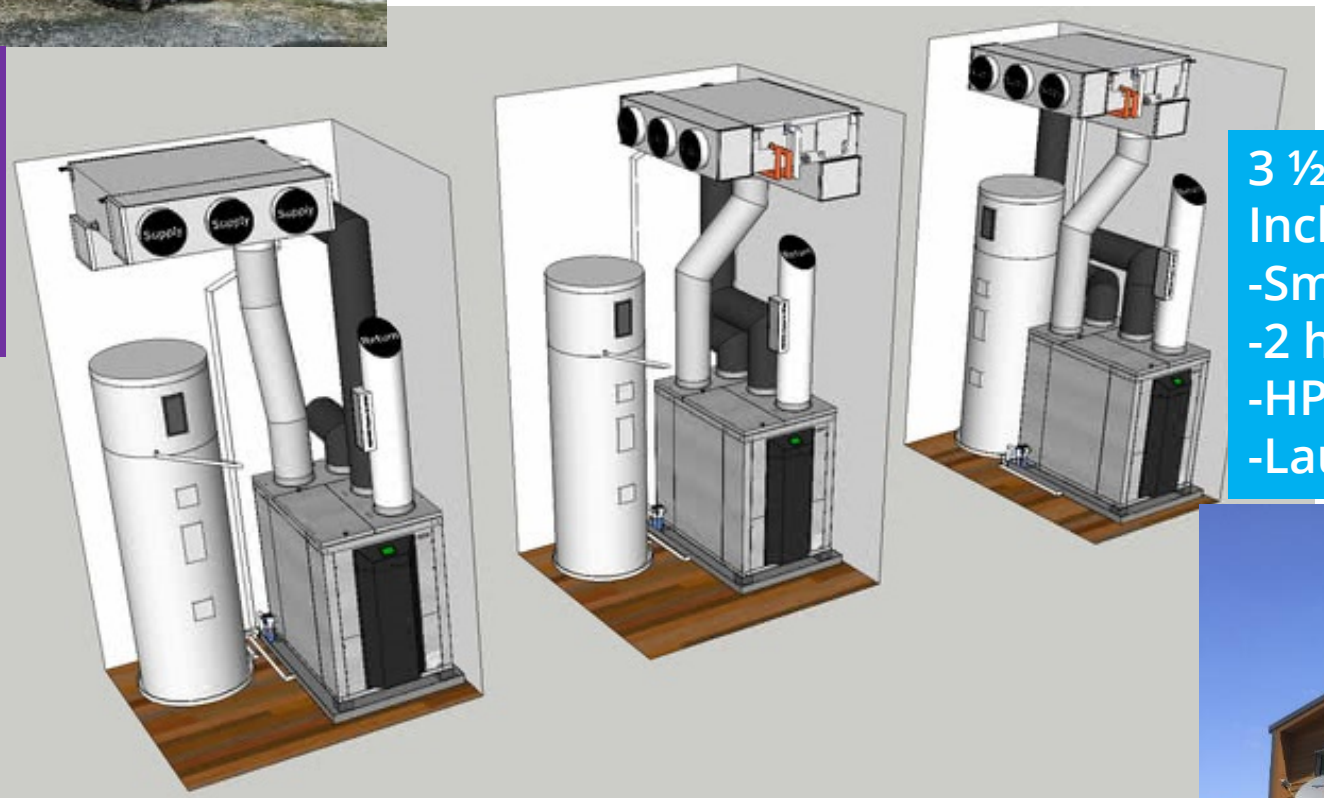
Residential Smart Vent & Heat/Cool/Dehum & DHW

$10-15k for Smart Vent & 1 ton Ducted HP & HPWH

- $8 per sqft mechanicals

1200sqft manufactured

average 3,650kWh per occupant and 9kWh/sqft per year



3 ½’ x 10’ Sliding door closet
Includes:
-Smart vent
-2 head distributed minisplits
-HPWH
-Laundry

5’x6’ Walk in closet
Includes:
-Smart vent
-1 ton ducted minisplit
-HPWH
-Elec dist panel
-PV inverter & battery

Small footprint, cookie cutter mechanicals

The Perfect Office Concept Study & Demo

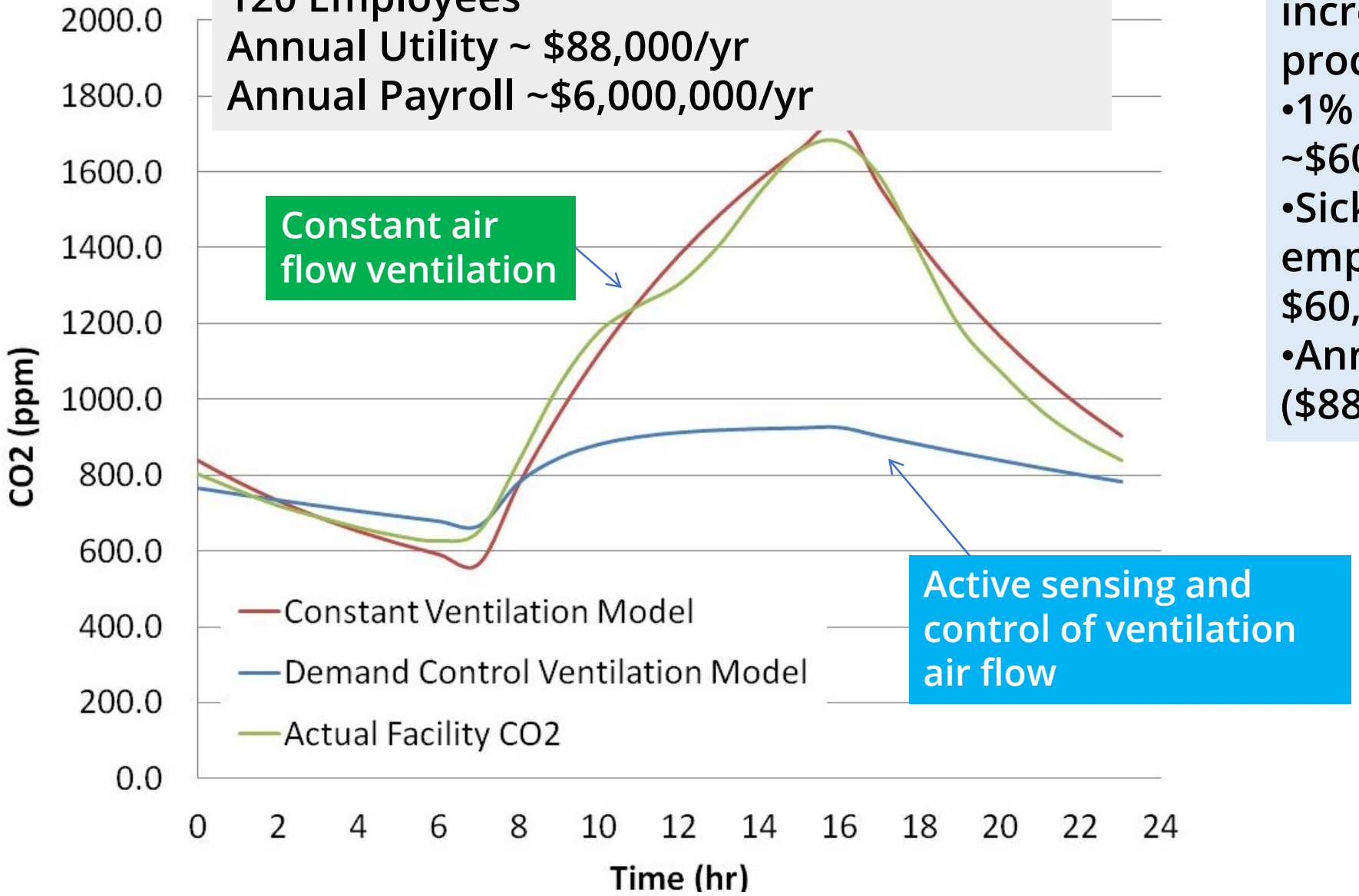
Personal IAQ and Comfort control

- Small ERV with CO_2 and VOC fresh air control
- Minisplit local comfort control
- 40% fewer sick days with improved IAQ!
- Maintenance savings with online control and diagnostics
- Capital cost savings vs central ducted HVAC

University of Illinois
UG Advising Office (Mech Engr)

Commercial Building

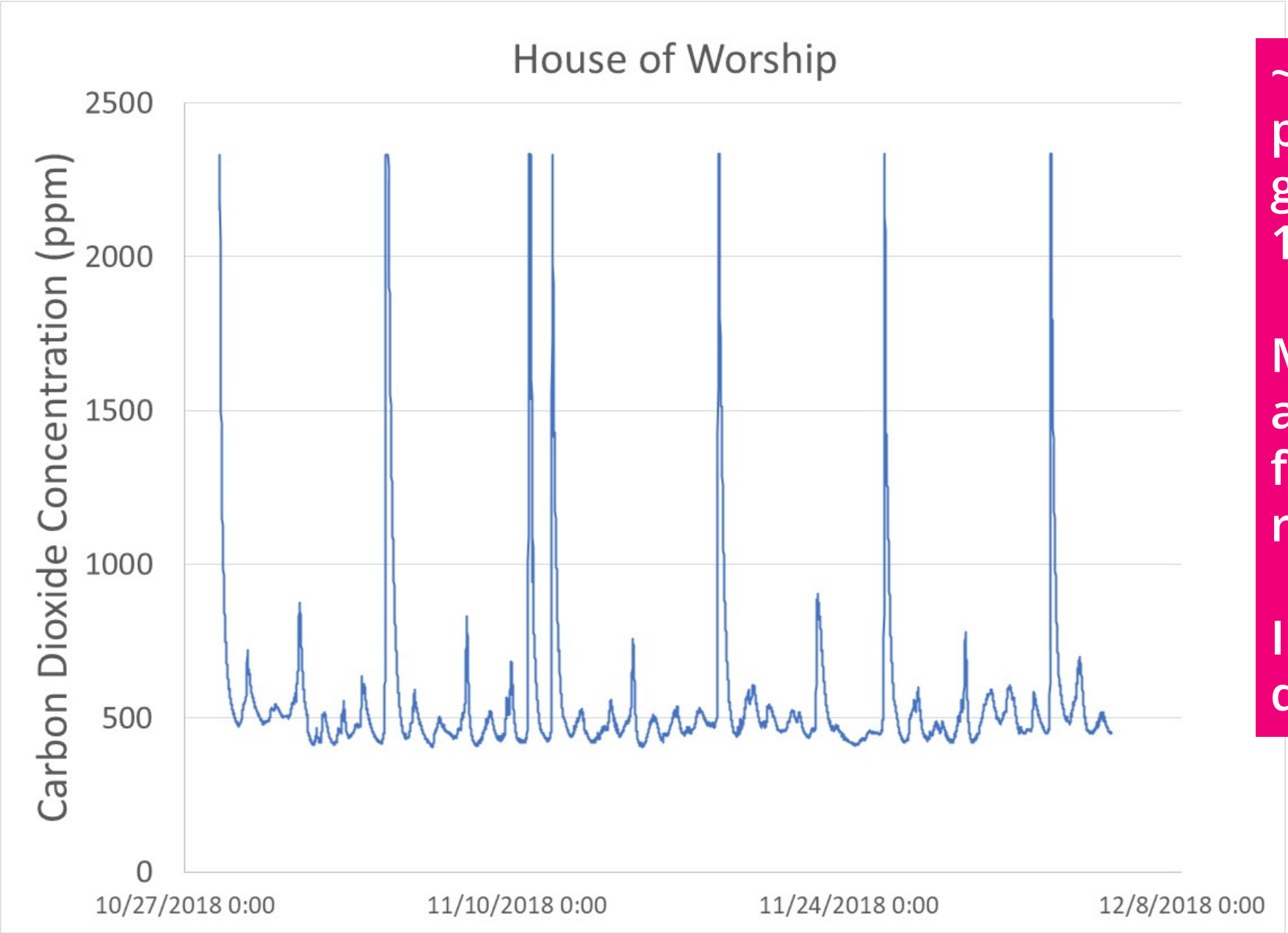
25,000 sqft facility with constant ventilation
120 Employees
Annual Utility ~ $88,000/yr
Annual Payroll ~$6,000,000/yr



- Fresh air control would increase employee productivity by $750,000/year
- 1% drop in productivity ~$60,000 per year
- Sick day reduction ~1 day per employee at $500/day cost $60,000
- Annual utility cost ($88,000/yr) is unaffected!

Humans deserve improved ventilation, and employers are rewarded with healthier more productive people.

House of Worship



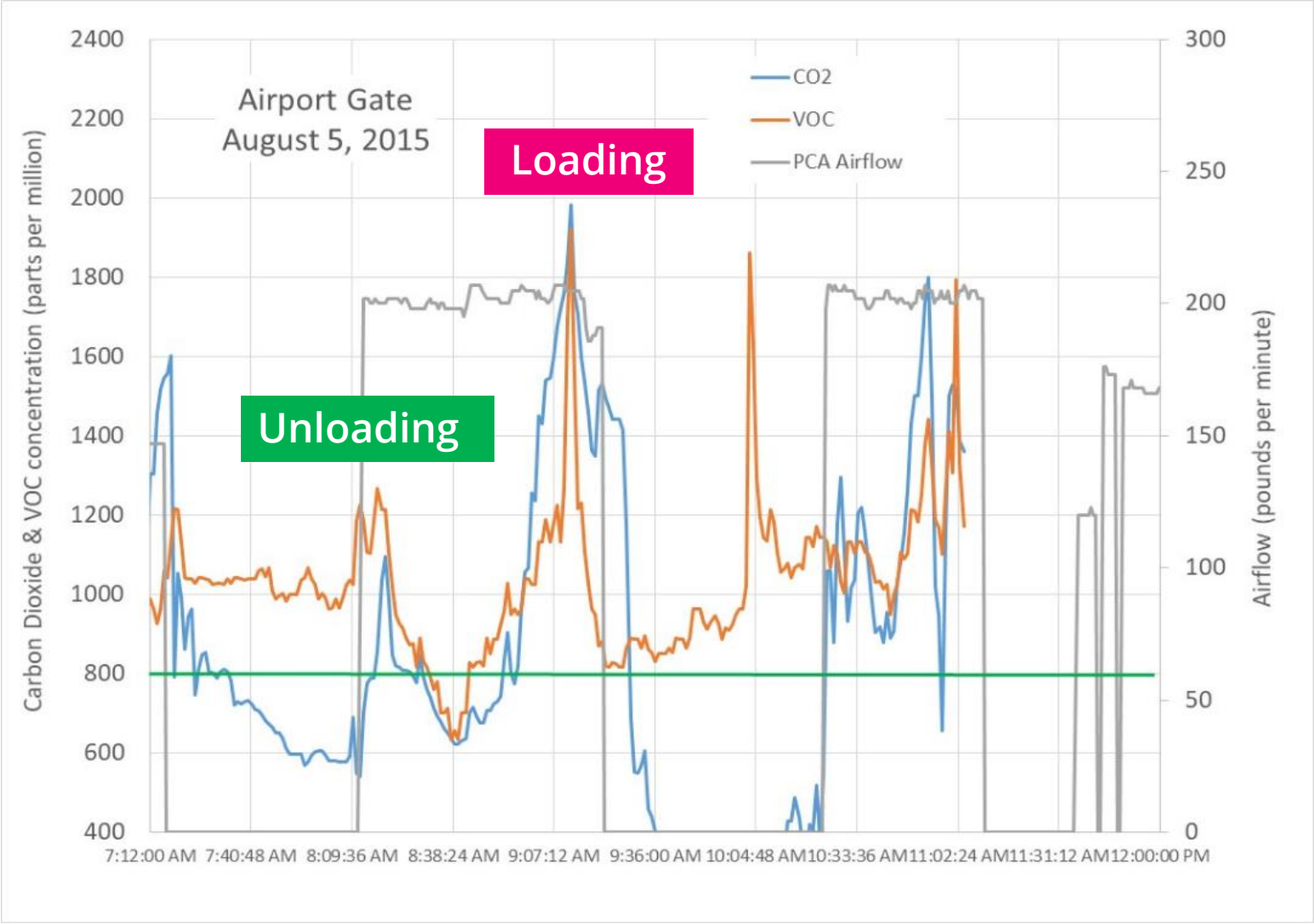
~2500ppm CO_2 indicates probability of infection greater than 50% in just 1 hour exposure

Must increase fresh air; add improved air filtration and sanitation recirculation for services

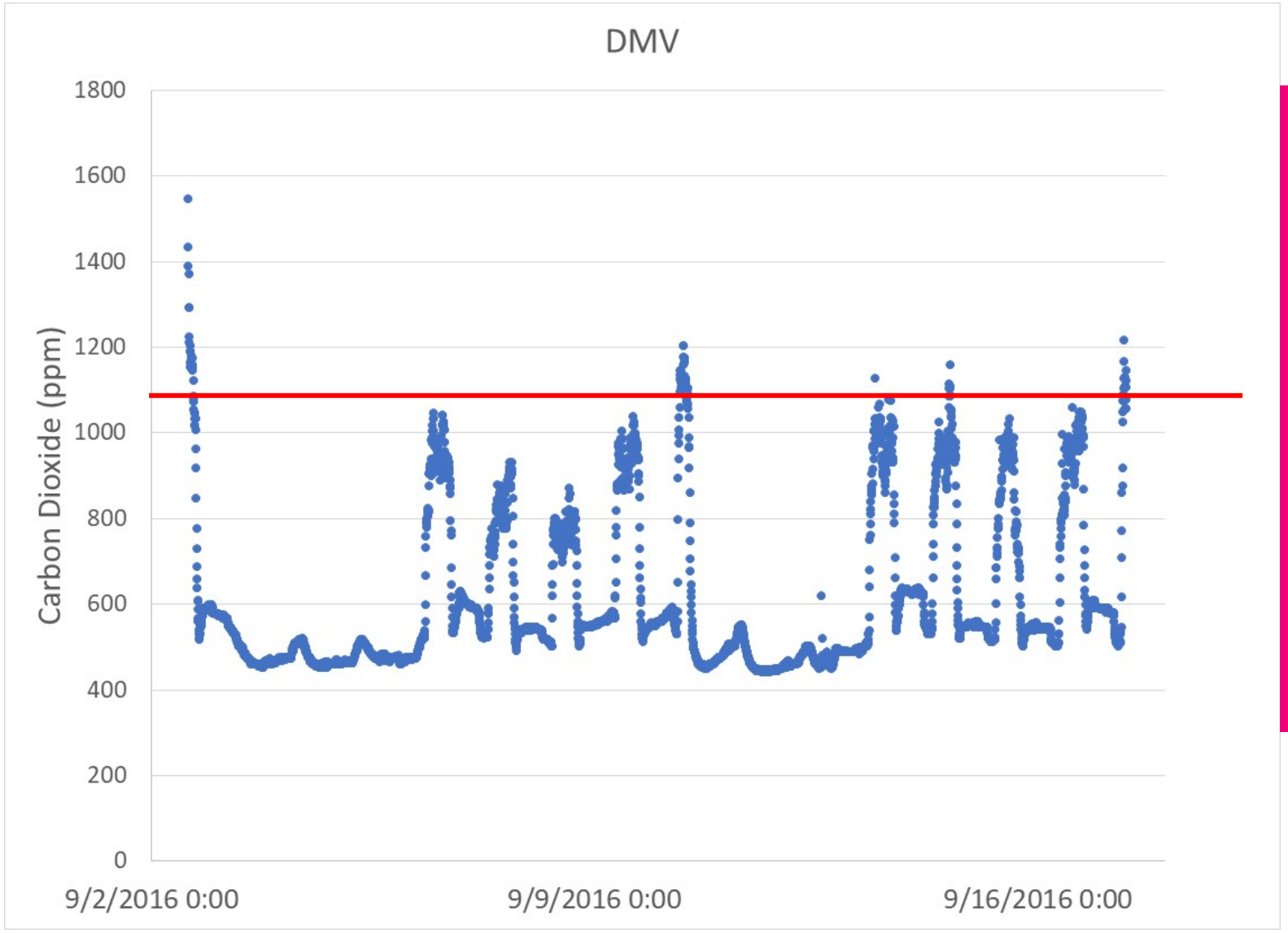
Increased attention during sermon, too?

Aircraft Boarding Bridge

Poor ventilation on aircraft boarding bridges -Loading periods = poor air quality

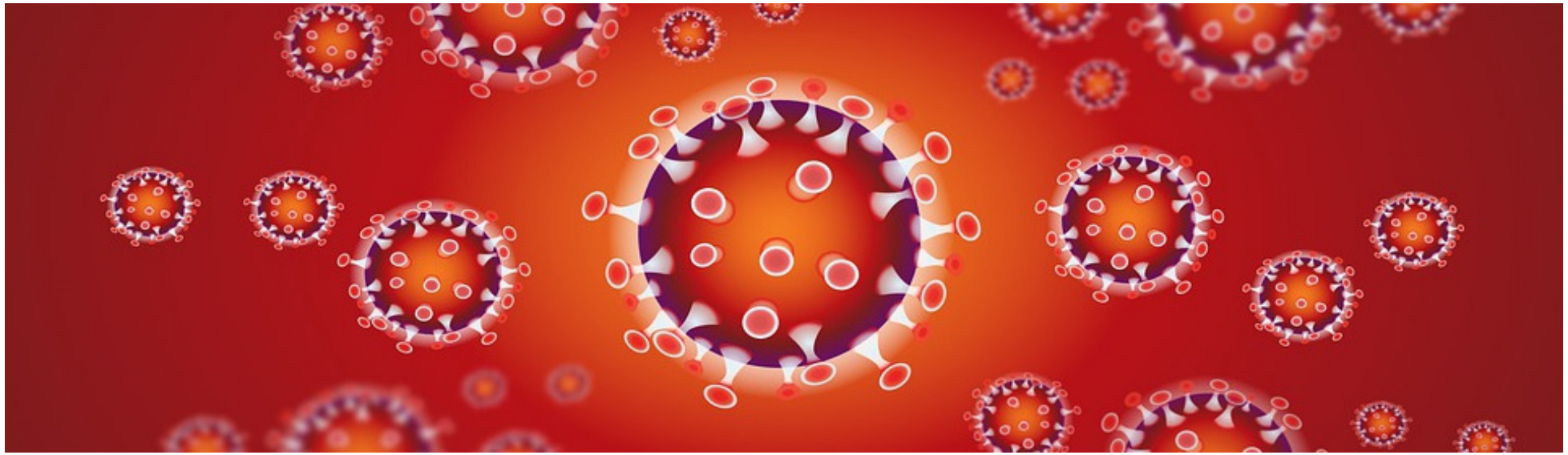


Offices - Illinois DMV – “Smart” Vent
aka – DCV – Demand Controlled Ventilation



- DMV locations have dynamic, high customer traffic
- Office set for “standard” (~1100ppm CO2 ~ 20cfm/person)
- How to convince people to increase when meeting “official” ventilation standards?

Covid Covid Covid!!!



We're sick-n-tired of hearing about Covid – and, we want out!
We've heard fuzzy, ill-defined, and ever changing "guidelines" too many times

We need specific guidelines..... Not the fuzzy CDC, WHO and ASHRAE recommendations ...
"increased fresh air", "improved filtration"... but how much?

Answer: 40cfm per person fresh air (800ppm CO_2), MERV 13 filtration & UVGI

Classroom Example - 20 Students, 1 Teacher Covid Safe Space (worksheet #1)

- Standard Conditions
  - 420 minute exposure
  - 1 Infectious
  - 1200ppm CO2
    - 20cfm/person
  - MERV 8 filters
    - 40cfm/person
  - No masks

		Immunity 0%	50%	75%
Standard Conditions	Infect Probability %	44	44	44
	Infection Multiplier	8.9	4.9	2.9
800ppm CO_2 40cfm/person	Infect Probability %	25	25	25
	Infection Multiplier	5.1	2.8	1.7
MERV 13 filter 40cfm/person	Infect Probability %	14	14	14
	Infection Multiplier	2.9	1.6	0.9
50% Mask Use 20% Mask Eff	Infect Probability %	12	12	12
	Infection Multiplier	2.4	1.3	0.8
80% Mask Use 80% Mask Eff	Infect Probability %	2	2	2
	Infection Multiplier	0.4	0.2	0.1