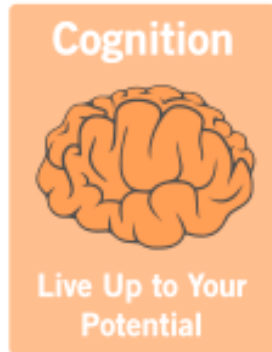


New IAQ Metrics



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



Mission



Research & Education

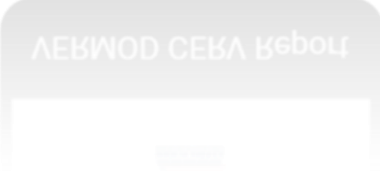


Ben Newell

Ty Newell

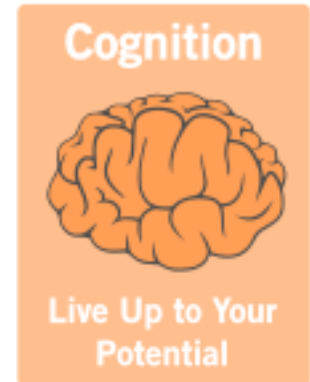
Alex Long

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?



New IAQ Metrics - Outline

- Conventional vs Smart Ventilation
- Energy cost versus cost of air quality
- New air quality metrics
 - Personal performance
 - Exposure
 - Basic statistics
- Field data
 - Comparing “leaky” homes to smart ventilated homes



ASHRAE President Visits Equinox House

“....a critical shift in thinking from a goal of indoor environments that are acceptable to the occupants to those that are **truly healthy and productive...**”

Bill Bahnfleth; 2013-2014 ASHRAE President



ASHRAE 62.2 is “Acceptable” ...but

- ASHRAE 62.2 is an agreed upon MINIMUM ventilation standard. It is NOT an indoor air quality standard
- Based on odor dissatisfaction threshold, not pollution
- Does not account for higher pollution events/occupancy changes
- Nominal 20cfm/person will result in >1,000ppm CO2 concentration
- New studies show venting to 62.2 will result in significant reduction in health, cognition, and sleep quality
- Smart ventilation surpasses 62.2 standards that gets us to truly and productive environments

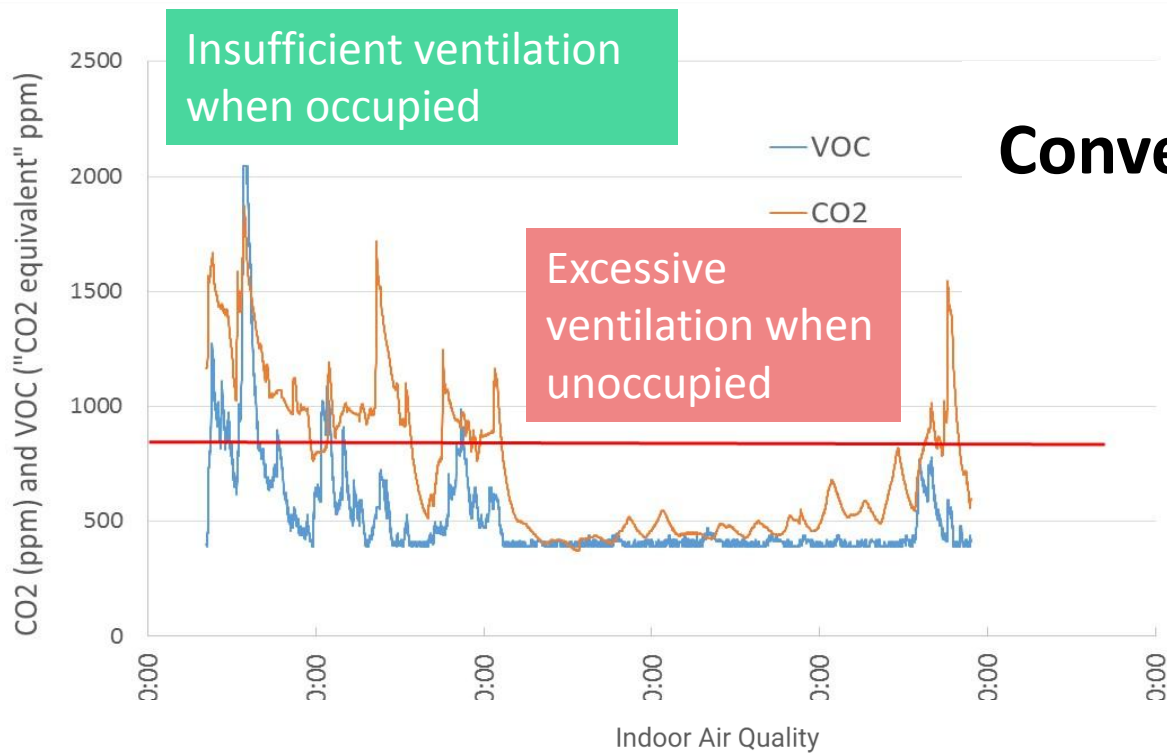
What is Smart Ventilation?

“Smart” ventilators

- Measure indoor air pollutants to ventilate when needed
- Sense when outdoor conditions are nicer than indoors, and maximize “free” conditioning
 - Recharges home with fresh air
- Maintain high quality air throughout the entire house
- Achieve **both** increased energy efficiency and air quality above levels achieved with conventional ventilation systems
- Monitor and archive indoor air quality conditions over time

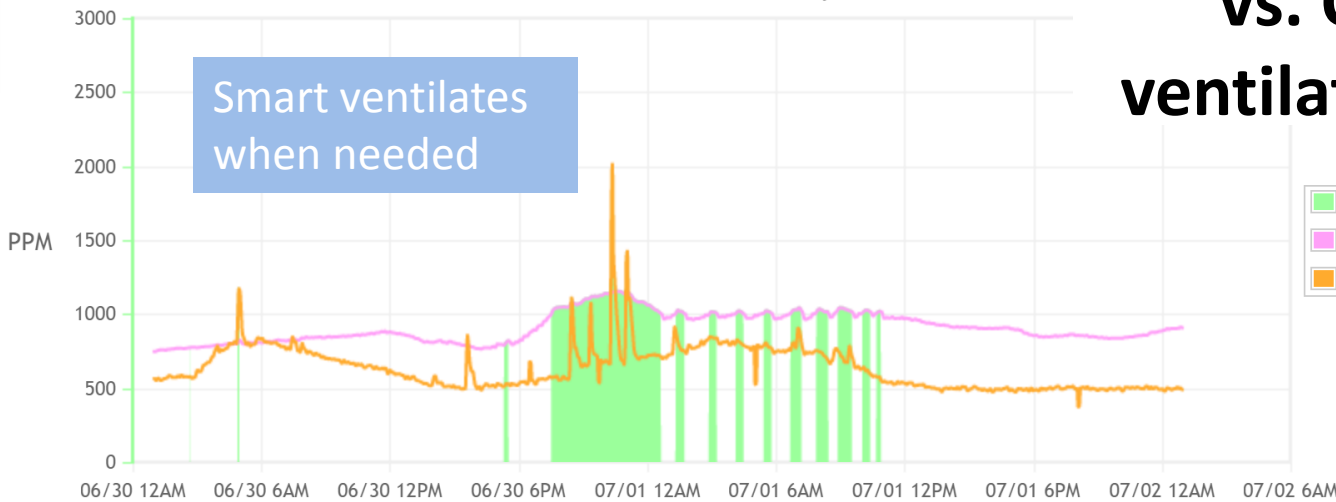
Smart ventilation systems allow us to define new sets of indoor air quality metrics providing us with information that quantifies our health and productivity

*It is evolving, with new research studies and technology



Conventional ventilator IAQ Trends

With today's sensors, automatic fresh air control improves our health and performance



vs. CERV smart ventilator IAQ Trends

Passive House & Smart Ventilation

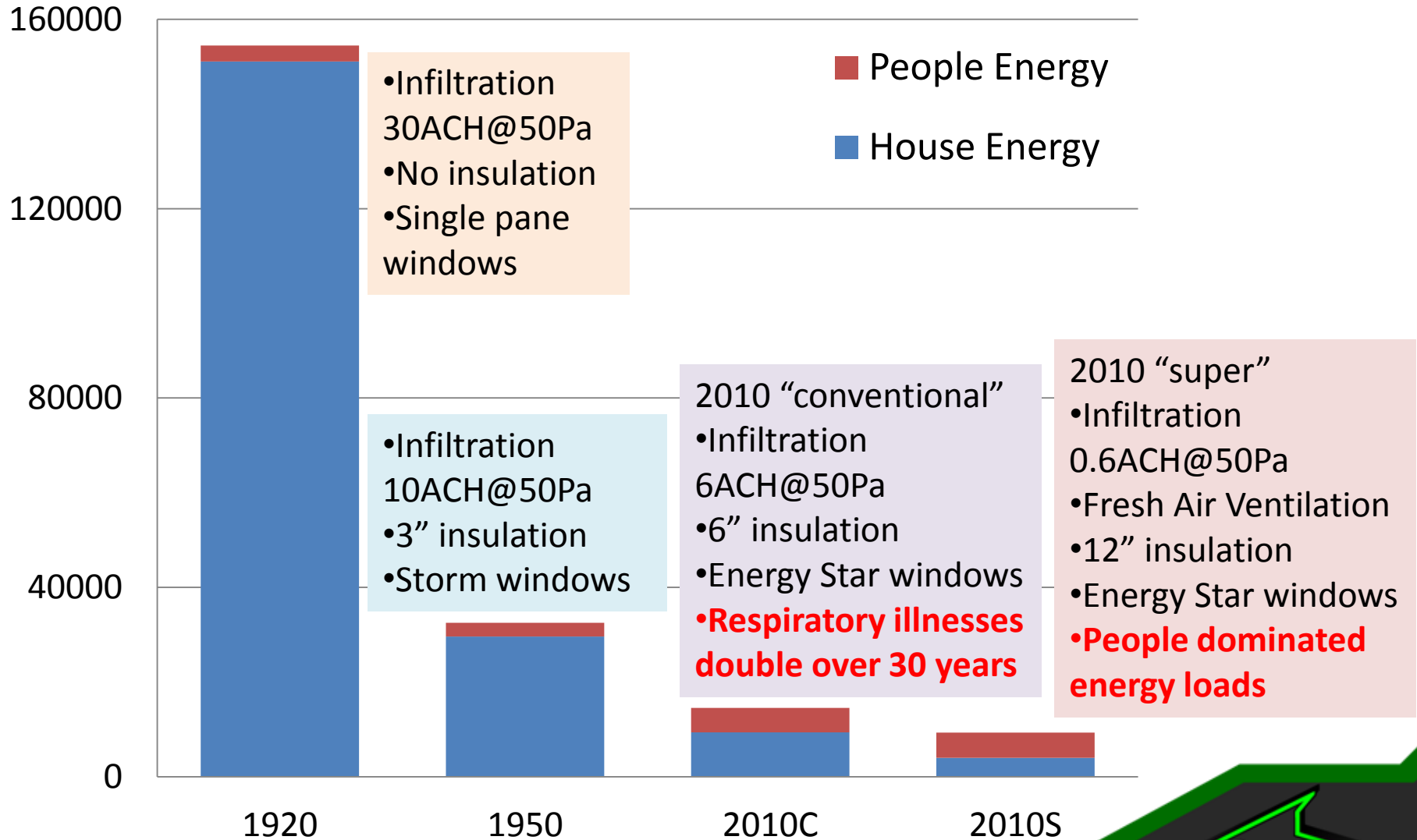
- Combining the most stringent housing standard with smart ventilation results in the healthiest, most productive and energy efficient residence



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

History of House Energy

Annual House Energy (kWh) Requirements



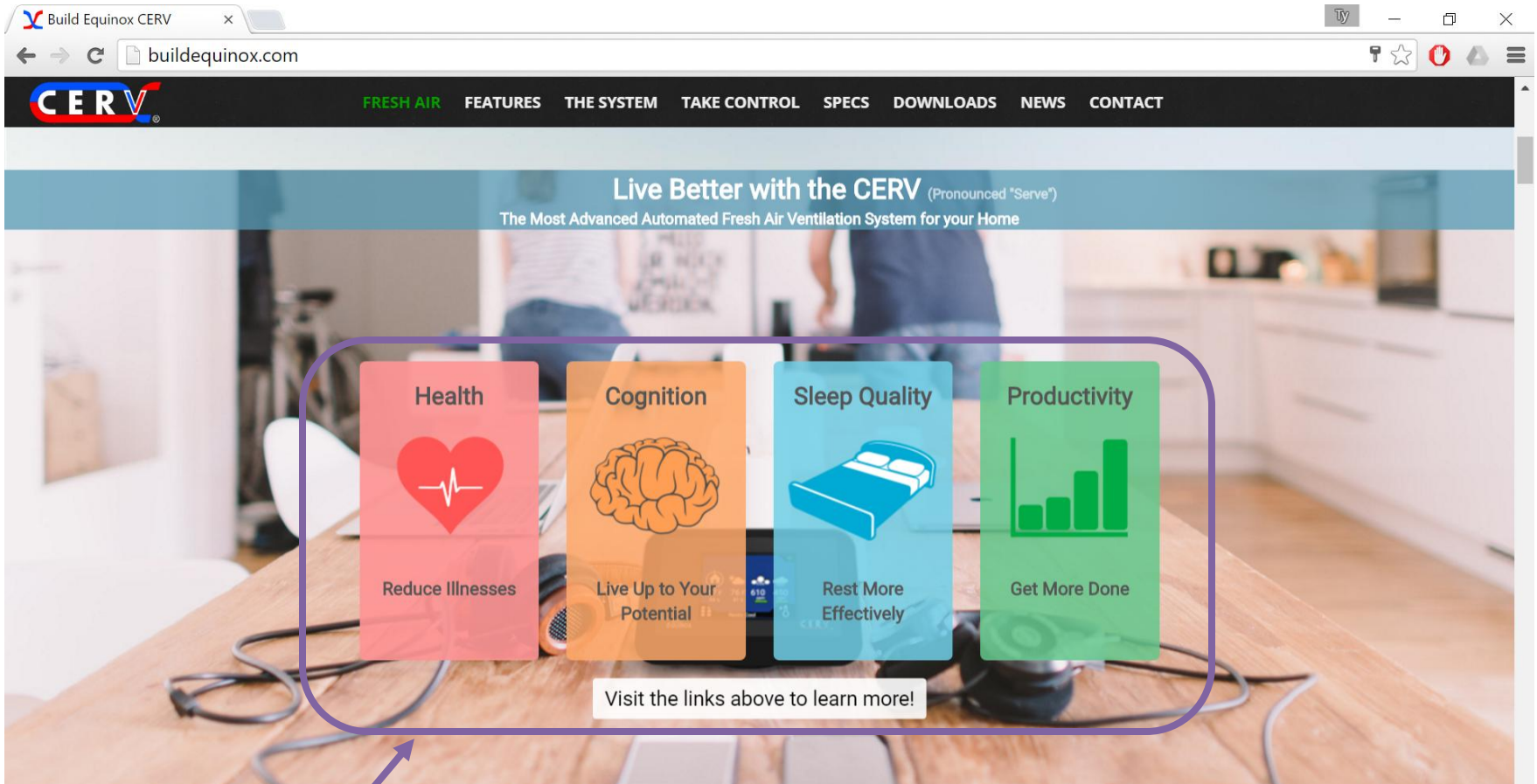
Health Cost

- Annual energy cost for 100M high performance residences = \$160B/yr; \$80B for people; ~\$80B for climate
 - 4000kWh/person, 12cents/kWh, 325M people
- Annual cost of seasonal influenza is \$87B/yr
 - Improved ventilation reduces contagion concentrations
- Asthma now afflicts nearly 10% of the population (~30% of households) for a total of \$56B/yr total cost
 - Can we reduce asthma to 5% of populace where it used to be....or even more?
- US refrigerator energy cost ~\$5B/yr
 - Note: cost of foodborne illness in US = \$50-70B/yr
 - Value of food in refrigerator \$600B/yr

10 Minutes

- 2% of an 8 hour workday is 10 minutes
- At \$25/hr, the loss of 2% productivity = \$4/day
 - 4,000kWh/year per person (solar) energy = \$1/day
 - 10 minutes per day of human productivity is 4x the daily cost of energy/person
- Productivity loss due to poor (but undetectable) air quality is often much greater than 10 minutes
 - CO2 impacts cognition
 - VOCs impact health

4 Important Papers



4 Reference papers on health, cognition, sleep and productivity on BuildEquinox.com Website

Carbon Dioxide (CO2) Impairs Cognitive Performance

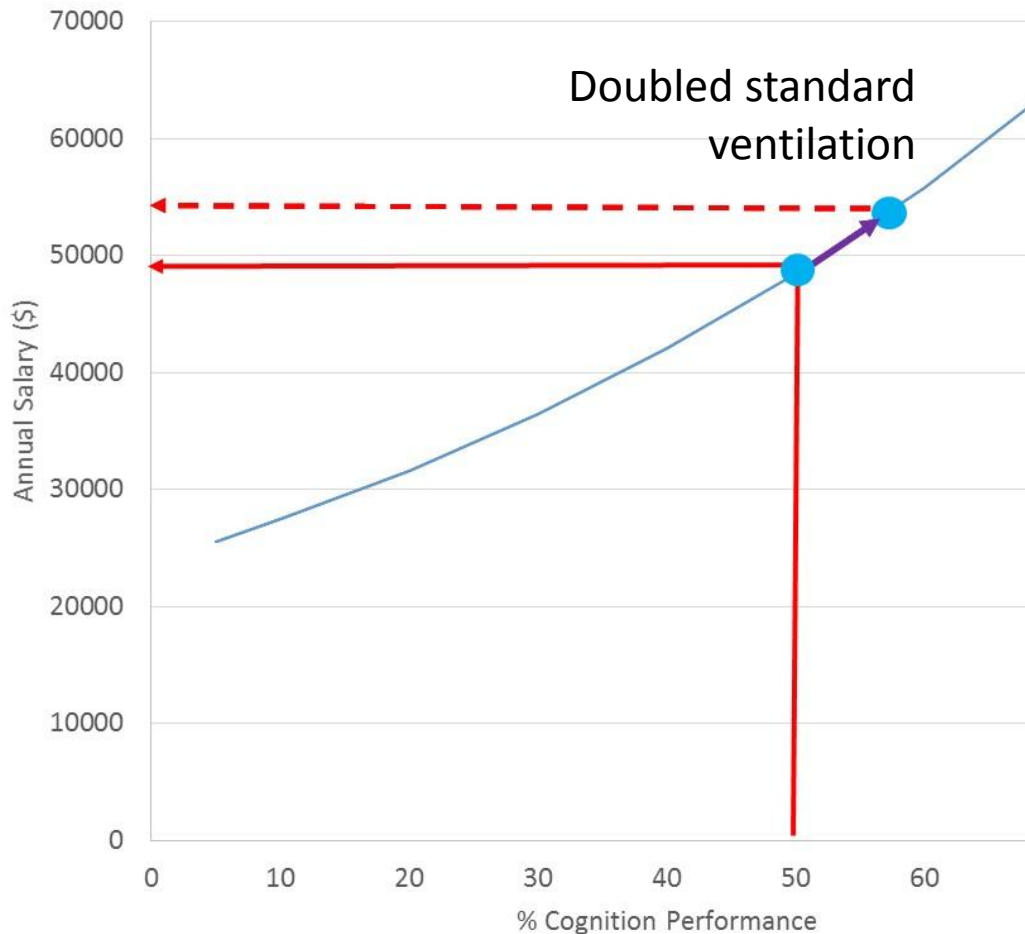
Impact of Carbon Dioxide (CO2) on Human Decision-making Performance*



* "Is CO2 Indoor Pollutant?", William Fisk, Usha Satish, Mark Mendel, Toshifumi Hotchi, and Douglas Sullivan, *ASHRAE Journal*, Vol. 55, No. 3, pp. 84-85, March 2013.

Strongly impairs: Initiative, Information Utilization, Breath of Approach, and Basic Strategy

Earnings vs Cognition Performance



Earnings correlate with cognition performance (see “productivity” paper on BuildEquinox.com)

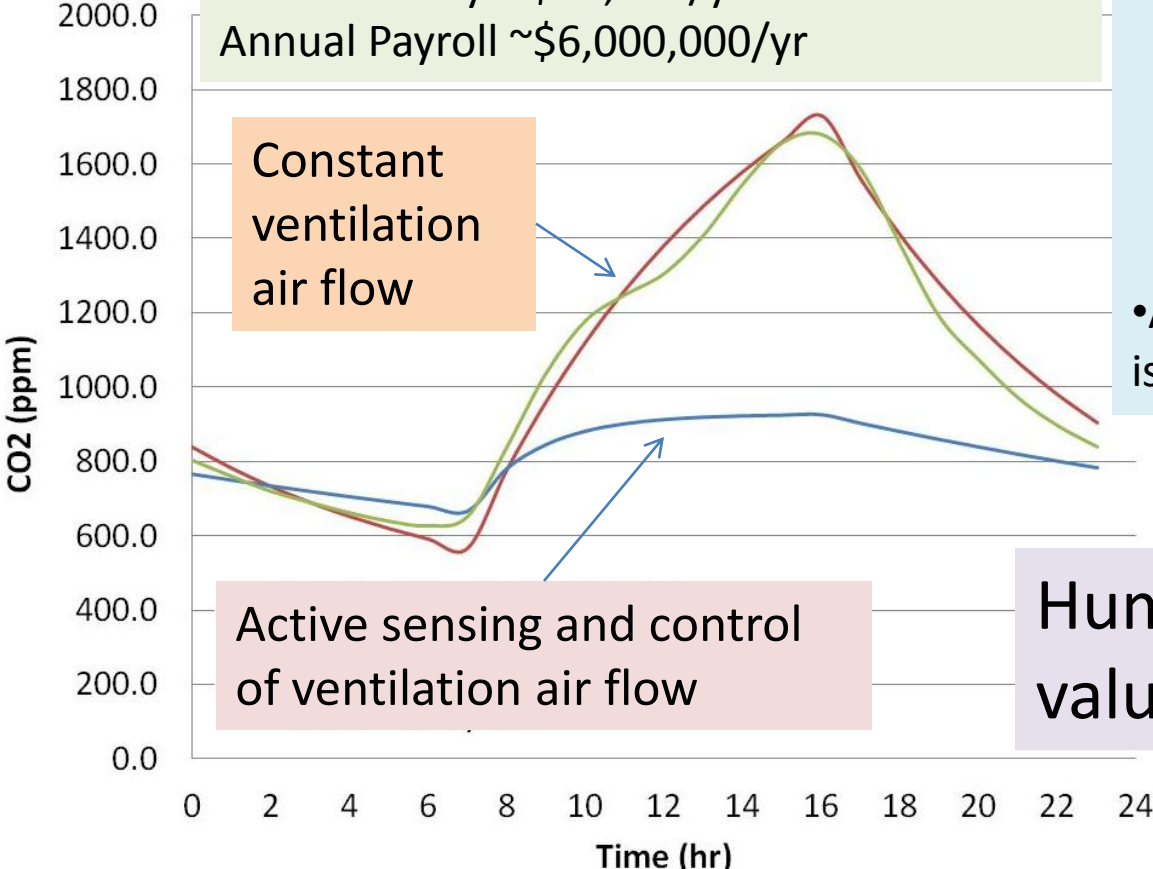
Cognition performance is directly linked to IAQ (see paper on “cognition” on BuildEquinox.com)

Doubling ASHRAE ventilation standards (20cfm to 40cfm per person) would increase productivity by \$6500/person with an energy cost of less than \$40/person

Value of Fresh Air - Commercial

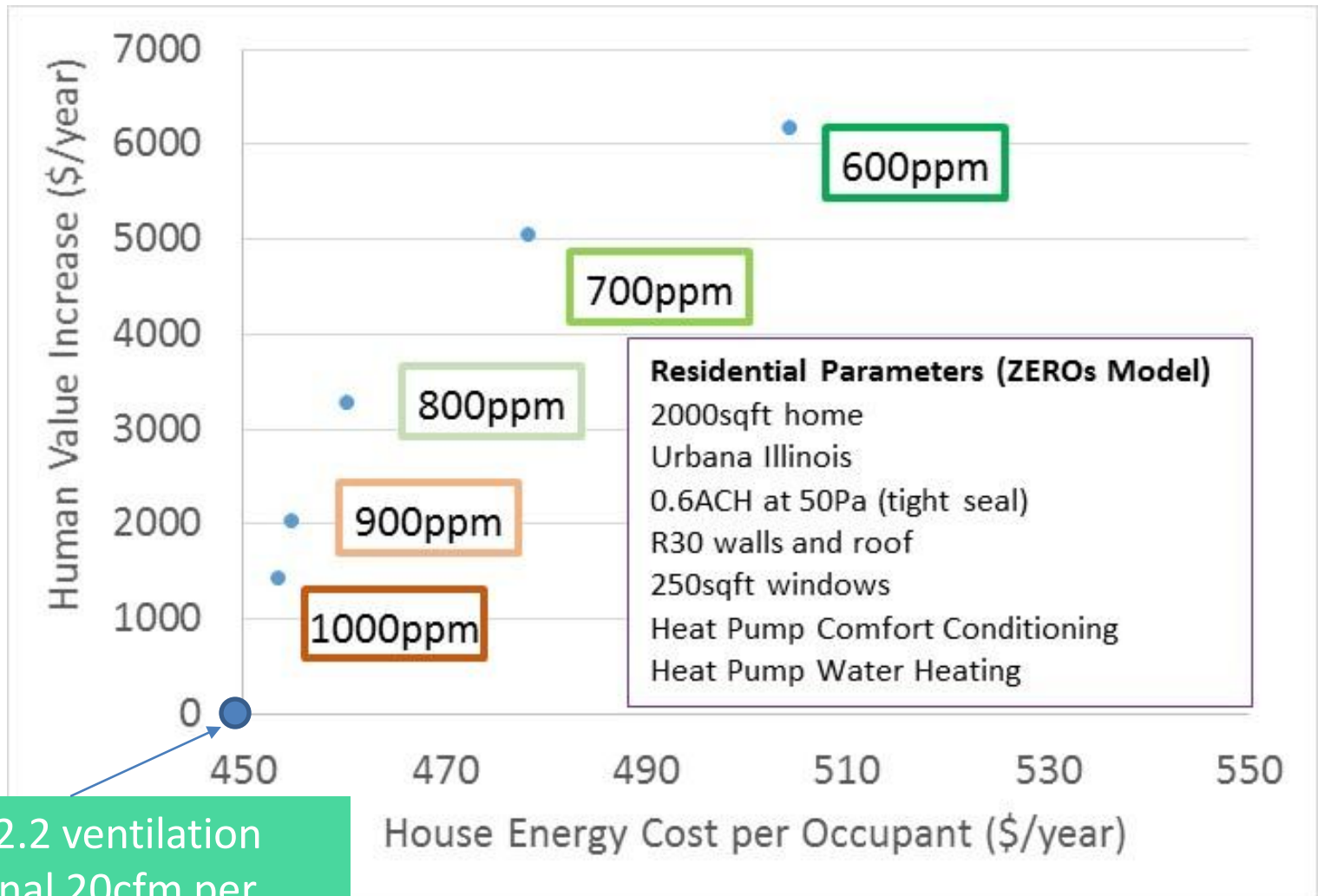
25,000 sqft facility with constant ventilation
120 Employees
Annual Utility ~ \$88,000/yr
Annual Payroll ~\$6,000,000/yr

- Fresh air control would increase employee productivity by \$750,000/year by reducing CO2
 - 1% drop in productivity ~\$60,000 per year
 - Additional benefit through reduced sick days not included
- Annual utility cost (\$88,000/yr) is unaffected



Humans are more valuable than energy!

Value of Fresh Air - Residential



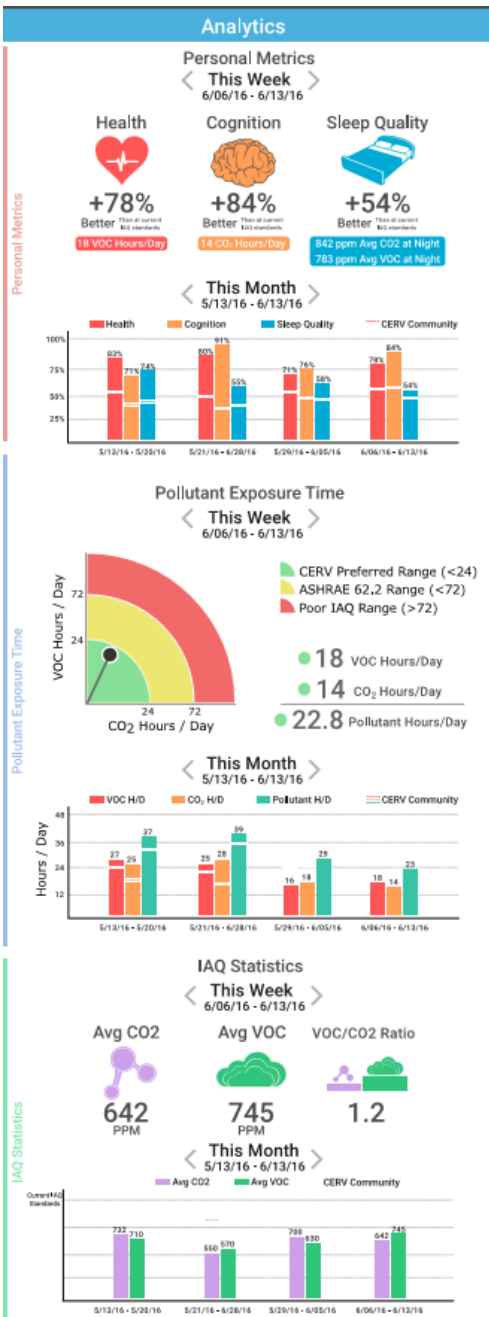
ASHRAE 62.2 ventilation with nominal 20cfm per person of ventilation results in ~1100ppm CO2

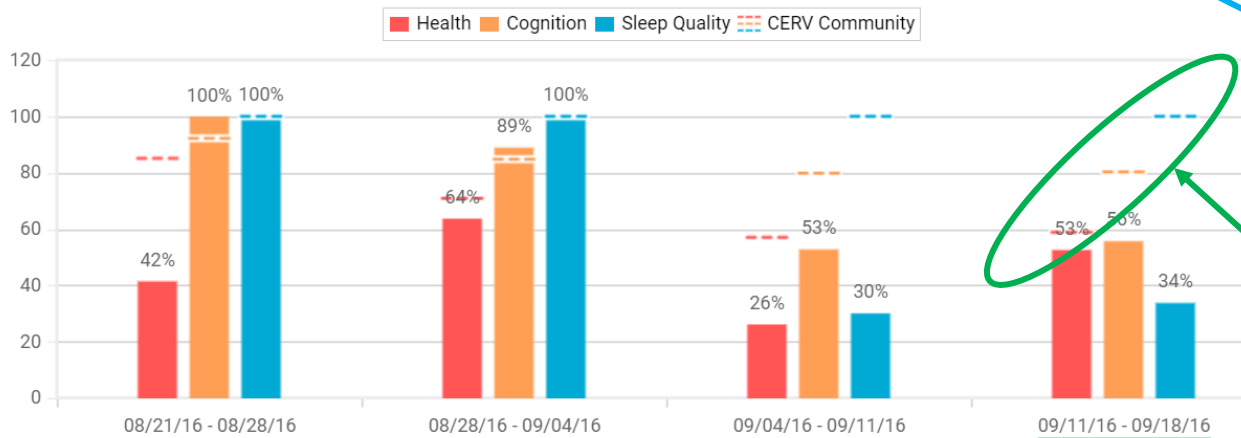
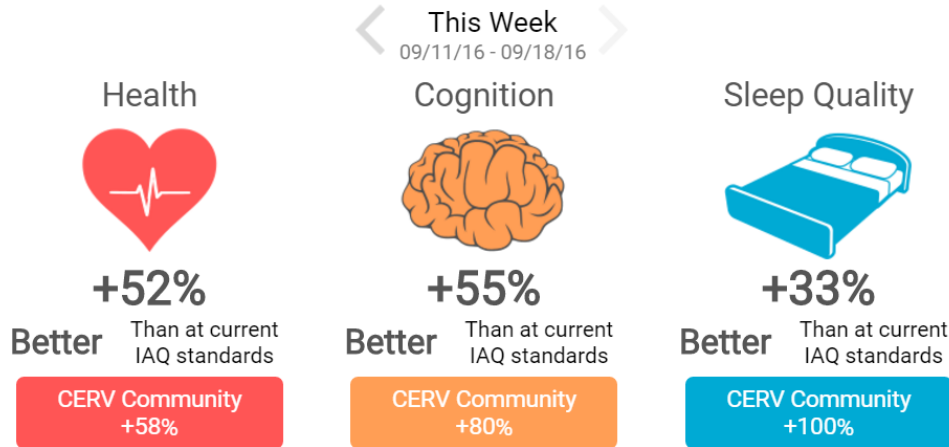
New IAQ Metrics

Personal Metrics: Immediate impact of pollutants on cognition and productivity

Pollutant Exposure Time: Accumulation monitoring of pollutants

IAQ Statistics: Basic CO2 and VOC pollutant trends in your home





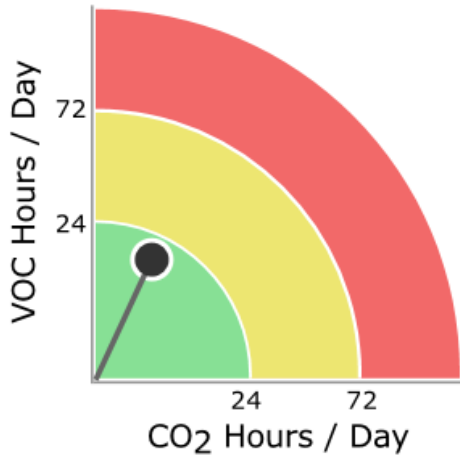
Defined as IAQ from 10pm to 7am
"Sleep hangover"

How do I compare with others?

Your Performance

Pollutant Exposure Time

< **This Week** >
6/06/16 - 6/13/16



- CERV Preferred Range (<24)
- ASHRAE 62.2 Range (<72)
- Poor IAQ Range (>72)

● **18** VOC Hours/Day
● **14** CO₂ Hours/Day

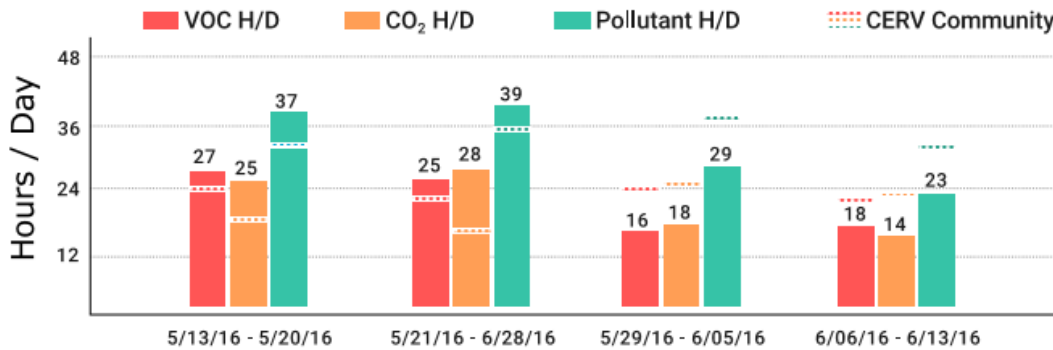
● **22.8** Pollutant Hours/Day

Energy efficient
Smart Ventilation

Likely IAQ due to human occupancy from ASHRAE 62.2 ventilation standards

Range exceeding ASHRAE ventilation levels

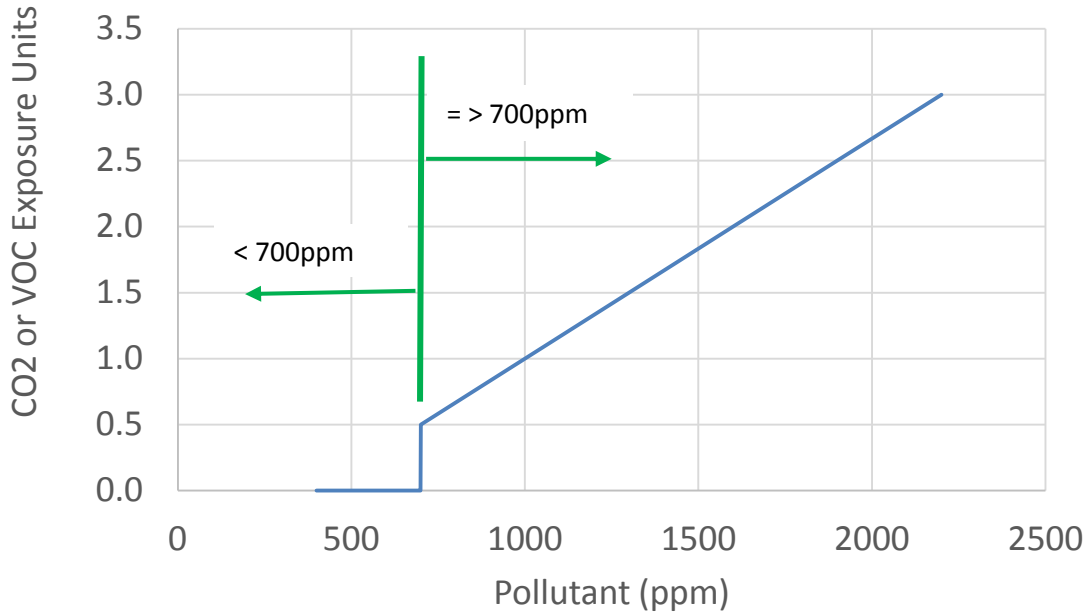
< **This Month** >
5/13/16 - 6/13/16



Weekly trends over the past month

Accumulated Health Impact

Pollutant Exposure



Exposure units are defined:

- Scale similar to “Olf”
- 1 person in a room with 10 liters/sec (~20cfm) is 1 Olf (Olfactory) ~ 1000ppm CO₂
- Current research indicates less significant impact with CO₂ less than 700ppm, but may change with future research
- VOC is a soup of chemicals, and current scale assumes similar impact to CO₂

CO₂ or VOC Exposure Units = 0 for <700ppm

CO₂ or VOC Exposure Units = $(X \text{ ppm} - 400)/(1000-400)$

Sum (Exposure Units X Time Increment) = Exposure-hours

IAQ Statistics

< **This Week** >
6/06/16 - 6/13/16

Avg CO2



642
PPM

Avg VOC



745
PPM

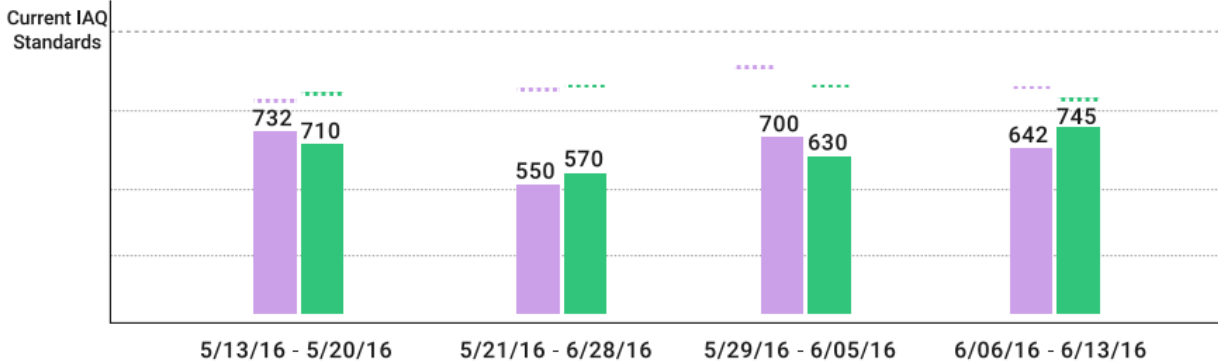
VOC/CO2 Ratio



1.2

< **This Month** >
5/13/16 - 6/13/16

■ Avg CO2 ■ Avg VOC ■ CERV Community



All electric homes:

VOC/CO2 < 1
indicates VOCs
primarily human
generated

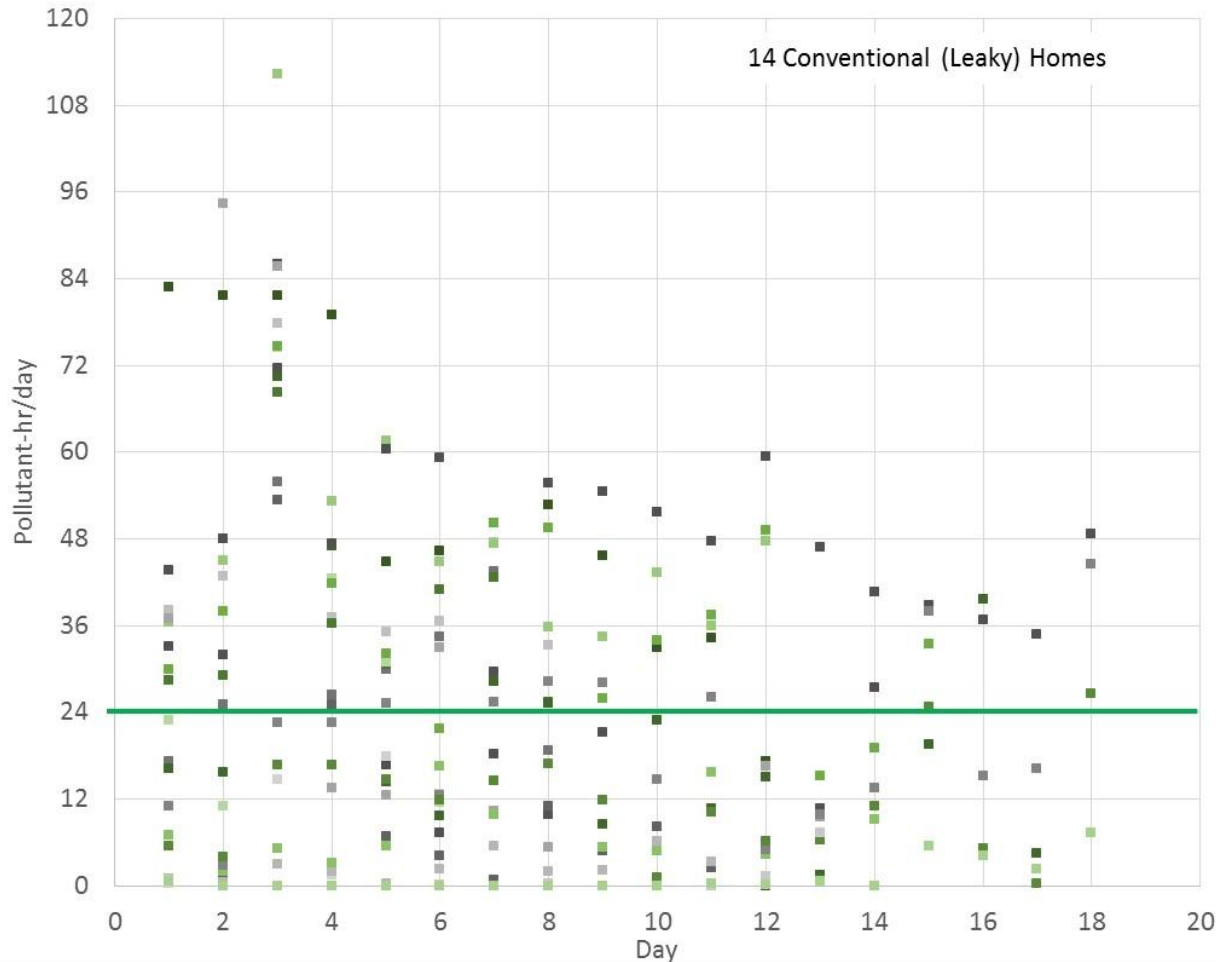
VOC/CO2 > 1
indicates additional
sources of VOC
emissions

Combustion homes:
both <1 and >1

Weekly trends over
the past month

Basic IAQ Statistics

Conventional “Leaky” Homes

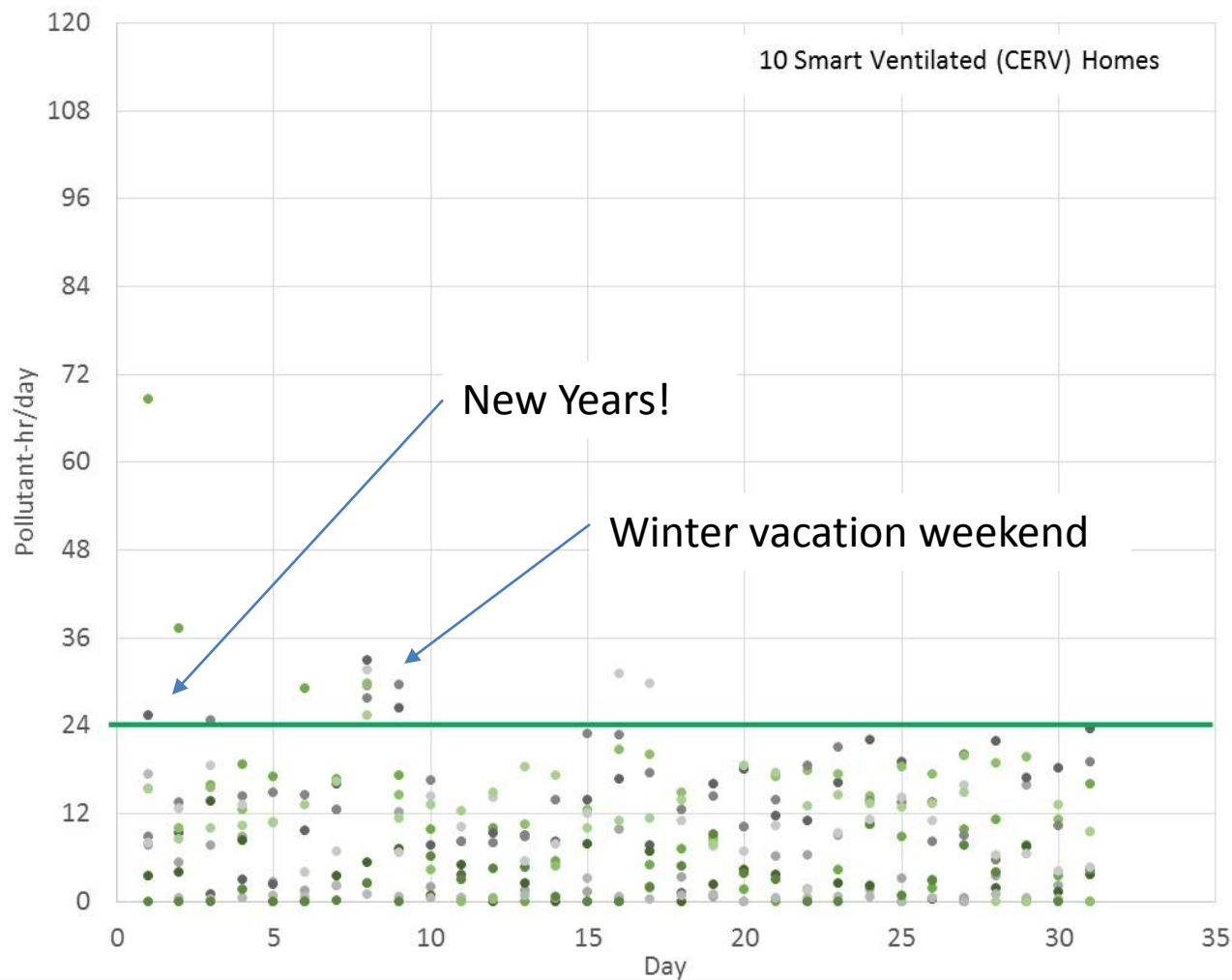


Various times of year

Homes in California,
Colorado, Vermont,
Minnesota, Illinois

~2 week assessment period with Build Equinox IAQ
monitoring technology (Black Box IAQ)

Smart Ventilated (CERV) Homes

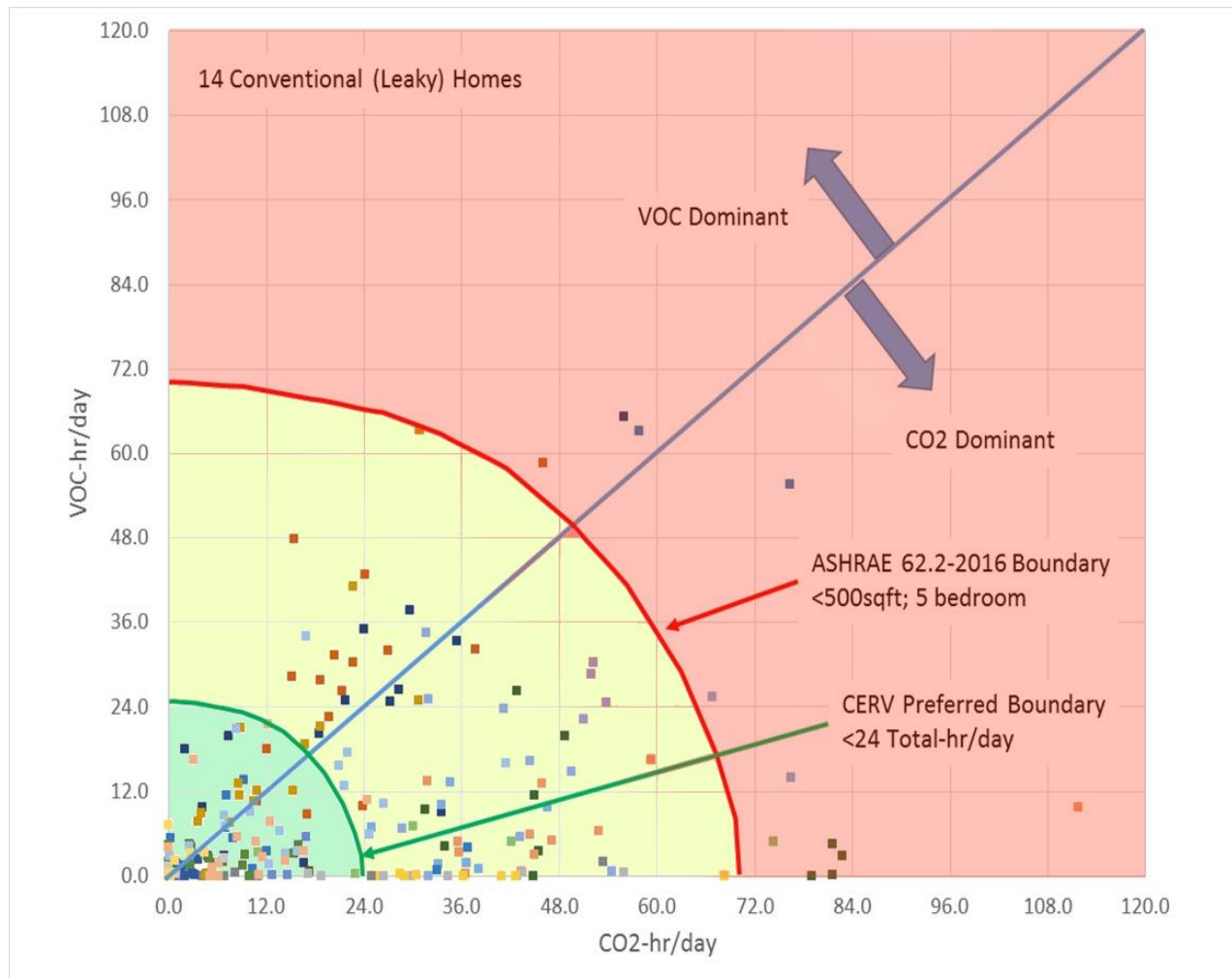


January data
(closed house)

Homes in Oregon,
Vermont, Colorado,
South Carolina,
Illinois

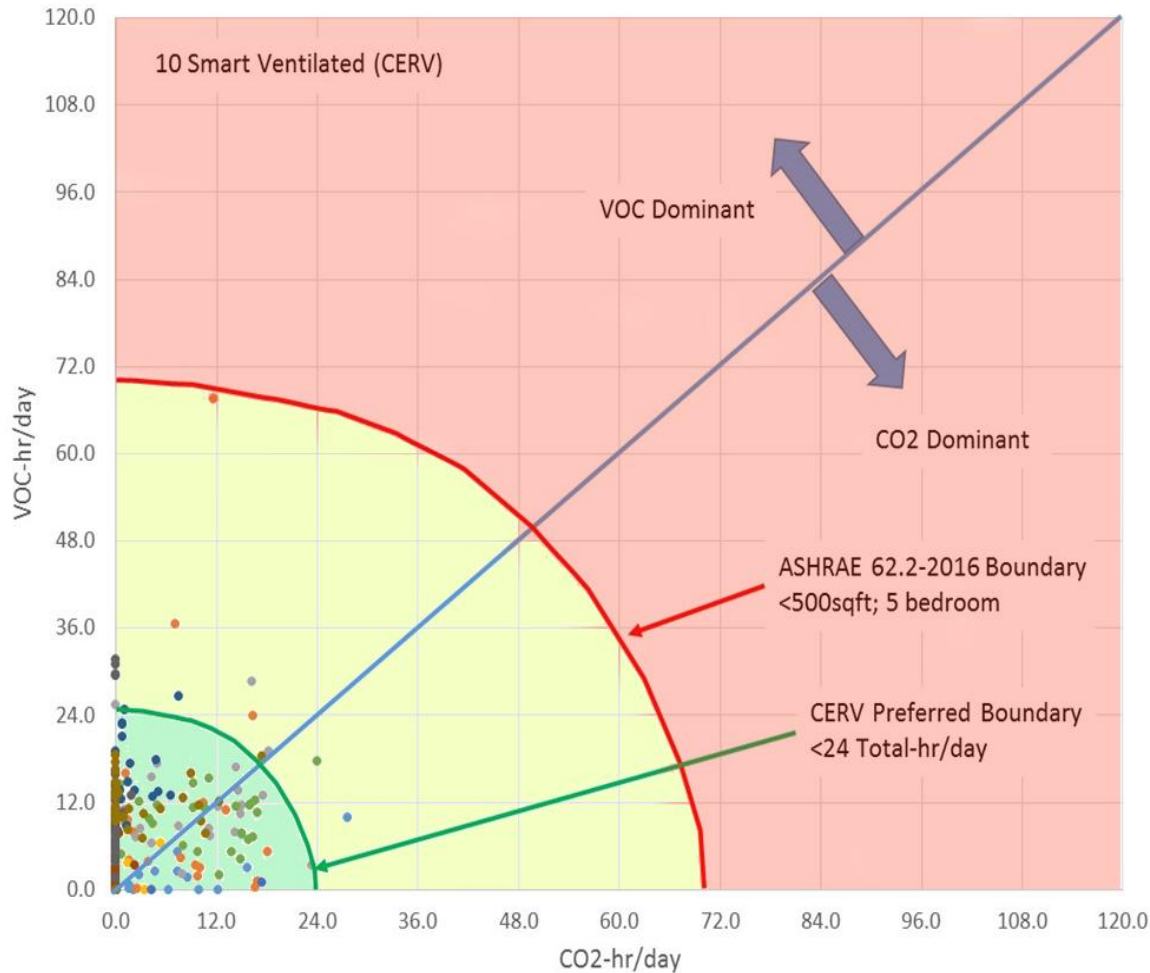
~4 week assessment period with CERV-ICE online
monitoring (January 2016 data)

14 Conventional “Leaky” Homes



~2 week assessment period with Build Equinox IAQ monitoring technology (Black Box IAQ)

10 Smart Ventilated (CERV) Homes



~4 week assessment period with CERV-ICE online monitoring (January 2016 data)

Summary

- The cost of poor IAQ at home and at work is much greater than the cost of energy (and associated ventilation) in efficient homes and buildings
- New IAQ metrics will help building occupants understand estimated impact of IAQ on their health, cognition and sleep
- Monitoring of accumulated pollutants will provide information for understanding future health effects of our indoor environments
- IAQ metrics provide a quantitative basis for comparing quality of construction, selection of materials, and occupant activities
- Basic Research is needed to continue defining interaction of pollutants on our health and productivity

Sign up