New IAQ Metrics

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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?

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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

Insufficient ventilation when occupied

Excessive ventilation when unoccupied

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

Smart ventilates when needed

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.

Vermod homes average 3,650kWh/occupant and 9kWh/sqft per year.
History of House Energy

Annual House Energy (kWh) Requirements

- **People Energy**
- **House Energy**

1920:
- Infiltration: 30ACH@50Pa
- No insulation
- Single pane windows

1950:
- Infiltration: 10ACH@50Pa
- 3” insulation
- Storm windows

2010 “conventional”
- Infiltration: 6ACH@50Pa
- 6” insulation
- Energy Star windows
- Respiratory illnesses double over 30 years

2010 “super”
- Infiltration: 0.6ACH@50Pa
- Fresh Air Ventilation
- 12” insulation
- Energy Star windows
- People dominated energy loads

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People Energy

- Increased energy loads due to higher infiltration rates and lack of insulation.

House Energy

- Lower energy requirements due to improvements in insulation and ventilation.

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Energy Star windows:

- Energy-efficient windows that reduce energy consumption.

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Fresh Air Ventilation:

- A system that introduces fresh air into the building, improving indoor air quality.

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Infiltration rates:

- The rate at which air enters a building through cracks and gaps.

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Respiratory illnesses:

- Increased due to poor indoor air quality.
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***


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

- 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!

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

Constant ventilation air flow

Active sensing and control of ventilation air flow

• 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
Value of Fresh Air - Residential

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

- Residential Parameters (ZEROs Model):
  - 2000sqft home
  - Urbana Illinois
  - 0.6ACH at 50Pa (tight seal)
  - R30 walls and roof
  - 250sqft windows
  - Heat Pump Comfort Conditioning
  - Heat Pump Water Heating
**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
Your Performance

How do I compare with others?

4 Reference papers on health, cognition, sleep and productivity on Build Equinox Website

Defined as IAQ from 10pm to 7am “Sleep hangover”

Health
Cognition
Sleep Quality

+52%
+55%
+33%

Better Than at current IAQ standards
Better Than at current IAQ standards
Better Than at current IAQ standards

CERV Community +58%
CERV Community +80%
CERV Community +100%
Accumulated Health Impact

Energy efficient Smart Ventilation

Likely IAQ due to human occupancy from ASHRAE 62.2 ventilation standards

Range exceeding ASHRAE ventilation levels

Weekly trends over the past month

Accumulated Health Impact
Pollutant Exposure

CO2 or VOC Exposure Units = 0 for <700ppm

CO2 or VOC Exposure Units = (X ppm – 400)/(1000-400)

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

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
Basic IAQ Statistics

All electric homes:
- VOC/CO2 < 1 indicates VOCs primarily human generated
- VOC/CO2 > 1 indicates additional sources of VOC emissions

Weekly trends over the past month

Combustion homes:
- Both <1 and >1

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

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Current IAQ Standards

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<th>Date Range</th>
<th>Avg CO2</th>
<th>Avg VOC</th>
<th>CERV Community</th>
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<td>6/06/16 - 6/13/16</td>
<td>642</td>
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Conventional “Leaky” Homes

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

Various times of year

Homes in California, Colorado, Vermont, Minnesota, Illinois
Smart Ventilated (CERV) Homes

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

January data (closed house)

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

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