Efficiency Vermont

MARCH 2018

The drawbacks of breathing:

Nighttime carbon dioxide (CO_2) levels in bedrooms in 22 Vermont homes

Brian Just

Learning objectives

- Understand why proper attention to carbon dioxide and other pollutant levels is important to avoid negative health impacts
- Learn which home characteristics had the largest impact on carbon dioxide levels in a 2016-17 New England study and how this relates to your next project
- Compare ventilation system types and understand the ability of each to impact a home's pollutant levels and indoor air quality
- Identify a concise list of best practices for getting design and commissioning of ventilation system done right

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Introduction

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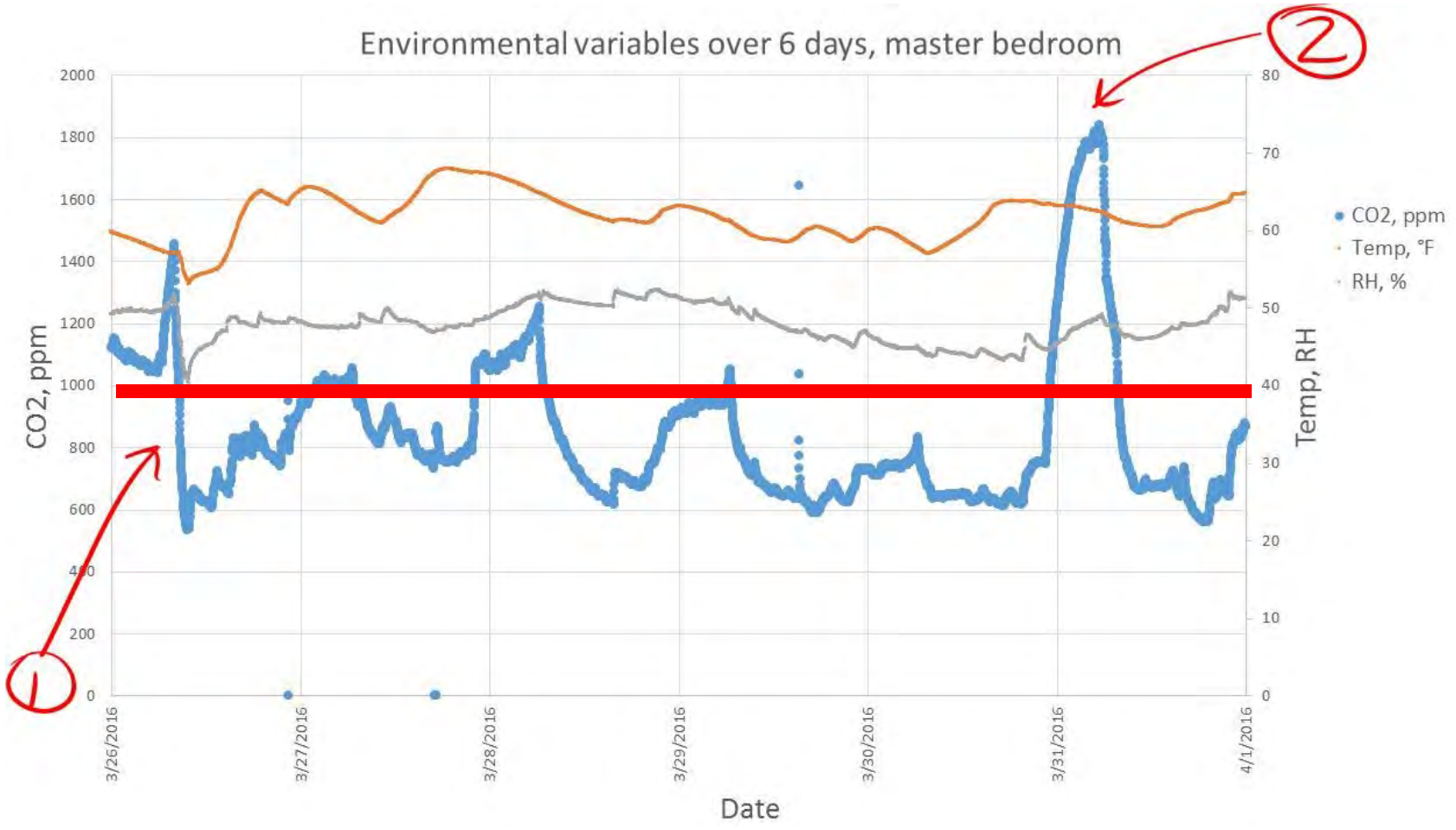
Why I asked



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Why measure CO2?

- Other stuff is probably far worse…
  - VOCs (e.g. formaldehyde)
  - Particulates
  - Radon
  - The rest: CO, moisture, smells, etc.

- But CO2 is:
  - Easy and cheap to measure in real time
  - Reliably created in every (occupied) home
  - Probably a decent proxy for a lot of the other stuff

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How much CO2 is too much?

- Codes target 1,000 ppm
- OSHA limit 5,000 ppm exposure limit (8-hr)*
- At 40,000 ppm, immediately dangerous to life or health concentrations (IDLH)*

*https://www.cdc.gov/niosh/idlh/124389.html

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Impacts of "low-level" CO2 exposure: 1

- 2016 Joe Allen / Harvard study*
  - 24 office workers, 6 days
  - Variables: CO2 (600-1,400ppm), VOCs, outdoor air
  - Cognitive testing at 3pm each day
- Cognitive scores
  - 61% higher on "Green" days
  - 101% higher on "Green+" days
  - VOCs and CO2 mattered independently, especially in higher level functions

*Allen JG, MacNaughton P, Satish U, Santanam S, Vallarino J, Spengler JD. 2016. Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: a controlled exposure study of green and conventional office environments. Environ Health Perspect 124:805–812. DOI: 10.1289/ehp.1510037

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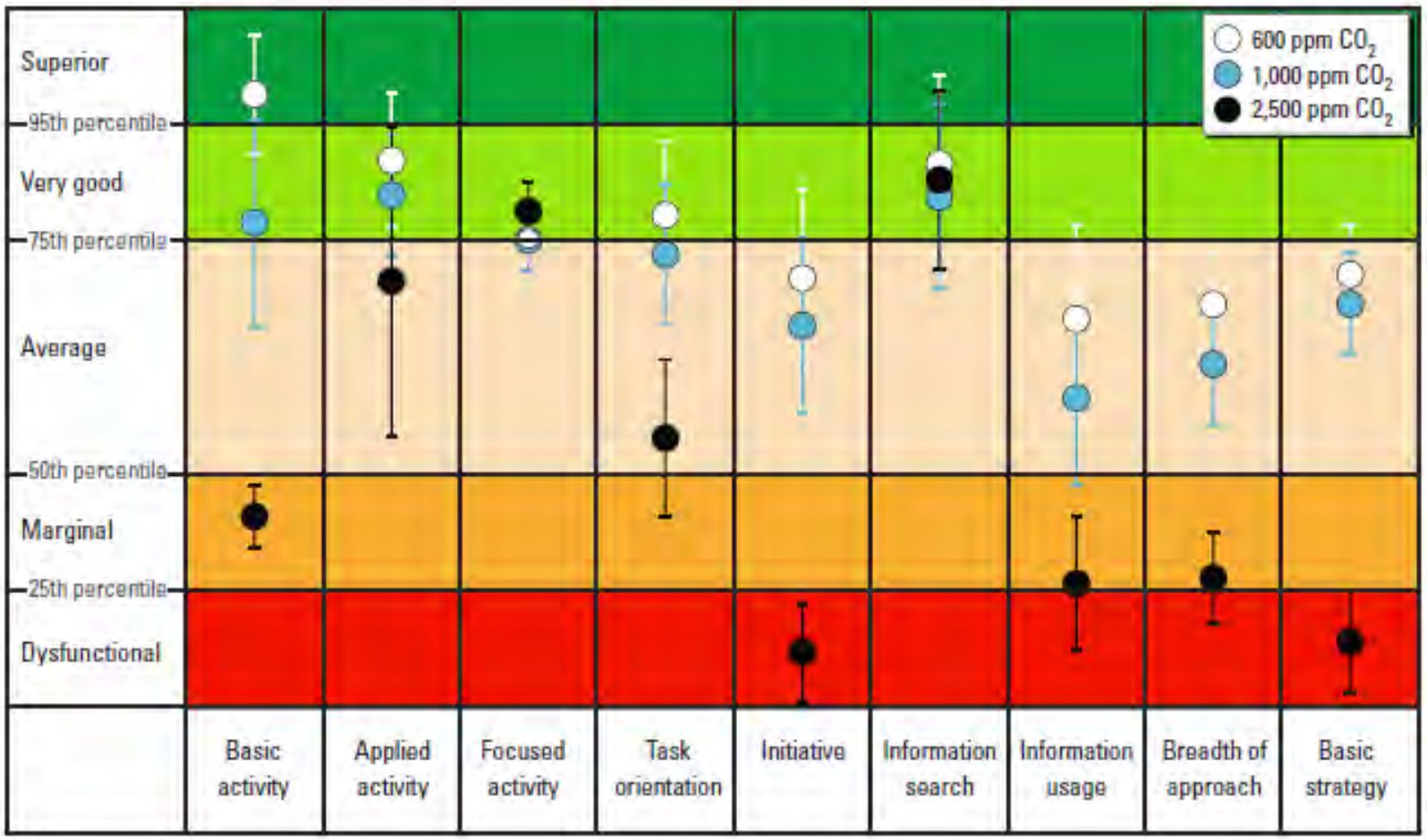
Impacts of “low-level” CO2 exposure: 2



*Satish U, Mendell MJ, Shekhar K, Hotchi T, Sullivan D, Streufert S, Fisk WJ. 2012. Is CO2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2 Concentrations on Human Decision-Making Performance. Environ Health Perspect 120:1671–1677; DOI: 10.1289/ehp.1104789

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Impacts of "low-level" CO2 exposure: 3

- 2015 Denmark survey*
  - 16 students in dormitories
  - CO2: 835ppm vs. 2,395ppm (avg)
- Results (with enhanced ventilation)
  - Higher perceived air quality
  - Sleep "efficiency" improved
  - Next-day sleepiness reduced
  - Grammatical reasoning improved

*Strøm-Tejsen, P., Zukowska, D., Wargocki, P., Wyon, D. P. 2015. The effects of bedroom air quality on sleep and next-day performance. Indoor Air Vol 26:5, 679-686. DOI: 10.1111/ina.12254

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How much CO2 is too much?

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*https://www.cdc.gov/niosh/idlh/124389.html

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Protocol

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Two phases

- Phase I: Home inspection
  - Screening
  - Building age
  - Building sketch, including master bedroom volume
  - Air tightness test (blower door)
  - Ventilation system type and flow test
- Phase II: CO_2 testing
  - 4 nights (door open/closed/open/closed)
  - Log to verify instructions and record irregular events

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Testing setup

- No restrictions on building age, building type, air tightness, size, ventilation system type
- Heating season (windows closed)
- CO2 probe in primary occupied bedroom
  - Draft free location, approx. 3’ above floor
  - Min. 3’ from nearest sleeping being
  - Min. 1’ free space between probe and nearest vertical surface

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Testing equipment

- TSI VelociCalc 9565-P meter with TSI 986 probe
  - CO2 range: 0-5,000 ppm
  - CO2 accuracy: ±3% of reading or 50 ppm, whichever greater
- Frequency: 1/min

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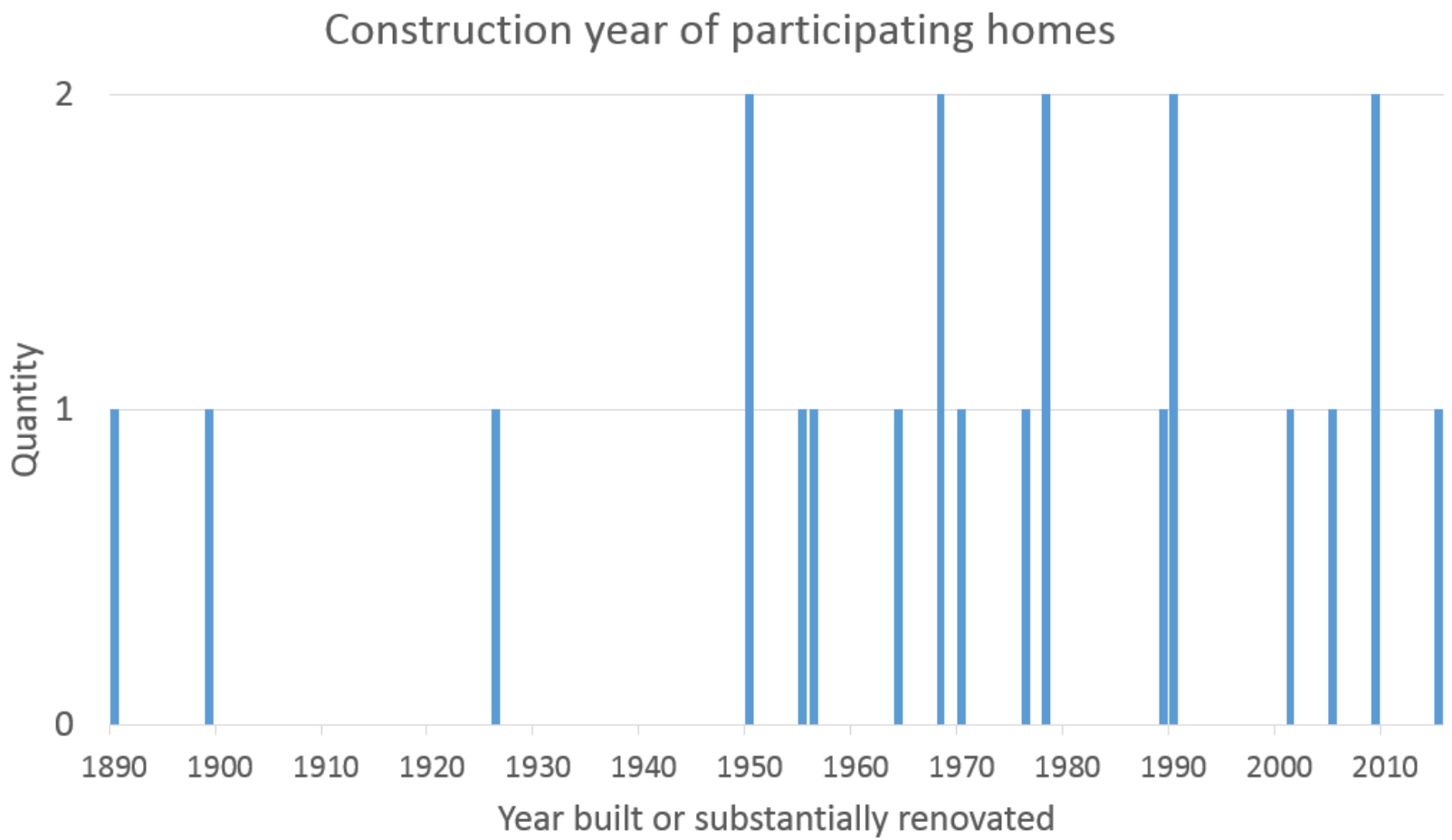
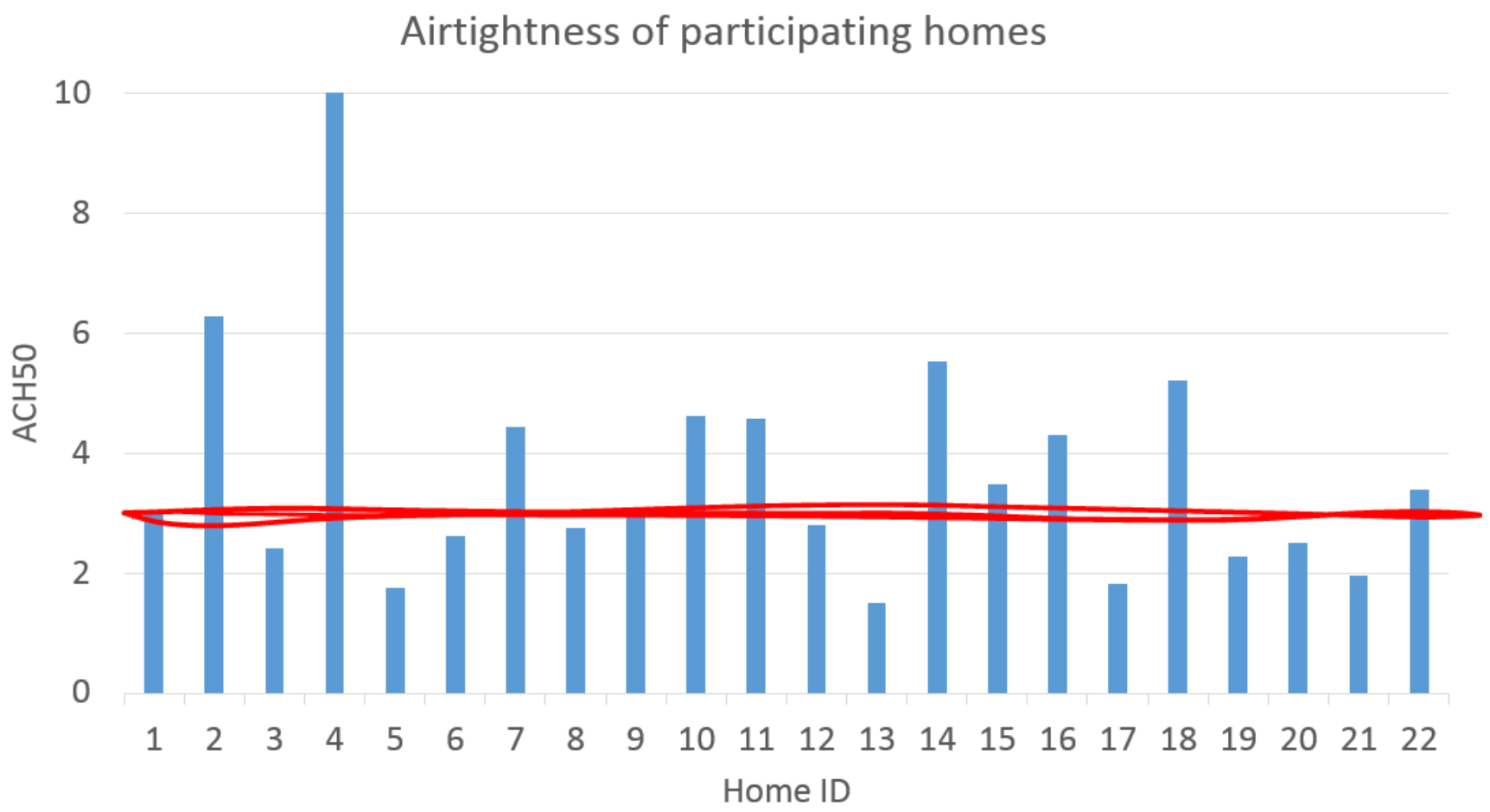
Home age


Construction year of participating homes
2
1
0
Quantity
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year built or substantially renovated

Home airtightness



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Other factors

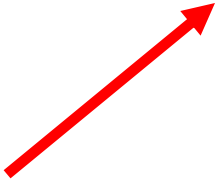
- Occupancy
  - Min. 1 person
  - Max. 3 people
    - Dogs, infants, and toddlers = 0.5
    - Don't read into this
- Bedroom volume
  - Min. 882 ft^3 (e.g. 10'x11' w/8' ceiling)
  - Max. 2464 ft^3 (e.g. 15'x21' w/8' ceiling)

Occupants / 1,000 ft^3

Min. 0.81

Max. 2.48

Avg. 1.53



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Other factors, cont.

- Heating system
  - 10 mechanically-moved air (furnace, minisplits, etc.)
  - 12 not (primarily boilers)
- Ventilation system
  - 13 exhaust only, no controls
  - 7 exhaust only, automated controls
  - 2 heat recovery ventilation
- Home type
  - 19 single family detached
  - 3 single family attached

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Results

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A glance at one home…

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A glance at one home…

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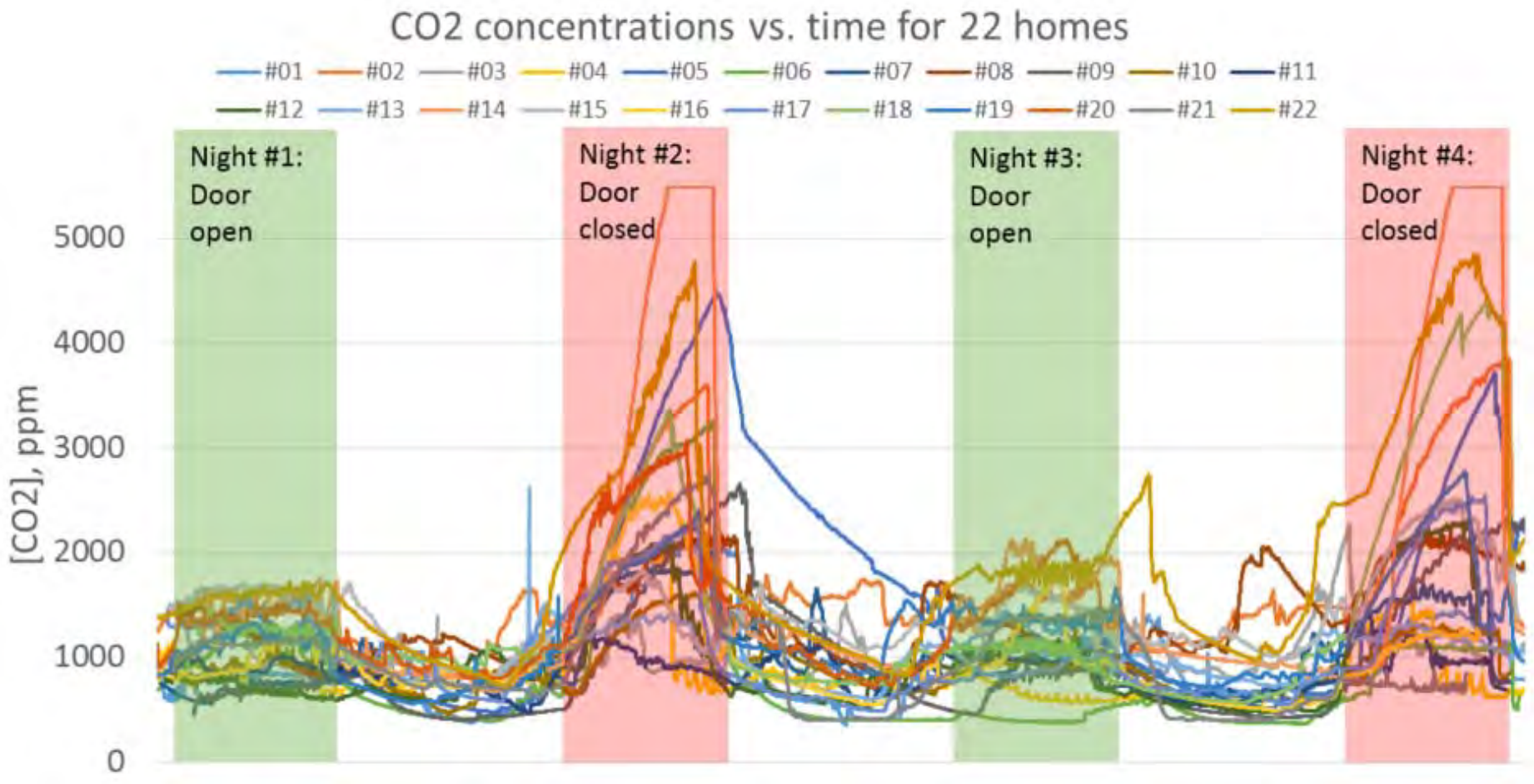
Data (all of it)



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Data highlights (or lowlights?)

- 86% of homes (19) exceeded 2000 ppm*
- 32% of homes (7) exceeded 3000 ppm**
- (Only) 1 home stayed below 1000 ppm on both open-door nights (#9)

* All but #10, 11, 13
** #2, 5, 6, 14, 18, 20, 22

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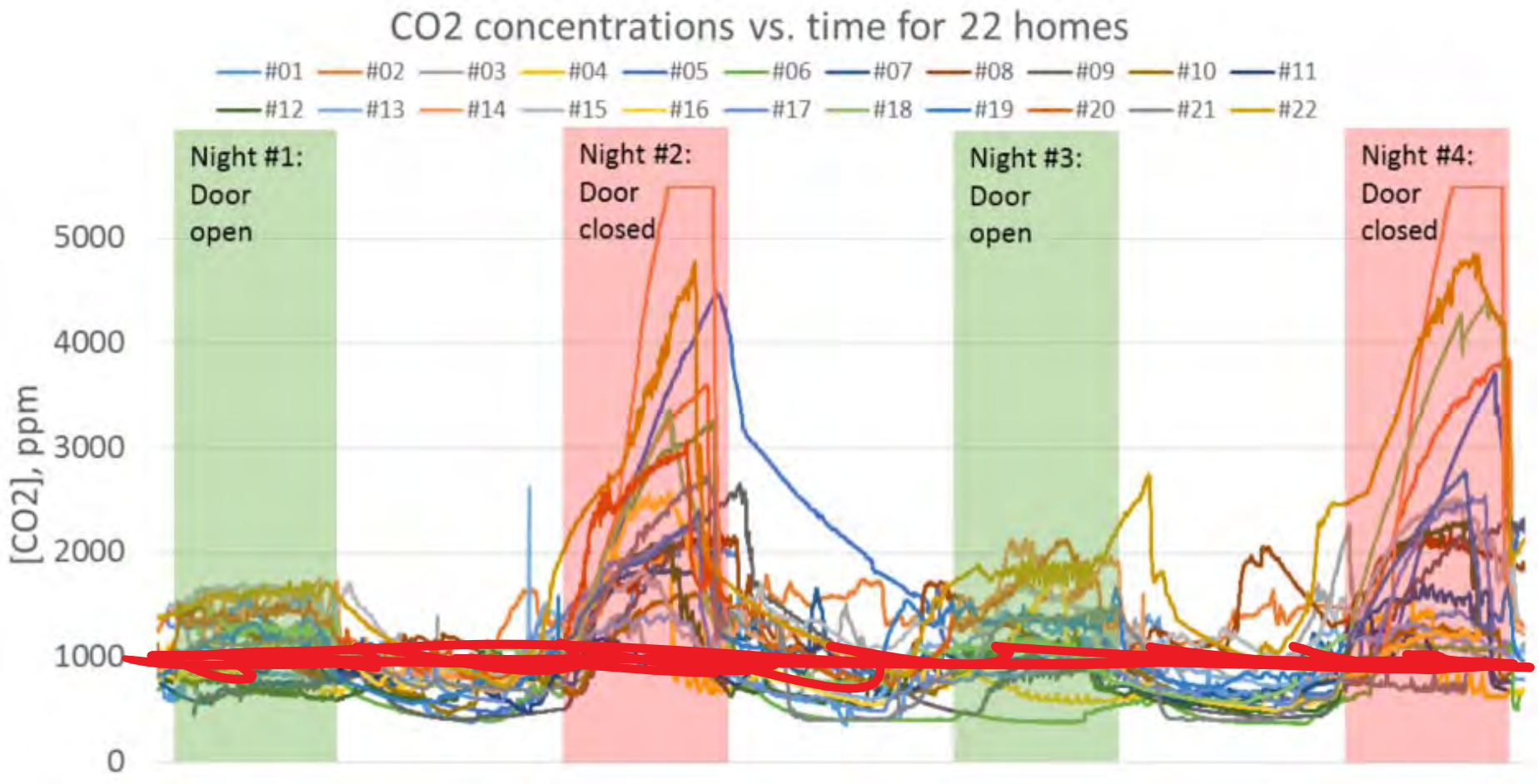
Data (all of it)



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Why?

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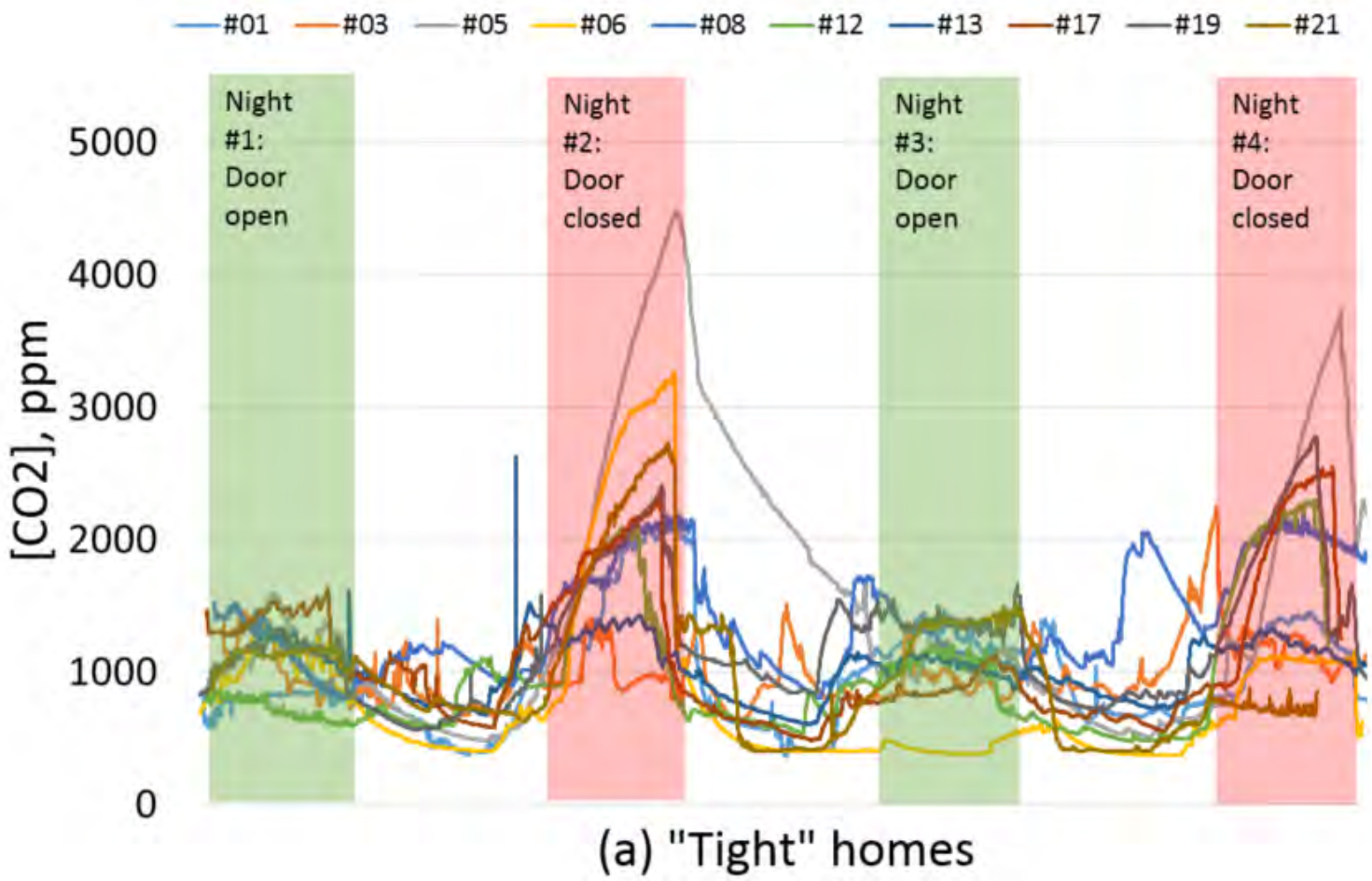
Theory #1

This isn’t as much of a problem in older / leakier homes

Theory #1: Tight homes (10)



* ACH50 < 3.0

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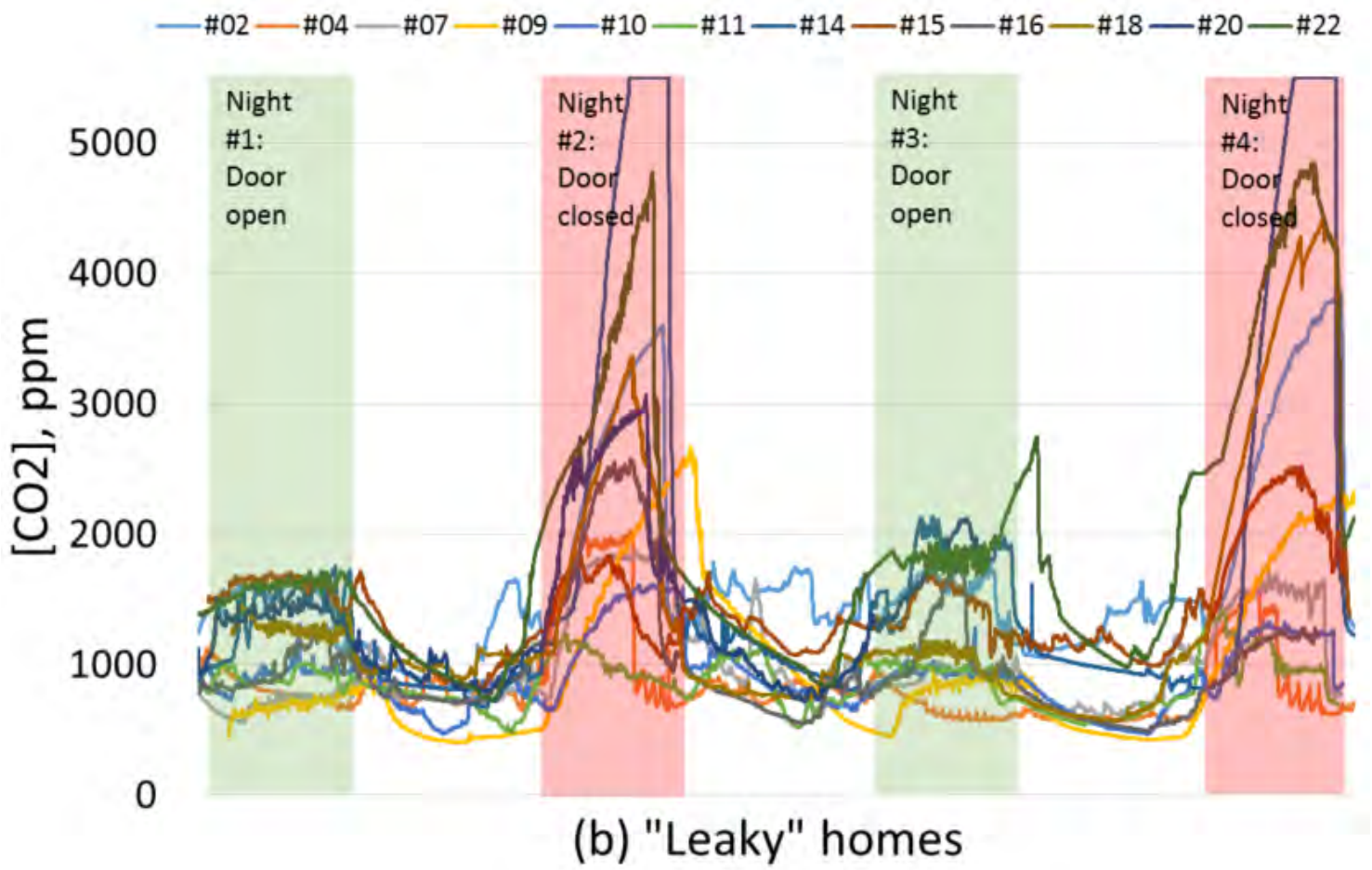
Theory #1: Leaky homes (12)



* ACH50 ≥ 3.0

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Theory #1

This isn't as much of a problem in older / leakier homes

Not necessarily…

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Theory #2

Mechanically moved air heat helps circulate, reduce CO2 levels

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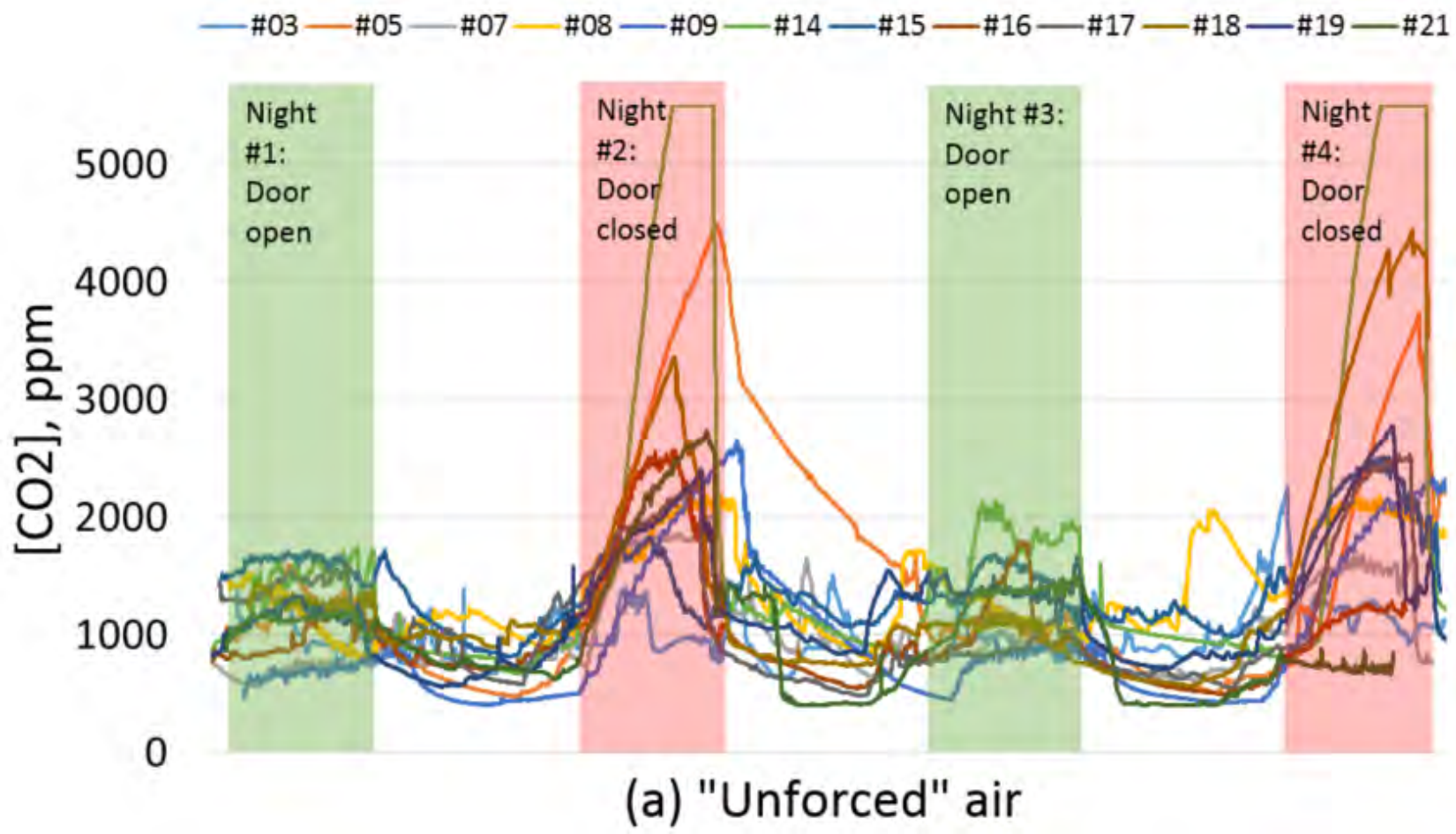
Theory #2: Unforced air (12)



* No mechanically moved air heat

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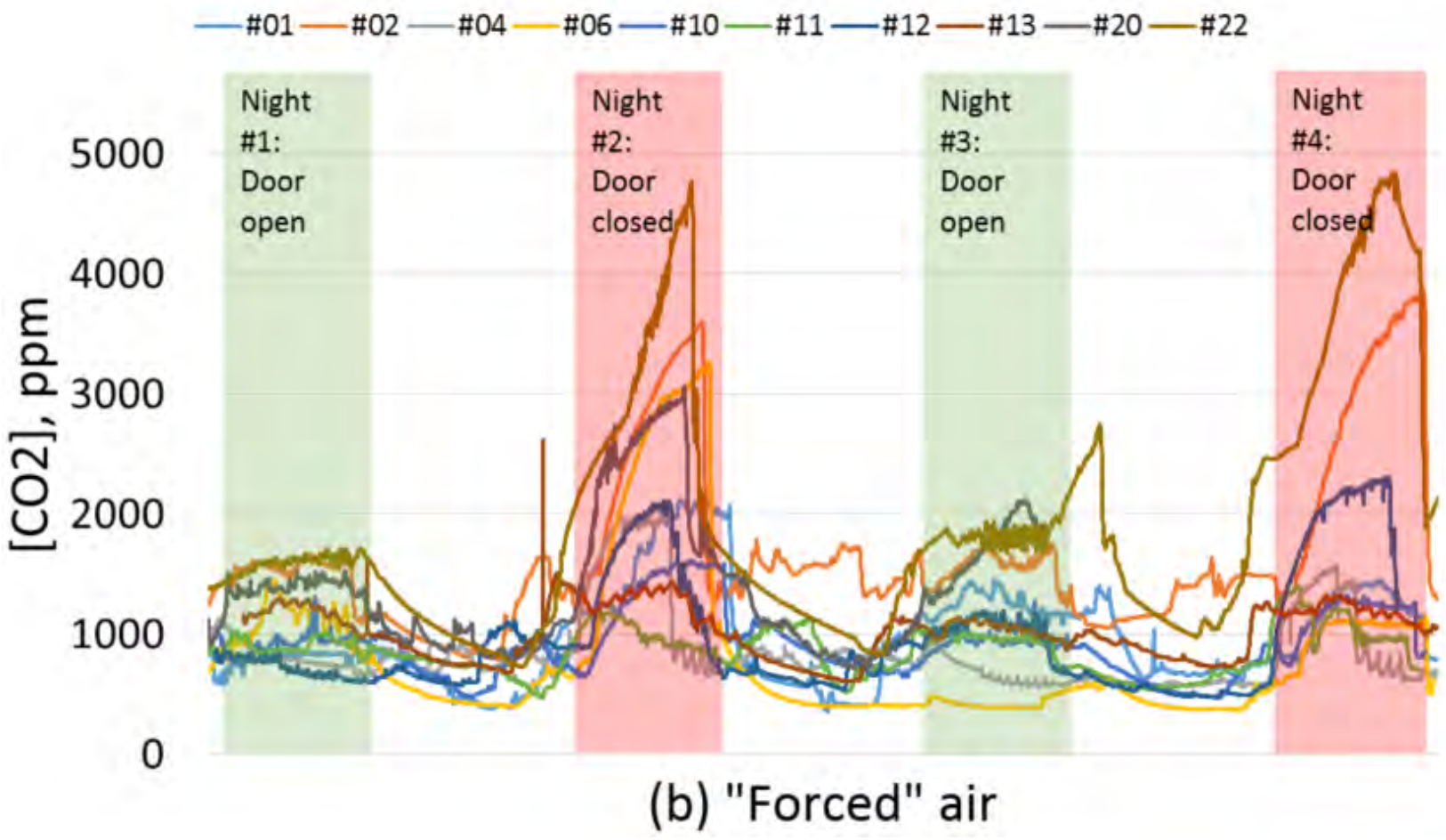
Theory #2: Forced air (10)



* With mechanically moved air heat

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Theory #2

Mechanically moved air heat helps circulate, reduce CO_2 levels

Not necessarily…

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Theory #3

Peak CO2 levels is linked to number of occupants and bedroom volume

I.e. the more people/pets and the smaller the bedroom, the worse things will look

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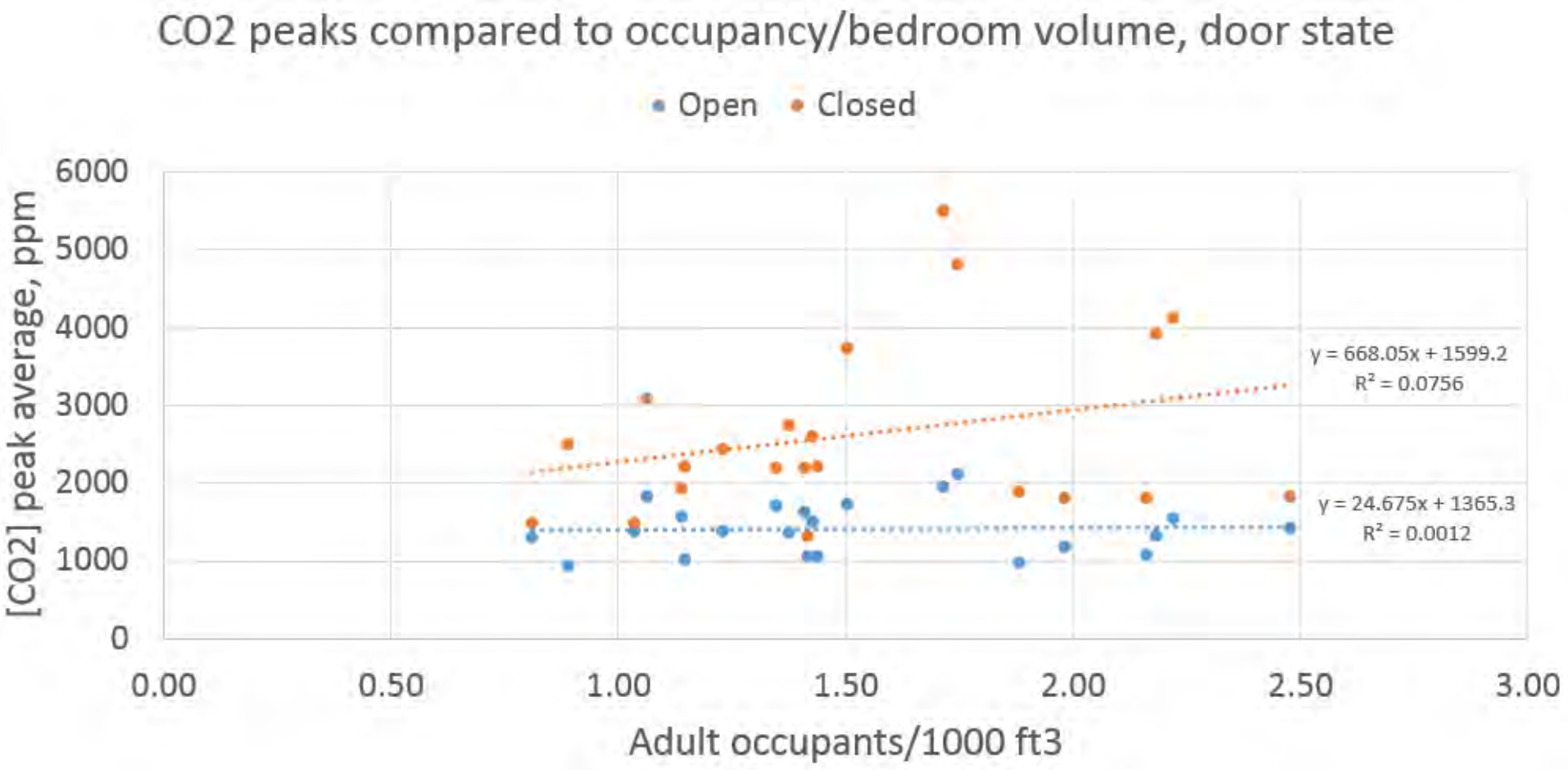
Theory #3: Occupancy/volume



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Theory #3

Peak CO2 levels is linked to number of occupants and bedroom volume

Yes, but:

a) Not as clearly as you may expect
b) What do you do with that?

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Theory #4

Intentional balanced ventilation helps

(or at least exhaust ventilation with controls)

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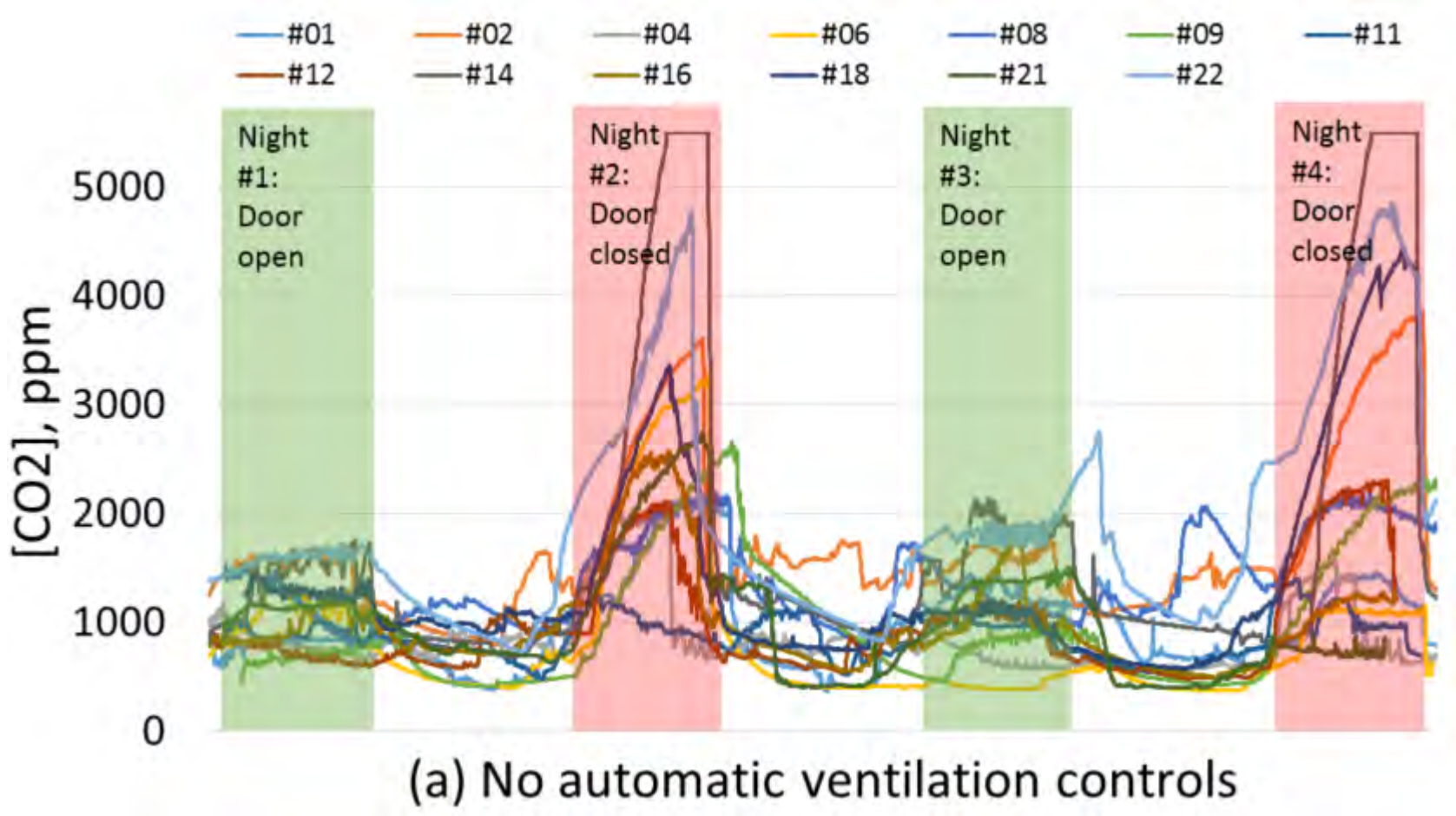
Theory #4: Homes with no automatic ventilation controls (13)



* No ventilation or ventilation only on manual switches

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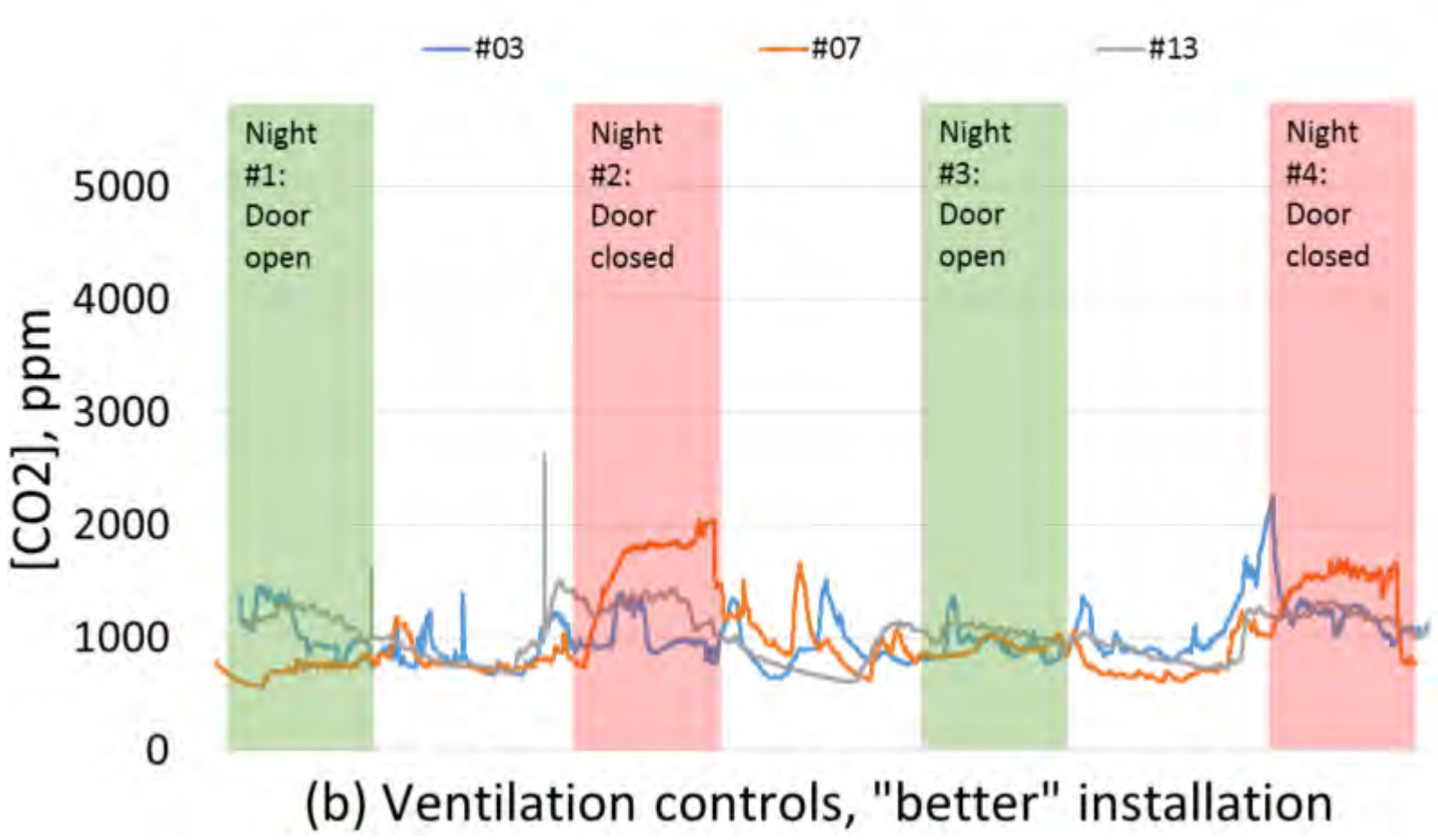
Theory #4: Homes with "better" installation and controls (3)



* Automatic controls and ventilation within 50% of ASHRAE 62.2-2013 whole-house flow rate

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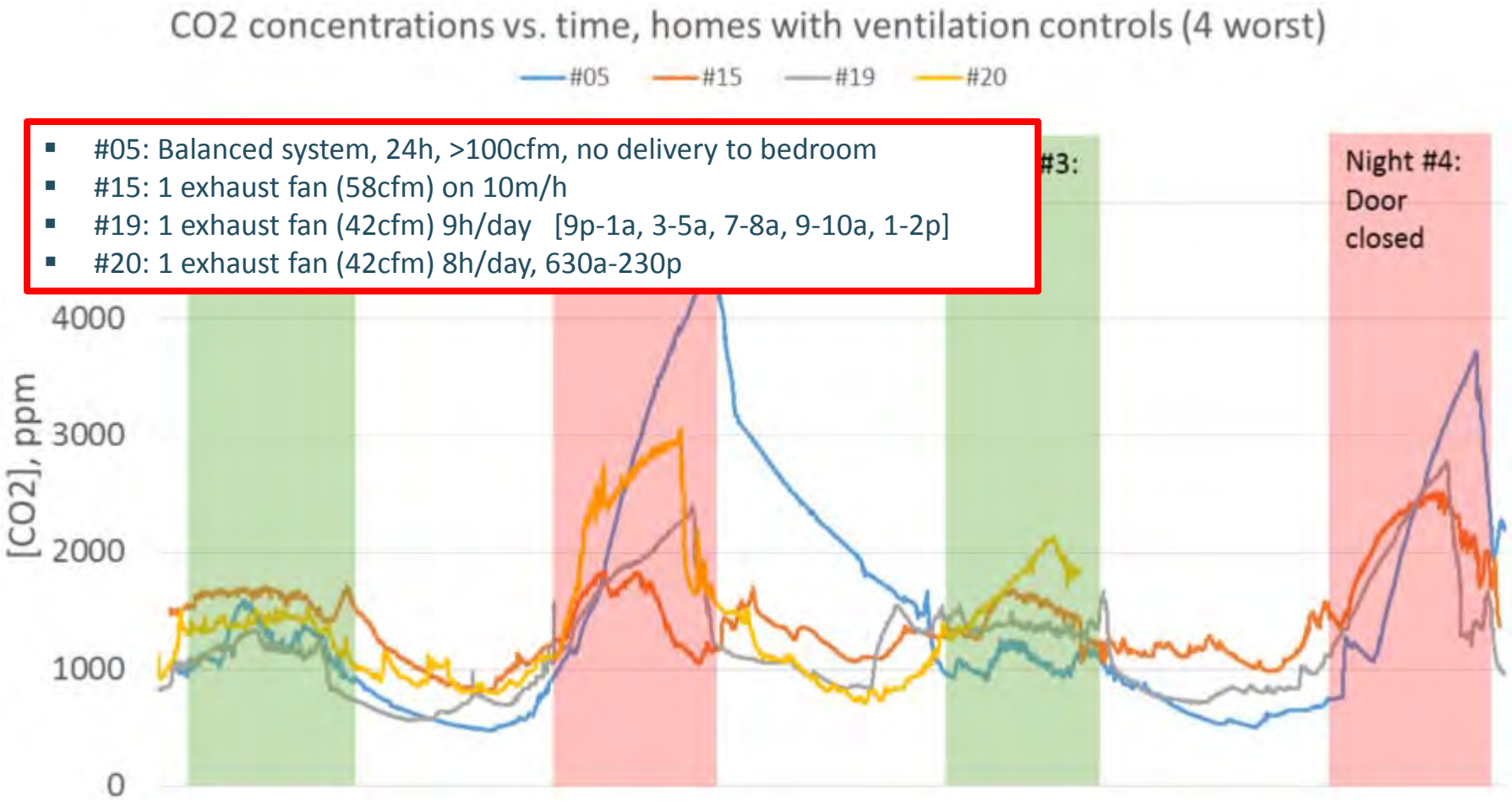
Theory #4: Homes with controls or balanced system but sub-par install (4)



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Theory #4

Intentional balanced ventilation helps

(or at least exhaust ventilation with controls)

Probably, yes

Especially when using best practices

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A word on Vermont code compliance

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Vermont energy code

Need to do both:

1. **Spot ventilation**: All bathrooms with a shower or tub need an exhaust fan that pulls 50 cfm (intermittent) or 20 cfm (24 hr/day)
2. **Whole-house system** that
   a. Meets flow (cfm) requirement for home size
   b. Has **automatic control** (runs without someone needing to turn it on)
   c. ENERGY STAR or equivalent equipment

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How many would pass?

None! Of the 22 homes,

- 10 failed the spot ventilation test
- 21 failed the whole house system test (on flow rate or controls)
- None passed both

Code = the worst you can legally build to

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Impacts and solutions

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CO2 levels > 1000 ppm

- Possible/probable impacts on cognitive function
- Sensitive individuals may experience symptoms like headaches, poor sleep quality, a general feeling of "stuffiness," etc.
- Higher likelihood that one or more other (likely worse) pollutants in the home are elevated
  - Moisture – mold, building durability, exacerbates impacts of VOCs
  - Radon – lung cancer*
  - Particulates – asthma; allergies; coronary and respiratory problems; eye, nose, and throat irritation*
  - VOCs – headaches; damage to liver, kidney, and central nervous system; eye, nose, and throat irritation; cancers*

*Source: https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

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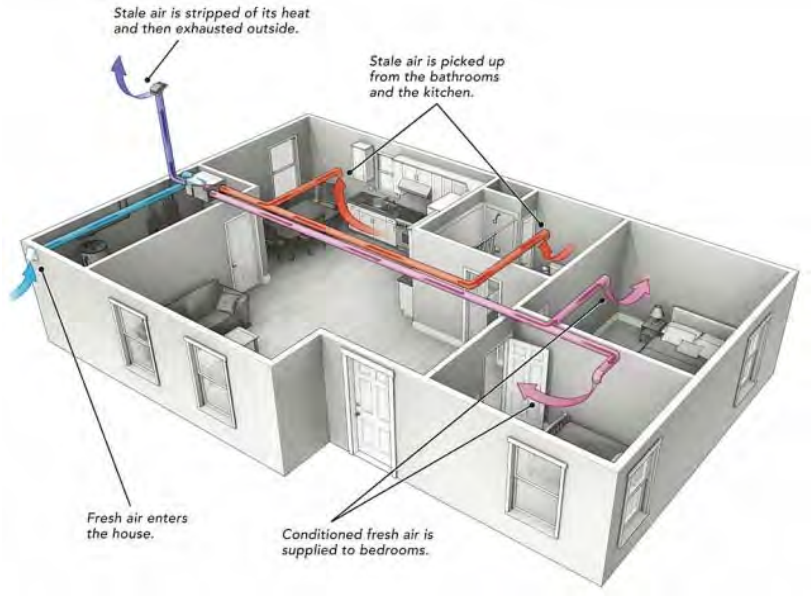
Exhaust-only vs. balanced



Think about bedrooms:

- Where does fresh air come from?
- Does the bath fan ensure fresh air gets to where you want it?

*http://www.greenbuildingadvisor.com/articles/dept/green-building-blog/breathe-easy-balanced-ventilation

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Solutions

- Option 1: **Best***
  - Install whole-home balanced ventilation system with heat/energy recovery
- Option 2: **Okay(?)***
  - Install room-specific / through-wall balanced ventilation system with heat/energy recovery
  - Retrofit controls onto existing bath fans (which may require fan replacements) such that you have 24/7 or at least hourly circulation
- (Probably) **Bad***
  - Do nothing

*Brian's opinion, not objective fact (n.b. objective fact may be elusive)

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Whole-house categories

- **Traditional**
  - High efficiency versions of H/ERVs from Venmar/Broan, Lifebreath, RenewAire, etc. with metal ducting
- **Traditional-plus**
  - With proprietary homerun ducting and integrated design/commisioning; e.g. Zehnder
- **Non-distributed**
  - E.g. Lunos
- **Demand-controlled** with heat pump
  - Build Equinox CERV (Minotair has capability, too)
  - 4 modes, linked to CO_2 and VOC levels
  - Small heat pump brings up delivered air temperature

Passive

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A year onwards:

Time for the ERVs and HRVs…

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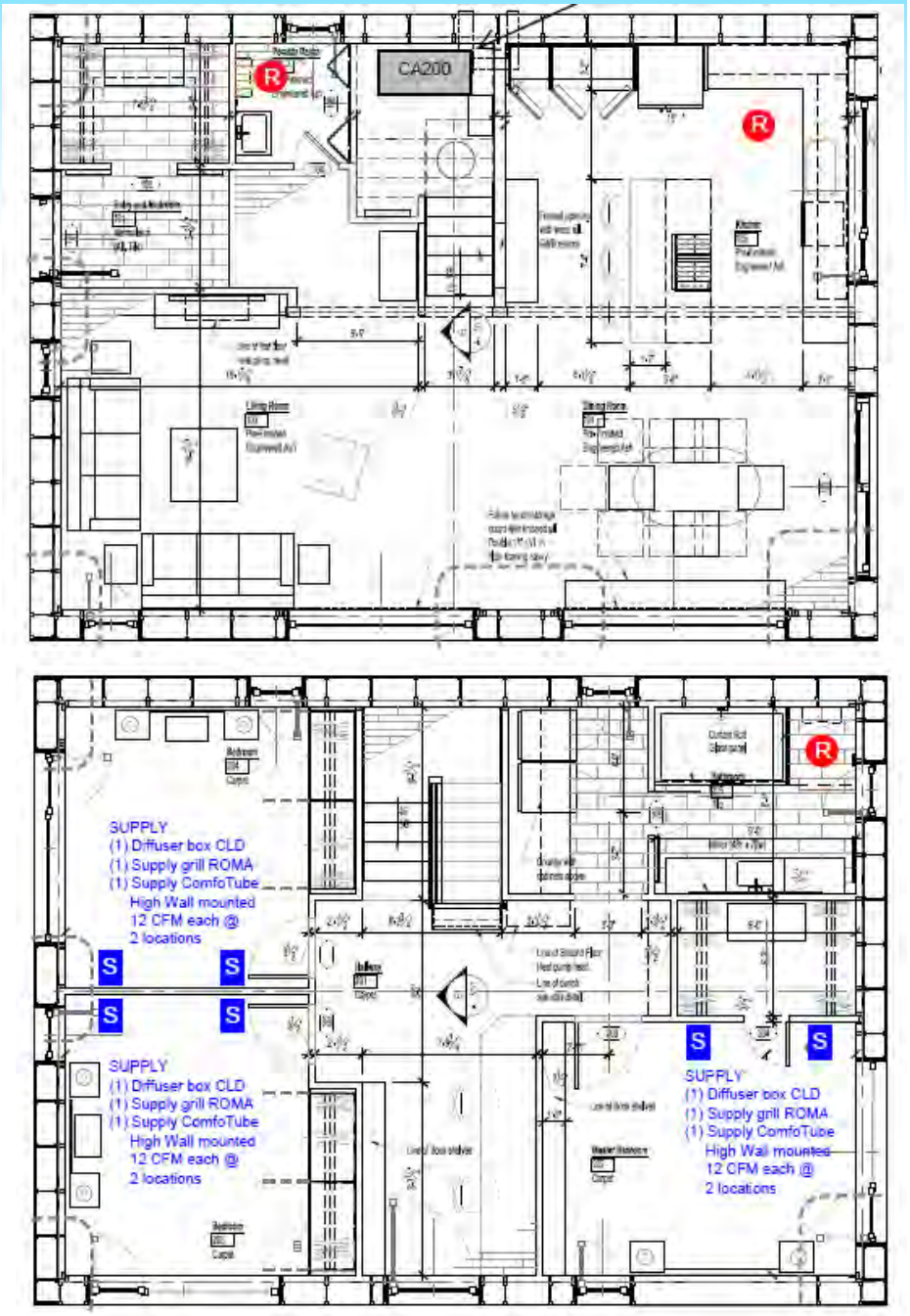
Home A

- New construction
- Zehnder CA200



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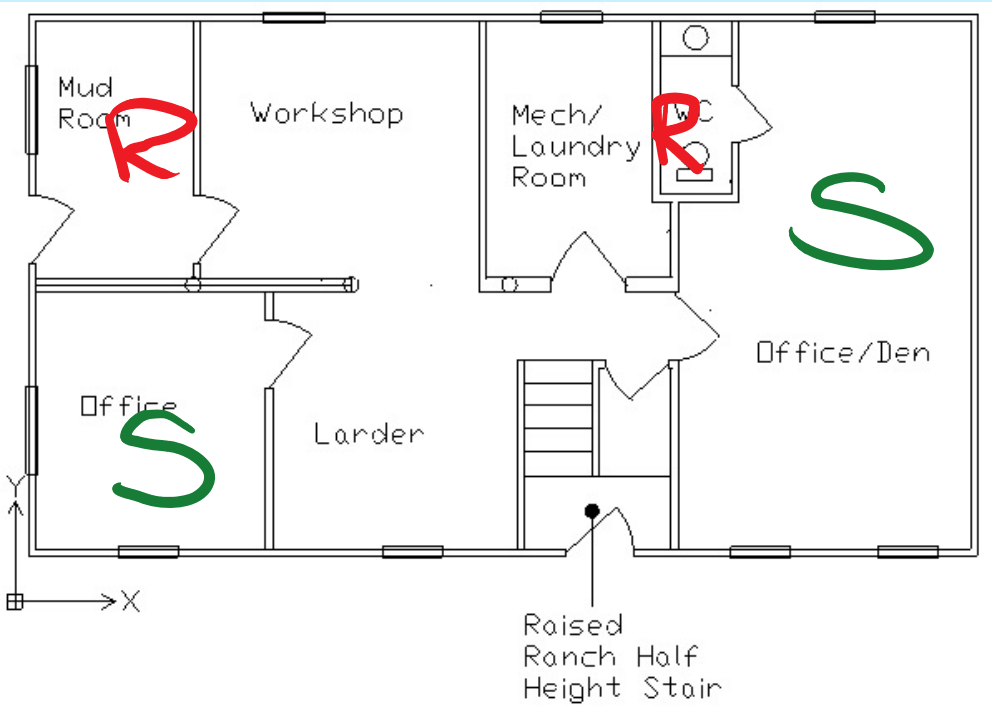
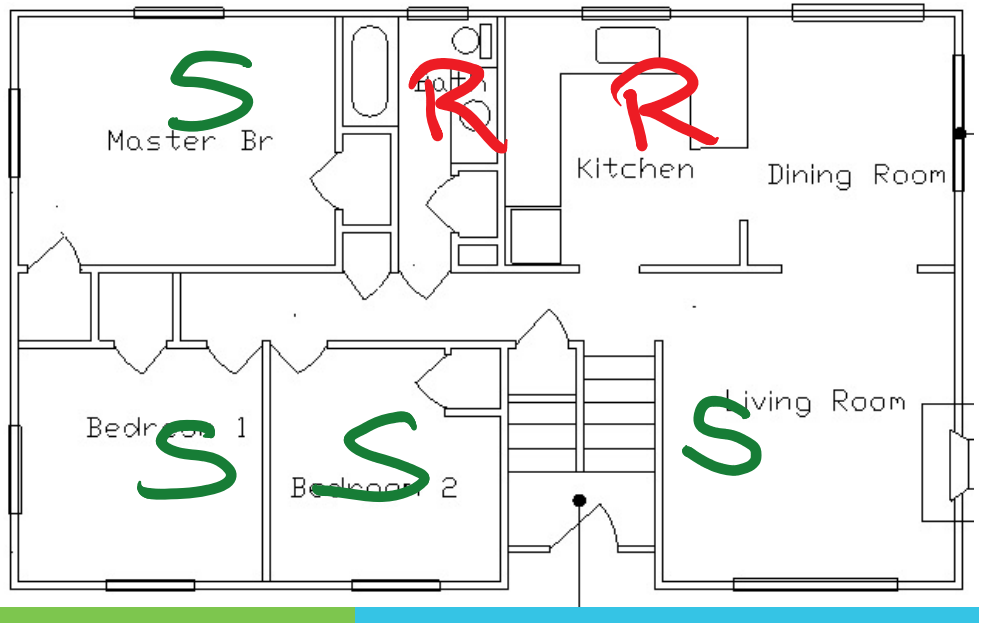
Home B

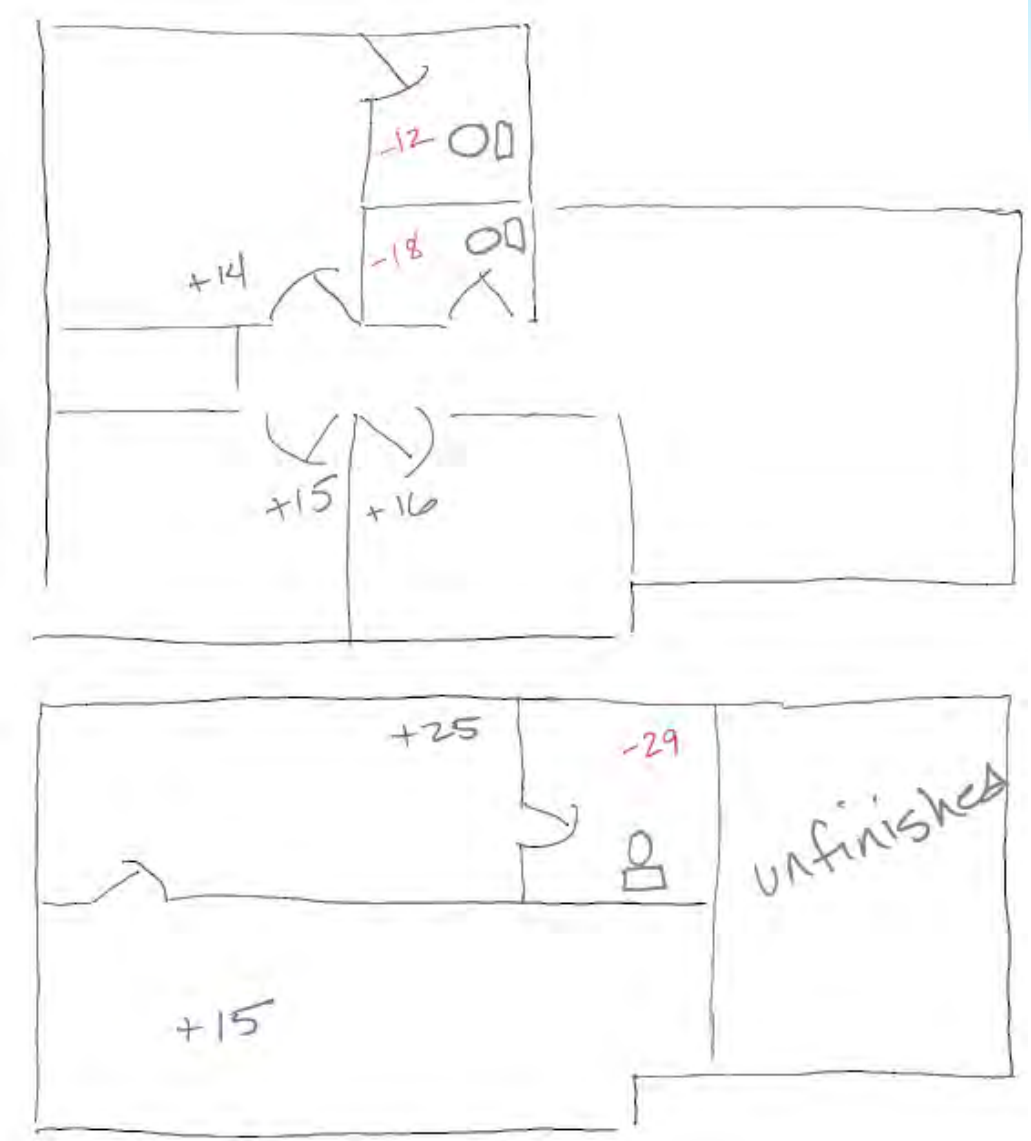
- Retrofit
  - 1976 raised ranch
- Zehnder CA350





Home C

- Retrofit
  - 1956 ranch
- Home #20 in study
- Broan ERV200TE (Venmar X30) with Zehnder tubing



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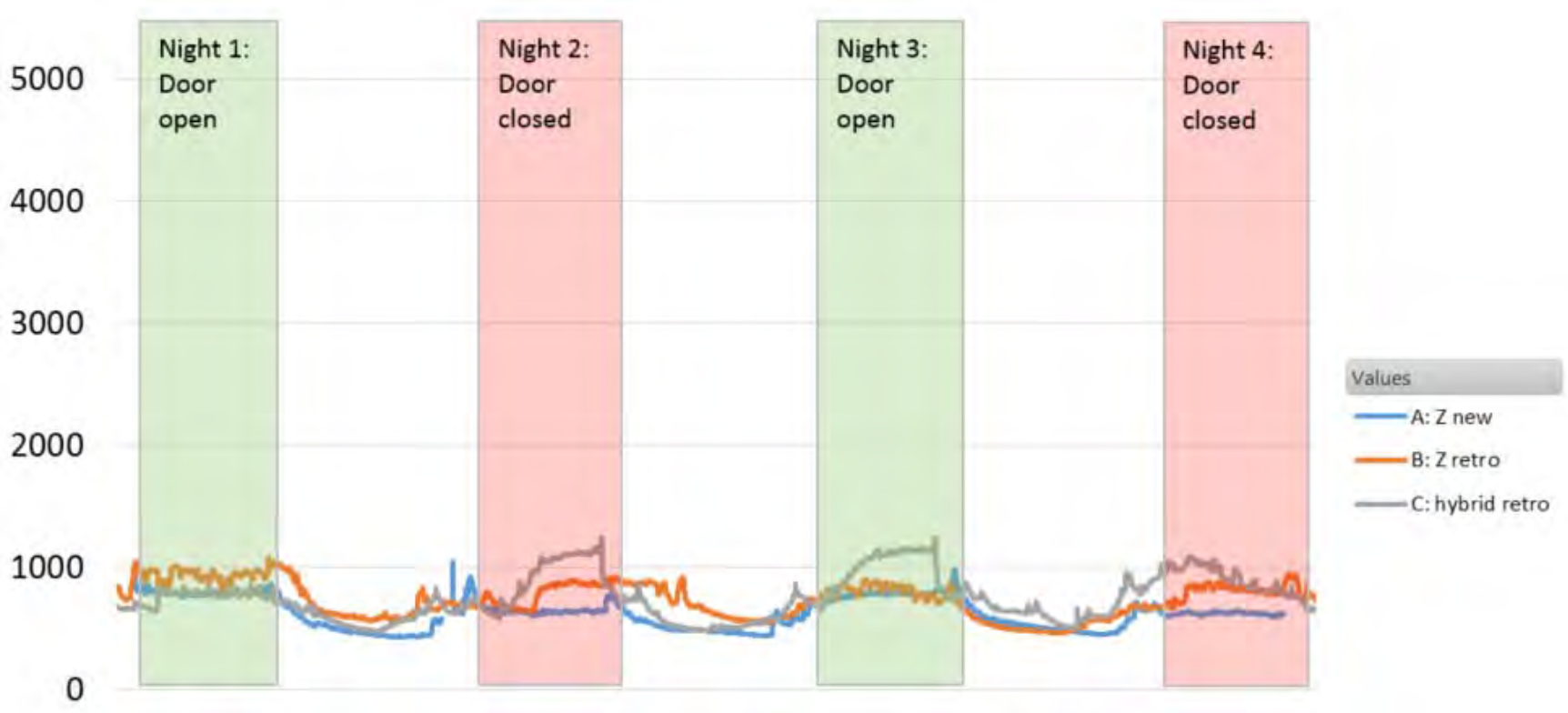
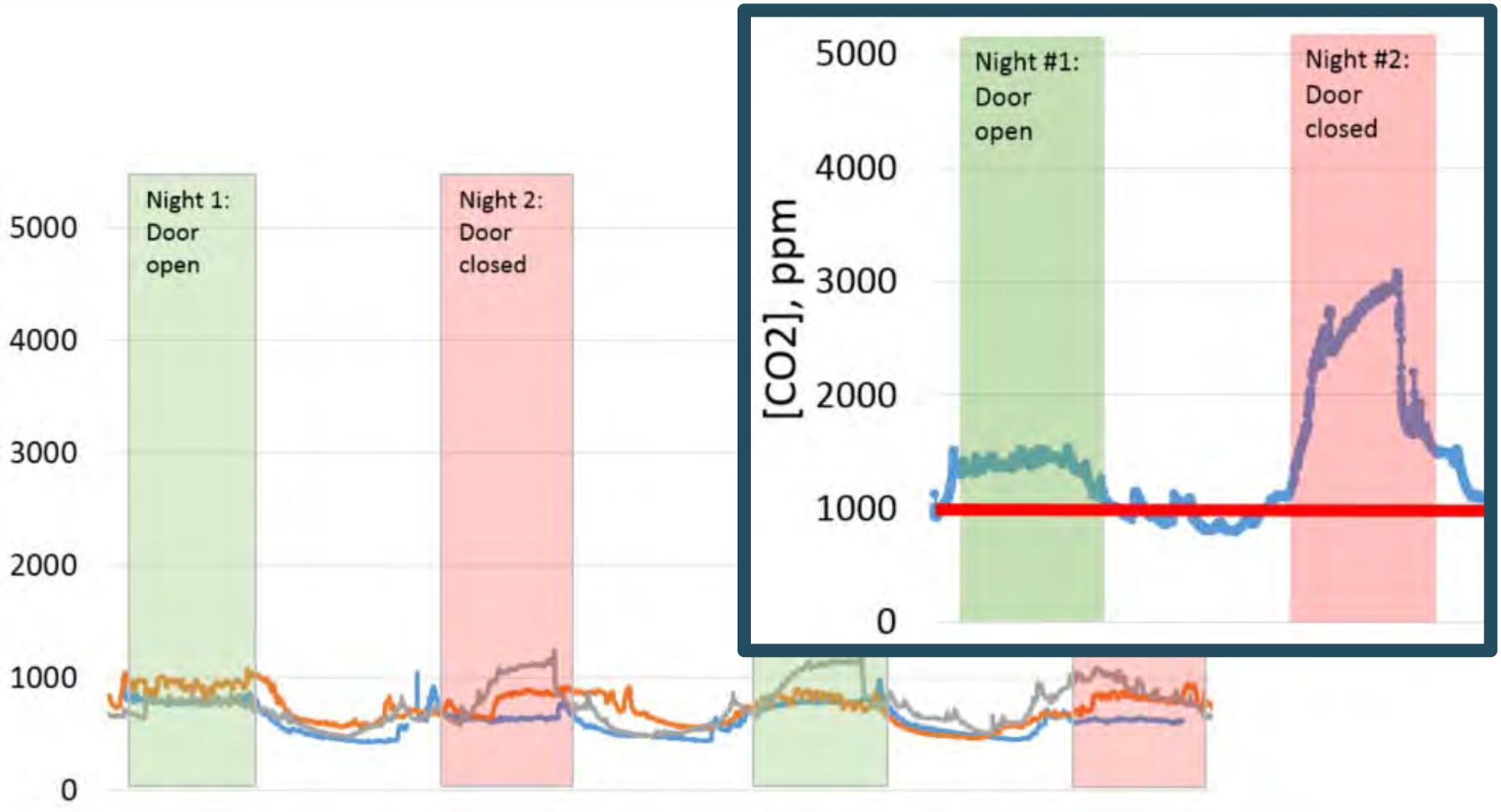
Homes A-C



*House C had door closed on night 3, open on night 4

Homes C before retrofit



*House C had door closed on night 3, open on night 4

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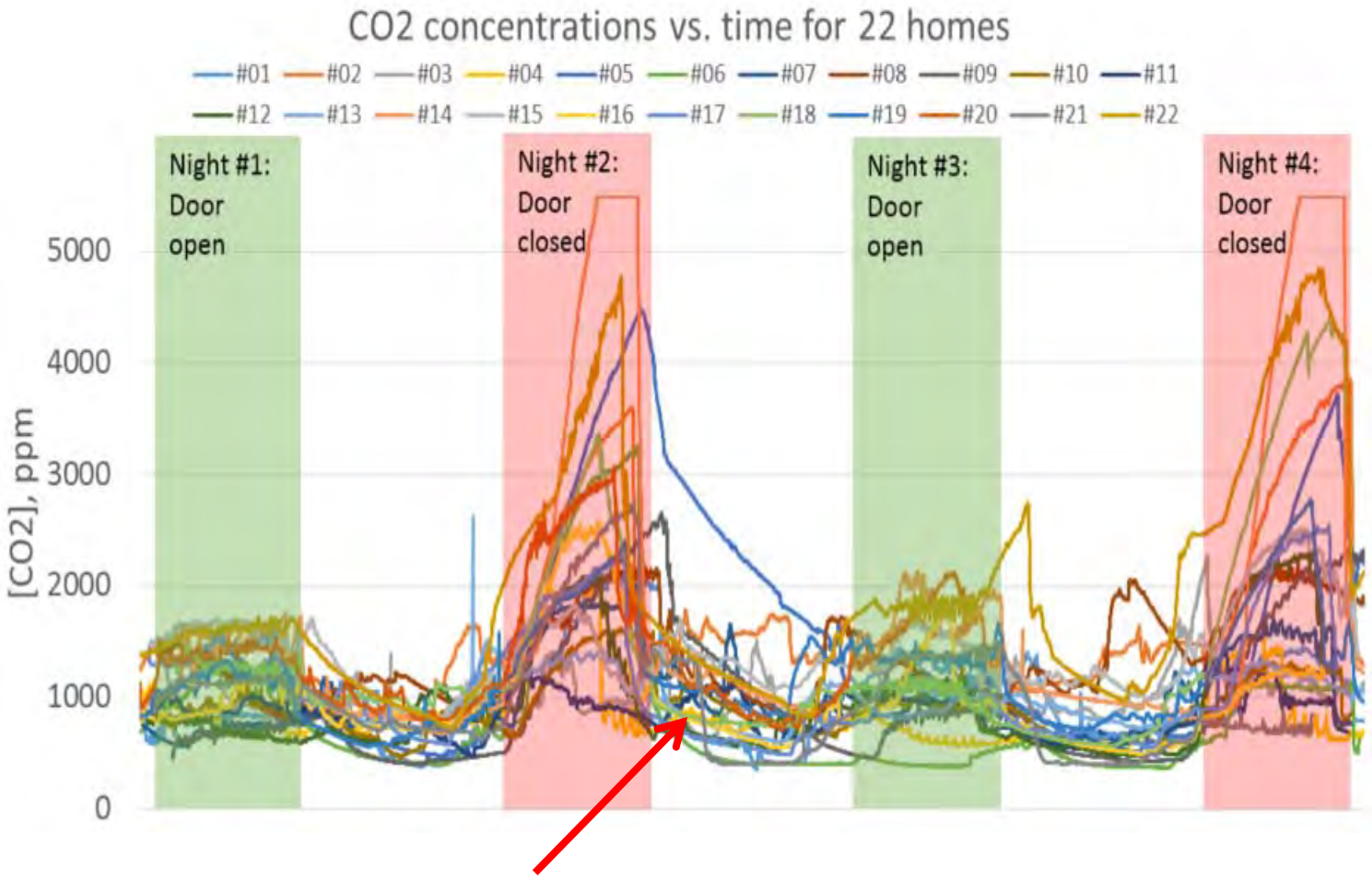
The other 22 homes (repeat)



Many of these homes aren't getting below 800-900 ppm, even after being unoccupied for 12+ hrs

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At what cost?

1.5 yrs of data for a CA350
(we have more examples
that look about the same)

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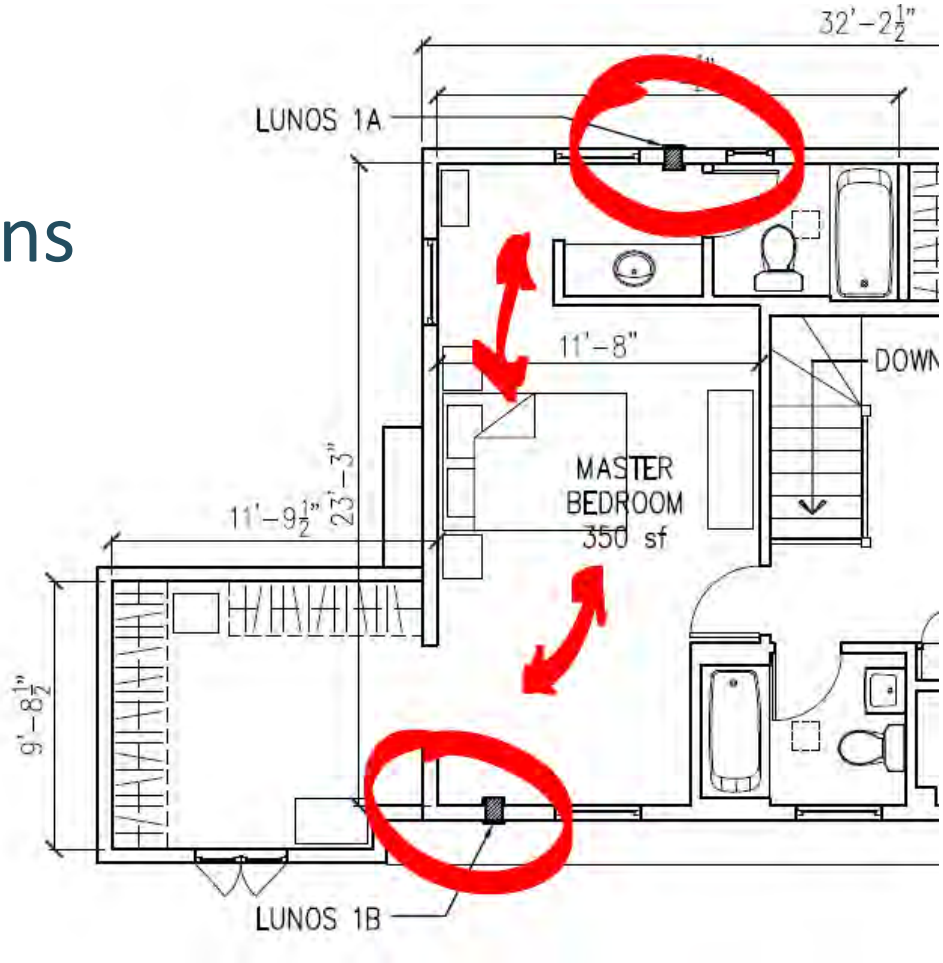
Home D, part 1 (Lunos)

- Retrofit
- Full set (2) Lunos fans in master bedroom



For another example, see also: https://foursevenfive.com/healthy-iaq-at-melpet-apartments-with-lunos-e2-co2-monitoring-shows-heat-recovery-ventilation-works/

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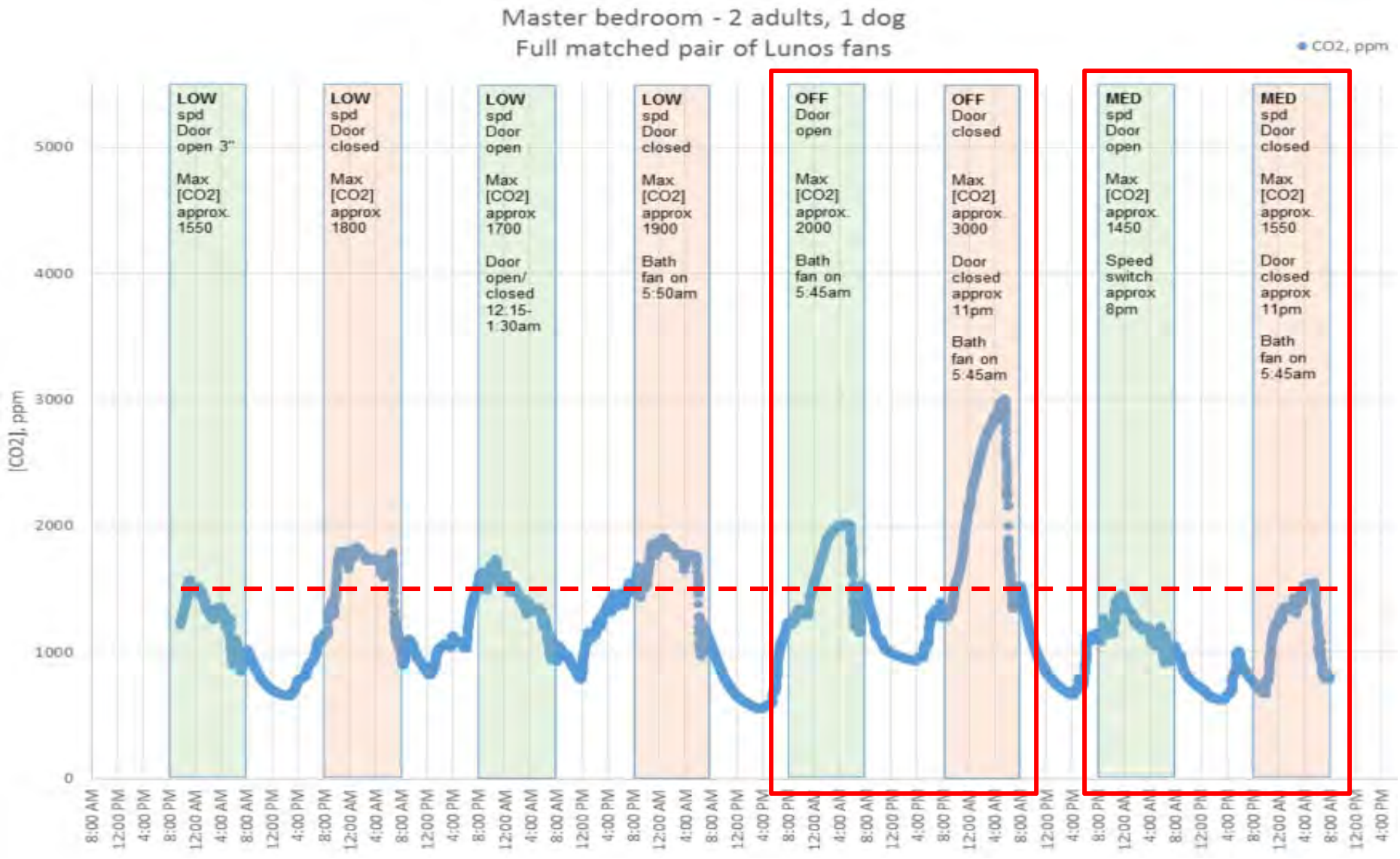
Home D, part 1 (master bedroom)



Home D, part 2

- Retrofit
- Half set (1) Lunos fan in the two kids' bedrooms

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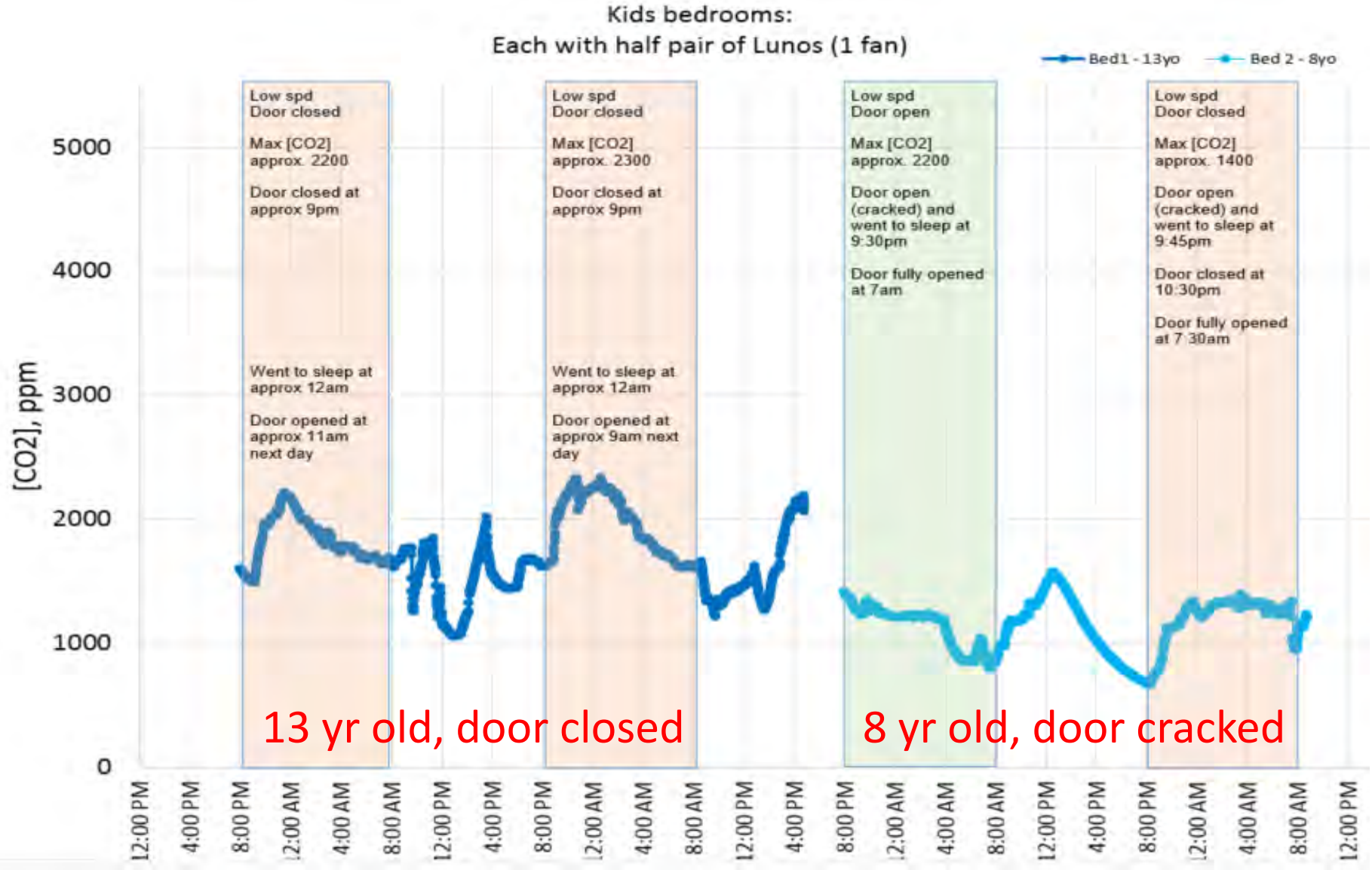
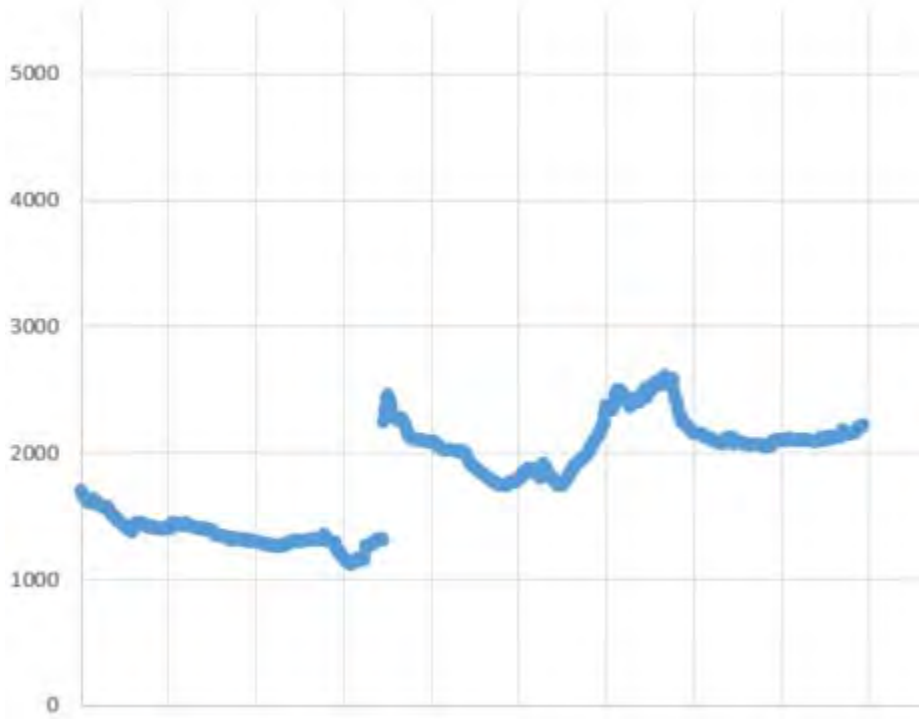
Home D, part 2 (kids' bedrooms)



Home __ (incomplete)

- Retrofit
- Through-wall, single-room system
- 2 obvious peaks occur in 10:00-11:30pm range



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Homes E, F, G, etc.

- Build Equinox CERV
- Demand-controlled “ERV” with CO2 and VOC closed-loop feedback
- Integral heat pump, 4 modes of operation

Mode	Fresh air?	Heat pump on?
RH = Recirc heat	No	Yes
VH = Vent heat	Yes	Yes
Vent setpoint	Yes	No
Off	No	No

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Homes E, F, G, etc. (cont.)

- Access to 66 homes with CERV systems
  - 81 of the 82 Zero Energy Modular (ZEM) homes in Vermont use this ventilation system
  - Plus a handful of other new/existing homes
- Sample ZEM layout:

Plans courtesy of Pill-Maharam Architects.

Home E, last week

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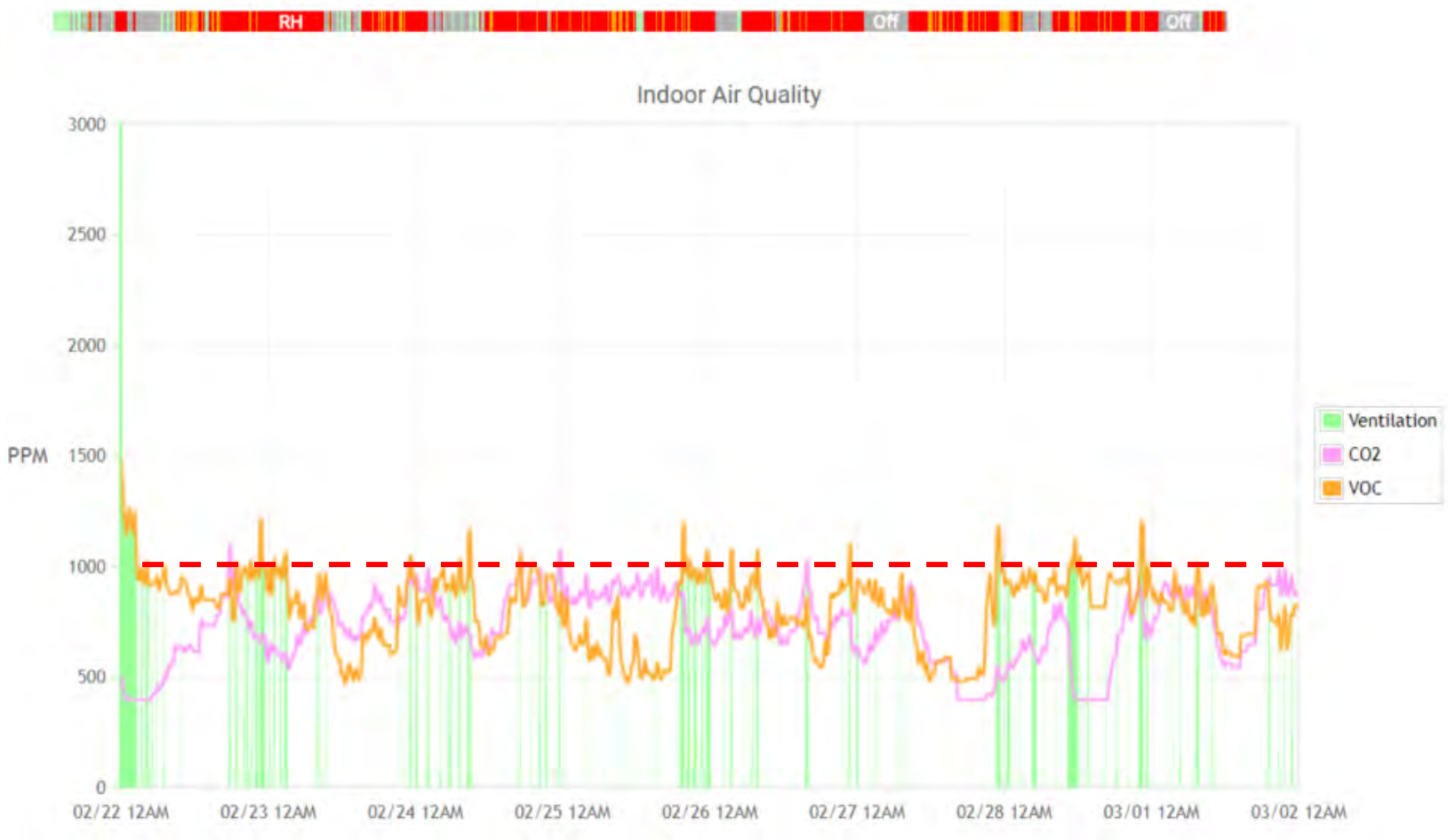
Home F, last week



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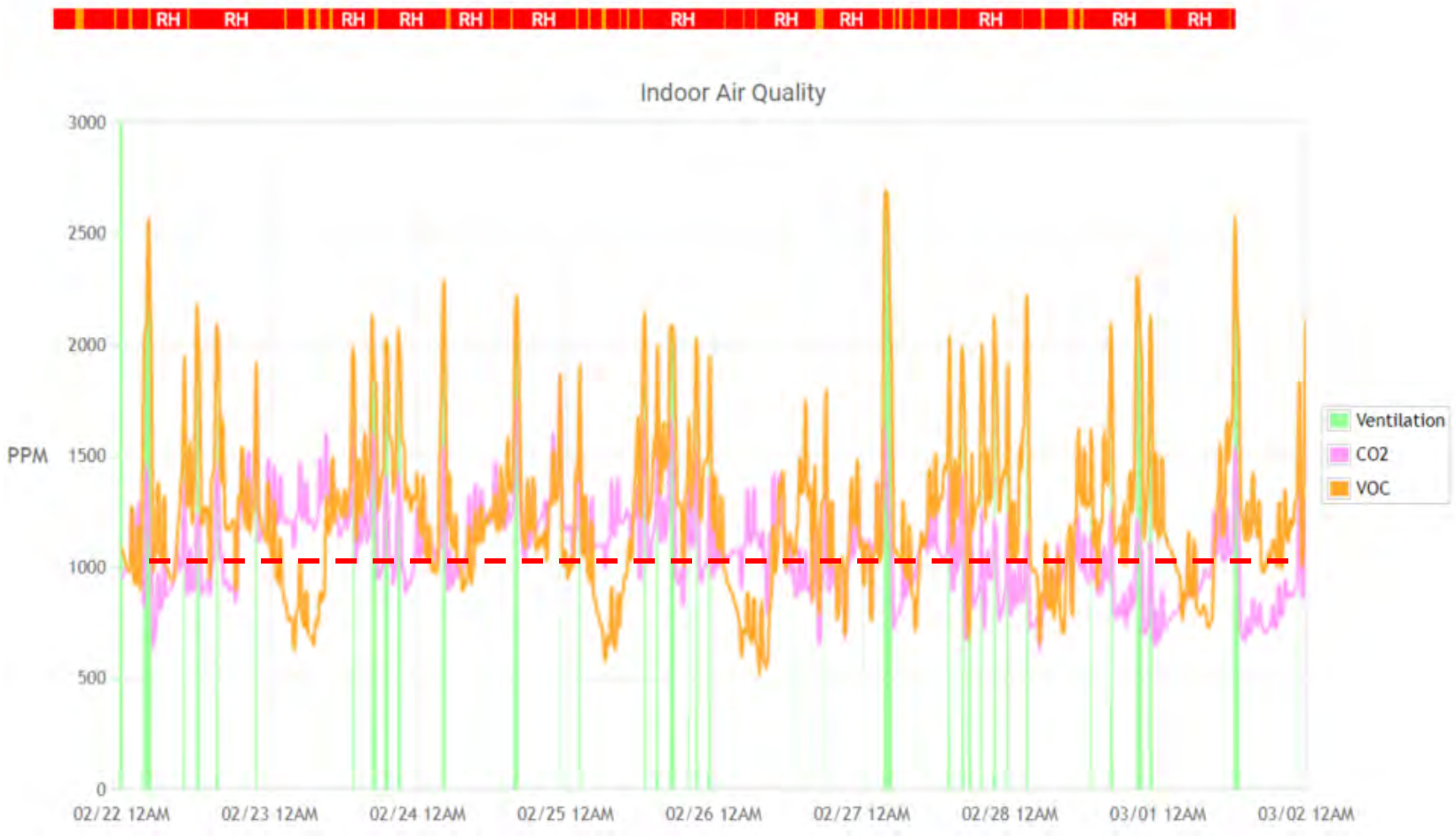
Home G, last week

Alternate slide titles:
"Why you shouldn't vape" or
"Why demand control is good"



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Quick notes on equipment

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All systems ≠ good

Consider equipment with:

- Coordinated, adequate distribution*
- High efficiency (higher delivered temperature)
- Nice to have: Swappable ERV/HRV core
- Nice to have: Ability for MERV 13 or HEPA filter upgrade (allergies, etc.)
- Easy accessibility** and simple controls

*Centralized systems?

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Wrap-up

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Takeaways

1. Recent evidence shows that CO2 levels above 1000 ppm aren't desirable
2. High CO2 is an indicator that other pollutants may be, too (VOCs, particulates, unwanted moisture, etc.)
3. #1 and #2 can mean significant health impacts
4. Residential ventilation leaves much to be desired – exactly in the places where you likely spend the most time
5. Most of us have ~~a problem~~ sub-optimal ventilation (me, too)
6. Solutions vary widely in price, complexity, and effectiveness
7. **No-brainer for new construction***

* My opinion

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A note on quick fixes

The version published in BuildingEnergy ends:

In situations where installing an HRV or ERV is not feasible, data from this study suggests that retrofitting exhaust fans with automatic controls and ensuring flow rates in accordance with energy codes and ventilation standards is a backup strategy worth considering.

And if nothing is done? At least open that bedroom door at night.

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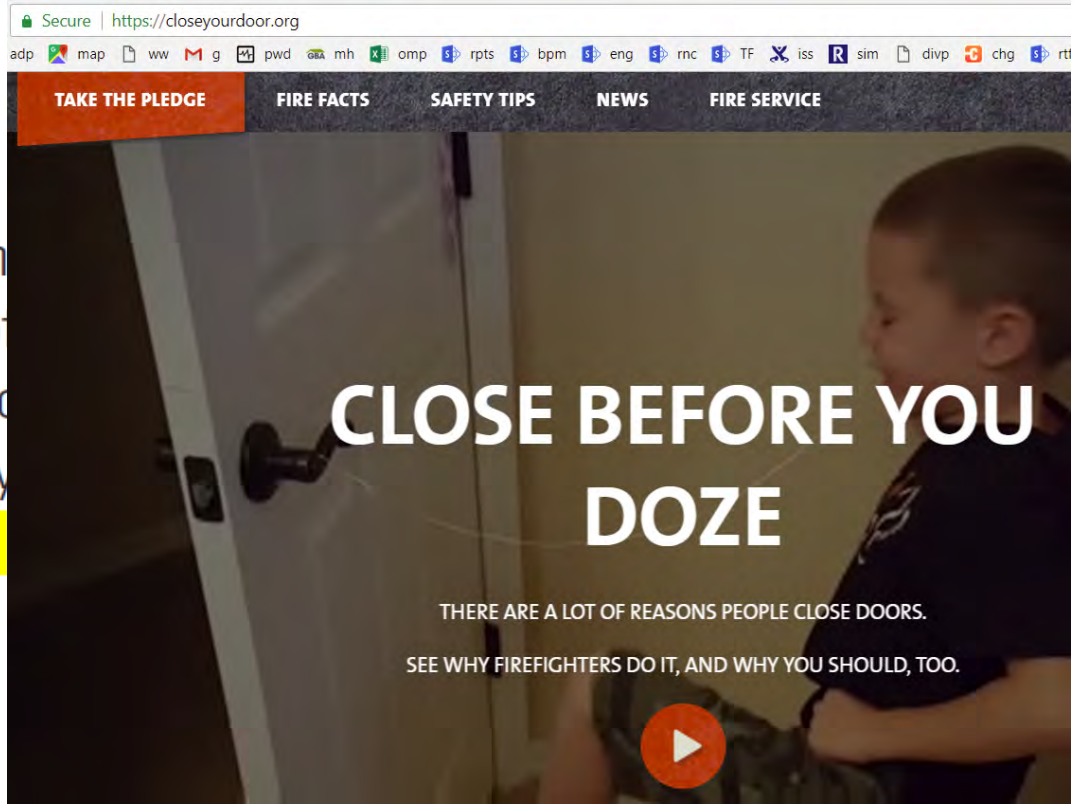
A note on quick fixes

The version publishe

In situations where installin
this study suggests that retro
and ensuring flow rates in acc
standards is a backup strategy
And if nothing is done? At



…yet a “Fire and Egress Door Assembly Professional” shared that bedrooms doors should remain closed at night

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More info…

- Article in Fall 2017 BuildingEnergy magazine

  http://www.nxtbook.com/naylor/ENEB/ENEB0217/index.php#/32

- Full report

  https://www.efficiencyvermont.com/news-blog/whitepapers/breathe-well-sleep-well-improving-ventilation-in-cold-climate-homes

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More info…

- High efficiency HRV/ERV list

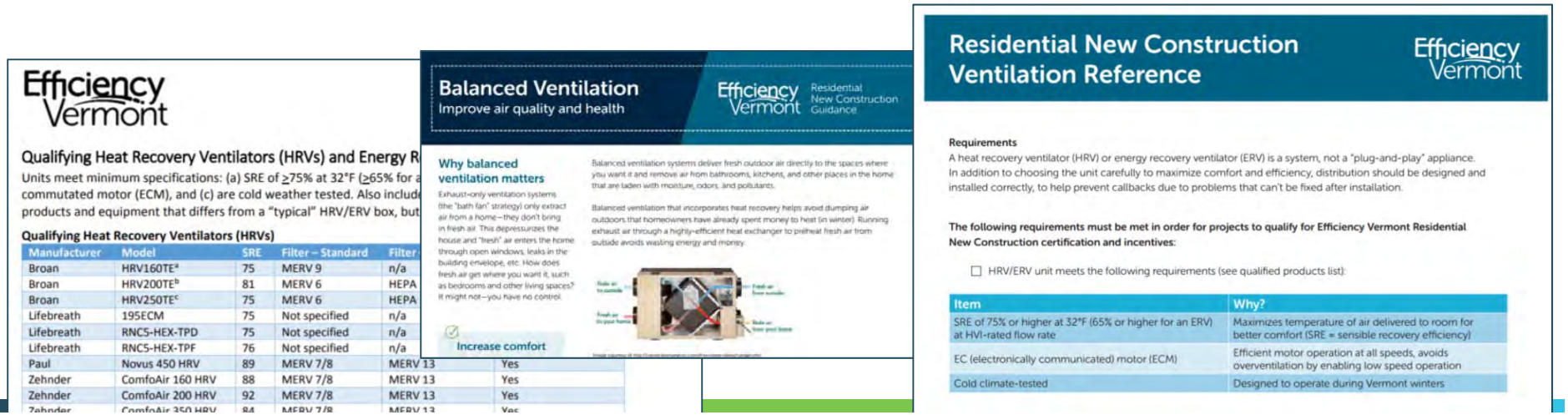
  https://contractors.efficiencyvermont.com/Media/Default/docs/programs/new-construction/efficiency-vermont-hrv-erv-qpl.pdf

- 1-page guide (homeowner focused)

  https://contractors.efficiencyvermont.com/Media/Default/docs/programs/new-construction/efficiency_vermont_balanced_ventilation.pdf

- Efficiency Vermont program requirements

  https://contractors.efficiencyvermont.com/Media/Default/docs/programs/new-construction/efficiency_vermont_balanced_ventilation_ref.pdf



Help:

This is for every home

(not just for “high performance”
or that boundary-pushing client)

Efficiency Vermont

bjust@veic.org

Efficiency Vermont

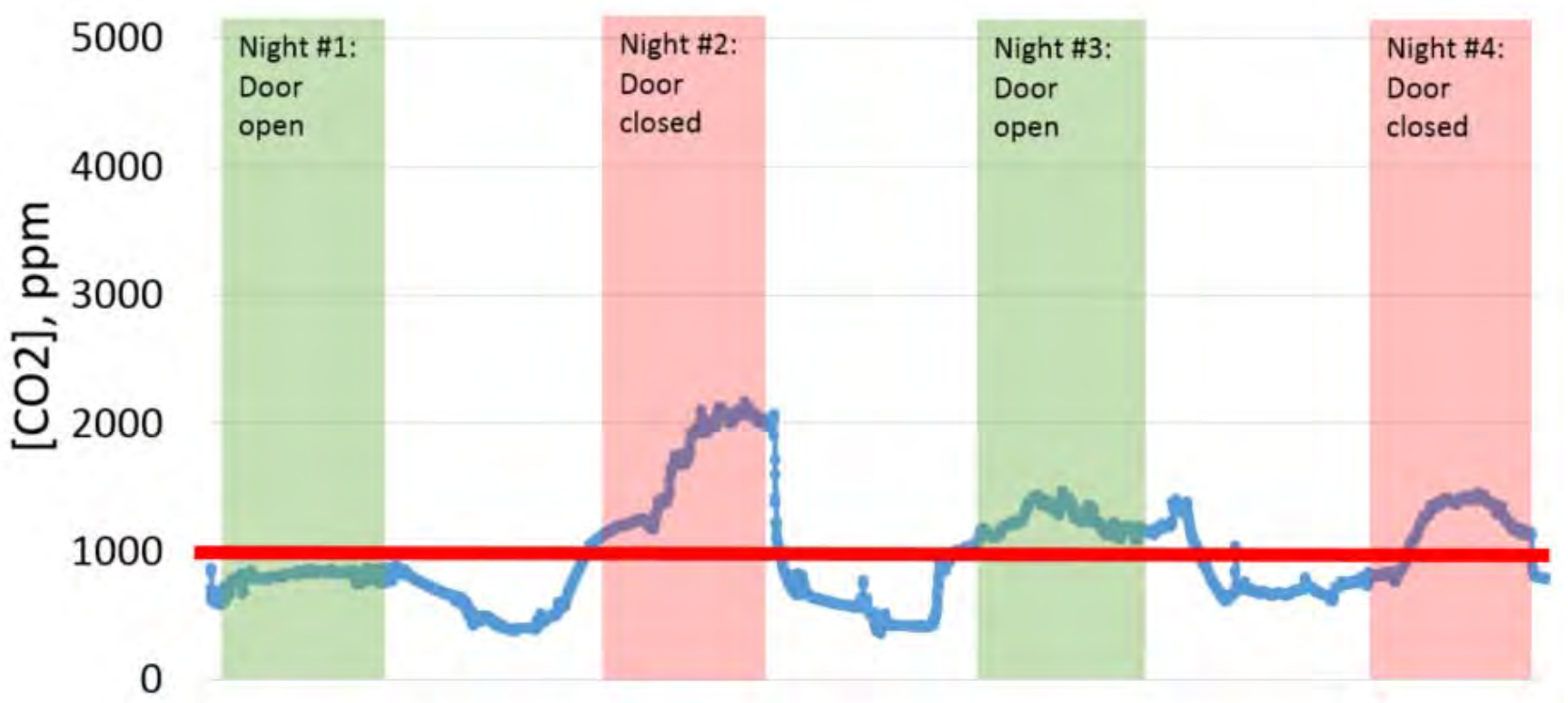
Extras

Efficiency Vermont

Home 1

Location: Ferrisburgh, VT
Dates: 17-21 Nov 2016
Type: Single family detached

ACH50	3.00
Ventilation strategy	EOV, <u>without</u> automatic controls
Occupants (avg)	1.5
Bedroom volume (ft^3)	882
Mechanically moved air (heat)?	Yes, CCHP
Year built/substantial reno	1978
Max [CO2], door open nights (ppm)	1465
Max [CO2], door closed nights (ppm)	2162

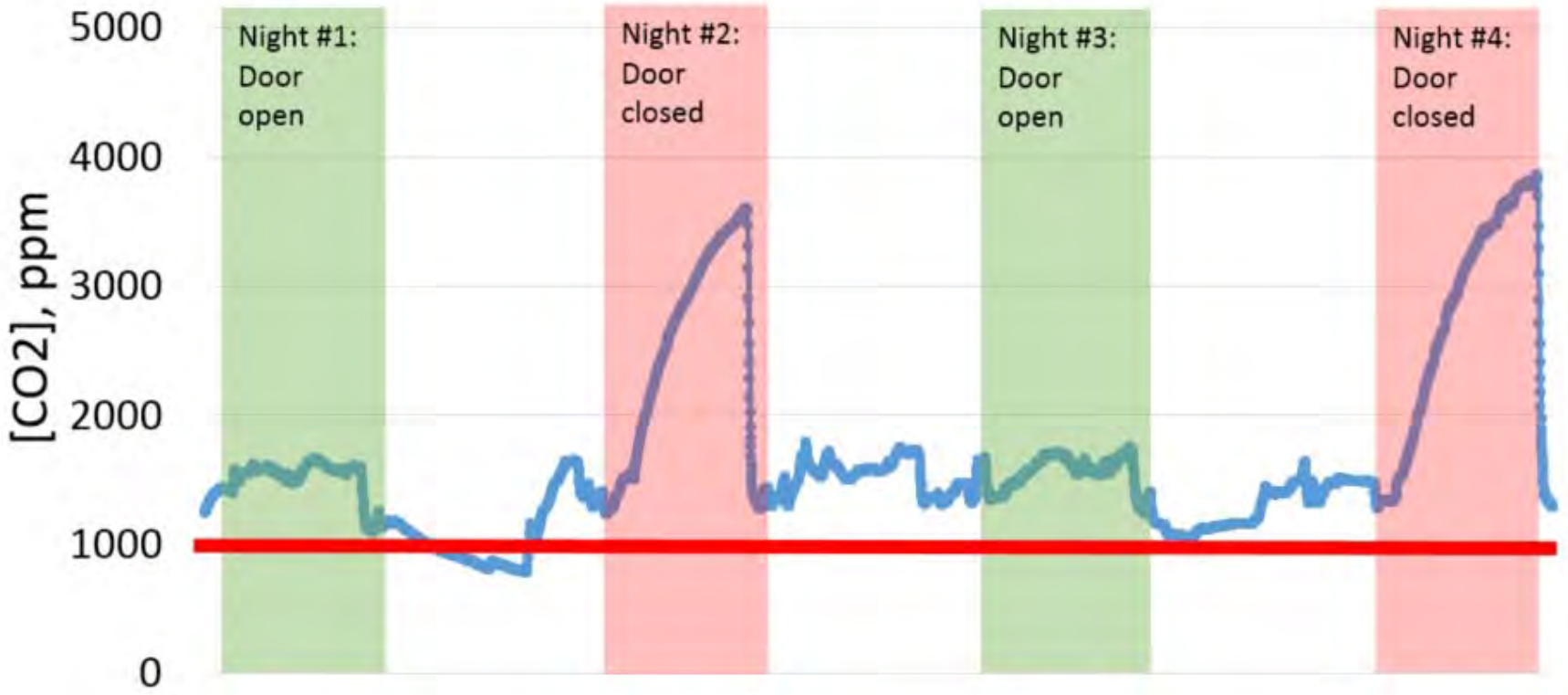


Efficiency Vermont

Home 2

Location: Colchester, VT
Dates: 22-26 Nov 2016
Type: Single family detached

ACH50	6.29
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	1.5
Bedroom volume (ft^3)	998
Mechanically moved air (heat)?	Yes, furnace
Year built/substantial reno	1950
Max [CO2], door open nights (ppm)	1758
Max [CO2], door closed nights (ppm)	3860



Efficiency Vermont

Home 3

Location: Burlington, VT
Dates: 28 Nov - 2 Dec 2016
Type: Single family detached

ACH50	2.41
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	2.5
Bedroom volume (ft^3)	1008
Mechanically moved air (heat)?	No
Year built/substantial reno	1926
Max [CO2], door open nights (ppm)	1456
Max [CO2], door closed nights (ppm)	2260

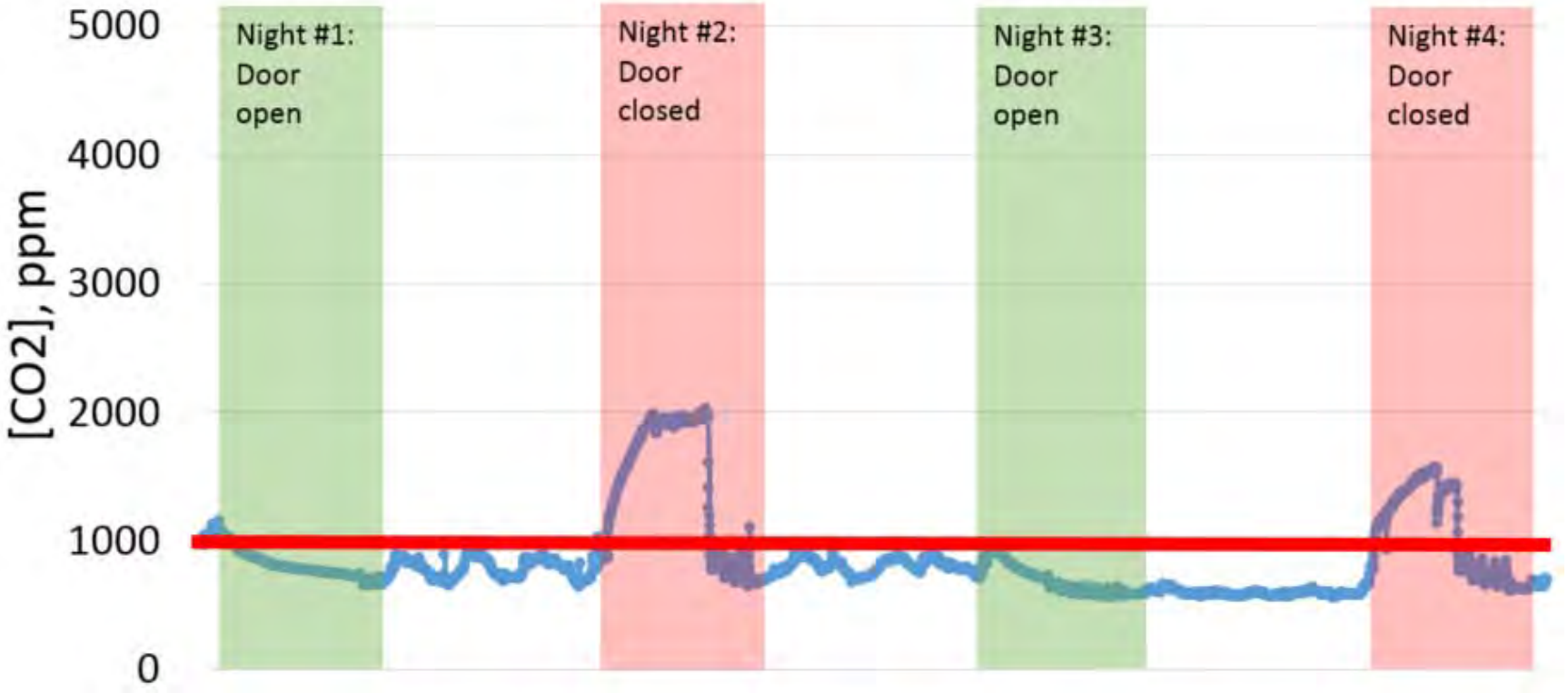
*(1) Exhaust only fan, continuous

Efficiency Vermont

Home 4

Location: Burlington, VT
Dates: 2-6 Dec 2016
Type: Single family detached

ACH50	10.07
Ventilation strategy	EOV, <u>without</u> automatic controls
Occupants (avg)	2
Bedroom volume (ft^3)	1040
Mechanically moved air (heat)?	Yes, furnace
Year built/substantial reno	1955
Max [CO2], door open nights (ppm)	1160
Max [CO2], door closed nights (ppm)	2028



Efficiency Vermont

Home 5

Location: Shelburne, VT
Dates: 6-10 Dec 2016
Type: Single family detached

ACH50	1.75
Ventilation strategy	HRV*
Occupants (avg)	2
Bedroom volume (ft^3)	900
Mechanically moved air (heat)?	No
Year built/substantial reno	1968
Max [CO2], door open nights (ppm)	1596
Max [CO2], door closed nights (ppm)	4486

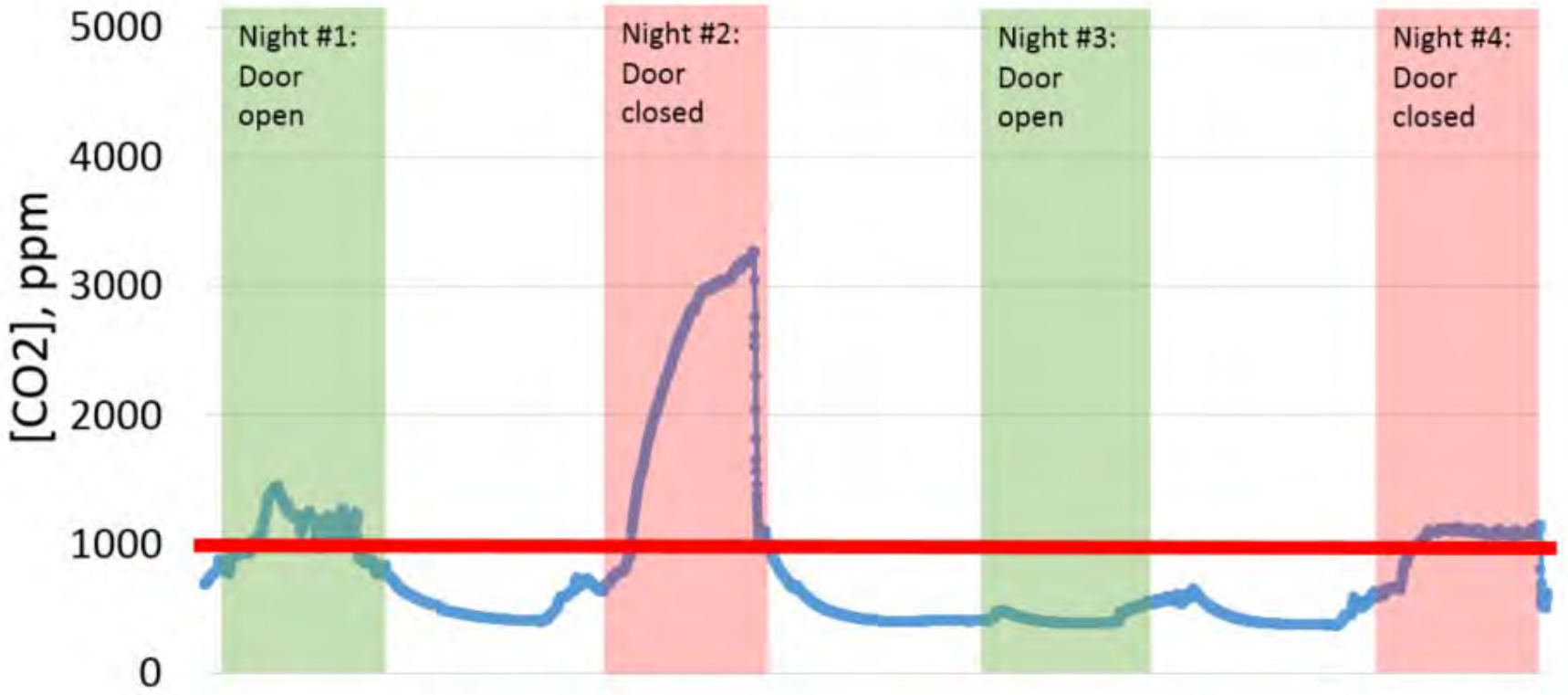
*Continuous, but no supply to tested bedroom

Efficiency Vermont

Home 6

Location: Burlington, VT
Dates: 12-16 Dec 2016
Type: Single family attached

ACH50	2.61
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	1.5
Bedroom volume (ft^3)	1308
Mechanically moved air (heat)?	Yes, CCHP + fireplace
Year built/substantial reno	1899
Max [CO2], door open nights (ppm)	1449
Max [CO2], door closed nights (ppm)	3268

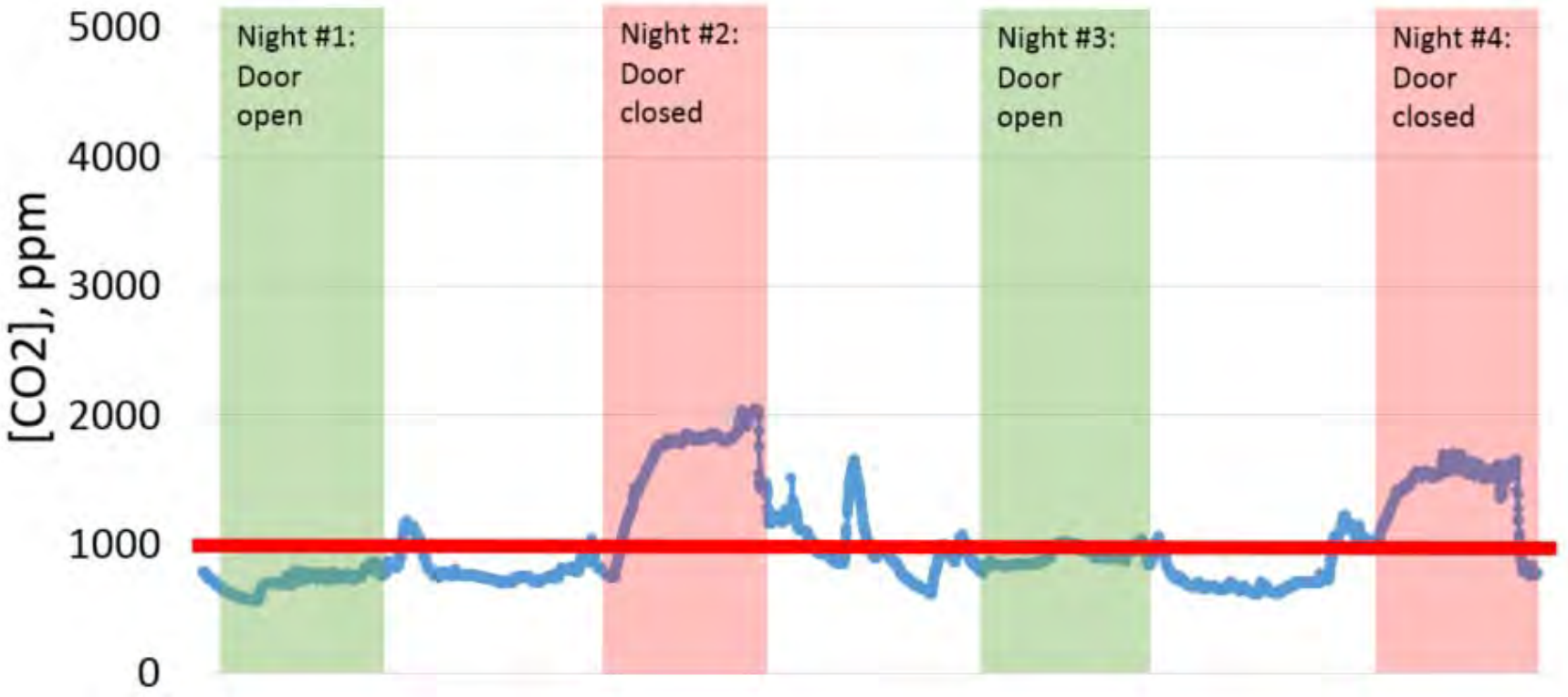


Efficiency Vermont

Home 7

Location: Burlington, VT
Dates: 16-20 Dec 2016
Type: Single family detached

ACH50	4.45
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	2
Bedroom volume (ft^3)	1196
Mechanically moved air (heat)?	No
Year built/substantial reno	1950
Max [CO2], door open nights (ppm)	1065
Max [CO2], door closed nights (ppm)	2045



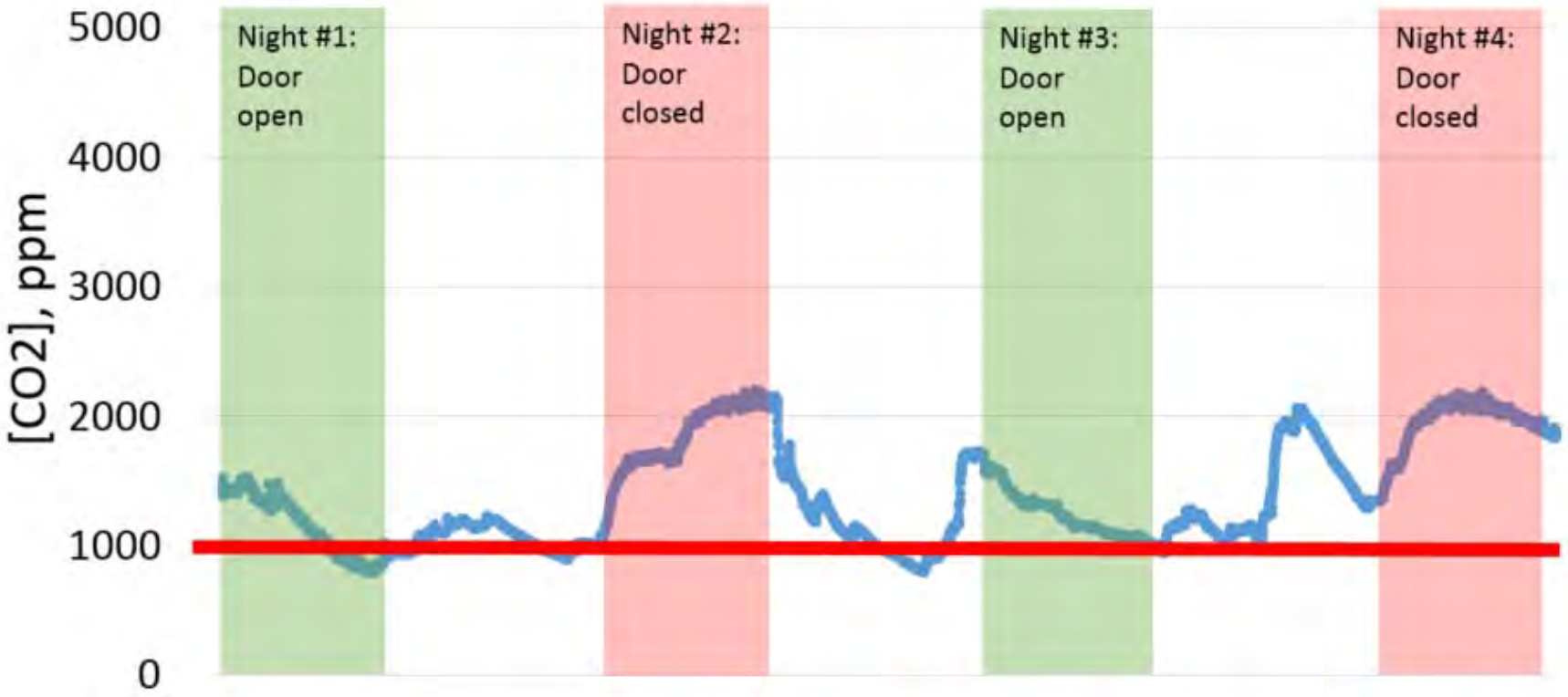
*1 bath on manual switch (master bath), 1 bath runs continuous

Efficiency Vermont

Home 8

Location: Jericho, VT
Dates: 21-25 Dec 2016
Type: Single family detached

ACH50	2.76
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	2
Bedroom volume (ft^3)	1416
Mechanically moved air (heat)?	No*
Year built/substantial reno	1990
Max [CO2], door open nights (ppm)	1721
Max [CO2], door closed nights (ppm)	2192



*Boiler plus CCHP and gas fireplace

Efficiency Vermont

Home 9

Location: Shelburne, VT
Dates: 26-30 Dec 2016
Type: Single family detached

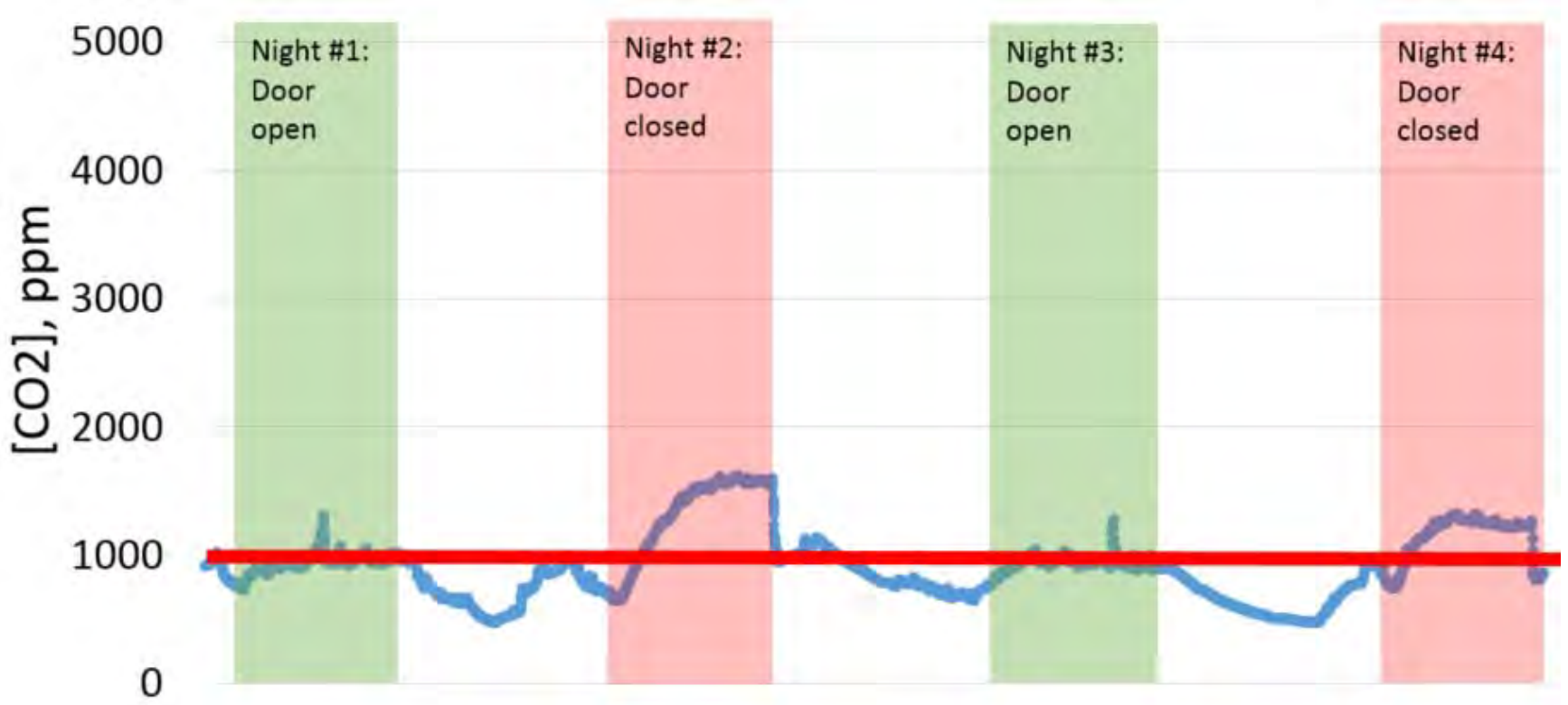
ACH50	3.03
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	2
Bedroom volume (ft^3)	2240
Mechanically moved air (heat)?	No
Year built/substantial reno	2009
Max [CO2], door open nights (ppm)	966
Max [CO2], door closed nights (ppm)	2662

Efficiency Vermont

Home 10

Location: Burlington, VT
Dates: 27-31 Jan 2017
Type: Single family attached

ACH50	4.63
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	1
Bedroom volume (ft^3)	1230
Mechanically moved air (heat)?	Yes, CCHP
Year built/substantial reno	1890
Max [CO2], door open nights (ppm)	1310
Max [CO2], door closed nights (ppm)	1614



*4h/day (12:30-4:30pm)

Efficiency Vermont

Home 11

Location: South Burlington, VT
Dates: 6-10 Feb 2017
Type: Single family detached

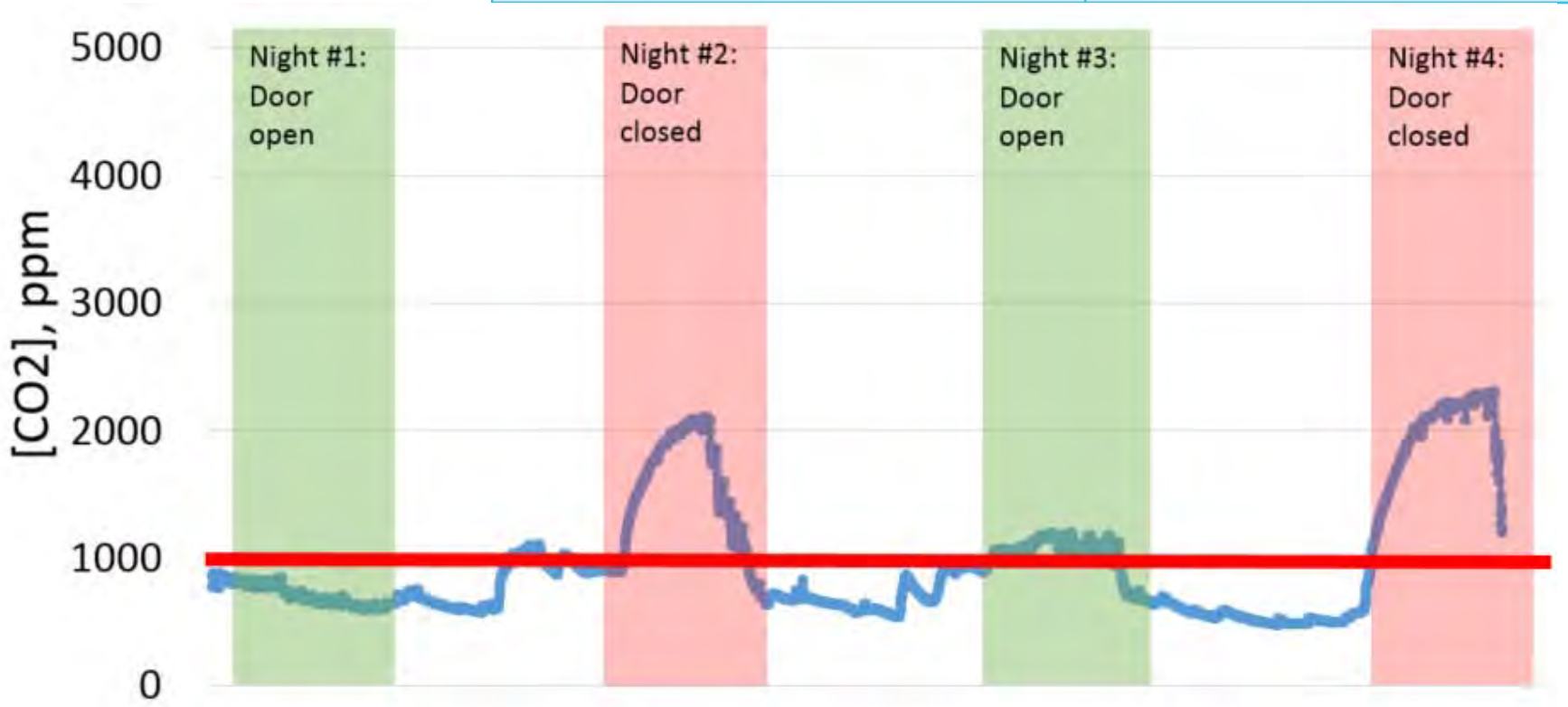
ACH50	4.58
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	1.5
Bedroom volume (ft^3)	1058
Mechanically moved air (heat)?	Yes, furnace
Year built/substantial reno	1964
Max [CO2], door open nights (ppm)	1068
Max [CO2], door closed nights (ppm)	1401

Efficiency Vermont

Home 12

Location: Milton, VT
Dates: 10-14 Feb 2017
Type: Single family detached

ACH50	2.81
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	2.5
Bedroom volume (ft^3)	1736
Mechanically moved air (heat)?	Yes, furnace
Year built/substantial reno	2005
Max [CO2], door open nights (ppm)	1199
Max [CO2], door closed nights (ppm)	2305



Efficiency Vermont

Home 13

Location: Burlington, VT
Dates: 14-18 Feb 2017
Type: Single family detached

ACH50	1.51
Ventilation strategy	HRV*
Occupants (avg)	2
Bedroom volume (ft^3)	1932
Mechanically moved air (heat)?	Yes, furnace
Year built/substantial reno	2015
Max [CO2], door open nights (ppm)	1615
Max [CO2], door closed nights (ppm)	1473

*Continuous

Home 14

Location: Burlington, VT
Dates: 20-24 Feb 2017
Type: Single family detached

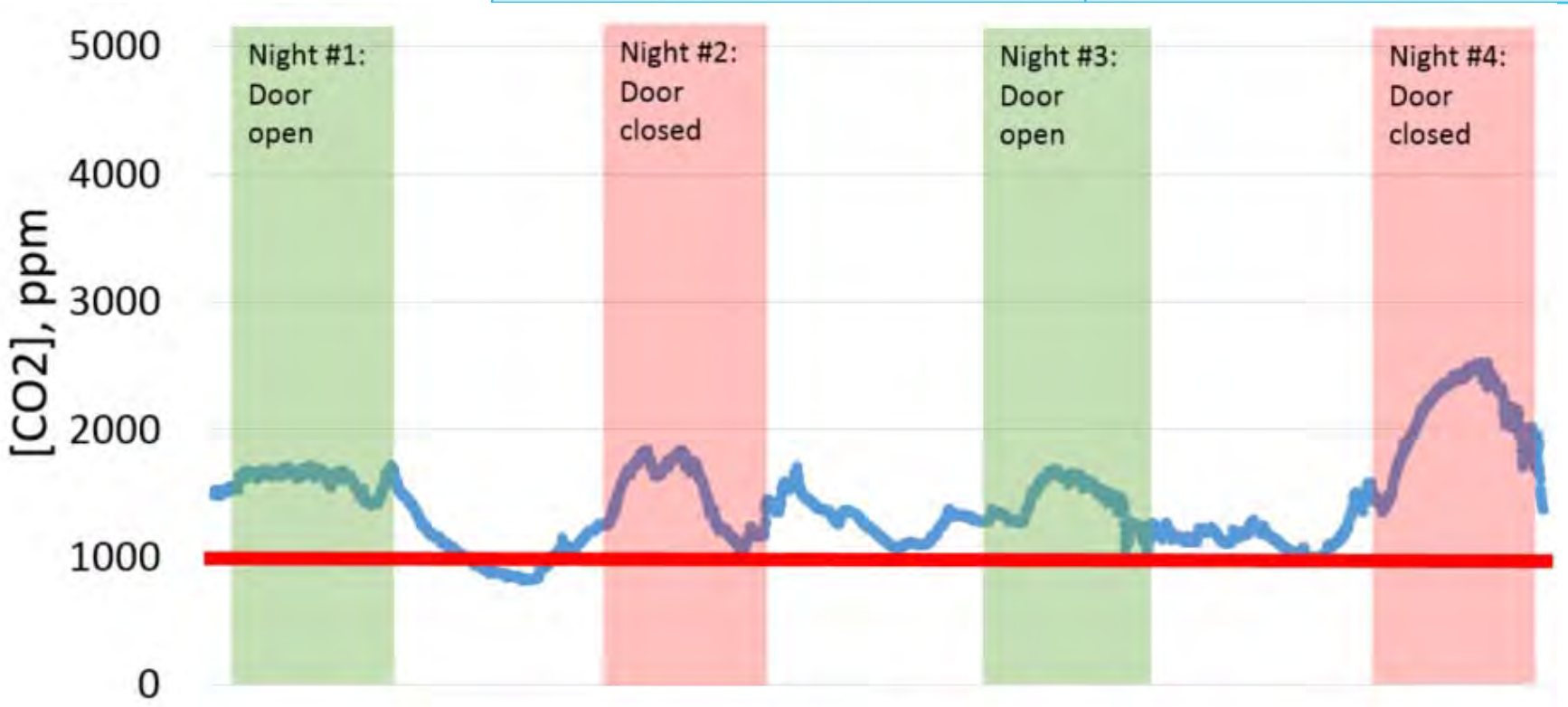
ACH50	5.54
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	2.5
Bedroom volume (ft^3)	1456
Mechanically moved air (heat)?	No
Year built/substantial reno	1970
Max [CO2], door open nights (ppm)	2133
Max [CO2], door closed nights (ppm)	5500

Efficiency Vermont

Home 15

Location: Colchester, VT
Dates: 28 Feb - 4 Mar 2017
Type: Single family attached

ACH50	3.49
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	2
Bedroom volume (ft^3)	1482
Mechanically moved air (heat)?	No
Year built/substantial reno	1990
Max [CO2], door open nights (ppm)	1719
Max [CO2], door closed nights (ppm)	2517



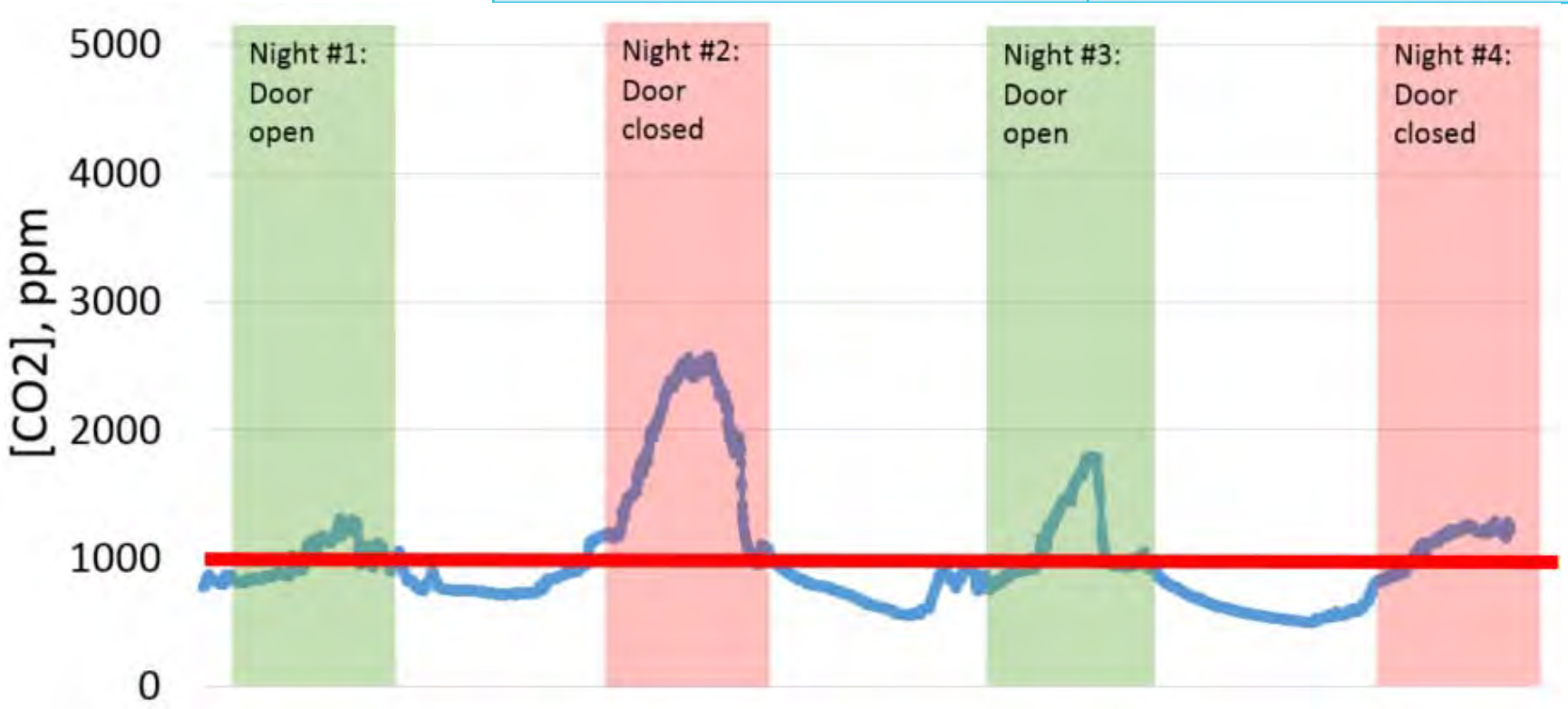
*5 minutes every hour

Efficiency Vermont

Home 16

Location: Essex, VT
Dates: 6-10 Mar 2017
Type: Single family detached

ACH50	4.30
Ventilation strategy	EOV, without automatic controls*
Occupants (avg)	2
Bedroom volume (ft^3)	1755
Mechanically moved air (heat)?	No
Year built/substantial reno	1978
Max [CO2], door open nights (ppm)	1790
Max [CO2], door closed nights (ppm)	2571



*Loosely speaking: occupancy/humidity sensor with 10-minute timer

Efficiency Vermont

Home 17

Location: Waitsfield, VT
Dates: 20-24 Mar 2017
Type: Single family detached

ACH50	1.82
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	2
Bedroom volume (ft^3)	1623
Mechanically moved air (heat)?	No
Year built/substantial reno	1976
Max [CO2], door open nights (ppm)	1631
Max [CO2], door closed nights (ppm)	2542

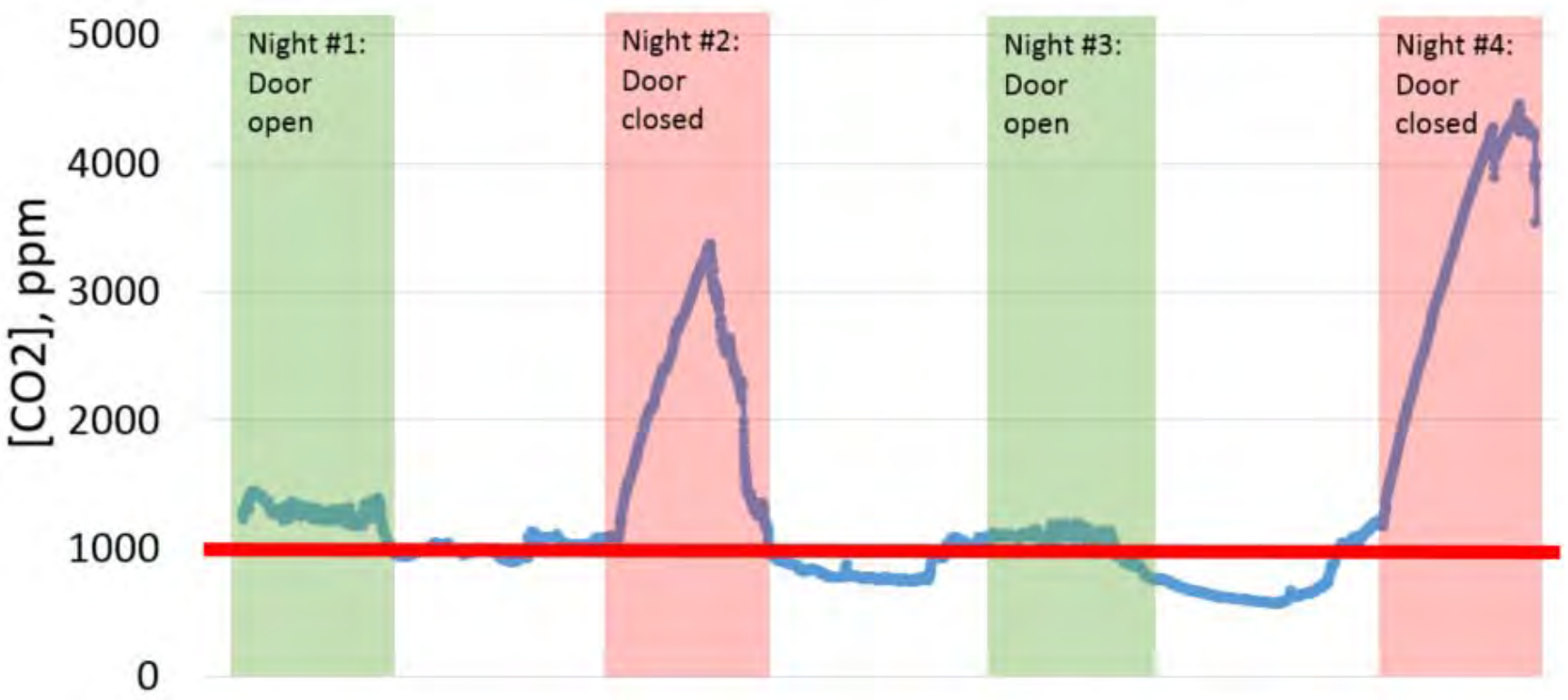
*(2) EOV fans run 5min/hr

Efficiency Vermont

Home 18

Location: South Burlington, VT
Dates: 24-28 Mar 2017
Type: Single family detached

ACH50	5.22
Ventilation strategy	EOV, without automatic controls*
Occupants (avg)	2.5
Bedroom volume (ft^3)	1144
Mechanically moved air (heat)?	No
Year built/substantial reno	1968
Max [CO2], door open nights (ppm)	1451
Max [CO2], door closed nights (ppm)	4450



*Occupancy sensors only

Efficiency Vermont

Home 19

Location: Georgia, VT
Dates: 3-7 Apr 2017
Type: Single family detached

ACH50	2.28
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	2.5
Bedroom volume (ft^3)	1750
Mechanically moved air (heat)?	No
Year built/substantial reno	2001
Max [CO2], door open nights (ppm)	1667
Max [CO2], door closed nights (ppm)	2778

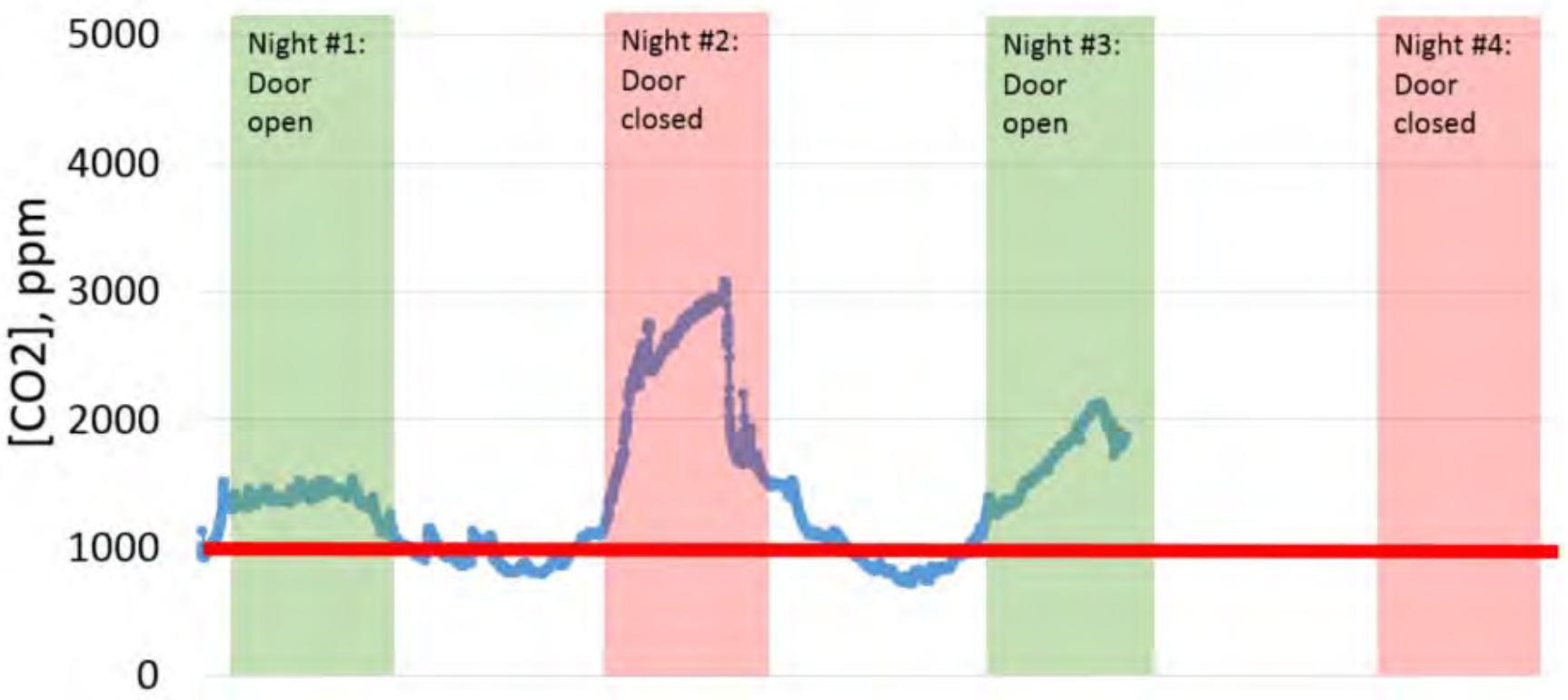
*Pin timer, 3-5am, 7-8am, 9-10am, 1-2pm, 9pm-1am (1 of 3 baths only, others manual)

Efficiency Vermont

Home 20

Location: Burlington, VT
Dates: 7-11 Apr 2017
Type: Single family detached

ACH50	5.64
Ventilation strategy	EOV, with automatic controls*
Occupants (avg)	2.5
Bedroom volume (ft^3)	2464
Mechanically moved air (heat)?	Yes, CCHP
Year built/substantial reno	1956
Max [CO2], door open nights (ppm)	2123
Max [CO2], door closed nights (ppm)	3069



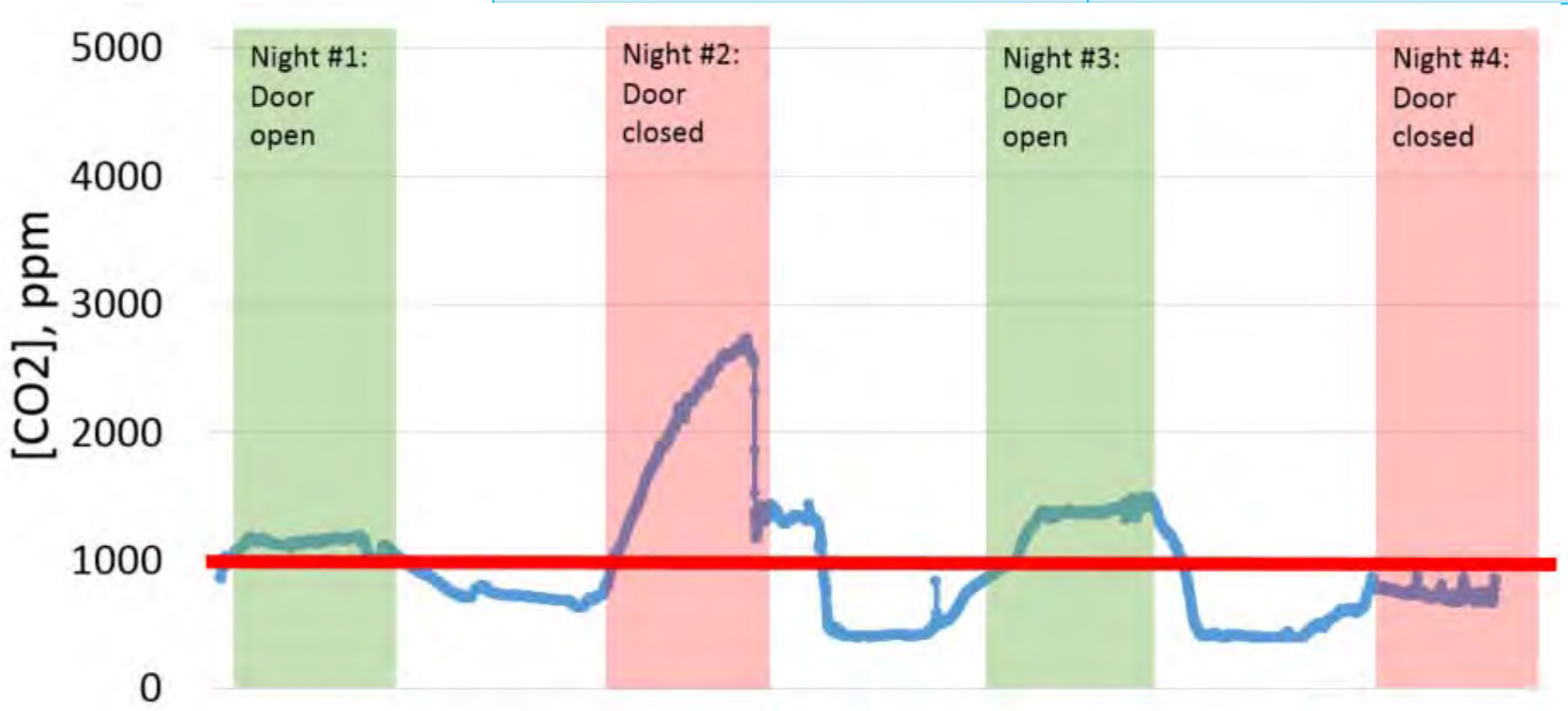
*Runs 6:30am-2:30pm

Efficiency Vermont

Home 21

Location: Shelburne, VT
Dates: 13-17 Apr 2017
Type: Single family detached

ACH50	1.95
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	2
Bedroom volume (ft^3)	1452
Mechanically moved air (heat)?	No*
Year built/substantial reno	1989
Max [CO2], door open nights (ppm)	1496
Max [CO2], door closed nights (ppm)	2734



*Forced air furnace, but rarely used (home heated with wood stove

Home 22

Location: Cambridge, VT
Dates: 19-23 Apr 2017
Type: Single family detached

ACH50	3.40
Ventilation strategy	EOV, without automatic controls
Occupants (avg)	2.5
Bedroom volume (ft^3)	1432
Mechanically moved air (heat)?	Yes*
Year built/substantial reno	2009
Max [CO2], door open nights (ppm)	2477
Max [CO2], door closed nights (ppm)	4844

*Pellet stove with distribution via (non-ducted) floor vents

Efficiency Vermont