SMART VENTILATION: CHALLENGES AND OPPORTUNITIES FOR PASSIVE HOUSE

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Passive House Conference, September 2014

Principles of smart ventilation

1. Maintain or improve IAQ

   Relative to standards – e.g., ASHRAE 62.2

2. Save energy

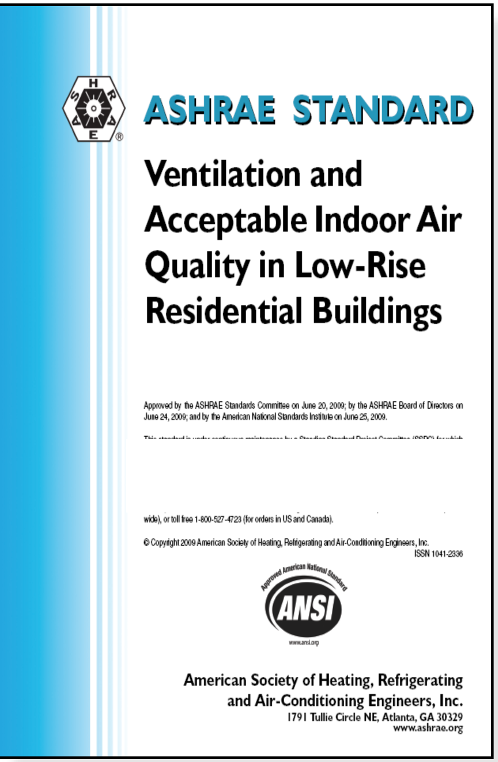
   Relative to "dumb" ventilation

Principle 1 – Maintain or improve IAQ

- Based on dose and exposure to indoor pollutants assuming constant emission for chronic issues
- Relative to a constant (or uniformly cycling) ventilation system
- Reduce ventilation when outdoor pollutants are high
  - Ozone, Traffic, “spare the air” days, other rare events
    - Schedule, sensors, manual override, respond to external signal
- Minimize acute issues (how high can the peak indoor concentration be) based on acute to chronic ratios for pollutants
  - Limit relative exposure during unoccupied times
  - PM2.5 is the critical pollutant – it has the lowest acute to chronic ratio

Principle 1 – Maintain or improve IAQ……Three versions of 62.2

2010



ASHRAE STANDARD

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

Approved by the ASHRAE Standards Committee on June 20, 2009; by the ASHRAE Board of Directors on June 24, 2009; and by the American National Standards Institute on June 25, 2009.

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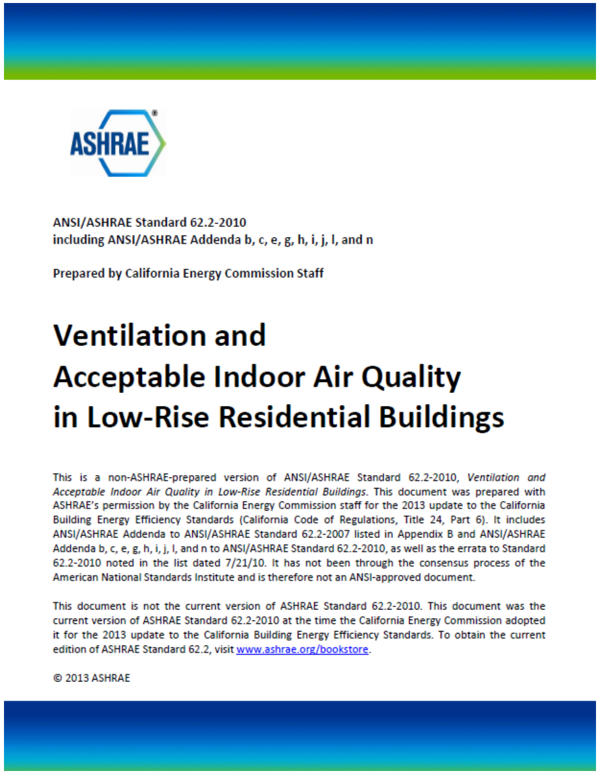
Used in some jurisdictions and programs

2010 + 2013



ASHRAE

ANSI/ASHRAE Standard 62.2-2010
including ANSI/ASHRAE Addenda b, c, e, g, h, i, j, l, and n

Prepared by California Energy Commission Staff

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

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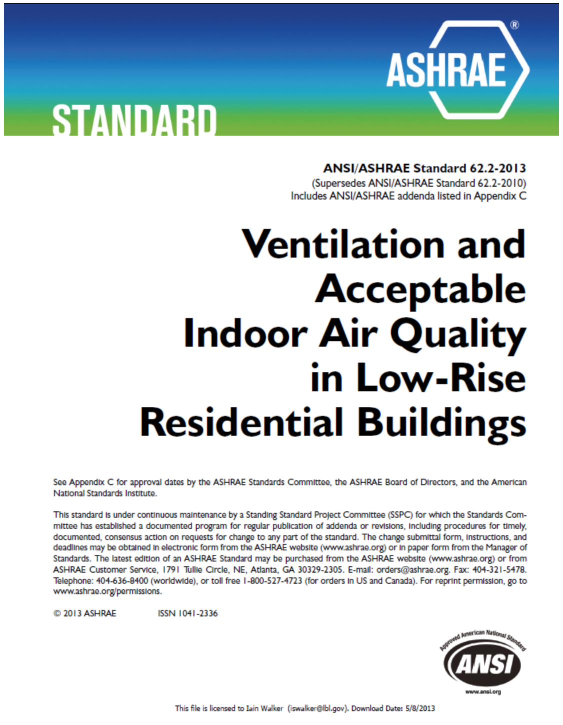
California Special
Has both 2010 and 2013 Compliance Paths

2013



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2013
(Supersedes ANSI/ASHRAE Standard 62.2-2010)
Includes ANSI/ASHRAE addenda listed in Appendix C

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

See Appendix C for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

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Gradually replacing 2010 (BPI, RESNET etc.)

Principle 1 – Maintain or improve IAQ

- Relative to air flows specified in standards
  - Current PH workbook refers to ASHRAE 62.2 - 2010
- Whole house ventilation: ASHRAE 62.2 2013

Fan size = 3 cfm/100 sq.ft. + 7.5 cfm (bedrooms +1)

  - Often met in PH with HRV/ERV
- Local Exhaust directly to outside
  - Kitchen: 100 cfm or 5 kitchen ACH
  - Bathrooms: 50 cfm or 20 cfm continuous
  - Generally not done in PH – A compliance problem?

Principle 1 – Maintain or improve IAQ

Floor Area (ft^2)	**Bedrooms**				
	1	**2**	**3**	**4**	**>5**
<500	30	40	45	55	60
500-1000	45	55	60	70	75
1001-1500	60	70	75	85	90
1501-2000	75	85	90	100	105
2001-2500	90	100	105	115	120
2501-3000	105	115	120	130	135
3001-3500	120	130	135	145	150
>3501	135	145	150	160	165

- For 2000 sq. ft. (and greater) house this is ~0.3 ACH
- For 500 sq. ft. 2 bed apt. this is ~0.5 ACH

Principle 1 – Maintain or improve IAQ

- PH infiltration credit… was ZERO in ASHRAE 62.2-2010
- Now, for 62.2-2013: For 0.5 ACH50, 2000 sq. ft. PH in SF:
  - Credit is 7 cfm
    - would be 70 cfm for 5 ACH50 typical home
  - So whole house ventilation fan size = 90 – 7 = 83 cfm
    - would only be 20 cfm for 5 ACH50 typical home

Principle 1 – Maintain or improve IAQ

- Upcoming changes to Kitchen Ventilation (**proposed**)

a. **Kitchens.** Kitchens shall be provided with one of the following demand-controlled options:

  - A vented range hood (including appliance-range hood combinations) having a minimum exhaust capacity of 100 cfm (50 L/s) airflow.
  - An exhaust fan other than a vented range hood in the kitchen with a minimum capacity of 300 cfm (150 L/s).
  - An exhaust fan in an enclosed kitchen with a minimum capacity of 5 air changes per hour based on kitchen volume.

May add flexibility for PH

HRV exhaust pickup in kitchen: switch to high flow?

Principle 1 – Maintain or improve IAQ

- Bathroom Ventilation
- **b. Bathrooms.** Bathrooms shall be provided with a minimum exhaust capacity of 50 cfm (25 L/s) demand-controlled airflow or 20 cfm (10 L/s) continuous airflow.
- **Proposed change**: To achieve the 20 cfm (10 L/s) continuous rate it is permissible to average intermittent airflow over an hour.

May add flexibility for PH

Cycling HRV/ERV may meet 20 cfm if averaged

Principle 2. Save Energy

1. Avoid times of highest temperature difference
   - Time shift ventilation to hours of lower temperature difference
   - Turn system off at high temperature difference and compensate by operating at higher air flow the rest of the time
     - For example, Use a simple timer – ventilation off for 4 hottest or coldest hours of the day adjusted by seasons
2. Account for other fans: kitchen/bath exhaust, dryers
   - Take credit for this existing ventilation
     - Sense operation of other fans

Account for reduced air flow with higher flows at other times ~ 25% oversizing

Principle 2. Save Energy

3. Don't ventilate when no-one is home
   - Don't count unoccupied pollutant levels in dose and exposure
   - Limited by acute levels
     - Schedule or sensors

Concentration [µg/m³]				
COMPOUND	Chronic	Acute		
		24 h	8 h	1 h
Formaldehyde*	1.67E+00	-	9.00E+00	5.50E+01
NO2*	4.00E+01	-	-	1.89E+02
PM2.5*	1.00E+01	2.5E+01	-	-
Lowest Acute-to-Chronic Ratio [-]	-	2.5	5.4	4.7

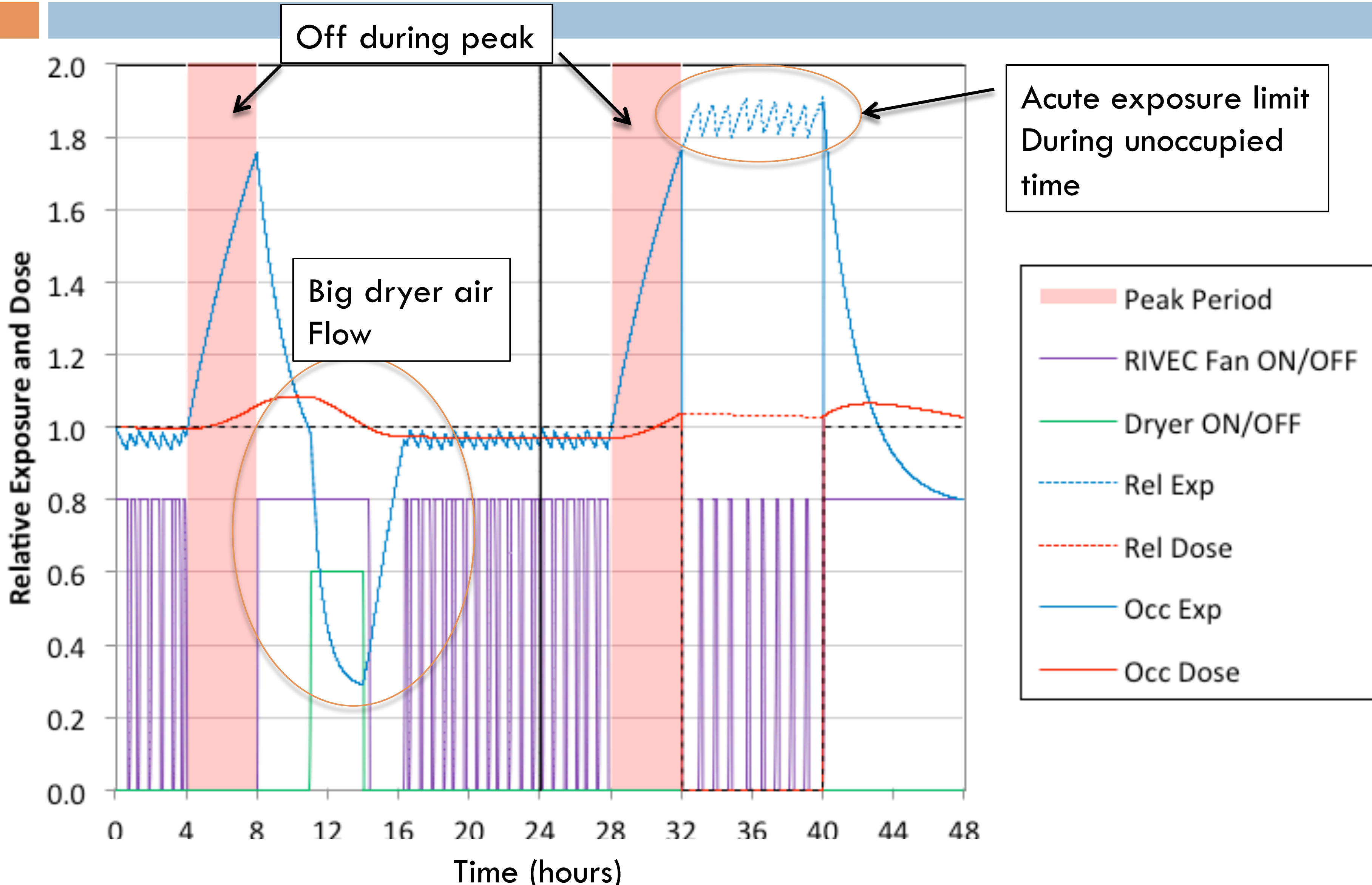
The smart part….

- Can't just average air flow rates because contaminant concentration **inversely** proportional to air flow
  - Use ventilation efficacy analysis to track dose and exposure
- Calculate dose and exposure (runnign 24 hour average of dose) for the airflows provided by the smart system (including other fans + infiltration if you want + possibly passive stacks if you know the air flow) relative to the non-smart system every minute
- Every10-15 minutes make a decision about turning whole house ventilation system on or off
- Only turn on controlled fan if relative dose > 1 or relative exposure >0.95

An Example smart controller: RIVEC

- Inputs for controller:
  - Target ventilation rate in air changes per hour (from standard)
    - Floor area of house
    - Volume of house
    - Number of bedrooms (a surrogate for the number of occupants)
  - Airflow capacities of each exogenous mechanical ventilation system (e.g. bathroom fans, kitchen range hoods and clothes dryers)
  - Infiltration contribution to ventilation from simple model (optional)
    - Envelope leakage + house geometry (number of stories, foundation type)
    - Weather data
  - Peak hours for turning off the whole-house fan
    - 4 am to 8 am heating, 2 pm to 6 pm cooling
  - Airflow capacity of the whole-house mechanical ventilation system that RIVEC controls

Example 1

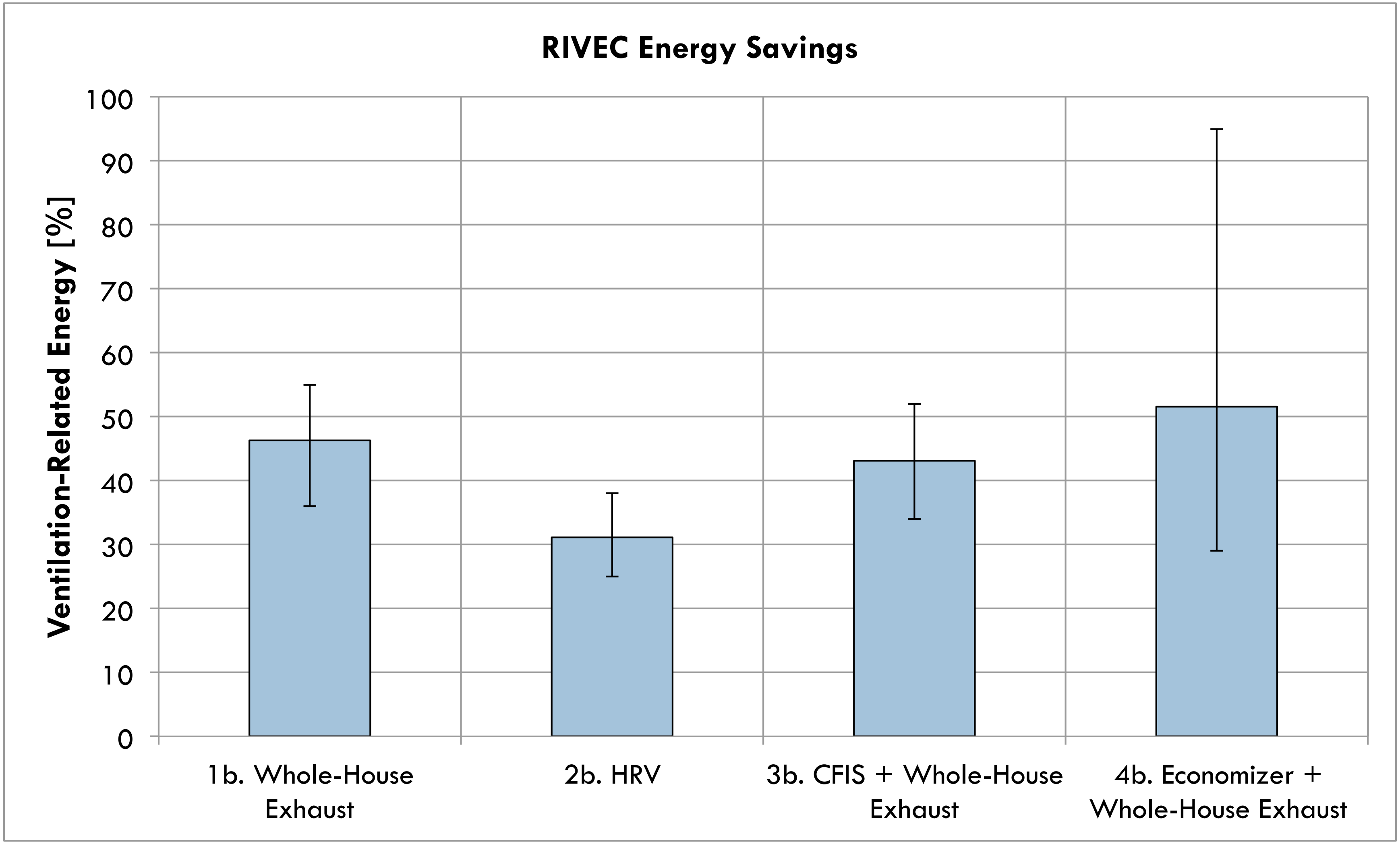


Off during peak
Acute exposure limit
During unoccupied
time
Big dryer air
Flow
Relative Exposure and Dose
Time (hours)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
4
8
12
16
20
24
28
32
36
40
44
48
Peak Period
RIVEC Fan ON/OFF
Dryer ON/OFF
Rel Exp
Rel Dose
Occ Exp
Occ Dose

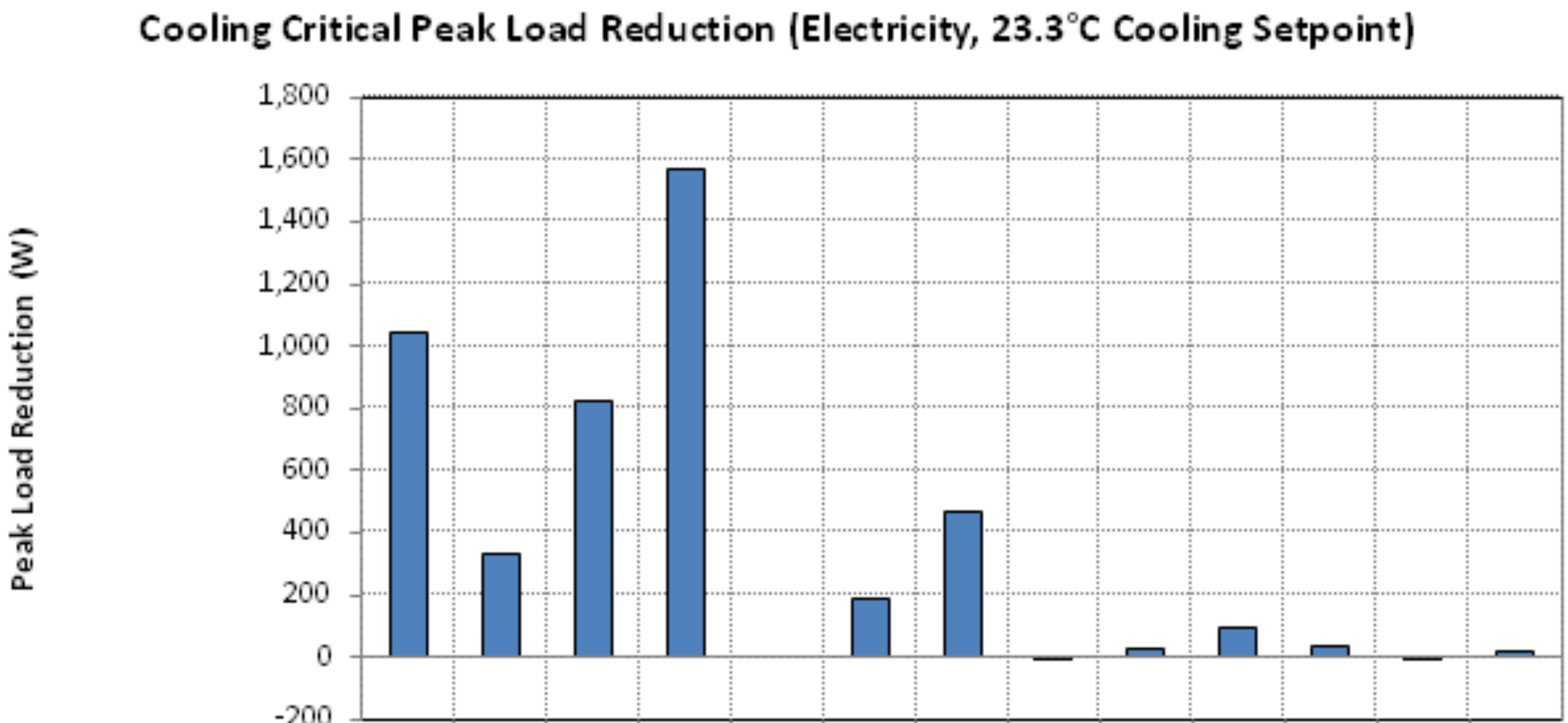
Performance – mostly simulated

- Saves at 20% to 40% of ventilation energy (fan power + conditioning)
  - Save more in PH due to less natural infiltration resulting in bigger air flow changes when ventilation system is off
- 20% to 40% less runtime for whole house system
- Robust independent of climate, house size & envelope leakage
  - 500 – 2000 kWh/yr for typical house depending on climate
- Reduce peak power by 500-2000 W
- No exposure to pollutants at acute levels
  - PM2.5 critical – has lowest acute to chronic ratio

Energy Savings for different systems – average over all US Climate Zones



Example cooling peak load reductions



Climate Zone	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7
Load Reduction [W]	1045	335	820	1566	0	184	471	-2	26	97	38	-6	15
Compressor Run Time [%]	77%	95%	82%	67%	0%	96%	85%	100%	100%	97%	100%	100%	100%

Climate Zone

Some Advantages for Passive House

- Get credit for systems that vent directly outside:
  - Kitchen Ventilation
  - Bathroom Ventilation
  - Clothes Dryers
- Get credit for passive stacks (if monitored)
- Allow use of simpler whole house ventilation systems, e.g., exhaust fans rather than HRV/ERVs
- This can simplify PH design and construction and allow use of less expensive systems

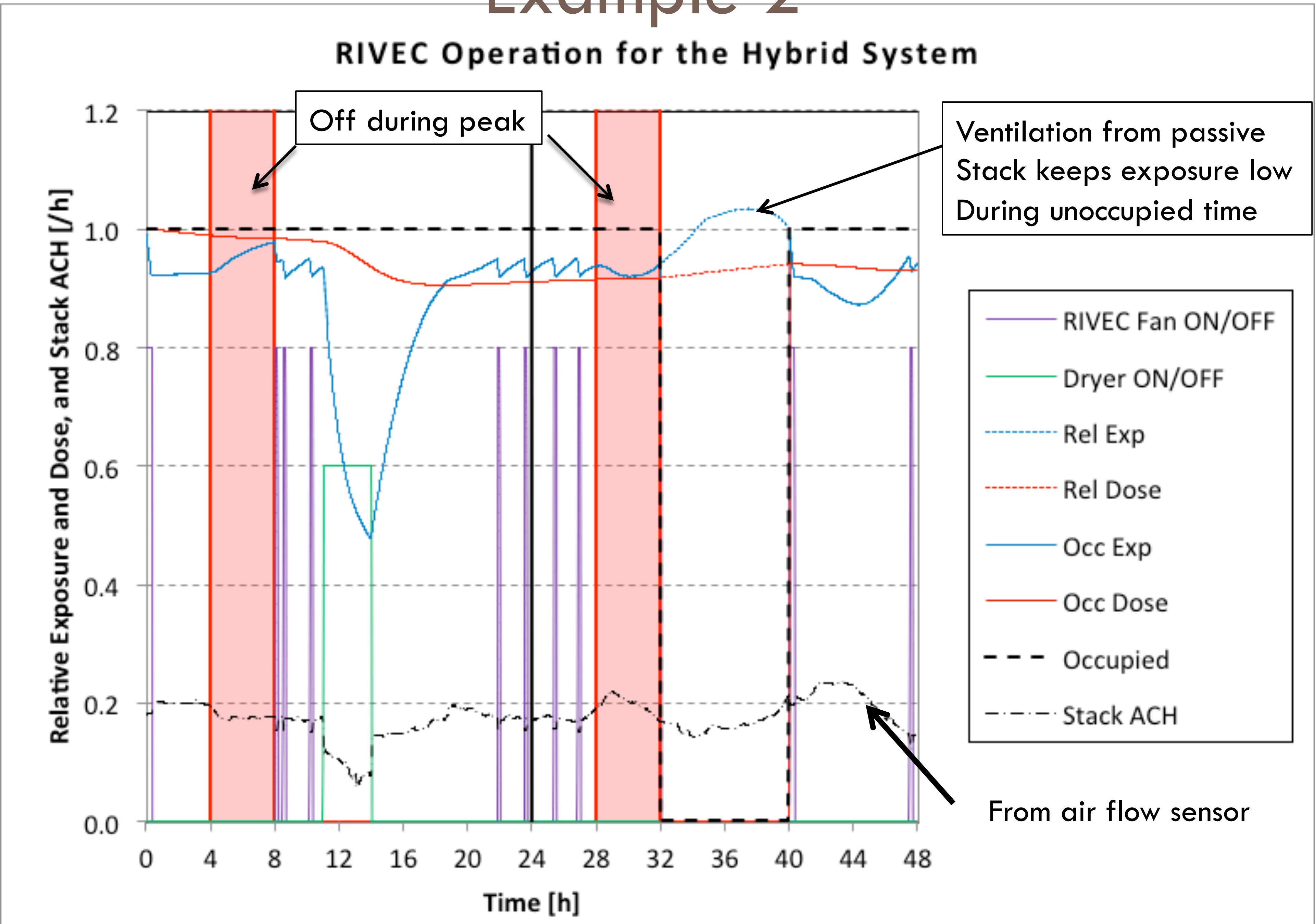
What about HRVs/ERVs

- Most PH will have HRV/ERV… there are still savings:
  - from 11% to 20% of site energy (depends on if we fine tune control for HRV)
  - HOWEVER – need to be careful about heating season savings if interlocked to central heating system
    - Reduced heat from large central blower can lead to extra gas usage
    - May be less of an issue for PH with small or no central forced air system

Other energy saving strategies

- Smart ventilation allows credit for:
  - Ventilation precooling (Economizers). Good in hot dry climates (like CA)
- Smart ventilation allows use of passive ventilation and prevents under-ventilation problems
  - Enables strategy of controlled “oversized” passive stack
  - Combine passive stack with occasional use of whole house ventilation system – a **hybrid** system, but directly controlled for IAQ equivalence

Example 2


RIVEC Operation for the Hybrid System
Off during peak
Ventilation from passive Stack keeps exposure low During unoccupied time
From air flow sensor
Relative Exposure and Dose, and Stack ACH [/h]
Time [h]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
4
8
12
16
20
24
28
32
36
40
44
48
RIVEC Fan ON/OFF
Dryer ON/OFF
Rel Exp
Rel Dose
Occ Exp
Occ Dose
Occupied
Stack ACH

Where to now?

- In discussion with several equipment and control companies to license technology
  - Integration with heating/cooling and other controls infrastructure
  - First version is RIVEC with TempoAir/Air King – simplified version not sensing other fans
- Evaluate potential for humidity control in hot humid climates with FSEC and others from DOEBuilding America
- Honda house (with Davis Energy Group) in Davis, CA
- Evaluating outdoor temperature control with Building America partners
- How to get control strategies accepted/adopted in codes & standards and how to include them in modeling: code compliance/HERS etc.

Questions

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Brett Singer is next on Kitchen Ventilation

The smart part….

- Dose and exposure calculations
- Turnover time: A_i is current air exchange rate

$$\tau_i = \frac{1 - e^{-A_i \Delta t}}{A_i} + \tau_{i-1} e^{-A_i \Delta t}$$

- Relative Exposure: A_{eq} is target ventilation rate

$$R(t) = A_{eq} \tau_e(t)$$

- Relative dose

$$d_i = A_{eq} \tau_i (1 - e^{-\Delta t / 24hrs}) + d_{i-1} e^{-\Delta t / 24hrs}$$