The Impacts of Cooking on Indoor Air Quality in Passive Houses

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- Low-energy home design is becoming more common in new and retrofitted homes, and energy-efficient designs often sell at a premium
- Efficiency measures, like tightening the building envelope saves energy, but can impact the indoor air quality (IAQ).
- We monitored the IAQ of nine tightly constructed homes, one tightly constructed public library, and one conventionally constructed home, and performed a repeatable cooking activity to observe the impact of the fine particulate matter ($PM_{2.5}$) emissions.
- We compared $PM_{2.5}$ concentrations from the cooking activity while operating the mechanical ventilation systems at default rates (~0.1-0.3 h^{-1}) and in a temporary boost mode (~0.3-0.8 h^{-1}).

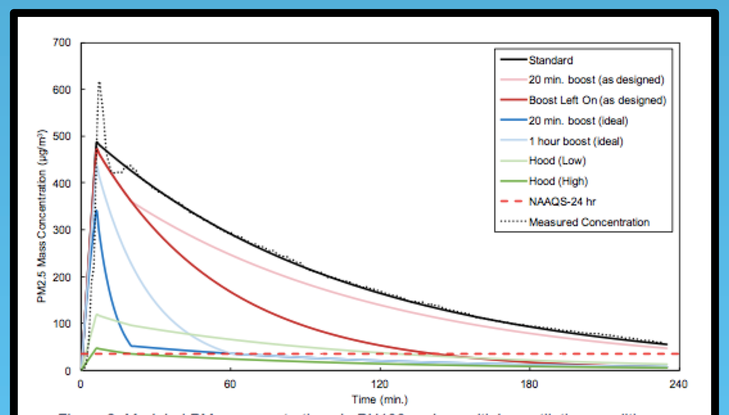


Figure 3. Modeled $PM_{2.5}$ concentrations in PH100 under multiple ventilation conditions

Table 1. Building and ventilation properties

	PH100	PH101	TH102	PH103	PH104	PH105	PH106	PH107	TH108	TH109	CH110
Building Properties											
Building ID	House	House	House	Library	House	House	House	House	House	House	House
Building Type	3	4	37	1	4	6	5	2	1	1	39
Building Age (yrs.)	1	2	2	1	2	3	2	4	3	3	3
# of Floors	1	3	3	0	3	4	3	3	2	3	4
# of Bedrooms	2A	1A	2A	Varies	1A	2A	2A	2A/1C	1A	2A	2A/2C
# Total Occupants	1A	1A	2A	n/a	1A	2A	2A	2A	1A	2A	2A
# Bedroom Occupants	PHI	No	No	No	PHIUS	PHIUS	PHIUS	No	No	No	No
Certification	116.1	204.8	184.1	352.4	616.1	204.0	338.9	327.4	153.1	228.4	287.2
Total Cond. Area (m²)	378.9	602.8	596.6	1446.6	1715.7	669.2	1009.9	809.2	426.3	632.3	769.8
Total Cond. Vol. (m³)	98.2	87.4	87.2	304.9	424.2	134.3	184.4	113.6	108.0	163.4	126.0
Test Area (m²)	290.2	263.0	347.9	1301.9	1144.2	405.2	451.1	292.6	295.2	452.3	274.0
Test Volume (m³)	18.6	38.5	11.4	n/a	28.8	24.3	19.9	30.3	16.0	38.6	24.8
Bedroom Area (m²)	69.4	105.5	27.8	n/a	74.6	105.7	66.7	78.5	39.0	100.1	71.4
Bedroom Volume (m³)	0.47	0.34	1.53	1	0.34	0.23	0.46	0.55	1.37	2.99	~4
Tightness (ACH50)	Propane	Electric	Electric	n/a	Electric	Gas	Electric	Induction	Electric	Electric	Electric
Stove Type	None	Recirc.	Recirc.	n/a	Recirc.	Recirc.	Recirc.	None	Recirc.	Recirc.	Exhausting
Hood Type	Passive	None	None	None	None	Active	None	None	None	None	Active
Radon Mitigation	**Ventilation Properties**										
Ventilator Type	HRV	ERV	CERV	ERV	ERV	ERV	CERV	ERV	CERV	CERV	HRV
Ventilator Manufacturer	~~Air Cycle~~	~~Air Cycle~~	Build-Equinox	Life Breath	~~Air Cycle~~	Zehnder	CERV	Ultimate Air	Build-Equinox	Build-Equinox	Carrier
Filter Rating	MERV-10	MERV-8	MERV-13	MERV-8	MERV-8	MERV-8	MERV-8	MERV-12	MERV-8	MERV-8	Unknown
Std. Design AER (h⁻¹)	0.22	0.08	0.42	0.59	0.22	0.32	0.18	0.21	0.60	0.40	0.31
Boost Design (h⁻¹)	0.67	0.51	n/a	1.17	0.40	0.76	n/a	0.34	n/a	n/a	n/a
Bedroom CO_2 AER (h⁻¹)	0.15	0.08	0.12	n/a	0.08	0.15	0.12	0.11	0.30	0.32	0.13
ASHRAE 62 AER (h⁻¹)	0.17	0.27	0.25	0.88	0.23	0.26	0.23	0.28	0.29	0.28	0.29
Est. Infiltration (h⁻¹)	0.02	0.01	0.07	0.03	0.02	0.01	0.03	0.00	0.06	0.15	0.17

Table 2. Air pollutant monitoring equipment and properties

Equipment	Pollutant	Measurement Period	Accuracy Notes
Outdoors			
Dylos DC1700	Particulate Matter (PM)	3-5 days	R^2 = 0.778 for mass conc. [21]
TSI Q-Trak	Carbon dioxide (CO_2)	10-15 min.	Max. of ± 3% or 50 ppm
Living Room			
Dylos DC1700	PM	3-5 days	R^2 > 0.90 for mass con. [22]
GrayWolf DirectSense TVOC	TVOC	3-5 days	Varies; Cal. 10-7500 ppb (C_4H_8)
SKC UMEx 100	Formaldehyde	3-5 days	+/- 22.7%
Bedroom			
TSI Q-Trak or	CO_2	3-5 days	Max. of ± 3% or 50 ppm
Telaire 7001			Max. of ± 5% or 50 ppm
Lowest Occ. Space			
Sun Nuclear Model 1027	Radon	3-5 days	Max. of ± 25% or 1 pCi/L

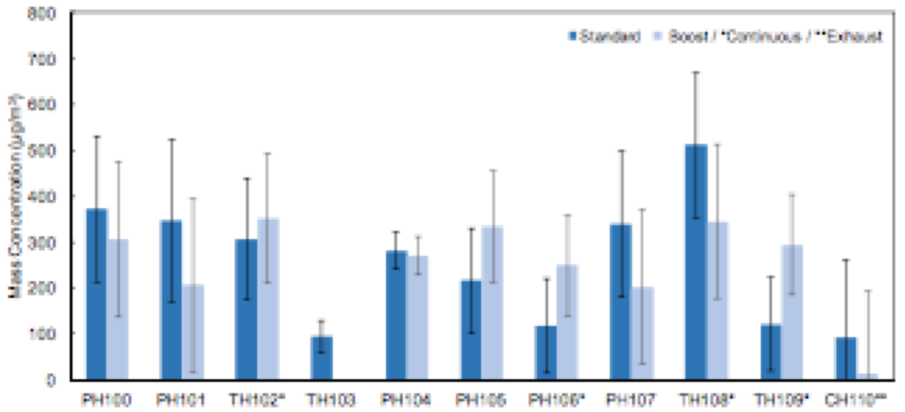
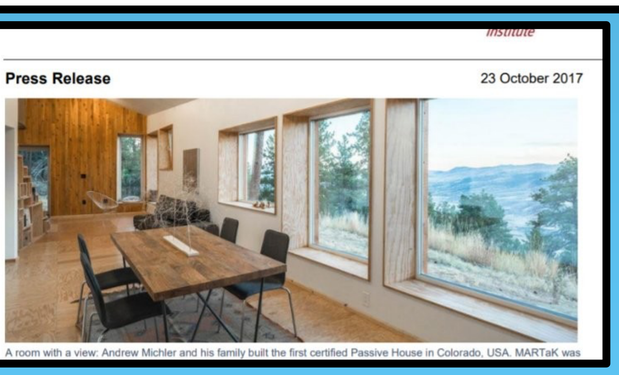
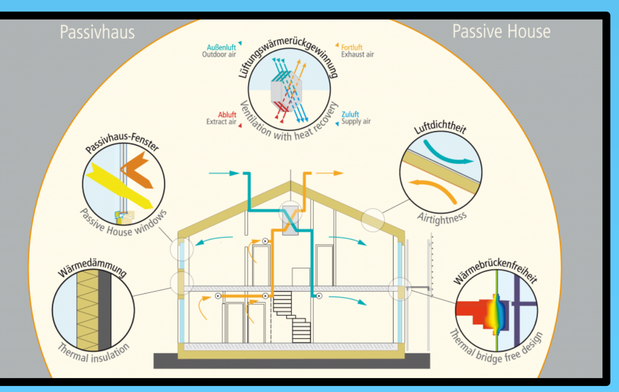


Figure 1. Short-term (20 or 30 minute) $PM_{2.5}$ average concentration after cooking for under each ventilation modes. Boost and Exhaust ventilators ran for 20 minutes, Continuous mode ventilators ran for 30 minutes. Bars represent a 95% confidence interval for concentration averages in each ventilation mode.





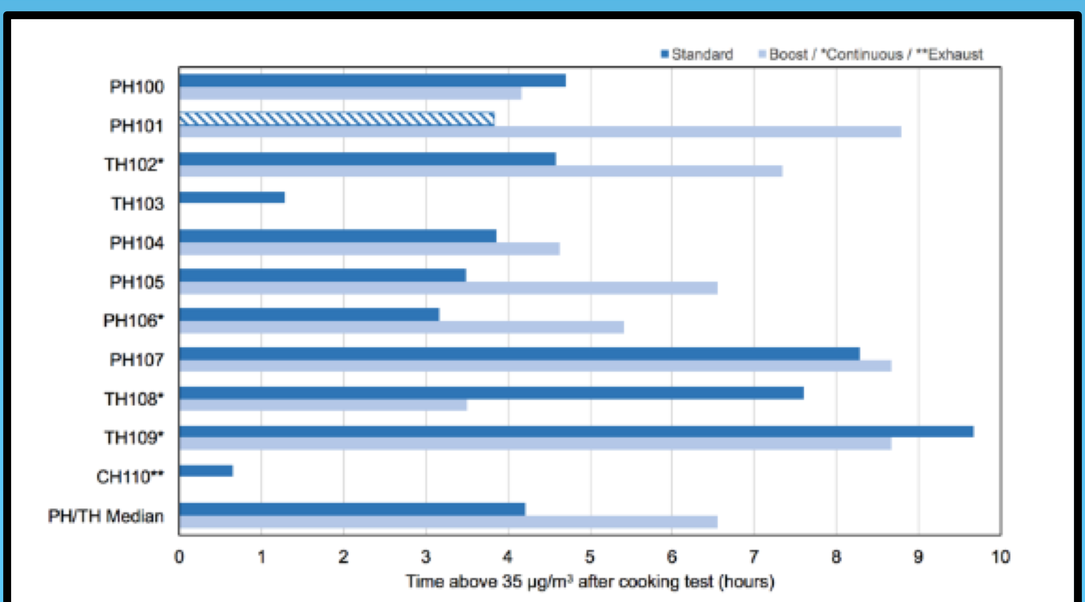


Figure 2. Number of hours each building exceeded NAAQS 24-hr limit after cooking test. Time under standard mode was directly measured. Time under boost/continuous/exhaust is extrapolated after ~ 3 hours. Diagonal-patterned bar reflects an artificially low time when one air cleaner was turned on about 30 minutes after cooking.

- The passive house concept can be an effective design approach to reduce energy use/improve thermal comfort, but it should not be assumed that this type of building has inherently good indoor air quality.
- Severe, but not atypical, cooking events drastically reduced the indoor air quality for many hours, and the temporary boost mode that many of the mechanical ventilators feature was ineffective at reducing PM emissions from the cooking activities.
- The conventional home that featured a dedicated exhaust hood experienced lower $PM_{2.5}$ concentrations that did not exceed 35 µg/m³ when used. However, this home also reached much lower concentrations under standard ventilation conditions.
- Outside of the cooking tests, the fine particle concentrations were reasonably low and were mostly affected by indoor activities rather than outdoor levels.

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