

# Mitigation of Fine PM from Cooking

Brett C. Singer

Lawrence Berkeley National Lab

[bcsinger@lbl.gov](mailto:bcsinger@lbl.gov)



Berkeley Lab research presented here was supported by the following institutions:



# Outline

Performance metrics and standards

Measured effectiveness under controlled conditions

Real-world performance and practical challenges

Resources

# Both cooking & burners are sources



CO<sub>2</sub> & H<sub>2</sub>O

NO, NO<sub>2</sub>, HONO,  
Formaldehyde

Ultrafine particles



PM<sub>2.5</sub>, Ultrafine particles

Formaldehyde, Acrolein, PAH, etc.



Ultrafine particles

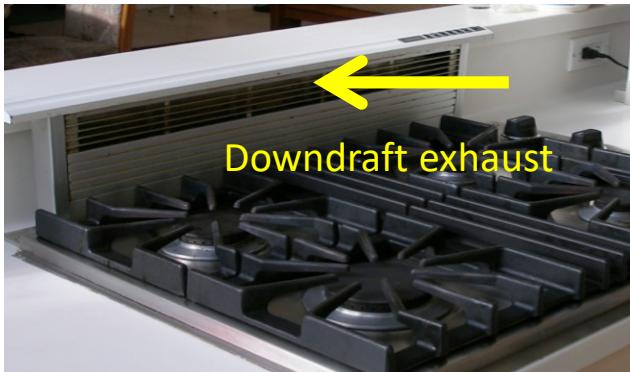


Induction burners appear to emit many fewer ultrafine particles (and no NO<sub>x</sub>)

Less et al. 2015



# Kitchen ventilation options



Ceiling exhaust fan



Wall exhaust fan



# Standards and Codes for Kitchen Ventilation

## California Building Code



- Range hood:  $\geq 100$  cubic feet per min (cfm),  $\leq 3$  sone
- Other fan:  $\geq 300$  cfm,  $\leq 3$  sone
- Verify installed airflow or use certified hood + prescribed ducting



### Guidelines:

- Minimum 40 cfm / ft = 100 cfm for 30" range
- Recommend 100 cfm / ft = 250 cfm for 30"



ENERGY STAR Certified Homes, Version 3

- Similar to ASHRAE 62.2
- Allowance for unrated hoods if using low resistance ducting



International Residential Code

- *When installed*,  $\geq 100$  cfm on demand or  **$\geq 25$  cfm continuous**, or recirculating hood!
- Make-up air required for  $>400$  cfm exhaust

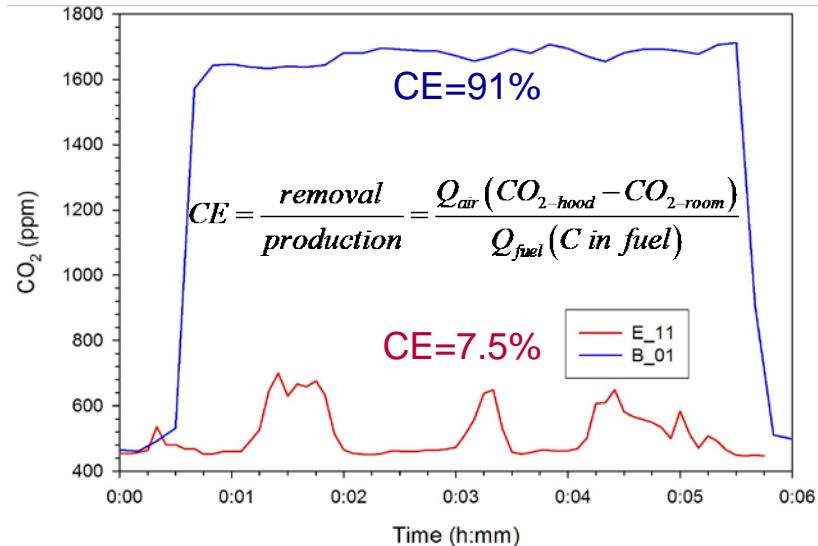


# How do we know if range hoods are effective?

**Capture efficiency (CE):** Fraction of pollutants released at cooktop or oven that are removed before mixing into home



Calculated by CO<sub>2</sub> from gas burners or tracer release  
(Different approach needed for particles)



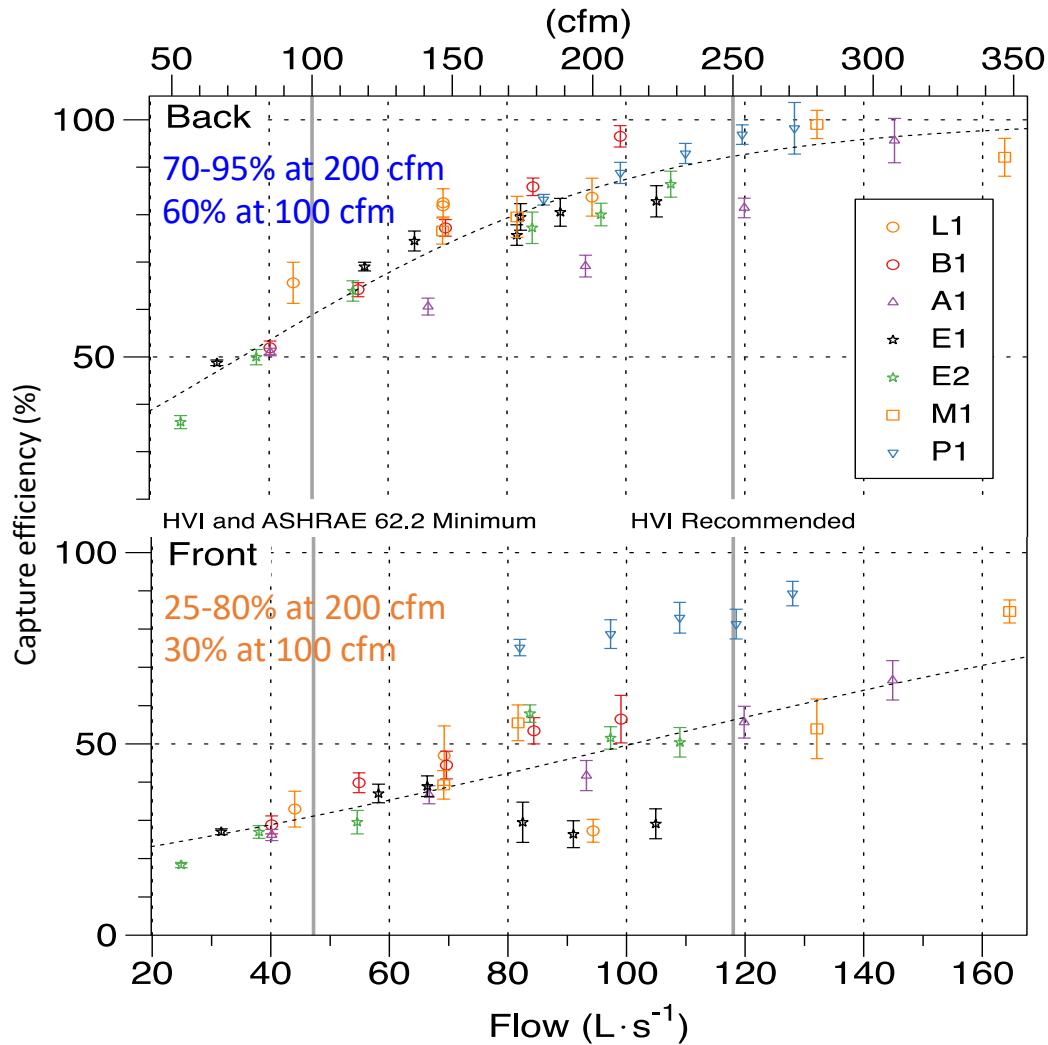
# CE for combustion pollutants, lab testing

## 7 off-the-shelf hoods (2012 cost)

- L1: Low-cost \$40
- B1: Basic, quiet \$150
- A1: 62.2-compliant, \$250
- E1: Energy Star, \$300
- E2: Energy Star, \$350
- M1: Microwave, \$350
- P1: Performance, \$650

Capture increases with airflow.  
Much better for back burners!

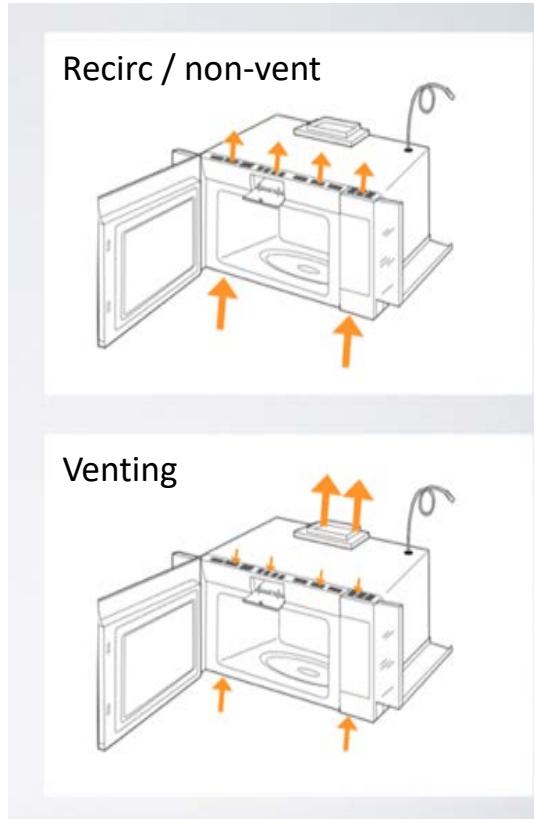
For front burners, range hood  
at 100 cfm captures ~30%



# “Over-the-range” microwave range hoods

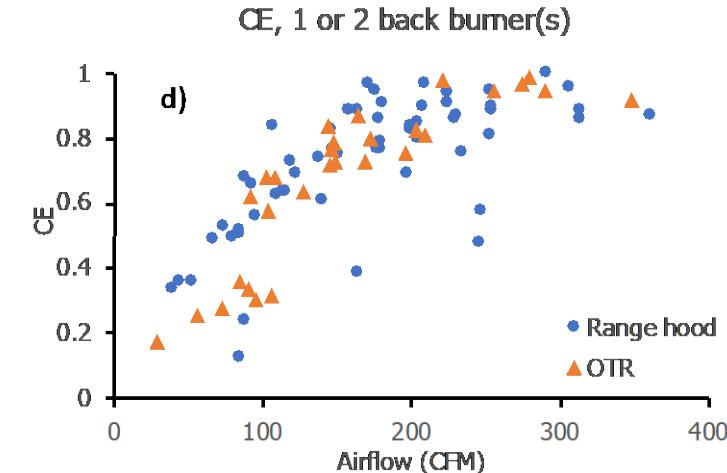
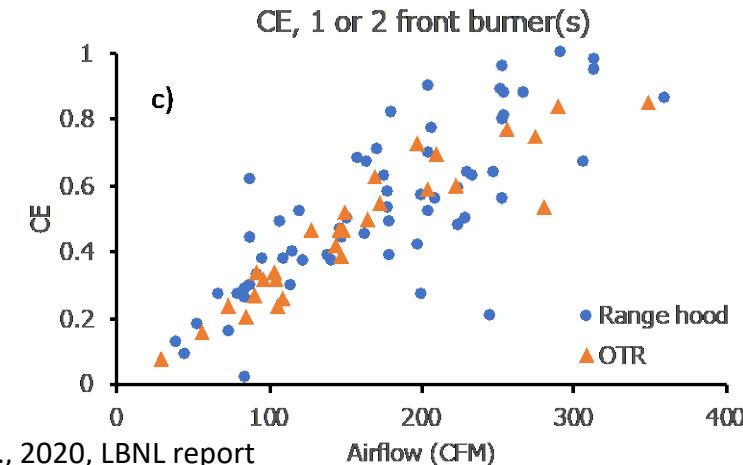
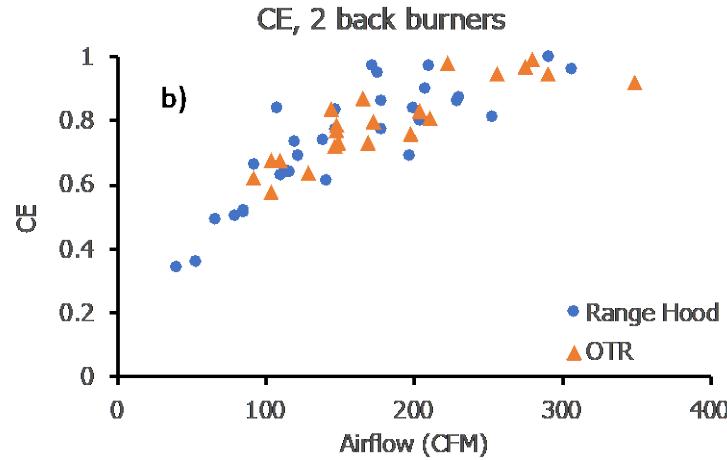
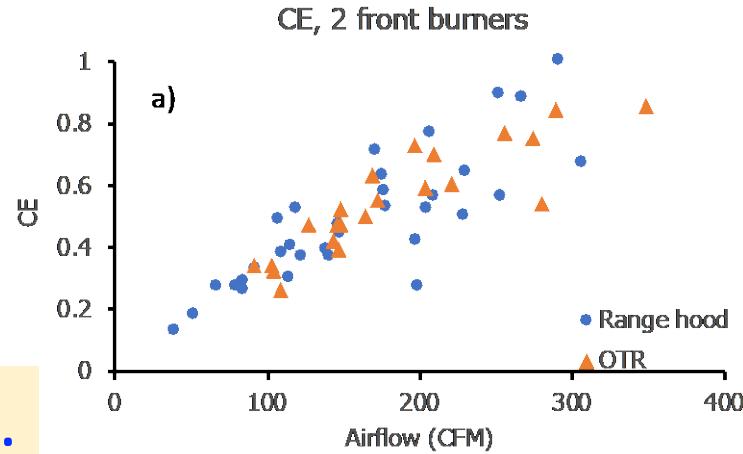
Can be installed as venting or recirculating. Shipped to recirc. Need to turn fan to vent.

Historically not rated for 62.2 and CA code compliance; now many certified models.

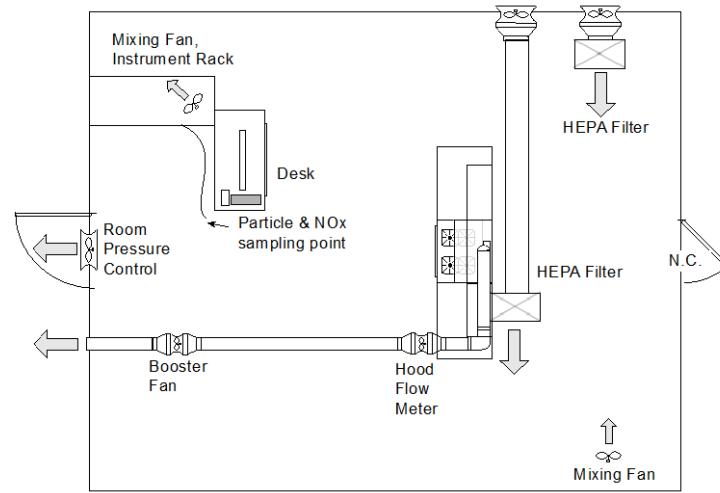


# Do OTRs have similar CE as other range hoods?

# Do OTRs have similar CE as other range hoods?

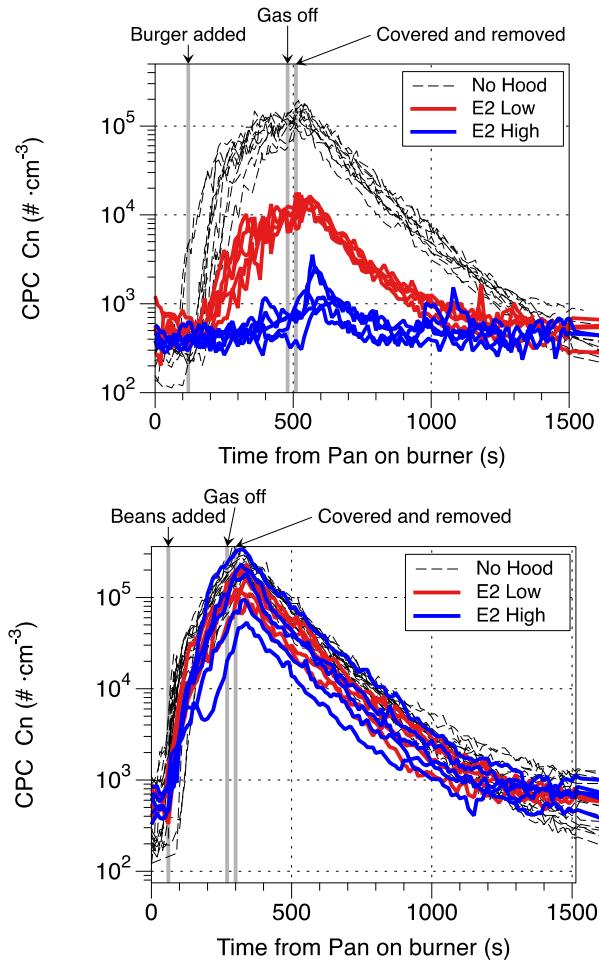


# Does CE differ for cooking particles and combustion products?



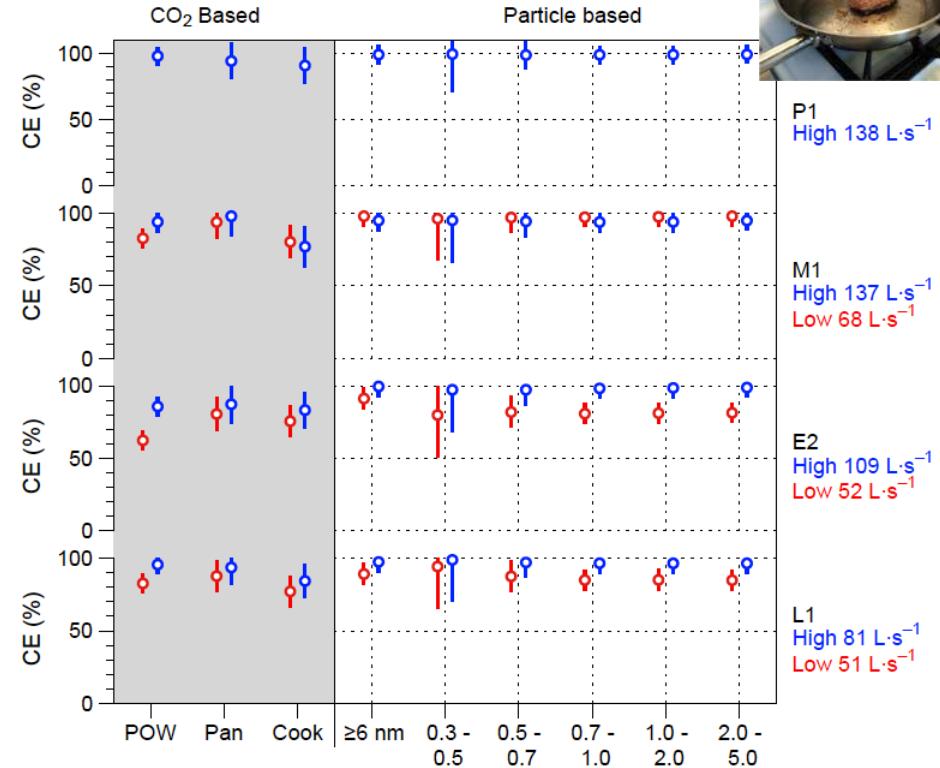
**121 m<sup>3</sup> (450 sf) room**

Front: stir-fry, wok, high  
Back: pan-fry burger, med  
Also stir-fry on back  
4 of the prior 7 hoods



# Particles & gases similar at high CE...

Burger / Med / Back



P1  
High  $138 \text{ L}\cdot\text{s}^{-1}$

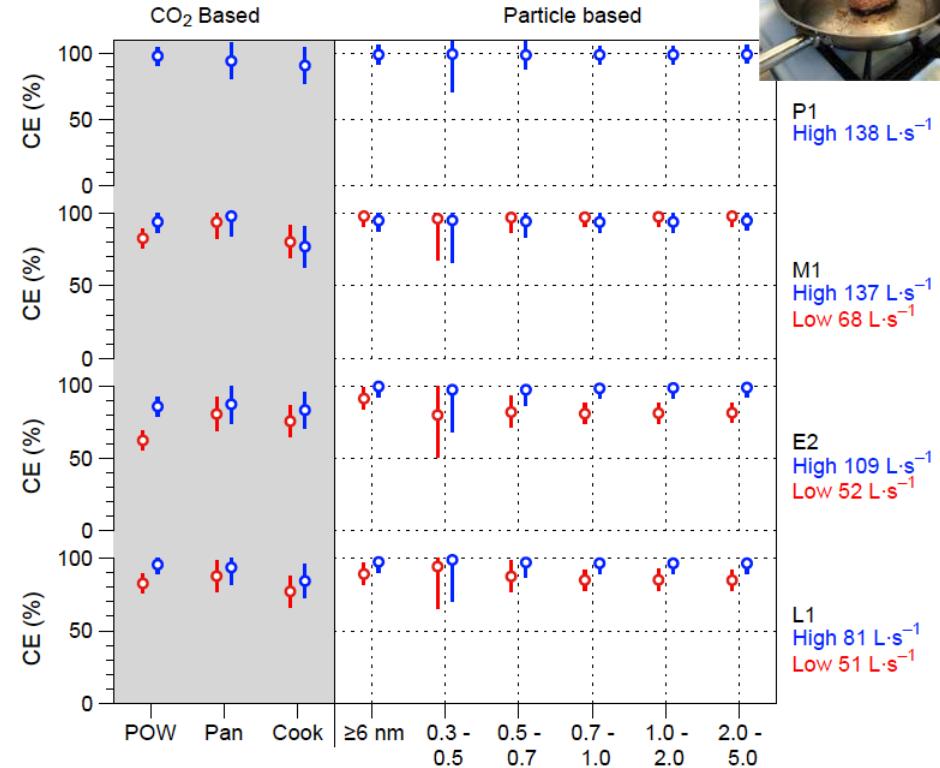
M1  
High  $137 \text{ L}\cdot\text{s}^{-1}$   
Low  $68 \text{ L}\cdot\text{s}^{-1}$

E2  
High  $109 \text{ L}\cdot\text{s}^{-1}$   
Low  $52 \text{ L}\cdot\text{s}^{-1}$

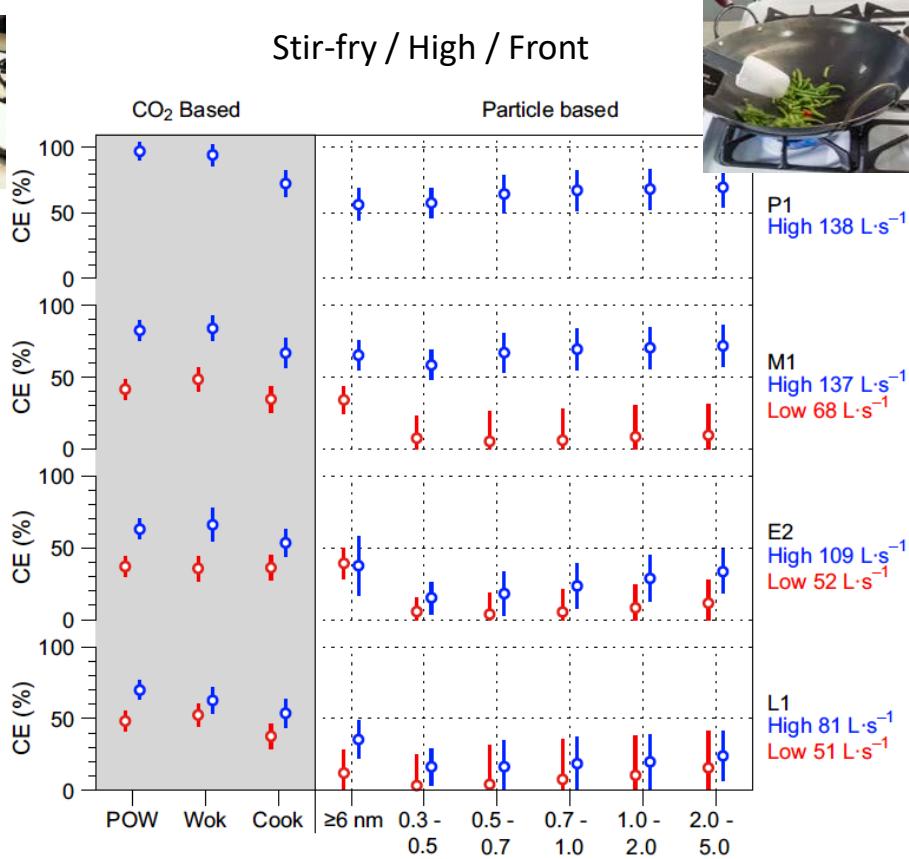
L1  
High  $81 \text{ L}\cdot\text{s}^{-1}$   
Low  $51 \text{ L}\cdot\text{s}^{-1}$

# Particles & gases similar at high CE... but differ at low CE

Burger / Med / Back



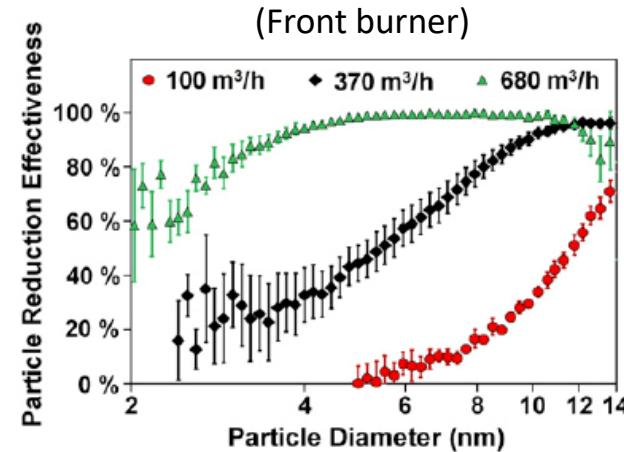
Stir-fry / High / Front



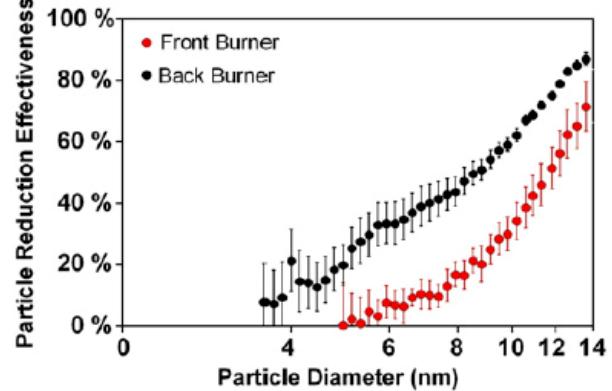
# Are RHs effective for nucleation particles from gas burners?



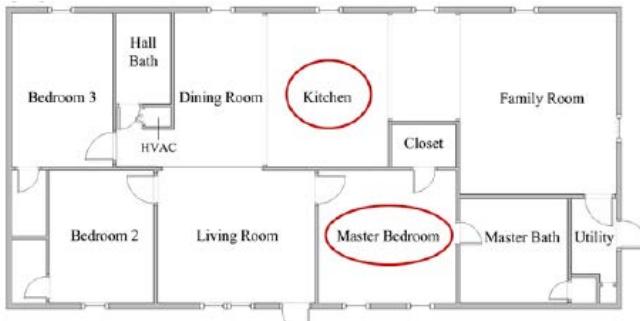
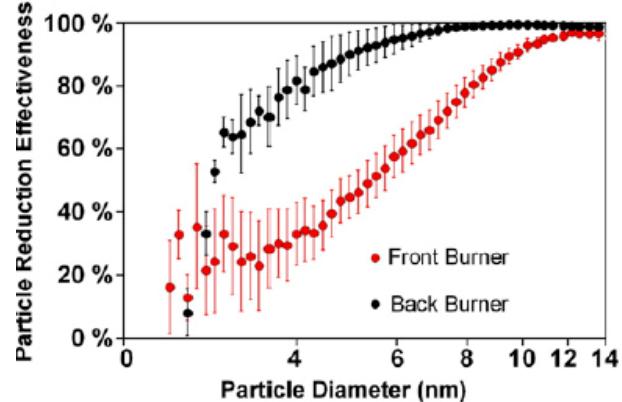
Testing in  
Manufactured House  
 $140 \text{ m}^2, 340 \text{ m}^3$



(a)  $100 \text{ m}^3/\text{h}$



(b)  $370 \text{ m}^3/\text{h}$



# Moving to the field: performance in 6 homes with gas

Use burners to heat water: no cooking

- Cooktop, oven, broiler use

Measure CO<sub>2</sub>, NO<sub>2</sub>, NO<sub>x</sub>, Particles >6 nm in kitchen, central and bedroom areas



# Range hoods and house volumes



H1: 134 m<sup>2</sup>

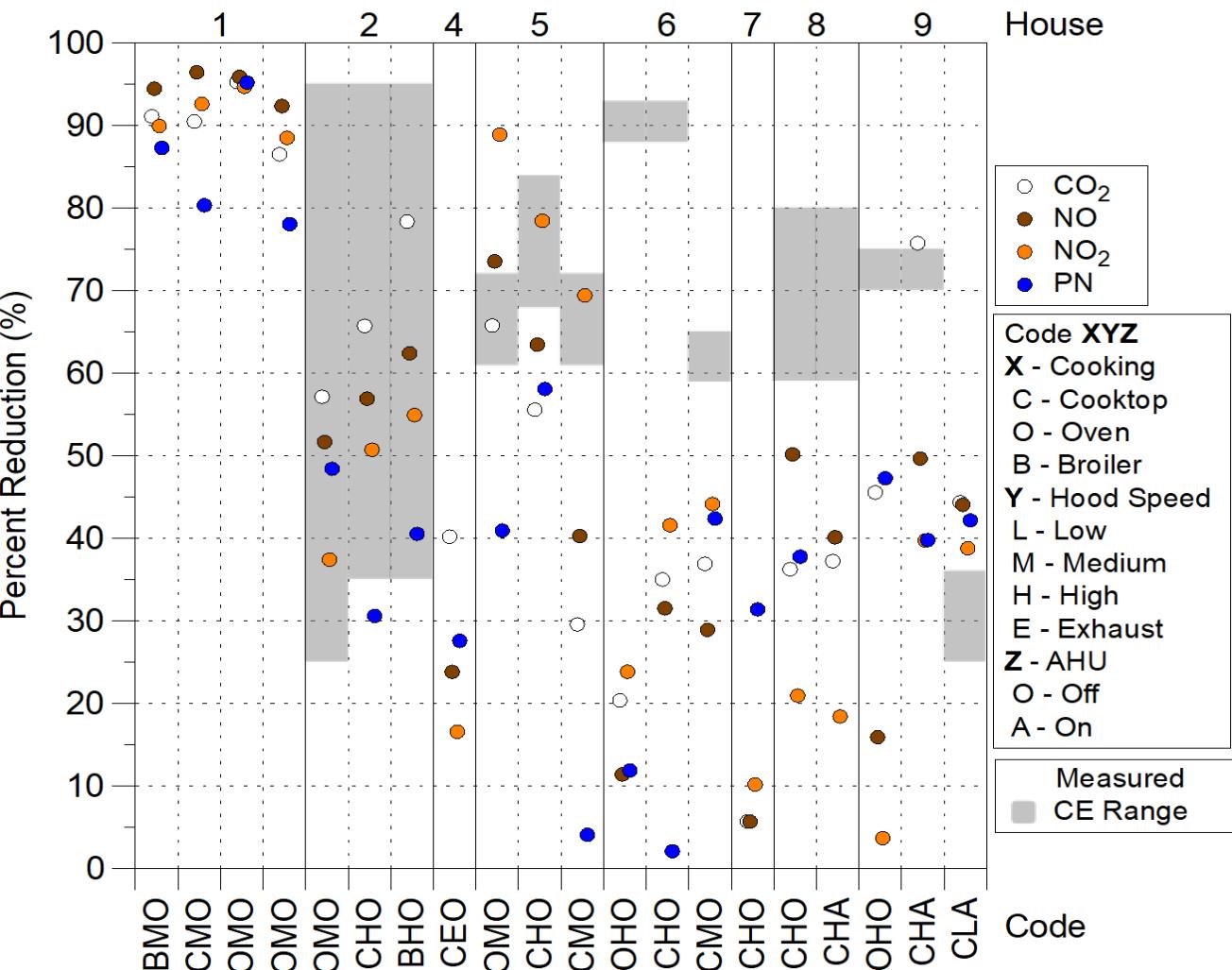


H6: 119 m<sup>2</sup>



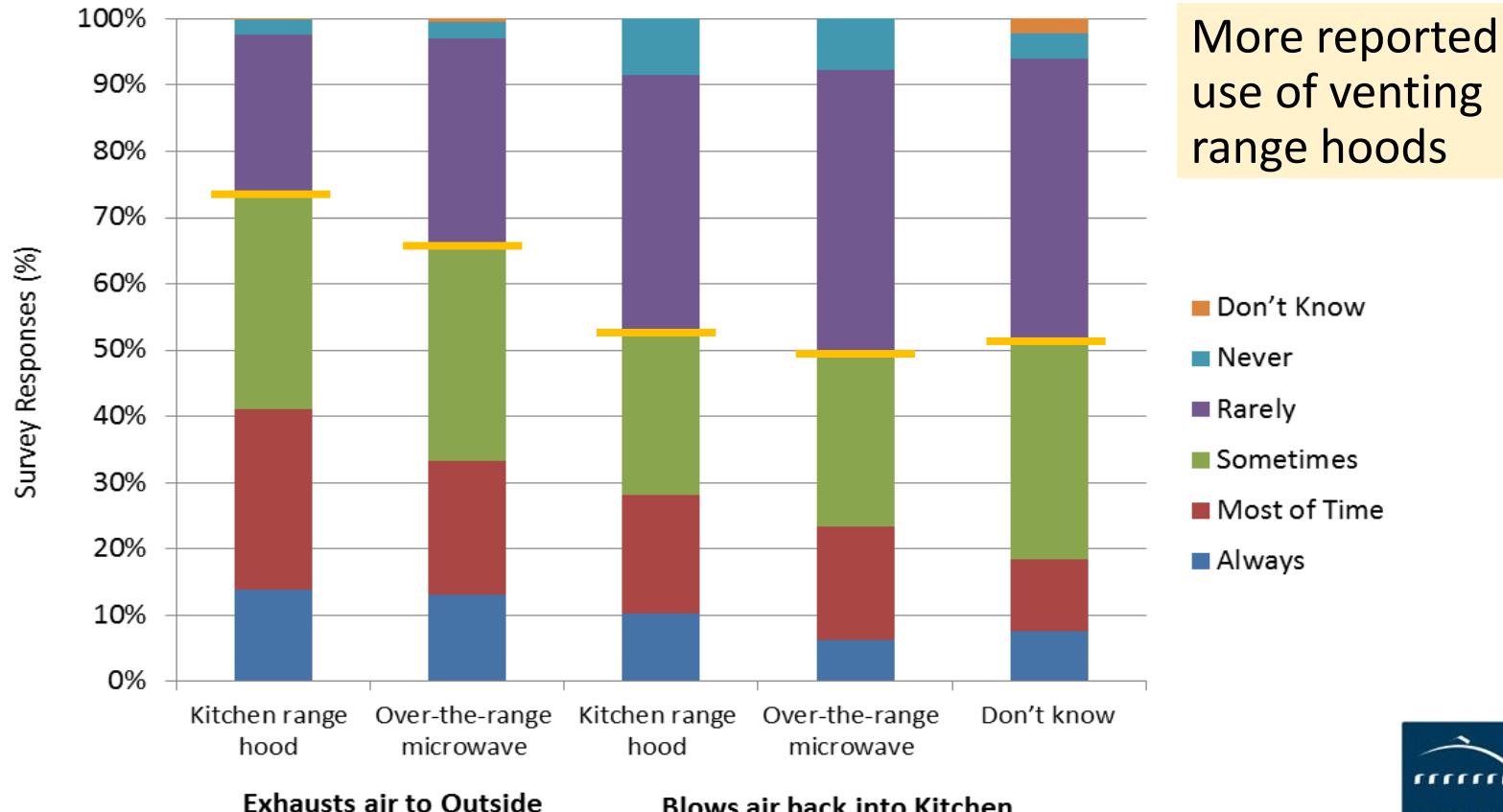
Installed range hoods provided varied levels of exposure reduction

(Kitchen data shown)



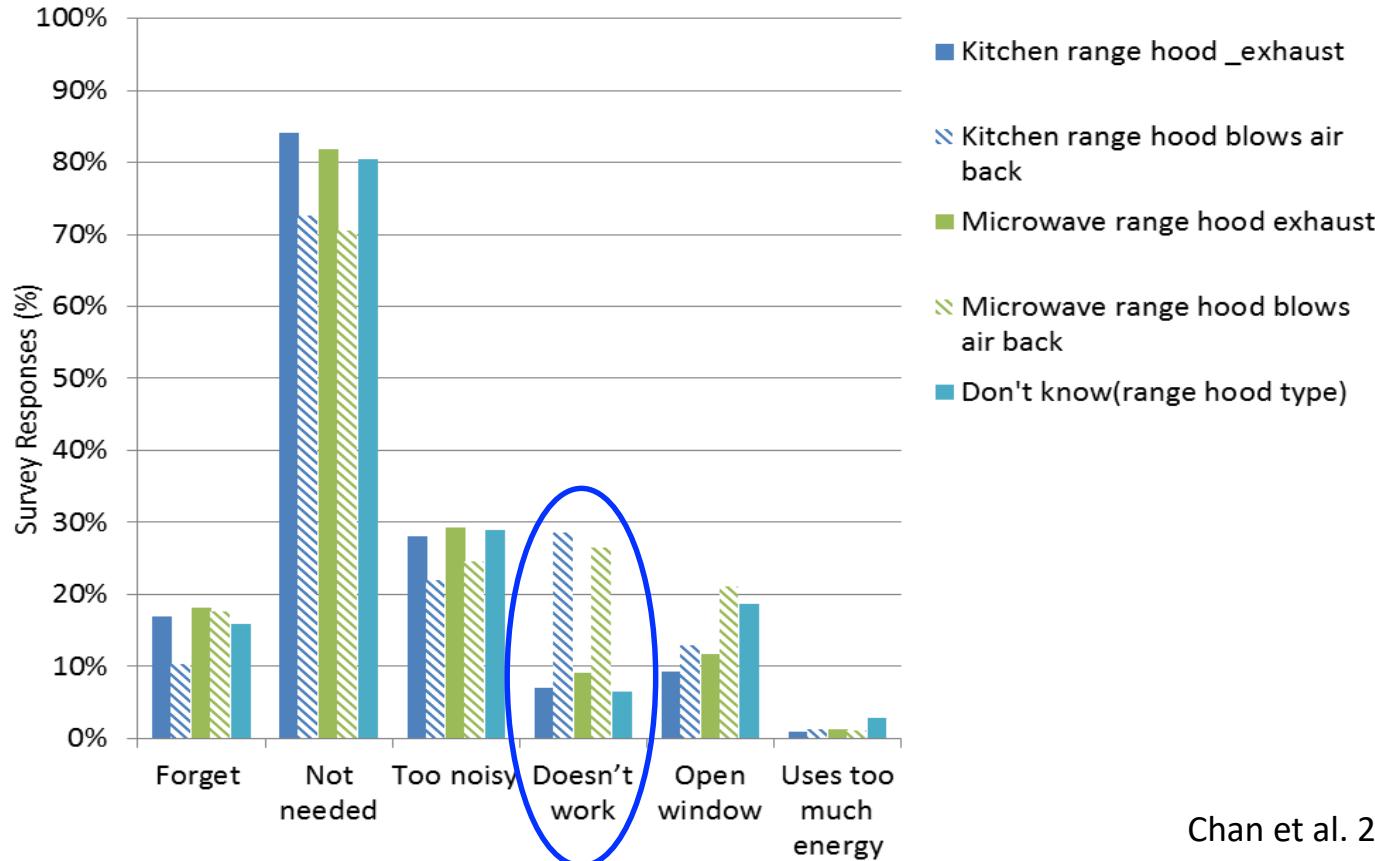
# How frequently do you use range hood with cooktop?

Web-based survey of >2000 mostly SoCal homes built 2003-2010



# Why do you *not* use your range hood?

Web-based survey of mostly SoCal homes built 2003-2010



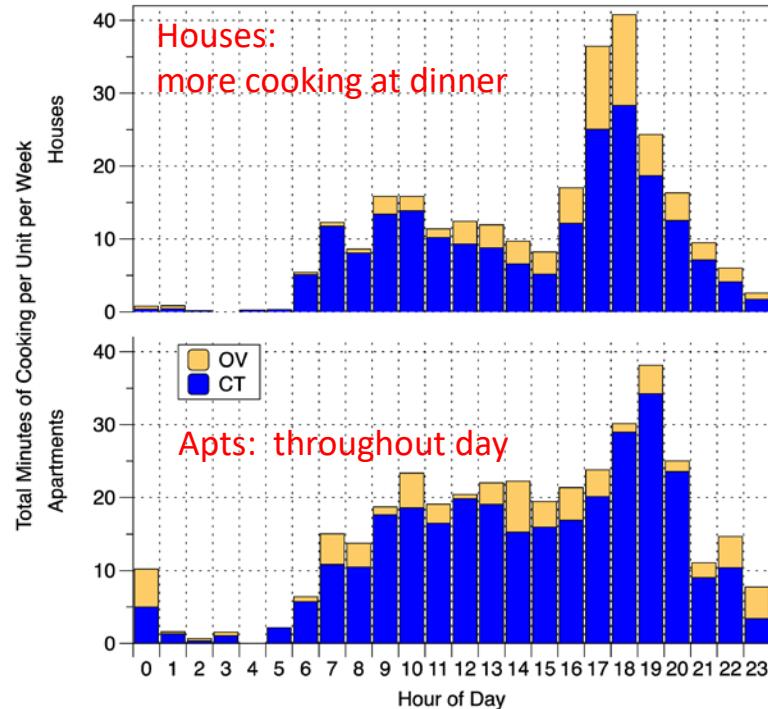
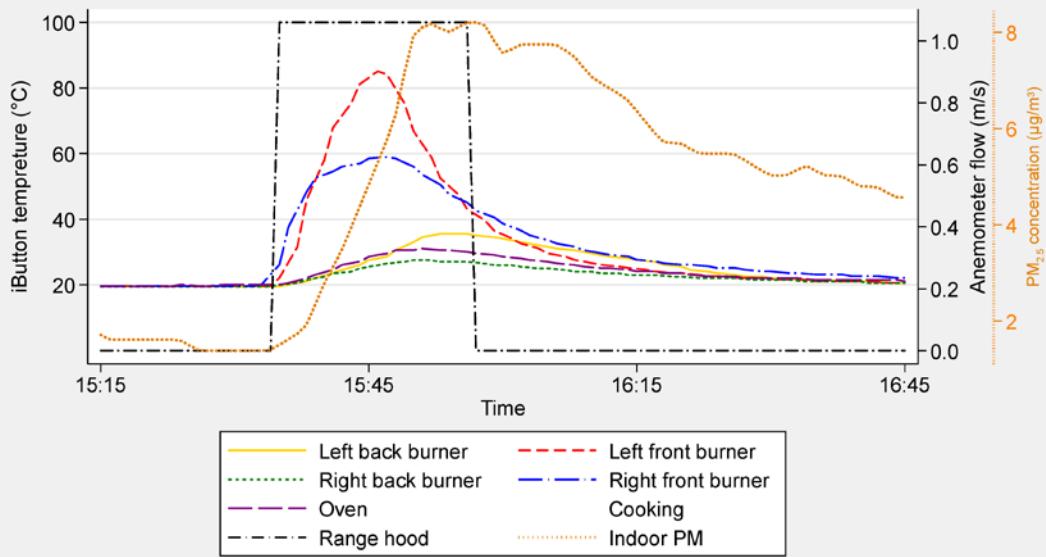
# Do people actually use their range hoods as frequently as they claim?

Zhao et al,  
IJERPH, 2020

1 week each in 54 houses, 17 apts

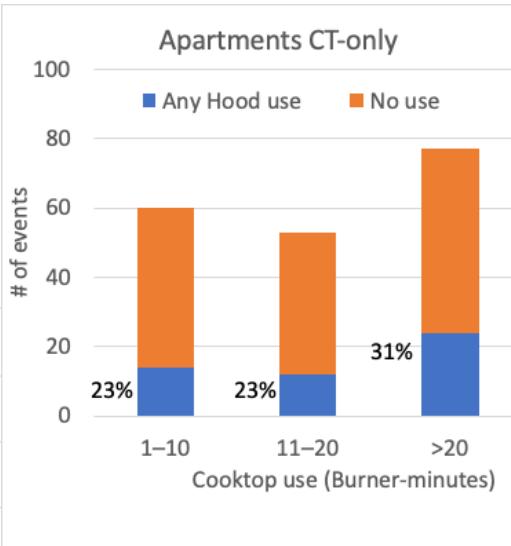
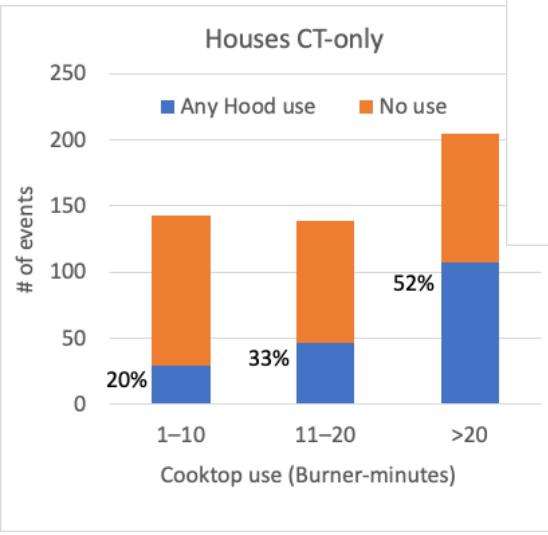
All had mechanical ventilation & vented range hoods

Monitored cooking & range hood + activity log

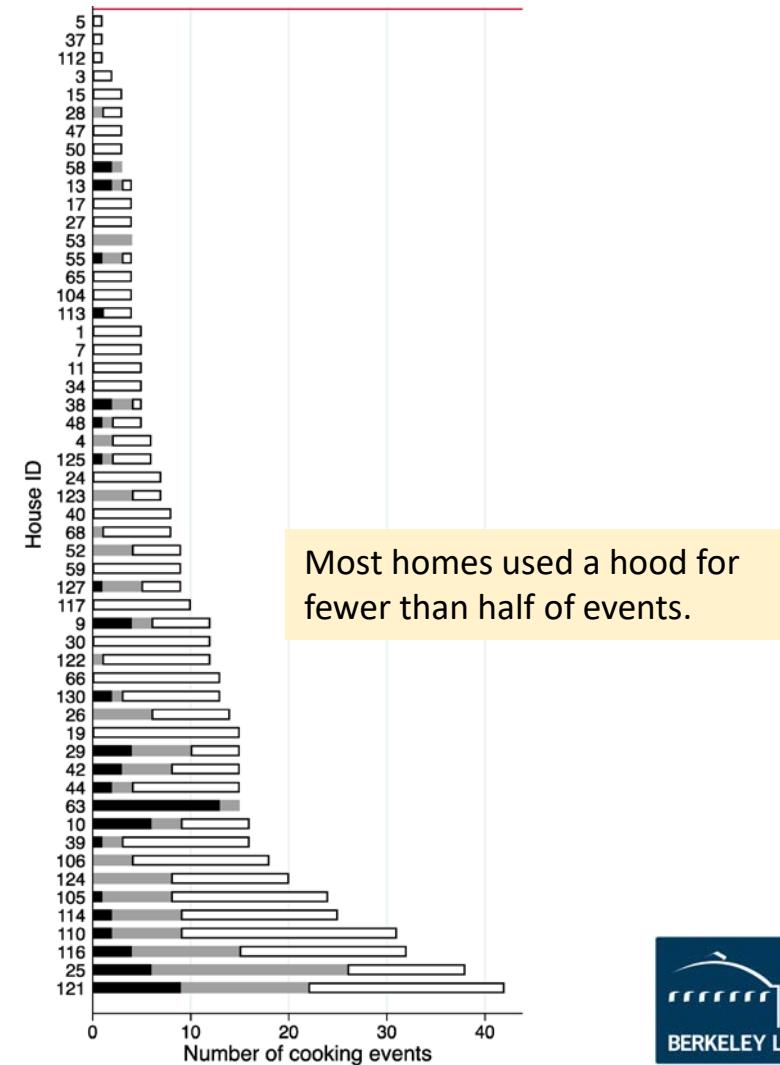


# Actual Range Hood Use in California Houses and Low-Income Apartments

Longer cooking event ->  
range hood use more likely



Use increased with PM emissions in houses, but not apartments.



# Residential cooking and use of kitchen ventilation: The impact on exposure

Sun and Wallace,  
J&AWMA, 2021

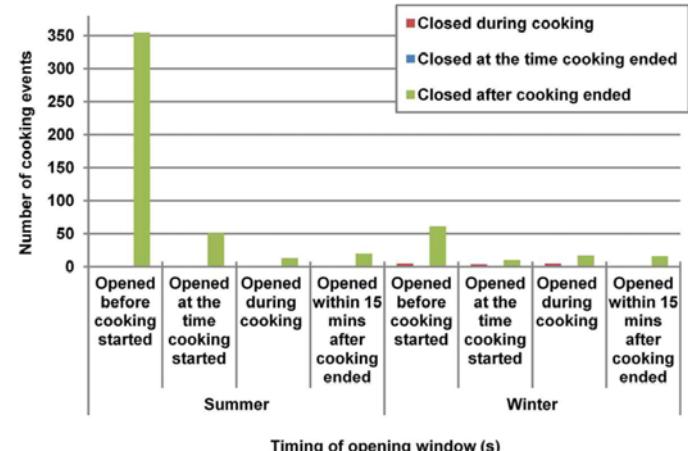
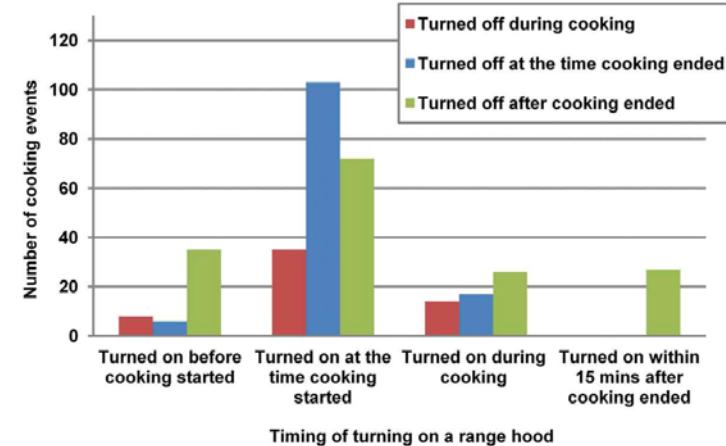
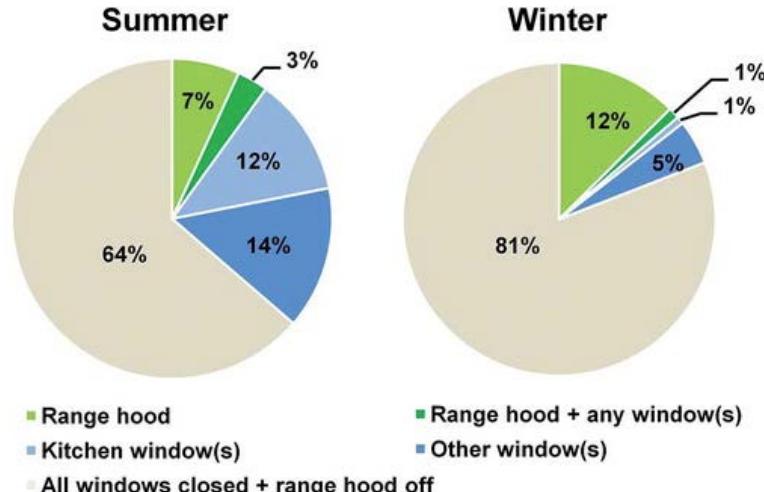
132 homes in Halifax and Edmonton (Canada)

55% vented, 22% unvented, 18% none, 5% unknown

Cooking by daily log; Monitored range hood, windows

2.4 cooking events per day, GM: 17 min

22% of PM from cooking

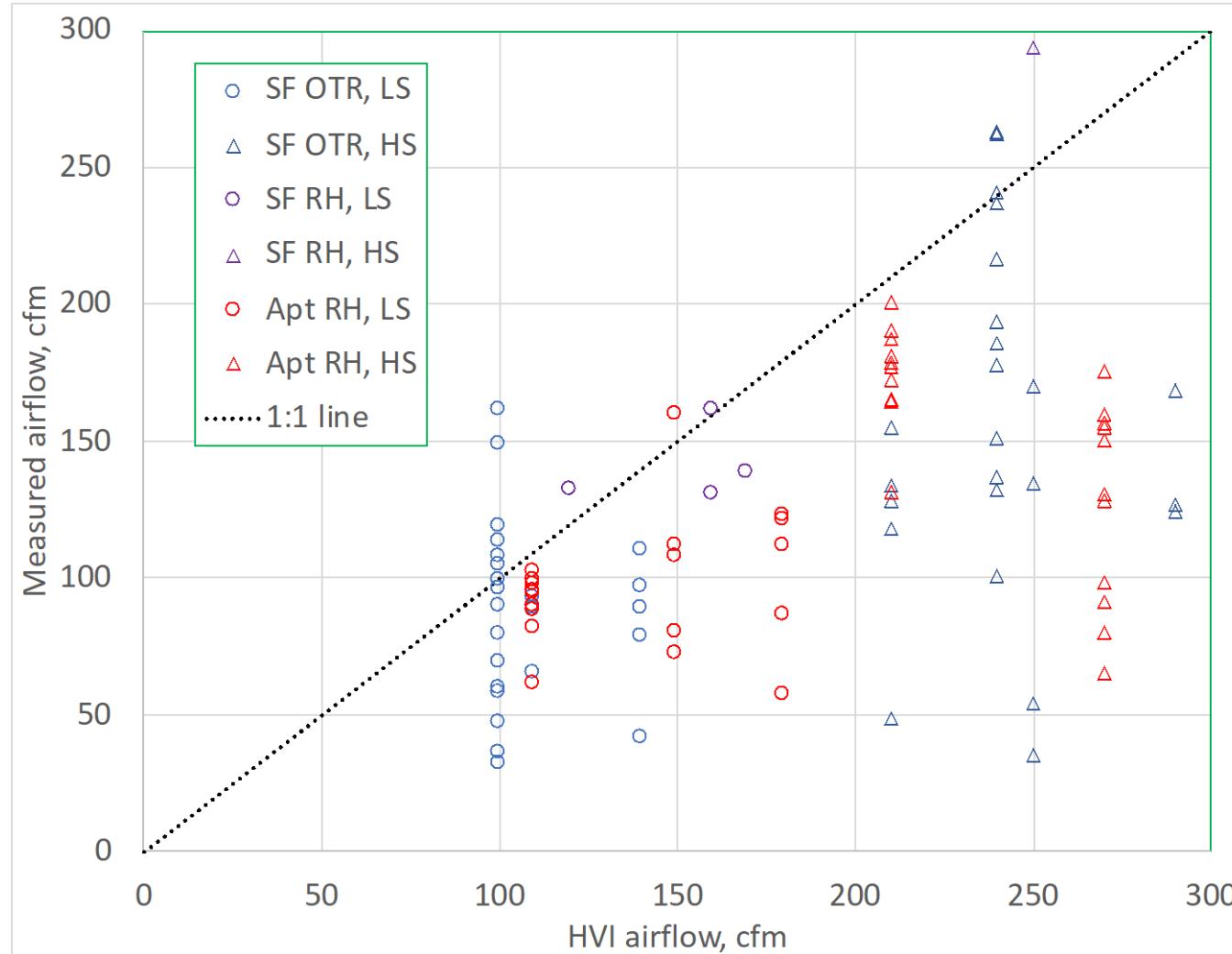


Airflows  
measured in  
California homes  
much lower than  
certification test  
results.

Why?

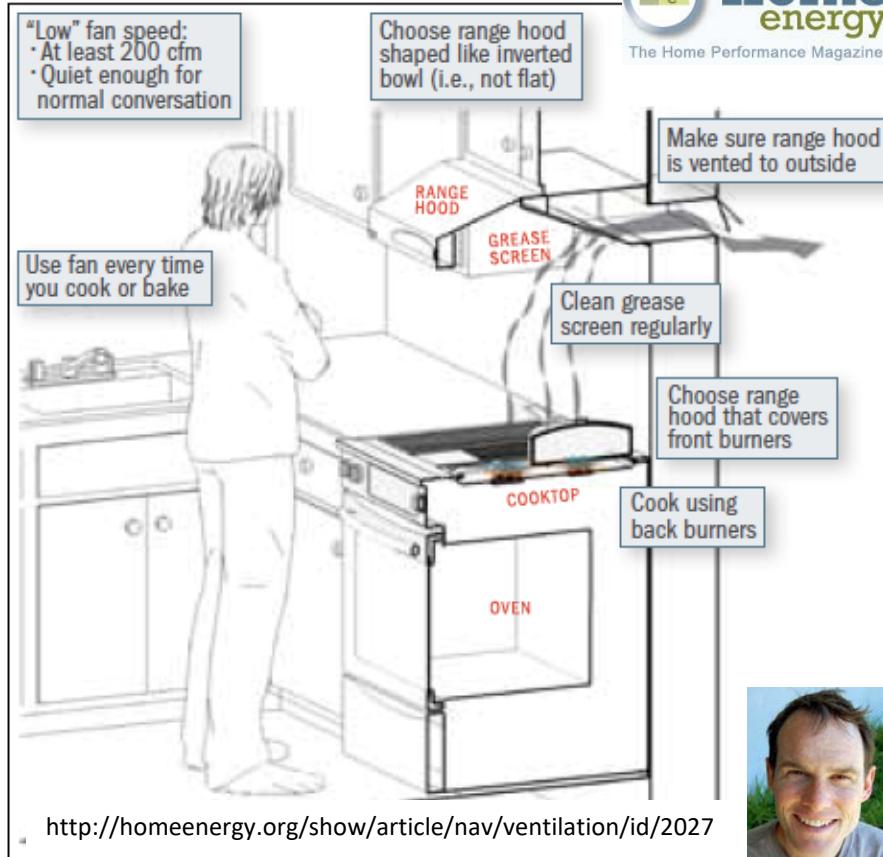
Consistent with static  
pressure as installed in  
homes being much  
higher than test  
conditions.

Data from Chan (2020)  
and Zhao (2019)



# Guidance and Resources

## Tips for Increasing Range Hood Efficacy



## Certified Airflow & Sound Ratings

### CERTIFIED HOME VENTILATING PRODUCTS DIRECTORY



Leadership > Knowledge > Innovation



Certified Ratings in Air Delivery, Sound and Energy for Accurate Specifications and Comparisons

Not Listed = Not Certified

[HVI Product Directory](#)



[AHAM Product Directory](#)

## Detailed Guidance & Webinar

<http://rocis.org/kitchen-range-hoods>



# Simple Range Hood Guidance

## Builder / Contractor

- Low-resistance ducting
- Quiet at 150–200 cfm
- 250 cfm available

## User

- Use it, especially for frying & ovens
- Cook on back burner
- Higher settings as needed

## Roofer

- Don't drop debris down the vent



Materials (287 g) extracted from RH vent.  
Photo & arrangement: M. Lunden

# Summary

- ***Venting*** range hoods ***can*** effectively capture cooking and burner particles.
- Capture efficiency varies by airflow, front vs. back burners, form factor.
- Capture for cooking particles can be lower than combustion gases.
- Over the range microwaves perform similarly to common range hoods.
- Many installed range hoods measured by LBNL performed worse than rated.
- Range hoods not used routinely and much less than people claim.
- Standard method for capture efficiency: Certified products coming soon
- Automatic range hood coming soon! LBNL testing indicated it works well.
- Need more studies of effectiveness for exposure reduction and health improvements when used as an intervention.

# Thanks to the best colleagues ever!



# Questions?

Brett C. Singer

Lawrence Berkeley National Lab

[bcsinger@lbl.gov](mailto:bcsinger@lbl.gov)



# References

Chan et al. 2019 Ventilation and Indoor Air Quality in New California Homes with Gas Appliances and Mechanical Ventilation. [LBNL-2001200R1](#).

Chan et al. 2020. Simulations of short-term exposure to NO<sub>2</sub> and PM<sub>2.5</sub> to inform capture efficiency standards, [LBNL-2001332](#).

Delp and Singer 2012. Performance assessment of U.S. residential cooking exhaust hoods. *ES&T* 46(11): 6167-6173. [LBNL-5545E](#).

Less et al. 2015. Indoor air quality in 24 California residences designed as high performance homes. *STBE*, 21(1): 14-24. [LBNL-6937E](#)

Lunden et al. 2015. Capture efficiency of cooking-related fine and ultrafine particles by residential exhaust hoods. *Indoor Air* 25(1): 45-58. [LBNL-6664E](#).

Mullen et al. 2015. Results of the California Healthy Homes Indoor Air Quality Study of 2011-13... *Indoor Air* 26(2): 231-245. [LBNL-185629](#).

Rim et al. 2012. Reduction of Exposure to Ultrafine Particles by Kitchen Exhaust Hoods: The Effects of Exhaust Flow Rates, Particle Size, and Burner Position. *Science of the Total Environment* 432 (August): 350–56. <https://doi.org/10.1016/j.scitotenv.2012.06.015>

Singer et al. 2012. Performance of installed cooking exhaust devices. *Indoor Air* 22: 224-234. [LBNL-5265E](#).

Singer et al. 2017. Pollutant concentrations and emission factors from scripted natural gas cooking burner use in nine Nor-Cal. homes. *B&E* 122: 215-229. [LBNL-1006385](#).

Singer et al. 2020. Indoor air quality in California homes built in 2011-2017 with code-required mechanical. *Indoor Air*. [dx.doi.org/10.1111/ina.12676](https://doi.org/10.1111/ina.12676)

**Sun et al. 2018. Effect of venting range hood flow rate on size-resolved ultrafine particle concentrations from gas stove cooking. *Aerosol Sci. Tech.* 52 (12):1370–81. doi:10.1080/02786826.2018.1524572.**

Sun and Wallace. 2021. Residential cooking and use of kitchen ventilation: The impact on exposure. JAWMA. doi: 10.1080/10962247.2020.1823525.

Zhao et al. 2020. Measured Performance of Over the Range Microwave Range Hoods. Lawrence Berkeley National Laboratory, Berkeley, CA. [LBNL-2001351](#).

Zhao et al 2020. Factors impacting range hood use in California houses and low-income apartments. *IJERPH*. 17(23), 8870.

Zhao et al. 2020. Indoor air quality in new and renovated low-income apartments with mechanical ventilation and natural gas cooking in CA. *Indoor Air*. [\[Journal Link\]](#)

## Datasets

Chan WR et al. (2020), Data from: Indoor air quality in California homes with code-required mechanical ventilation, Dryad, Dataset, <https://doi.org/10.7941/D1ZS7X>

Zhao H et al. (2020), Data from: Indoor air quality in new and renovated low-income apartments with mechanical ventilation and natural gas cooking in California, Dryad, Dataset, <https://doi.org/10.7941/D1T050>

# Extra Slides

# Goal

Venting range hood in all homes,  
required by code

Effective for front burners  
Quiet at 200+ cfm  
Automatic

Use with frying, bake, broil, meals;  
Cook on back burners

Effectiveness confirmed with home  
IAQ monitors

# Reality

Above the stove venting not required in  
most building codes, absent from many  
homes; renters especially vulnerable

Large & quiet both exist; rarely together.  
Quiet @150-200 cfm and >250 cfm \$250+  
Auto hood coming to market

Variable use; as need is perceived  
Most cook on front; use less with oven

\$200 monitor not accessible to  
many