Indoor Exposure to Fine Particulate Matter and Practical Mitigation Approaches – A Workshop

The National Academies of Sciences, Engineering, and Medicine

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Mitigation of Fine PM from Cooking

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

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Outline

Performance metrics and standards

Measured effectiveness under controlled conditions

Real-world performance and practical challenges

Resources

Both cooking & burners are sources

CO_2 & H_2O

NO,NO_2, HONO, Formaldehyde

Ultrafine particles

$PM_{2.5}$, Ultrafine particles

Formaldehyde, Acrolein, PAH, etc.

Ultrafine particles

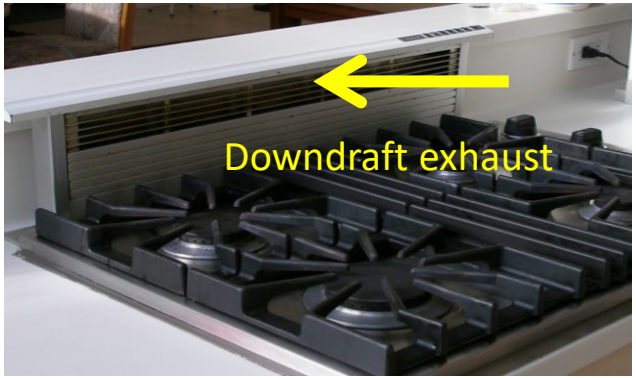
Induction burners appear to emit many fewer ultrafine particles (and no NO_X)

Less et al. 2015

Kitchen ventilation options

Ceiling exhaust fan

Wall exhaust fan



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Standards and Codes for Kitchen Ventilation

California Building Code

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

HVI
HOME VENTILATING INSTITUTE

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

ENERGY STAR

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*, ≥100 cfm on demand or **≥25 cfm continuous**, or recirculating hood!
- Make-up air required for >400 cfm exhaust

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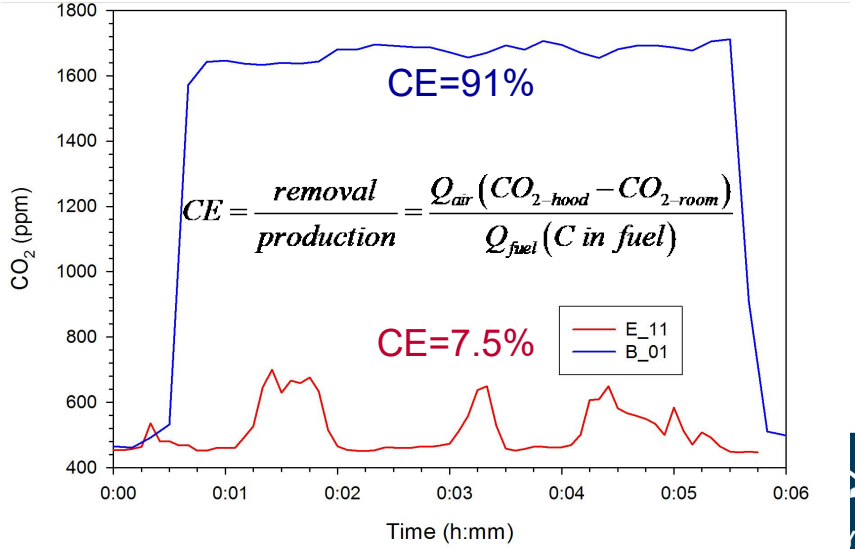
How do we know if range hoods are effective?

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

Calculated by CO_2 from gas burners or tracer release
(Different approach needed for particles)

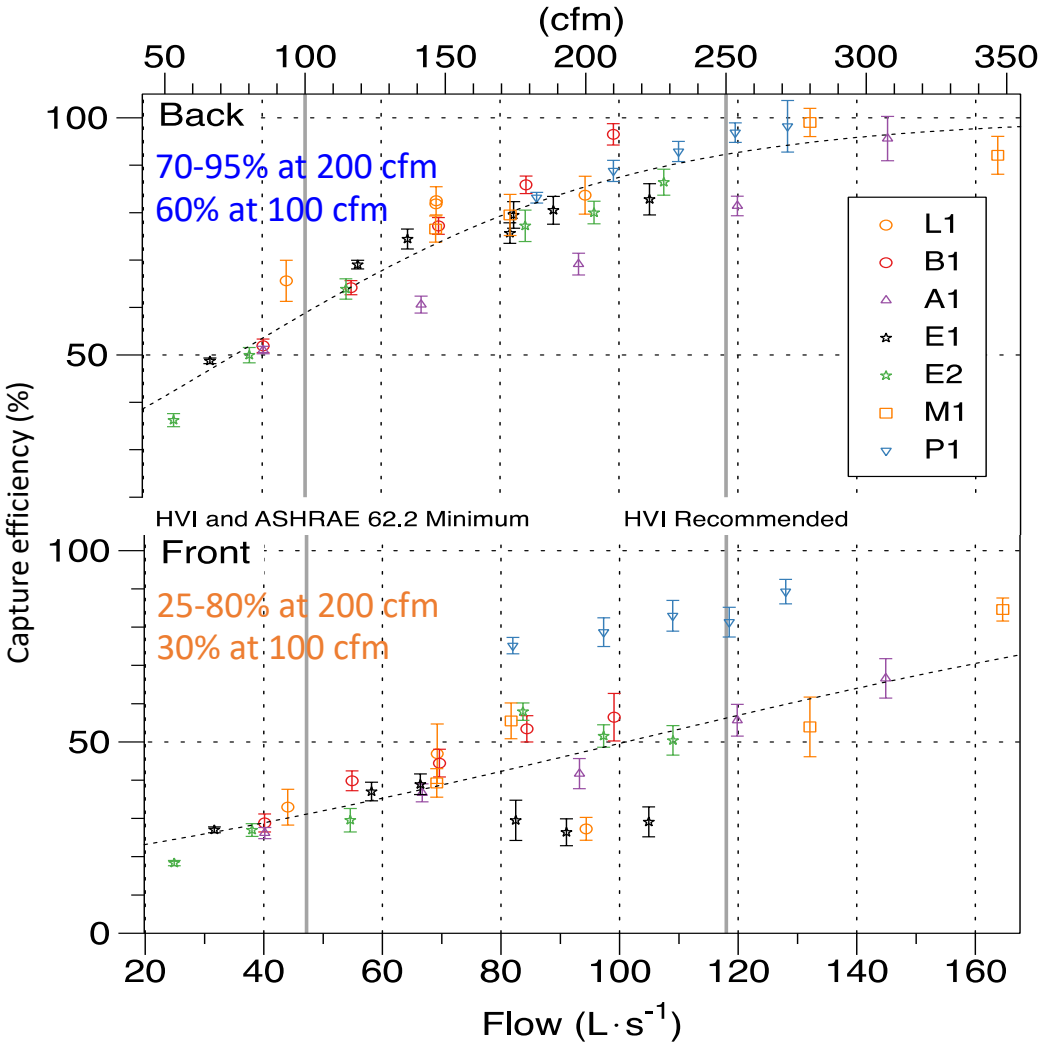


CE for combustion pollutants, lab testing

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%

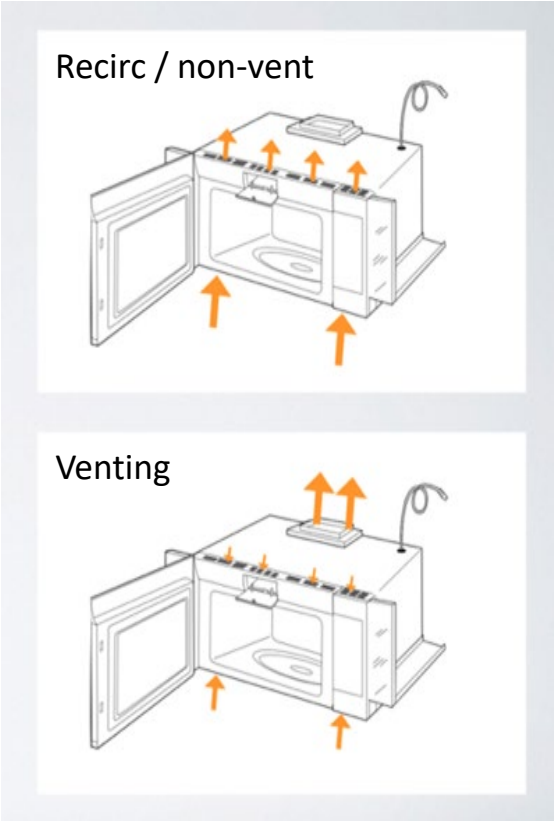


Delp and Singer, 2012

“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.



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Do OTRs have similar CE as other range hoods?

[9] Zhao et al., 2020, LBNL report

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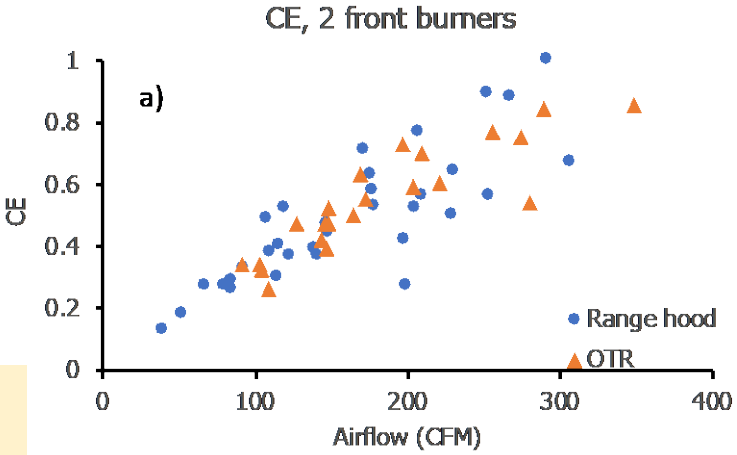
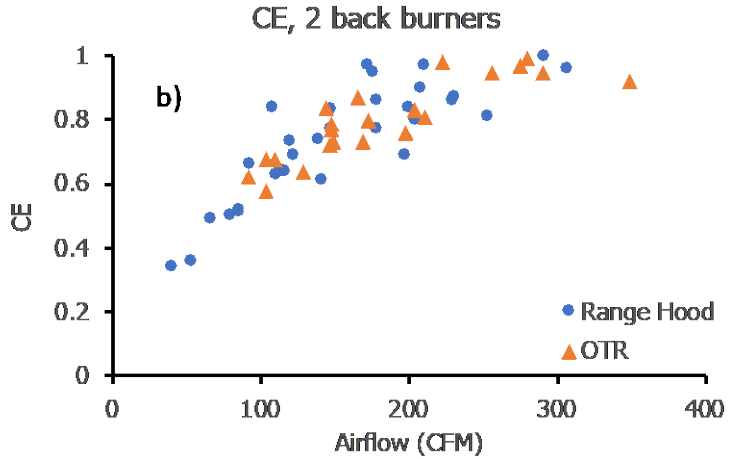
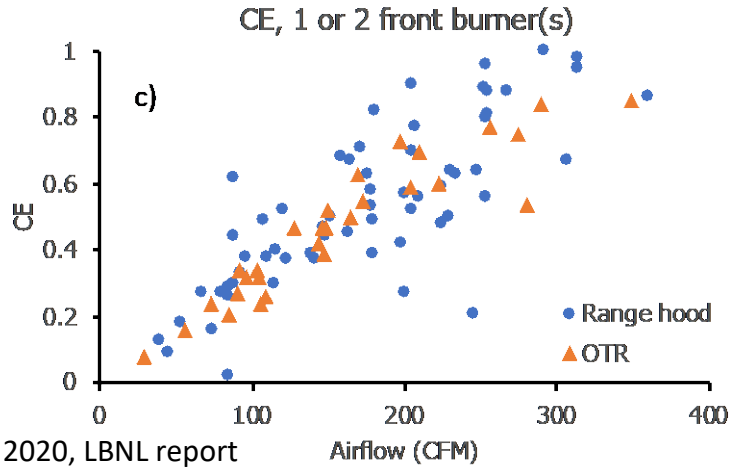
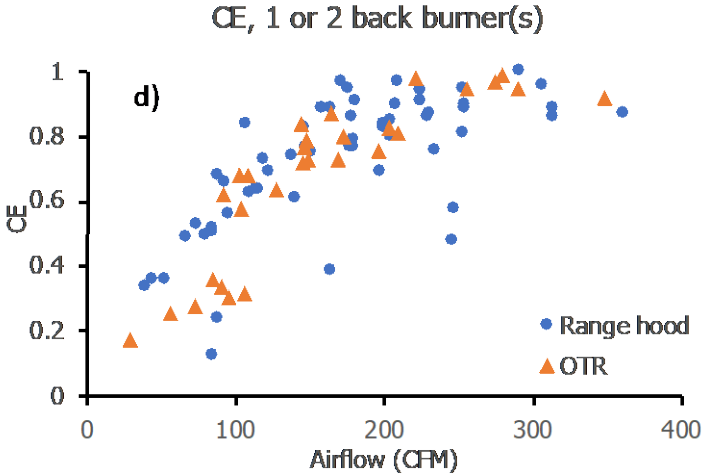
Do OTRs have similar CE as other range hoods?

~Yes.









[10] Zhao et al., 2020, LBNL report

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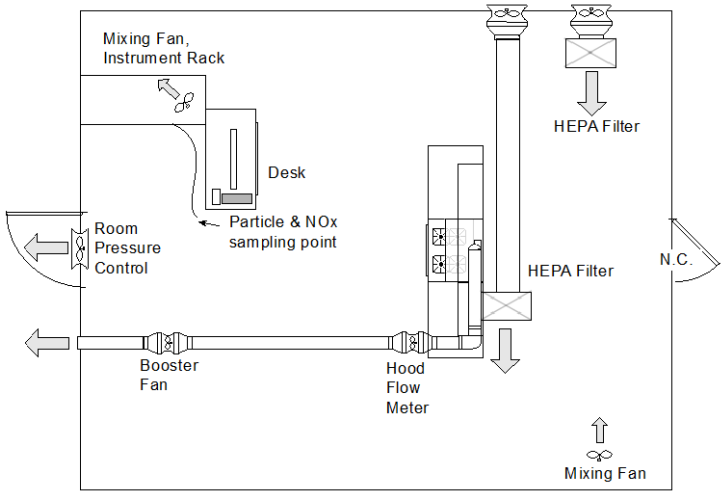
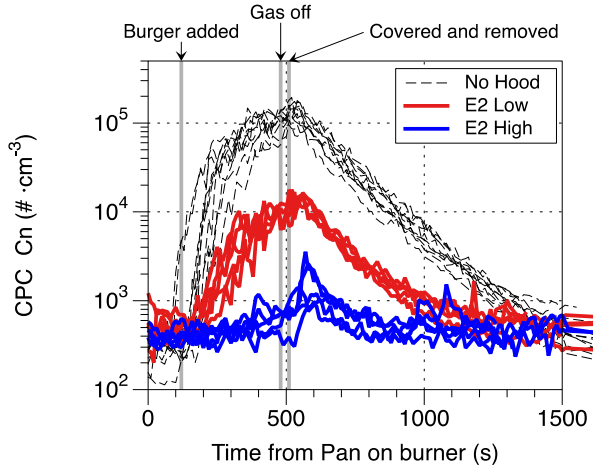
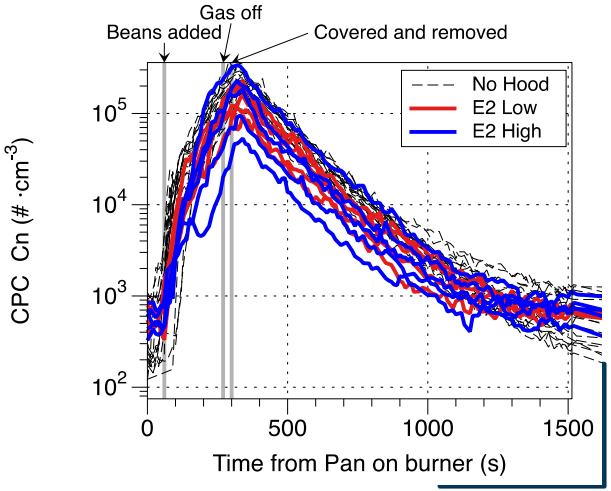
Does CE differ for cooking particles and combustion products?







121 m³ (450 sf) room

Front: stir-fry, wok, high

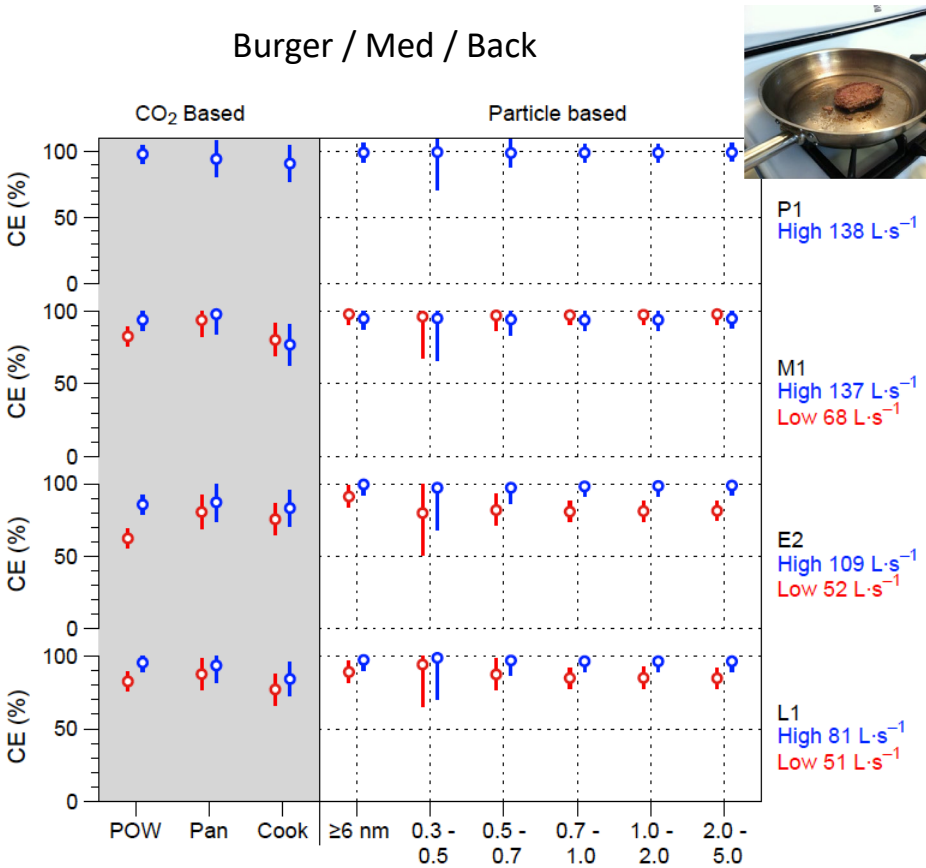
Back: pan-fry burger, med

Also stir-fry on back

4 of the prior 7 hoods

 Lunden et al. 2015

Particles & gases similar at high CE…



Lunden et al. 2015

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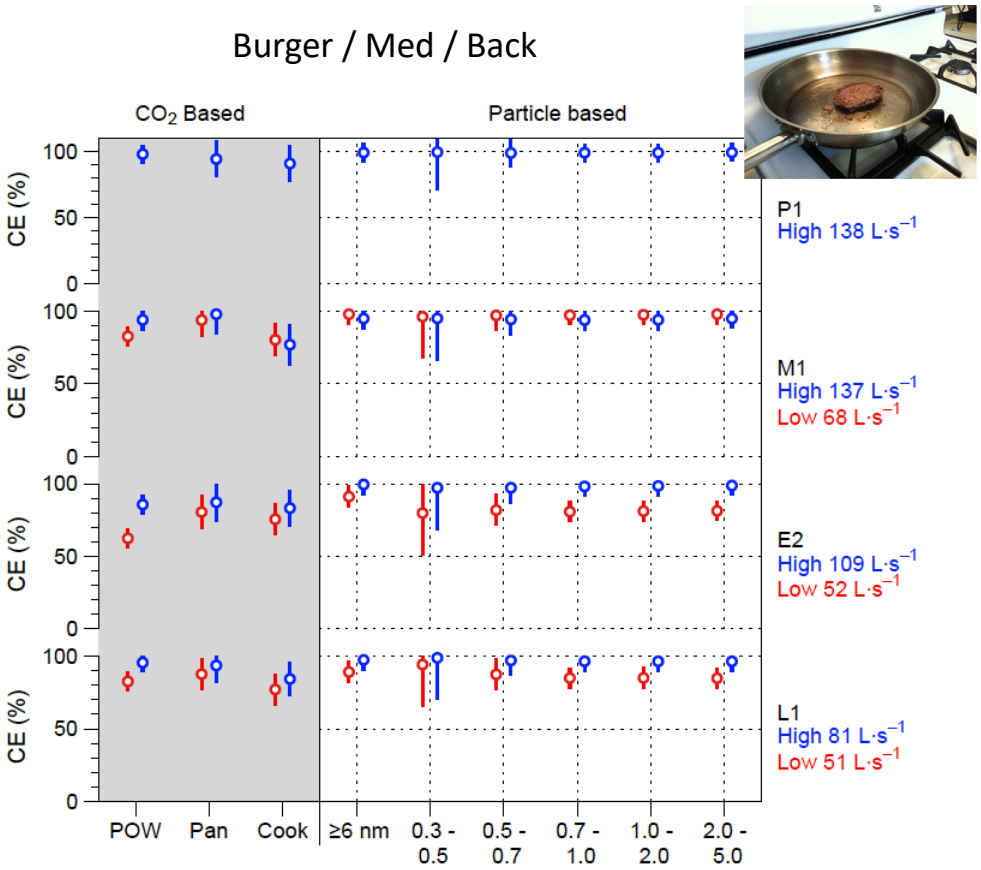
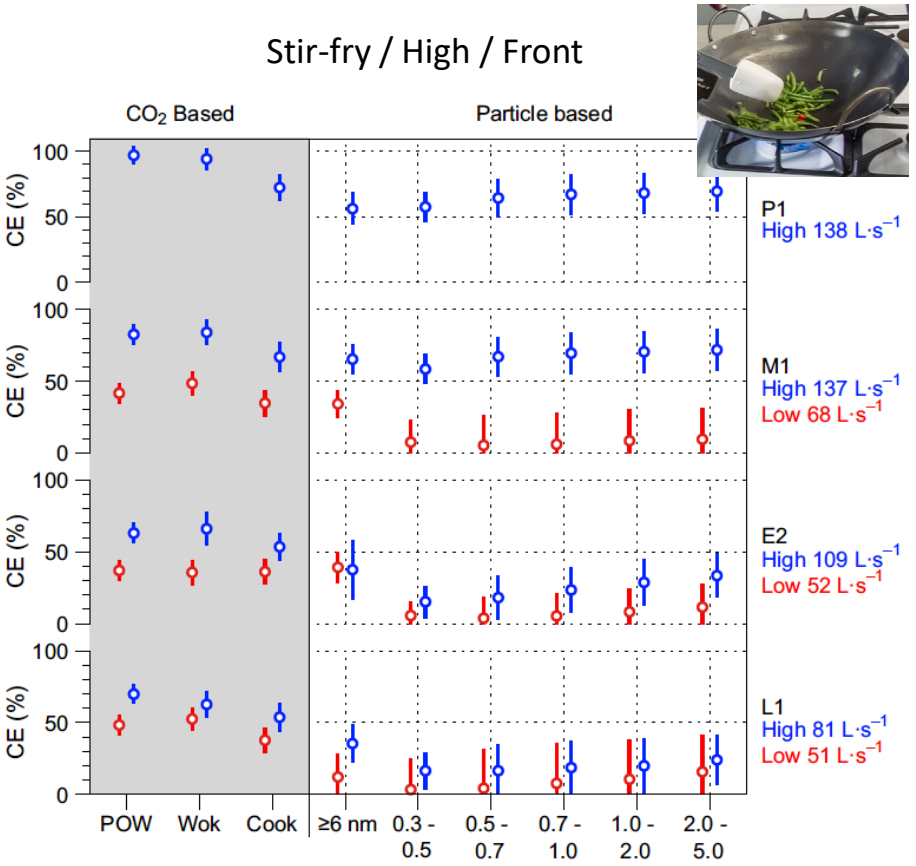
Particles & gases similar at high CE… but differ at low CE

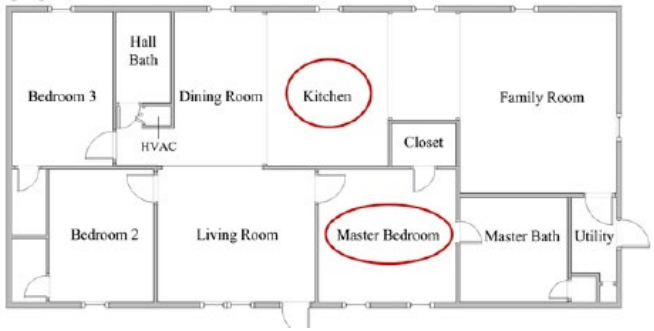




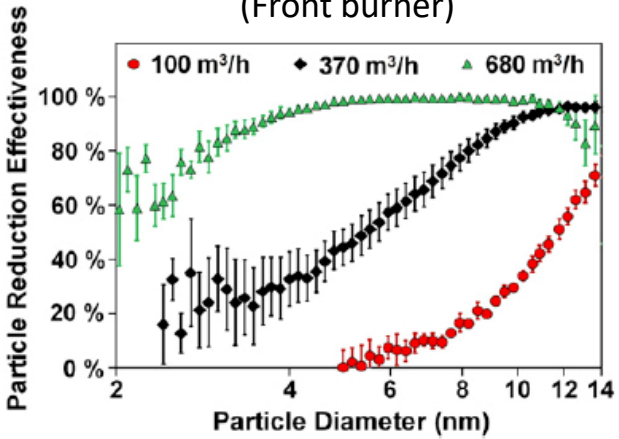
Lunden et al. 2015

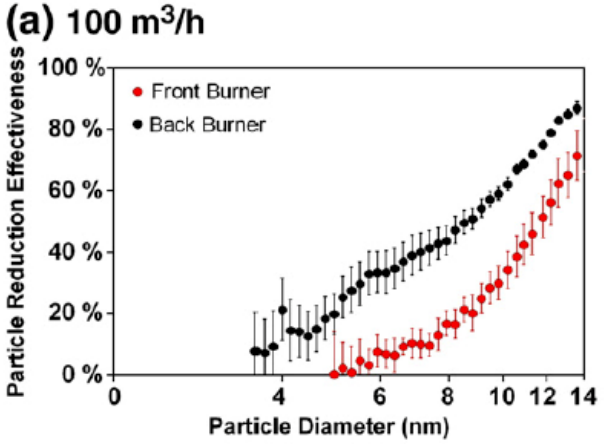
Are RHs effective for nucleation particles from gas burners?

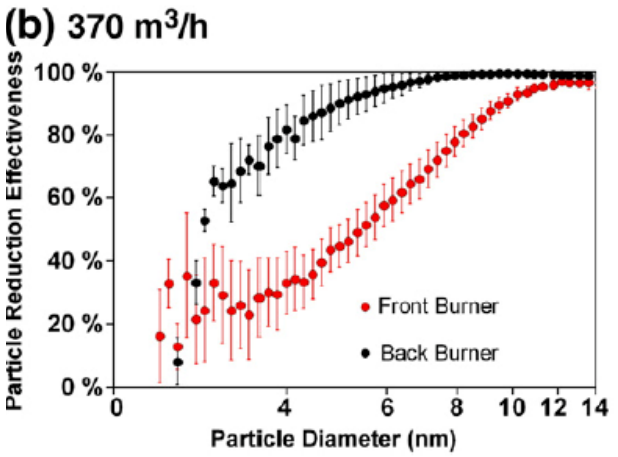
Testing in Manufactured House 140 m^2, 340 m^3



(Front burner)







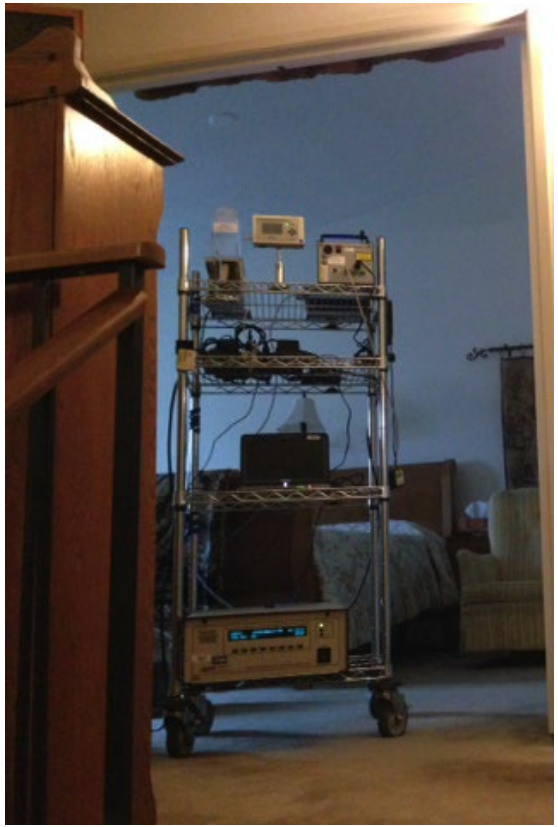
Rim et al. (2012)

Moving to the field: performance in 6 homes with gas

Use burners to heat water: no cooking

- Cooktop, oven, broiler use

Measure CO_2, NO_2, NO_x, Particles >6 nm in kitchen, central and bedroom areas



Singer et al., 2017, Building Environment

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Range hoods and house volumes

H1: 134 m^2

H2: 124 m^2

H5: 108 m^2

H9: 139 m^2

H8: 219 m^2

H6: 119 m^2

Singer et al., 2017, Building Environment

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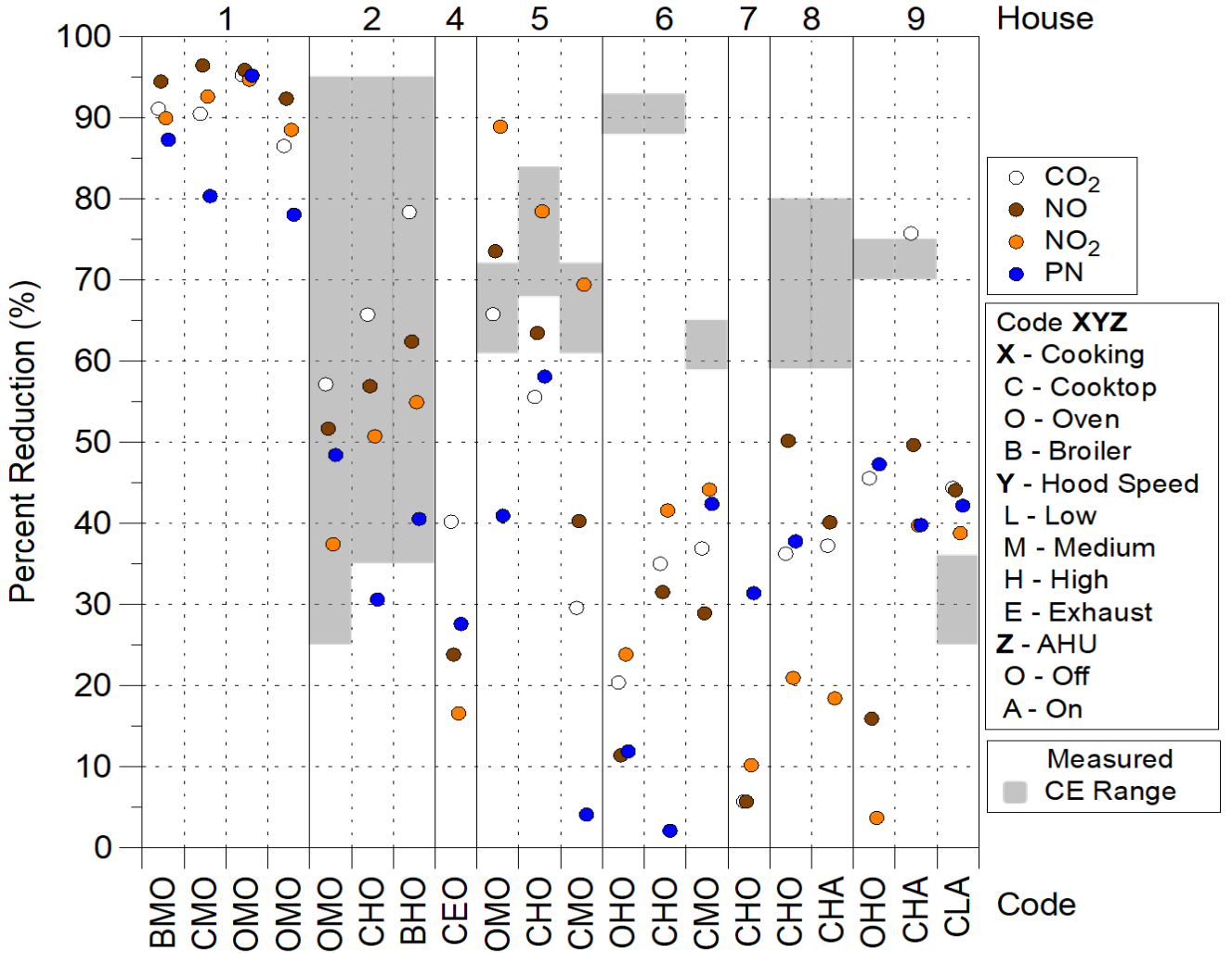
Installed range hoods provided varied levels of exposure reduction

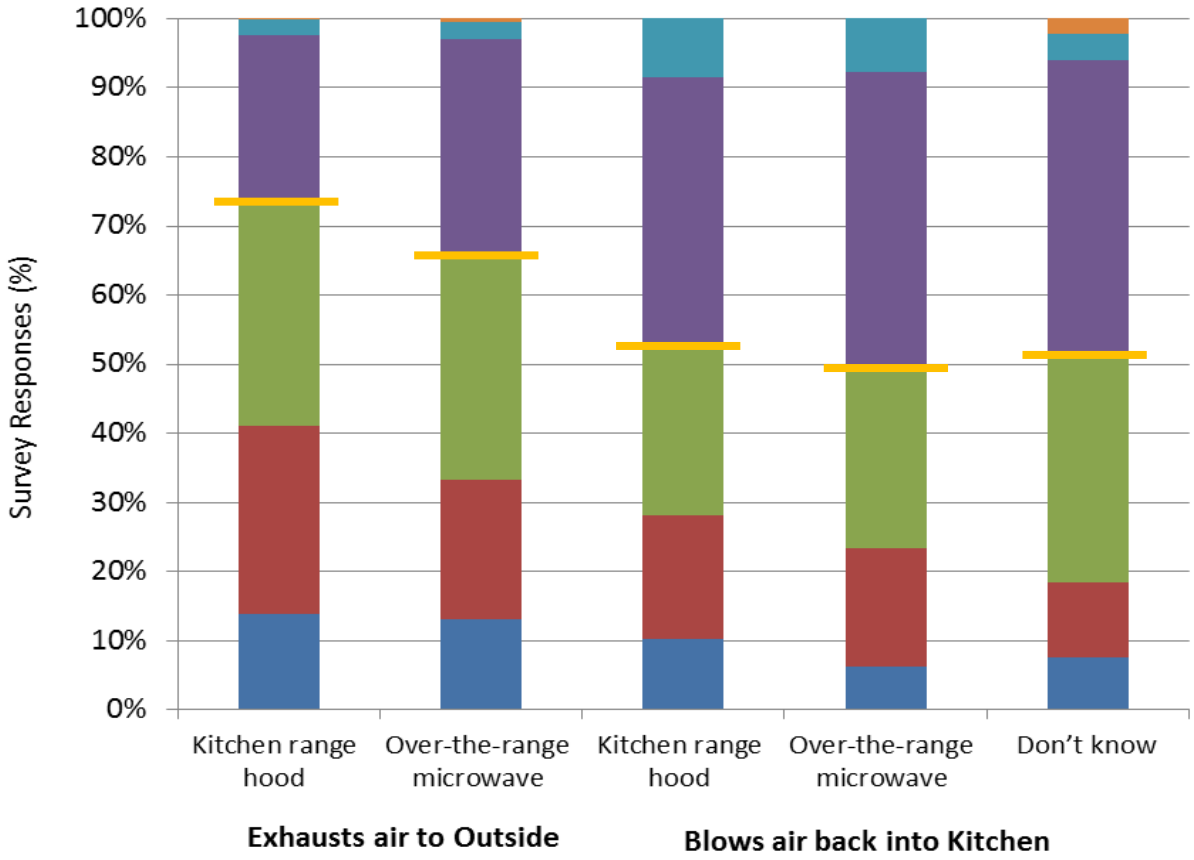
(Kitchen data shown)



Singer et al., 2017, Building Environment

How frequently do you use range hood with cooktop?

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



More reported use of venting range hoods

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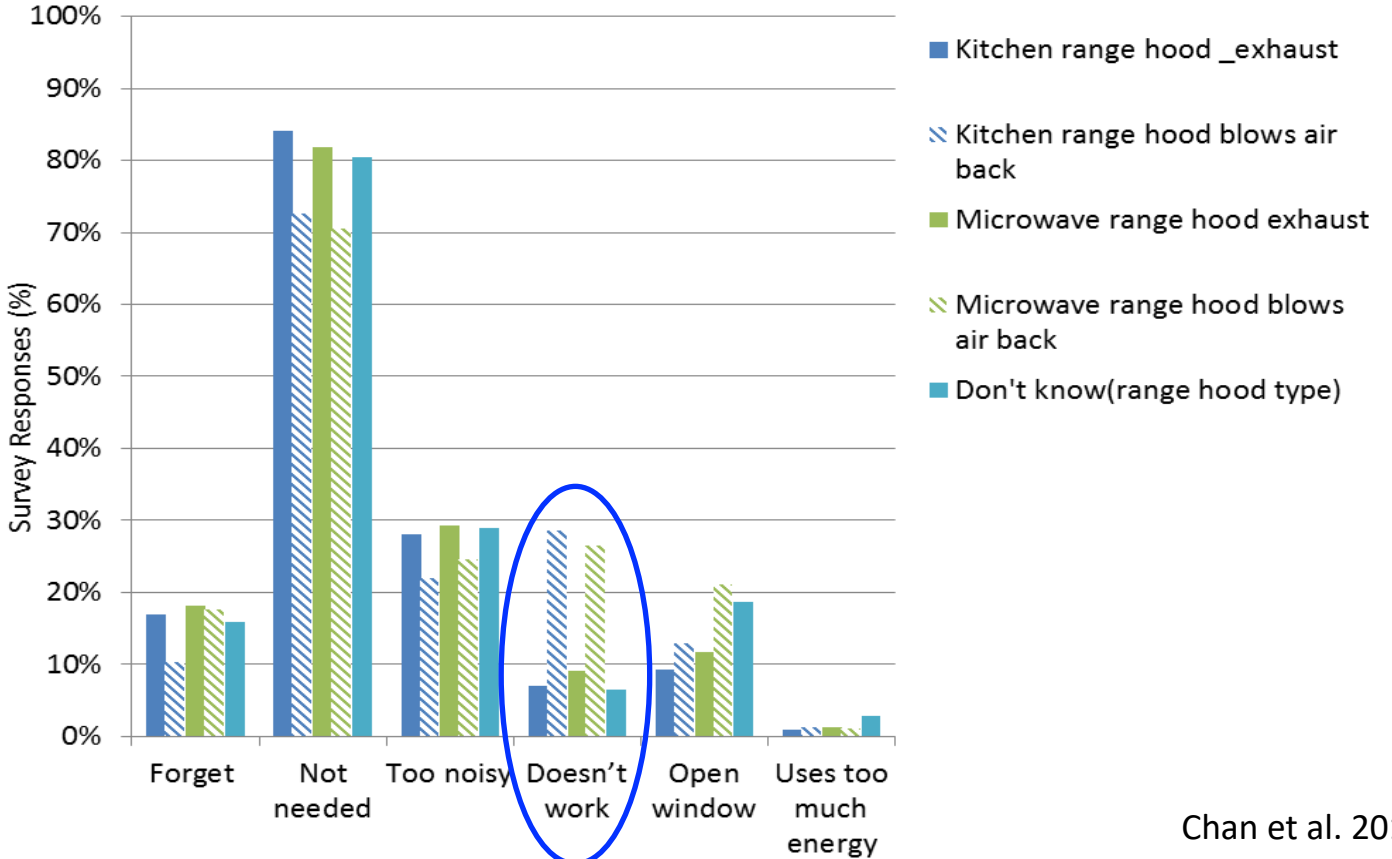
Why do you *not* use your range hood?

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



Chan et al. 2019

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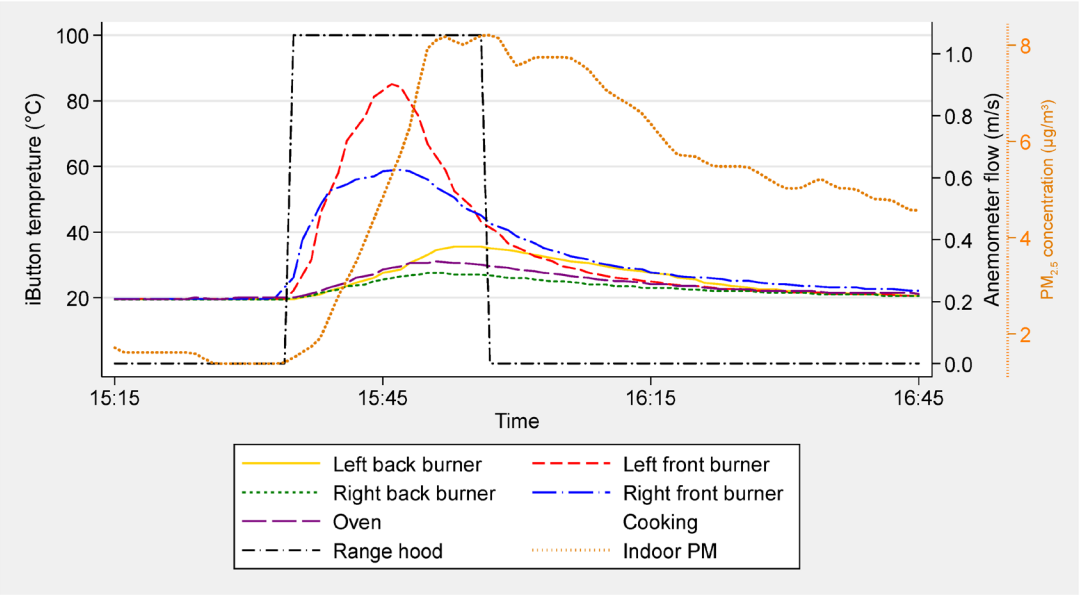
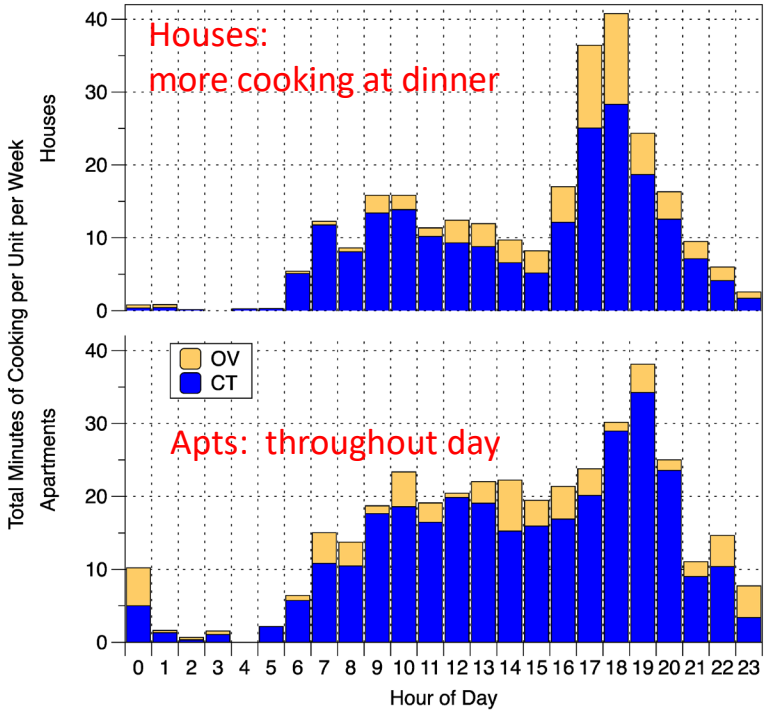
Do people actually use their range hoods as frequently as they claim?

Zhao et al,
IJERPH, 2020

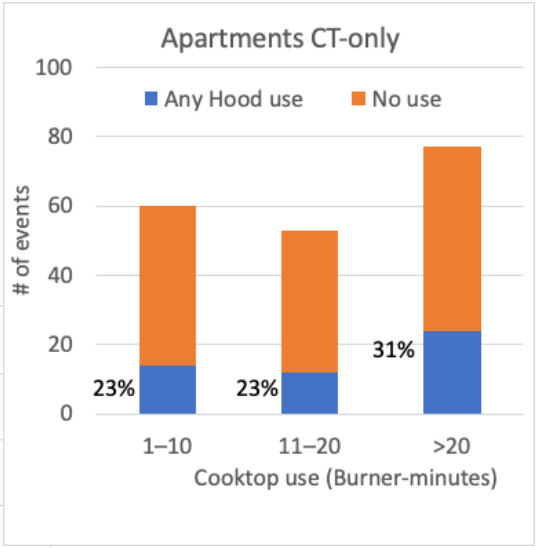
1 week each in 54 houses, 17 apts
All had mechanical ventilation & vented range hoods
Monitored cooking & range hood + activity log

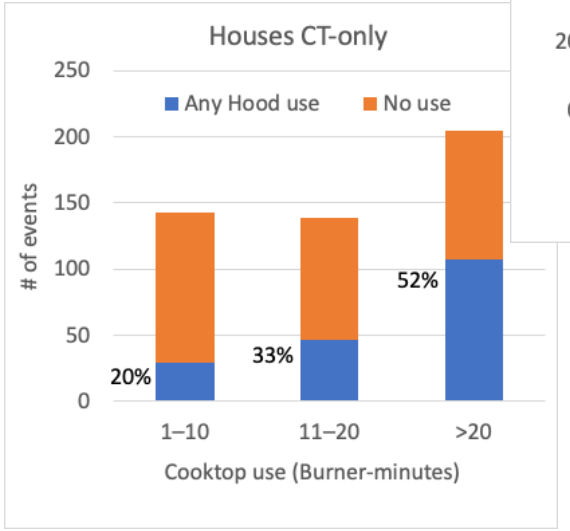




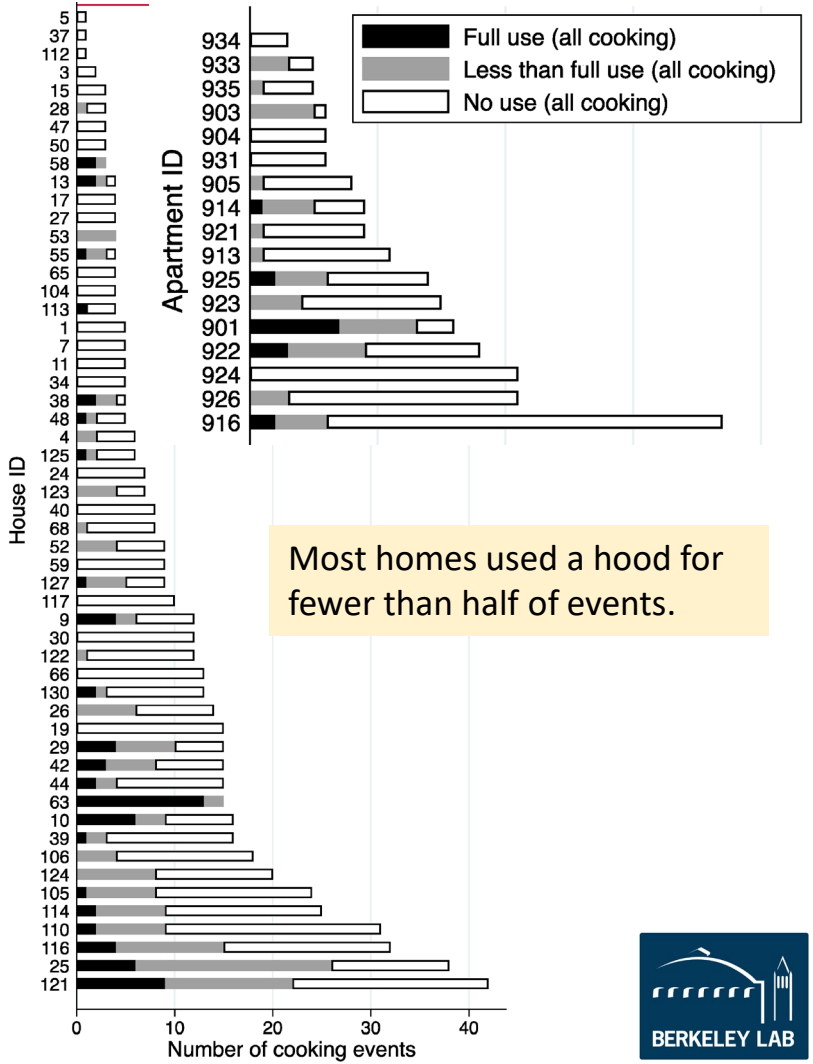
Actual Range Hood Use in California Houses and Low-Income Apartments

Longer cooking event -> range hood use more likely





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



Most homes used a hood for fewer than half of events.

Zhao et al, IJERPH, 2020

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

Sun and Wallace, J&AWMA, 2021

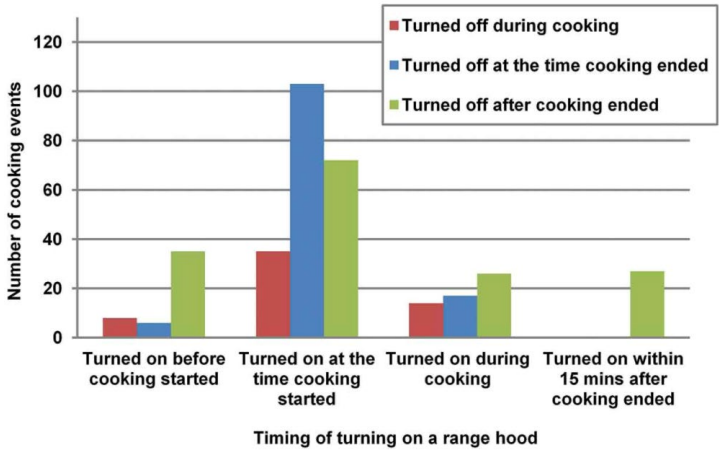
132 homes in Halifax and Edmonton (Canada)

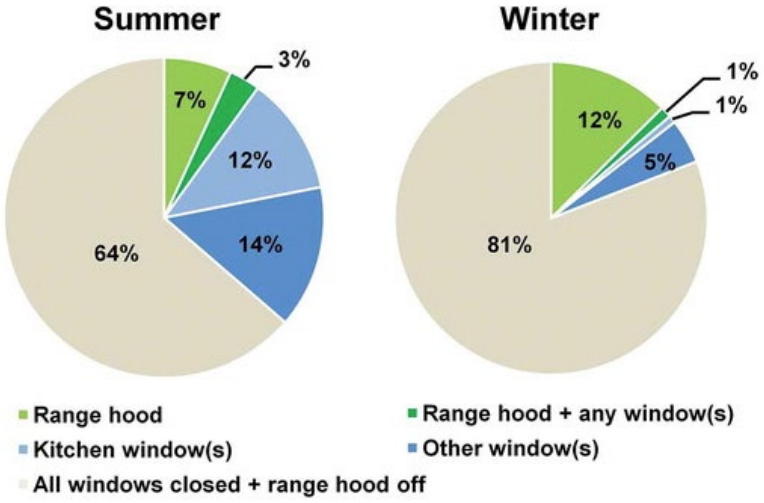
55% vented, 22% unvented, 18% none, 5% unknown

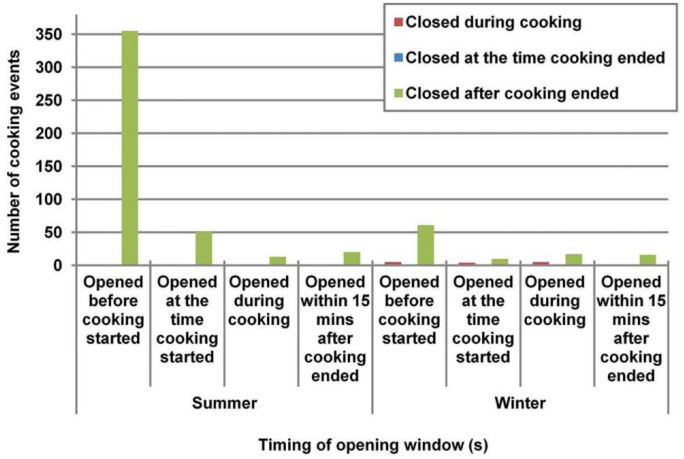
Cooking by daily log; Monitored range hood, windows

2.4 cooking events per day, GM: 17 min

22% of PM from cooking





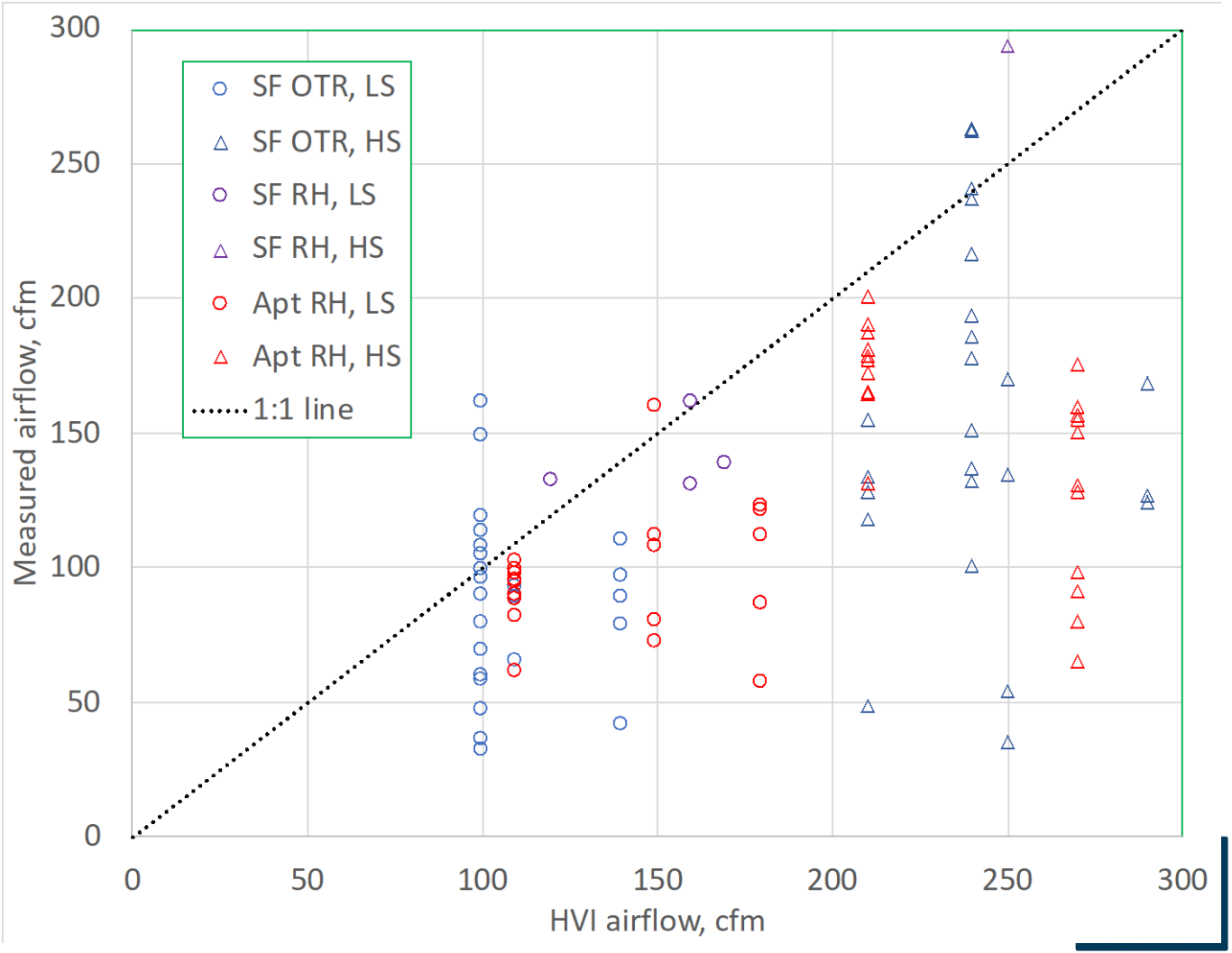


Airflows measured in California homes much lower than certification test results.

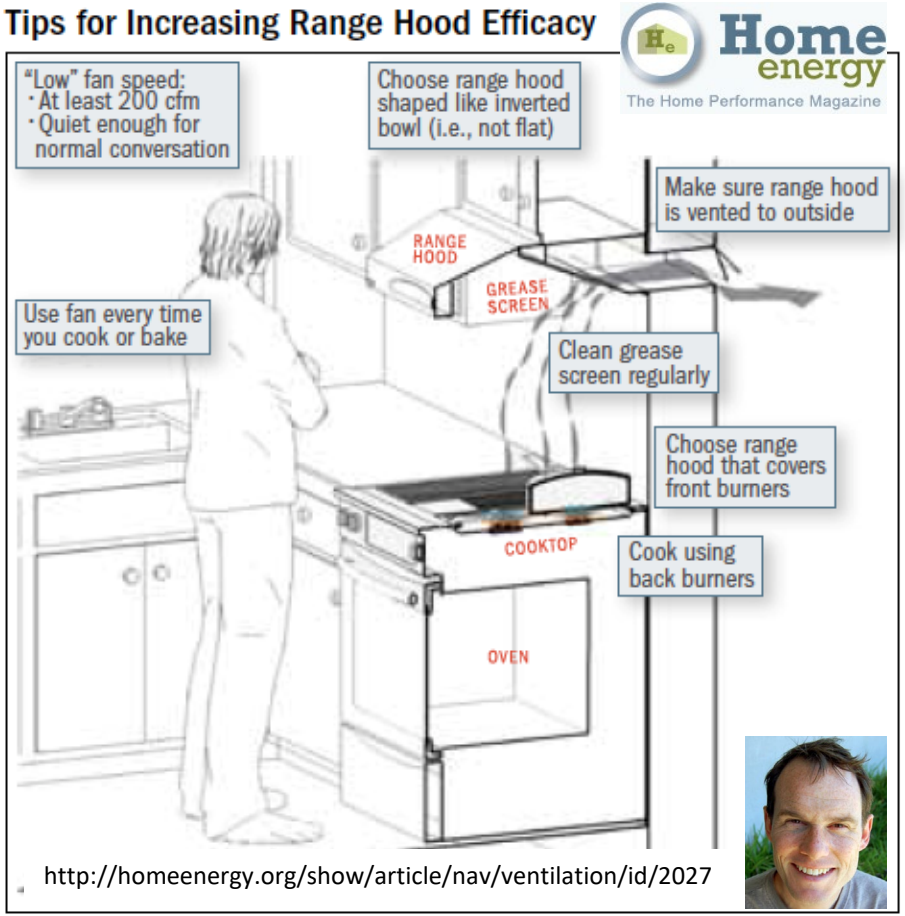
Why?

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

Data from Chan (2020) and Zhao (2019)



Guidance and Resources



Certified Airflow & Sound Ratings

CERTIFIED HOME VENTILATING PRODUCTS DIRECTORY

HVI HOME VENTILATING INSTITUTE

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

Not Listed = Not Certified

HVI Product Directory

AHAM ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

Leadership ➤ Knowledge ➤ Innovation

AHAM VERIFIDE Independently Tested. Consumer Trusted.

AHAM Product Directory

Detailed Guidance & Webinar

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

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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!







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Goal	Reality
Venting range hood in all homes, required by code	Above the stove venting not required in most building codes, absent from many homes; renters especially vulnerable
Effective for front burners Quiet at 200+ cfm Automatic	Large & quiet both exist; rarely together. Quiet @150-200 cfm and >250 cfm $250+ Auto hood coming to market
Use with frying, bake, broil, meals; Cook on back burners	Variable use; as need is perceived Most cook on front; use less with oven
Effectiveness confirmed with home IAQ monitors	$200 monitor not accessible to many

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Questions?

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These studies not linked to specific data presented, but they are highly relevant to the topic.

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Datasets

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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

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Extra Slides