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Paper session 11, Update on Kitchen Ventilation Research

Performance and usage of mechanical residential kitchen ventilation

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Learning Objectives

- **Understand the impact of various design and operating parameters on the performance of residential kitchen ventilation**
- Learn how mass balance approach can be employed in the parametric analysis of kitchen ventilation
- **Understand the impact of exhaust flow rates on the performance of residential kitchen ventilation.**
- Learn how to employ CFD analysis to optimize the performance of kitchen ventilation
- Understand the three changes to range hood metrics that are in process
- Know when these objectives will be published by ASHRAE
- Understand the role energy source has on cooking and indoor air quality
- **The issues that need to addressed concerning cooking and IAQ**
- **Provide an overview about the recent studies and development on kitchen ventilation device performance**
- **Get a view about the remaining question about kitchen ventilation design and rating**

Acknowledgements

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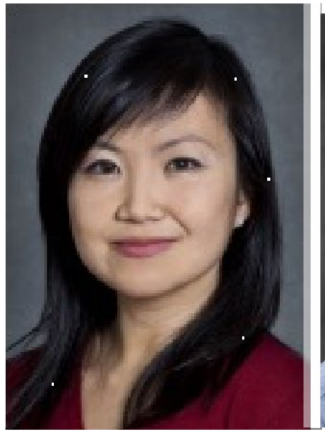


Outline

- Review studies of intrinsic kitchen ventilation product performance, including under controlled laboratory conditions and measurements of devices as installed in homes. Intrinsic performance parameters include airflow, sound level, and contaminant capture efficiency.
- Summarize measurement- and model-based studies of kitchen ventilation effectiveness in reducing pollutant concentrations for North American homes.
- Summarize results from several large surveys which aimed to quantify both the actual usage patterns of kitchen exhaust ventilation in occupied homes and the factors that impact usage

Both cooking & burners are sources

CO_2 & H_2O

NO, NO_2, HONO, Formaldehyde

Ultrafine particles

$PM_{2.5}$, Ultrafine particles

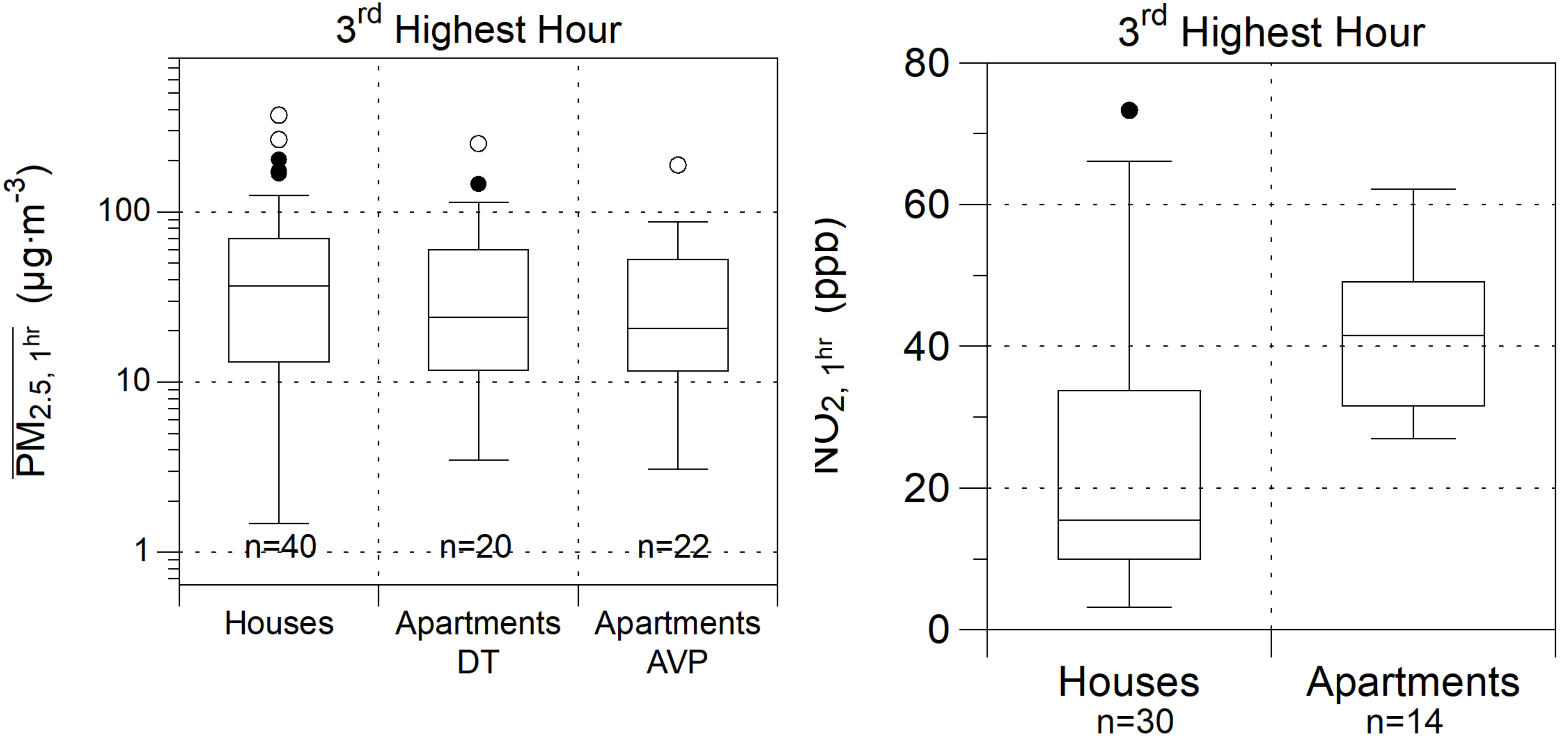
Formaldehyde, Acrolein, PAH, etc.

Ultrafine particles

Gas cooking, NO_2 associated w/asthma & COPD symptoms.
$PM_{2.5}$ at levels produced by cooking has cardiovascular and respiratory impacts.

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

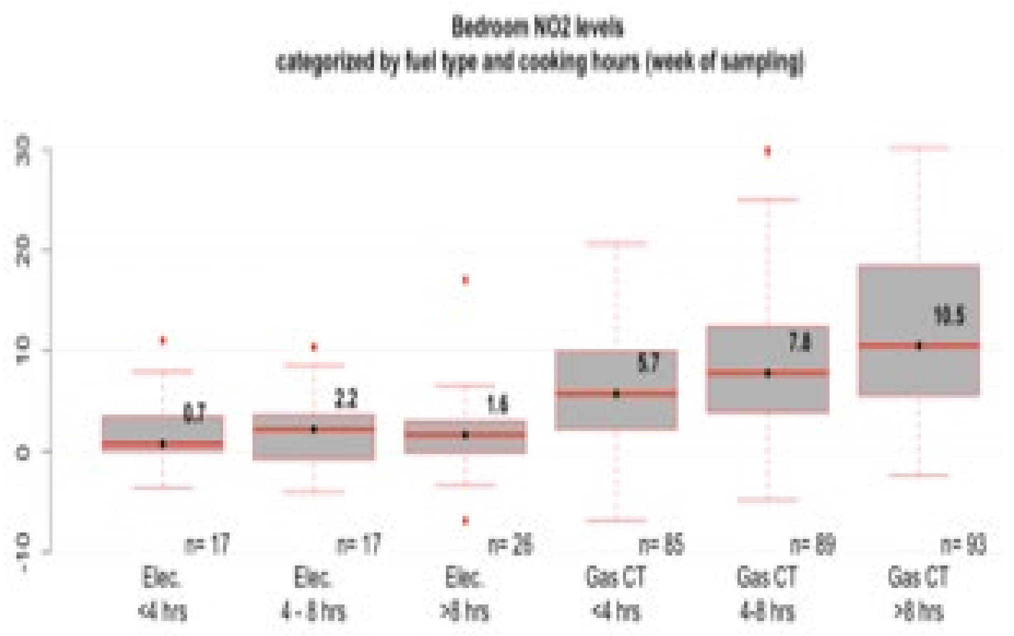
Recent in-home data affirmed acute PM2.5 and NO_2 concerns



Zhao et al 2020 *Indoor Air*

Data from occupied homes shows that gas cooking yields higher NO_X, NO_2, & CO

- Mailed samplers to 350 homes
- Oversampled homes that use gas and cook
- Measured CO, NO_X, NO_2, formaldehyde over 1 week
- Participants noted cooking time & range hood use
- Accounted for outdoor NO_X to estimate impact of indoor emissions



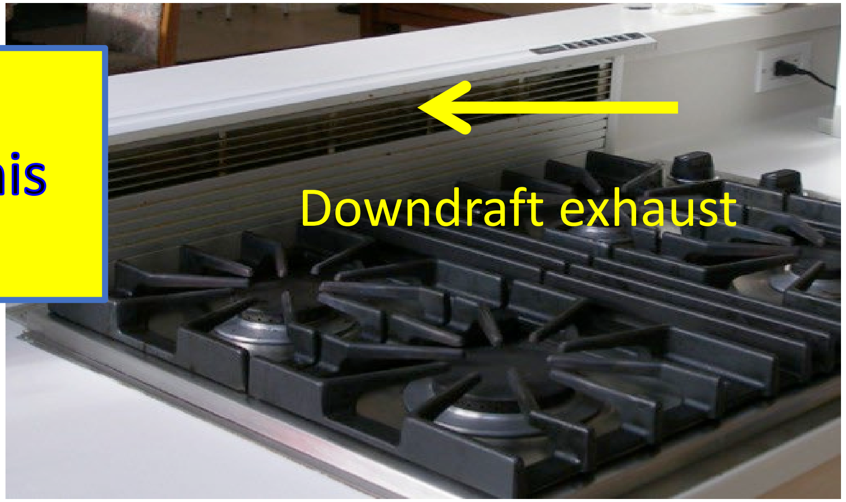
Mullen et al., 2015, Indoor Air

Kitchen ventilation options

Ceiling exhaust fan

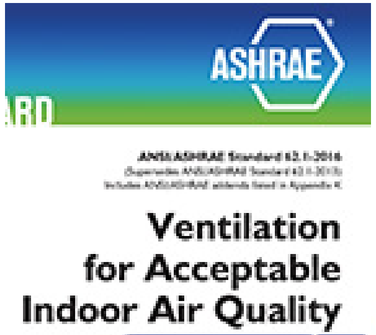
Wall exhaust fan

Kitchen ventilation can help address this hazard



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

Guidelines:

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

ENERGY STAR Certified Homes, Version 3

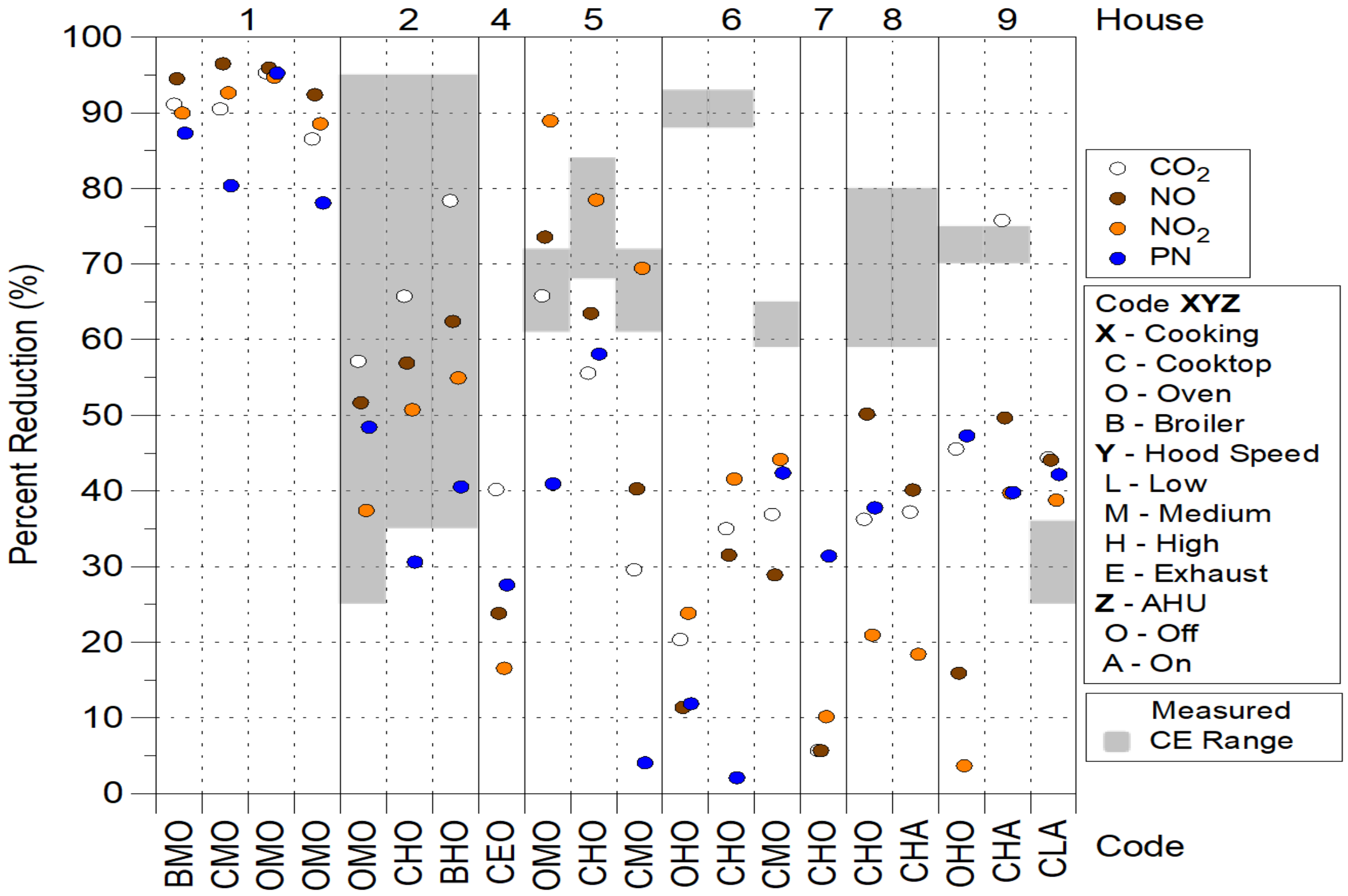
- Similar to ASHRAE 62.2
- Allowance for unrated hoods if using low resistance ducting

International Residential Code

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

Installed range hoods provided varied levels of exposure reduction

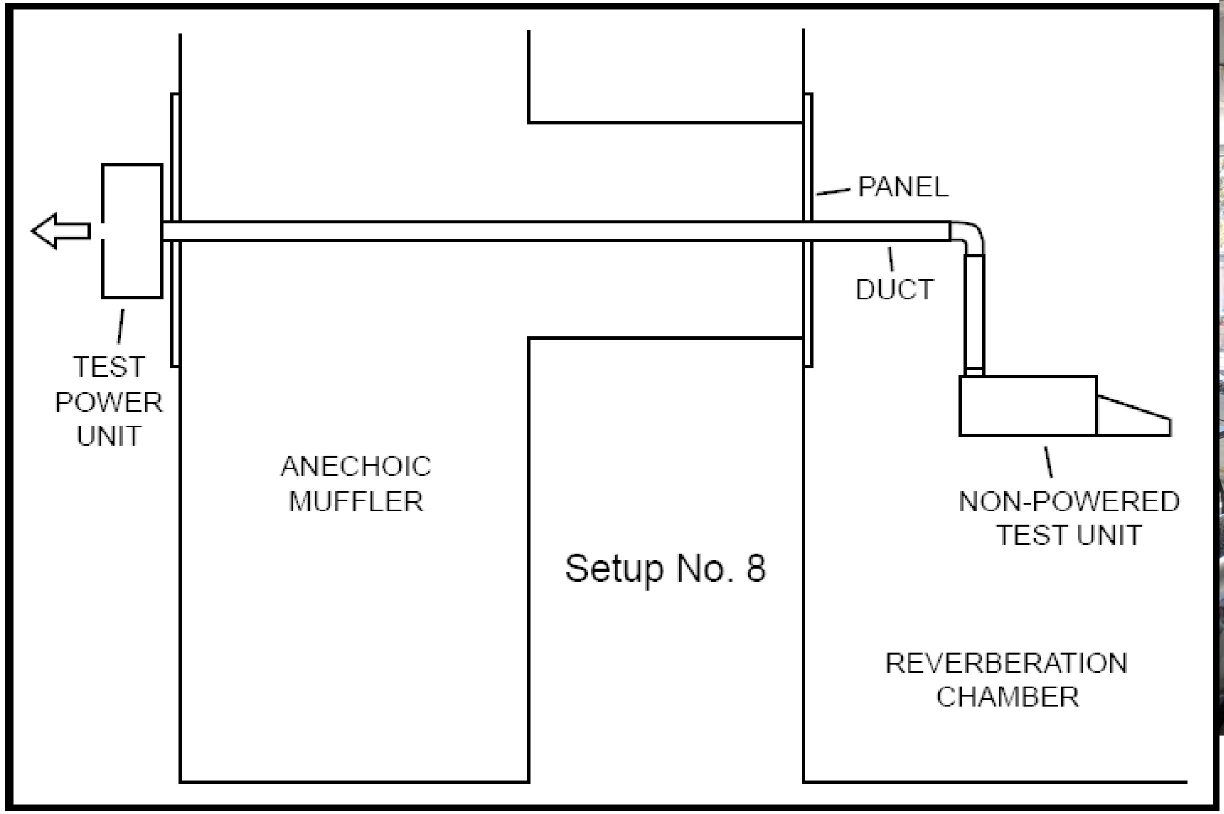
- Key factors impact range hood effectiveness on pollutants control:
- Airflow
- Capture efficiency
- Usage by household



Singer et al., 2017, Building Environment

Range hood airflow measurement at lab and real homes

HVI method 915 and 916

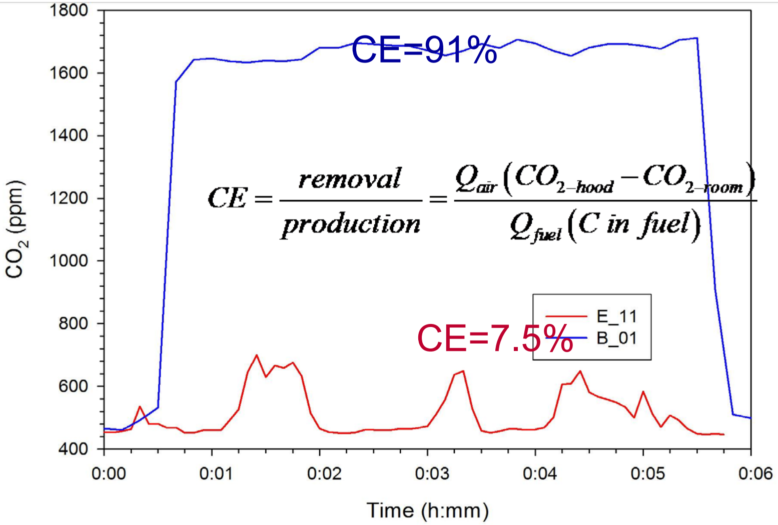


Walker et al 2016

Table 1. Studies that have measured kitchen ventilation product performance in laboratory or field settings					
Lead author, Yr	Brief description	# devices	Sound	Airflow	CE
Lab study					
Delp and Singer 2012	POW, CE using CO_2 mass balance, airflow measured at exhaust	7 (1 OTR)	Y	Y	Y
Lunden et al. 2015	Real cooking, CO_2 mass balance, particle mass balance, airflow measured at exhaust	4 (1 OTR)	N	Y	Y
Walker et al. 2016	Chamber steady-state CO_2, developing ASTM method	8 (1 OTR)	N	Y	Y
Kim et al., 2018	Chamber steady-state CO_2, developing ASTM method	2	N	Y	Y
Clark, 2018	Overhead/island Hood, CO_2 as tracer	1	N	Y	Y
Meleika and Pate, 2020	ASTM, cooktop temp on CE	5 (1 OTR)	N	Y	Y
Meleika et al., 2020	ASTM	7	N	Y	Y
Zhao et al., 2020	LBNL report comparing OTRs to RHs	8 (6 OTR)	Y	Y	Y
Field study					
Singer et al., 2012	CO_2 mass balance, airflow measured at inlet	15 (2 OTR, 2 downdraft)	Y	Y	Y
Chan et al. 2019; Singer et al., 2020	70 California homes with code-required MV	70	Operating dB only	Y	N
Zhao et al., 2021	California Apartments	23	N	Y	N
Antonopoulos et al., 2023	Oregon and Colorado Single Family homes	55	Operating dB only	Y	N

Range hood airflow capture efficiency measurement at lab and real homes

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



- Typically CO2 as tracer
- ASTM E3087
- Efficiency on other pollutants also studied

Table 2. Studies of kitchen ventilation effectiveness to reduce indoor air pollutants from cooking

Lead author, Yr	Condition	# homes	Airflow msd?	Pollutants measured
Study in Controlled homes				
Rim et al., 2012	Controlled unoccupied house	1	Y	Ultrafine particles (UFP)
Singer et al., 2017	Study of 9 homes, 6 w/KV, in controlled kitchen	6 (2 OTR)	Y	CO_2, NOX, particles
Dobbin et al., 2018	Controlled unoccupied test house	2	Y	UFP, PM2.5 NO, NO_2
Sun et al., 2018	Controlled unoccupied test house, 6 flow setting of 3 hood, real cooking protocol	1	Y	UFP
Observational field studies				
Mullen et al. 2016	California homes measured with pass samplers	352	N	NO_2, NO, CO, HCHO
Sun and Wallace 2021	Calculated PM decay rates when KV used or not.	132	N	PM2.5
STOVE study by NCHH	3 visits, study group and comparison group, multifamily and townhomes	152 total; 76 met ASHRAE 62.2 WHMV	About 80% homes	NO_2, PM2.5, CO_2, CO, HCHO

Studies on household range hood usage

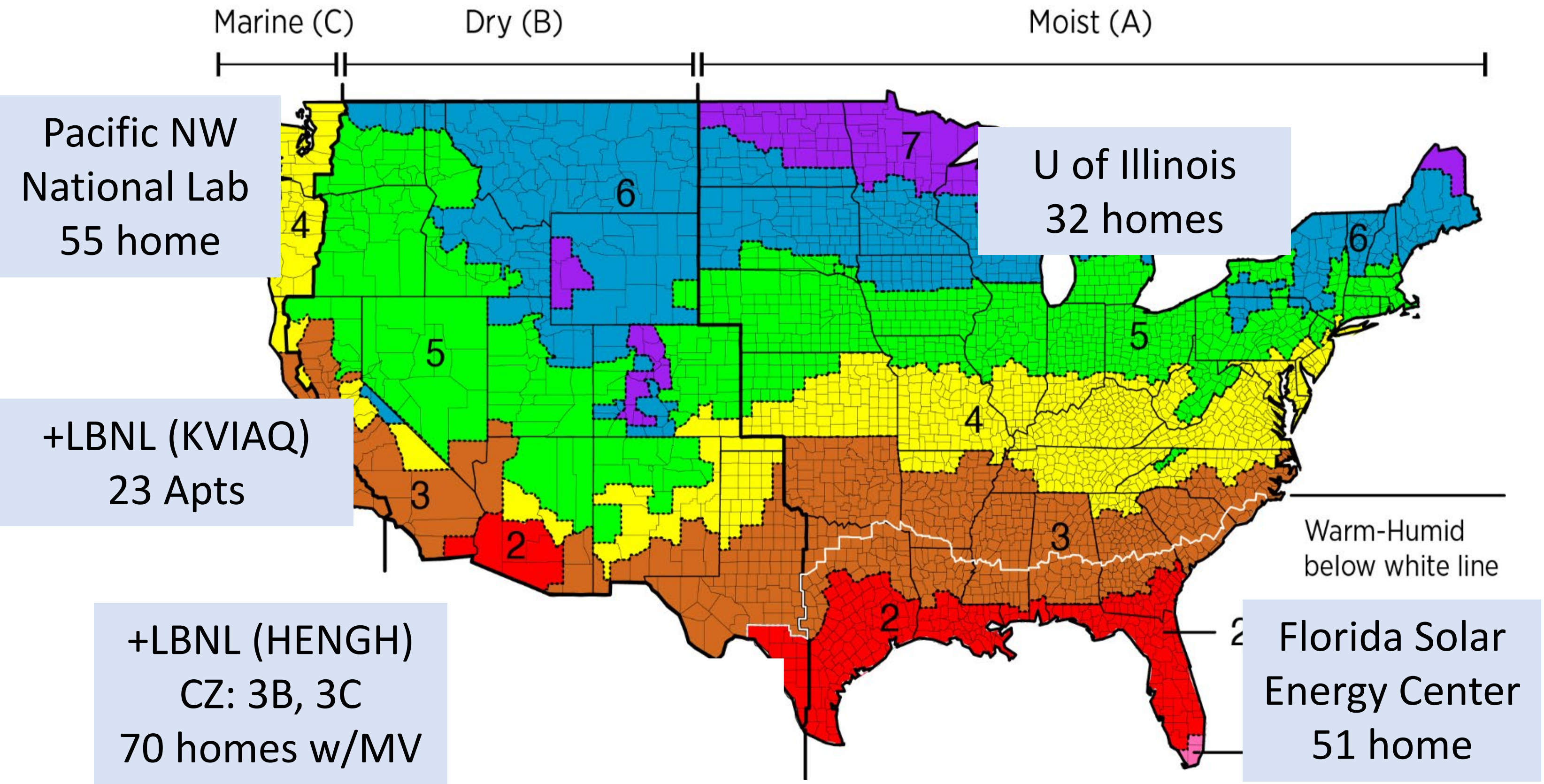
- Range hood only works when people use them
- Most are in-home survey
- Only one study with in-home measurements
- self-reported use during cooking ranged from 10% to 34%

Table 3. Studies of kitchen ventilation usage during cooking

Lead author, Yr	Type	Condition	Result
Piazza et al., 2003	In home survey	1448 detached home in California	28% reported using KV with cooktop, 15% with oven
Chan et al., 2019	Web-based survey	2781 California homes built since 2003	34% reported always use a hood, 30% sometimes use and 32% rarely or never
Klug et al., 2011	Web-based survey	372 homes	34% reported using range hood during cooking
Sun and Wallace 2021	Activity log	132 Canadian homes	13% reported range hood use in winter and 10% in summer
Zhao et al., 2021	In home measurement	54 houses and 17 apartments in CA	Range hood actually used in 36% of cooking events in houses and 28% in apts

The airflow of devices installed in homes is often lower than minimum airflow requirements of ventilation standards

- 25-30 homes per climate zone (CZ)
- All home recent built to have code-required MV (including range hood)

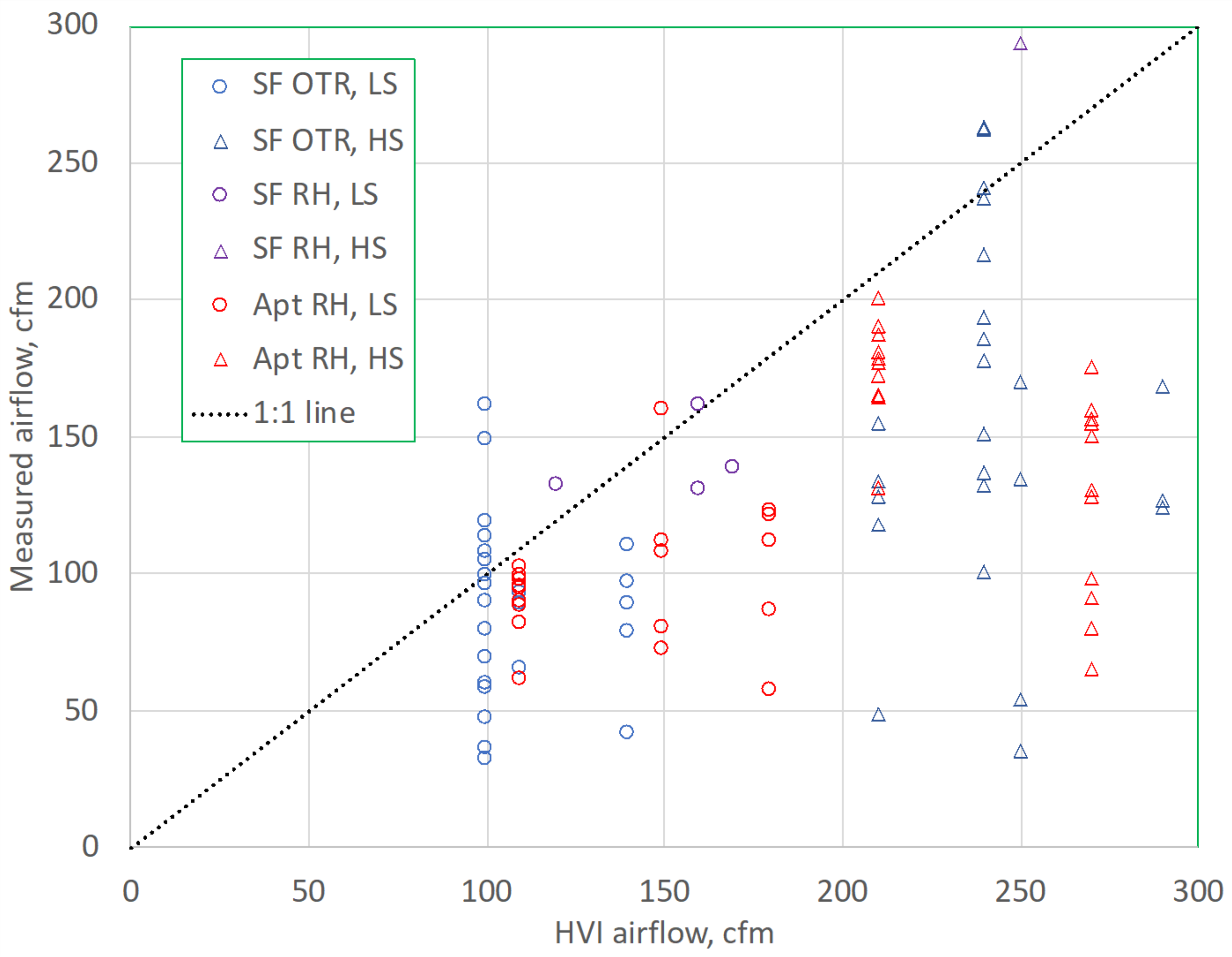


- Current data successfully collected from 142 homes (20 apt+ 122 SF)
- 82 of them (57%) have a certificated airflow greater than the minimum air flow requirement of 100 cfm
- Only 79 (55%) had installed airflow met the requirement of 62.2 (100 cfm @ 3 sone)

The airflow of devices installed in homes is often lower than the certified airflow measured from lab

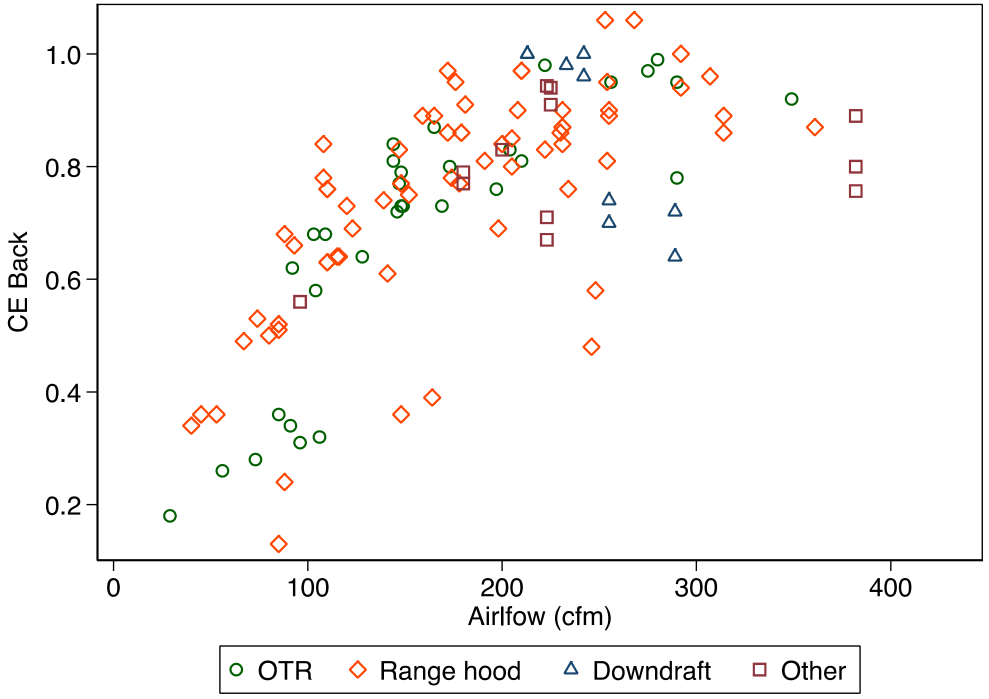
- 82 out of 142 home have a AHAM/HVI certificated range hood
- Only 44 of them had installed airflow that matched the rating.
- The average ratio of installed versus rated flow was 0.76
- Performance are similar between certificated RH and non certificated RH

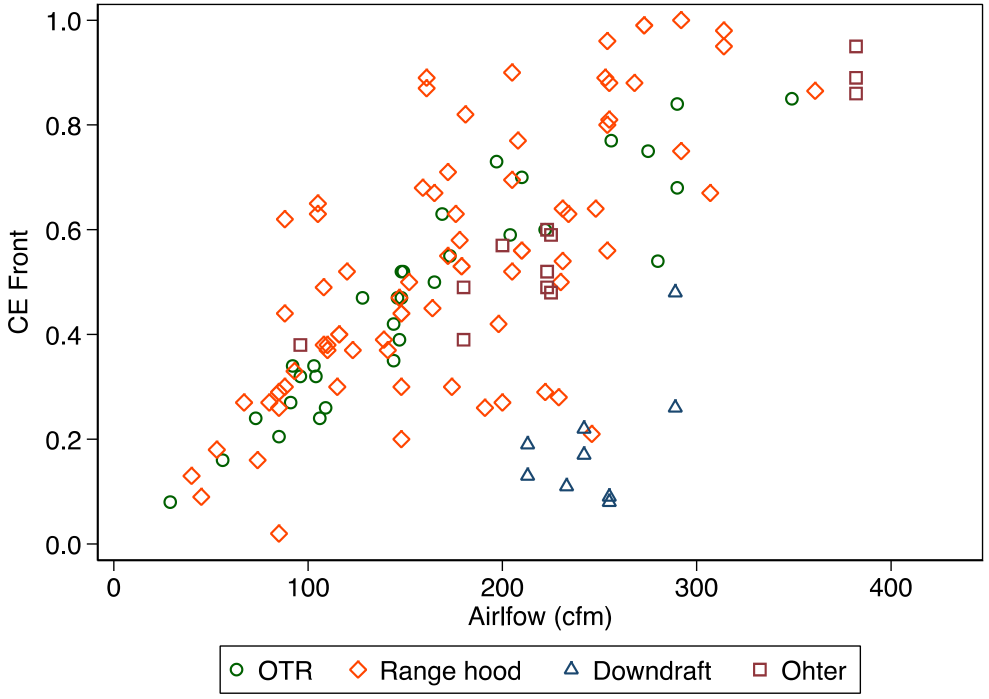
- Why?
- Consistent with static pressure as installed in homes being much higher than test conditions.
- Better standard airflow test method needed!



Example data from Chan (2020) and Zhao (2019)

While data are limited, they show that pollutant removal effectiveness by range hoods has a large range



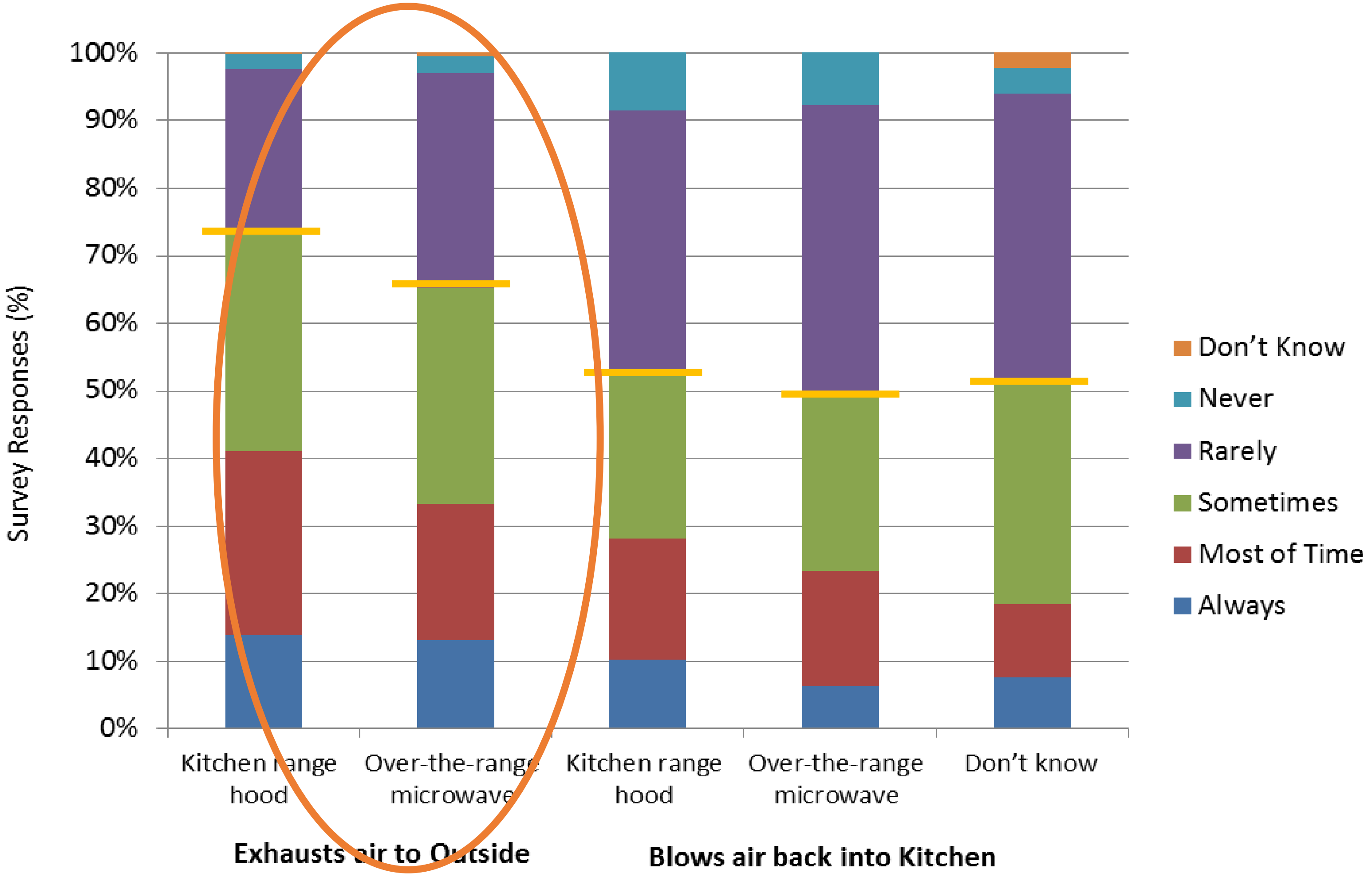


- Measured capture efficiency has been reported for only 57 hoods in 9 studies in the US, either in the lab or in the field
- Main reason is the difficulty to conduct the test
- The measured capture efficiency ranged from 10% to 100%, generally increasing with airflow, with back burner typically higher than front
- OTR and regular RH are similar

Survey shows most people reported use of venting range hoods,

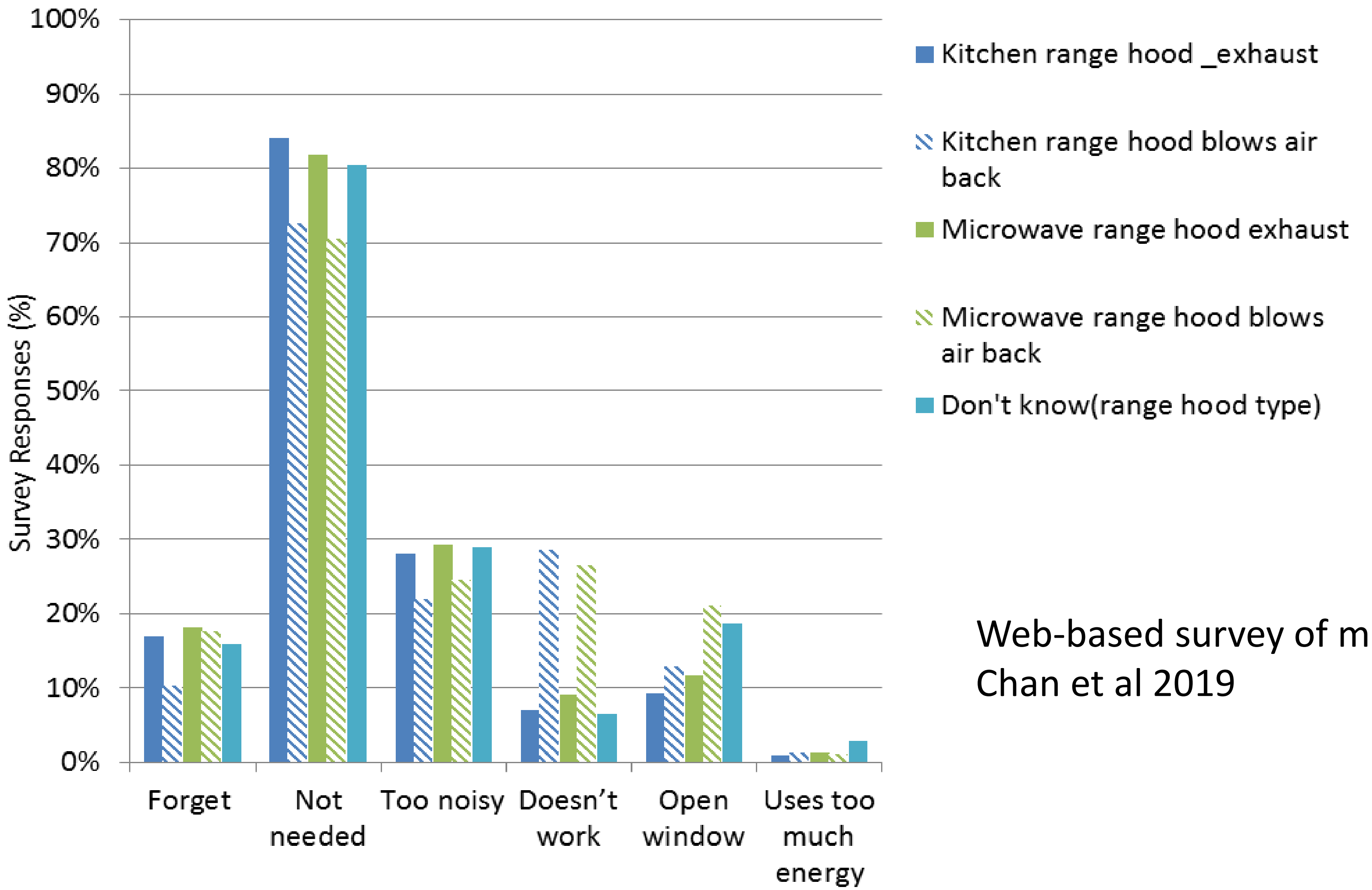
- How frequently do you use range hood with cooktop?

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



Chan et al. 2019

Reason not to use a hood is not need



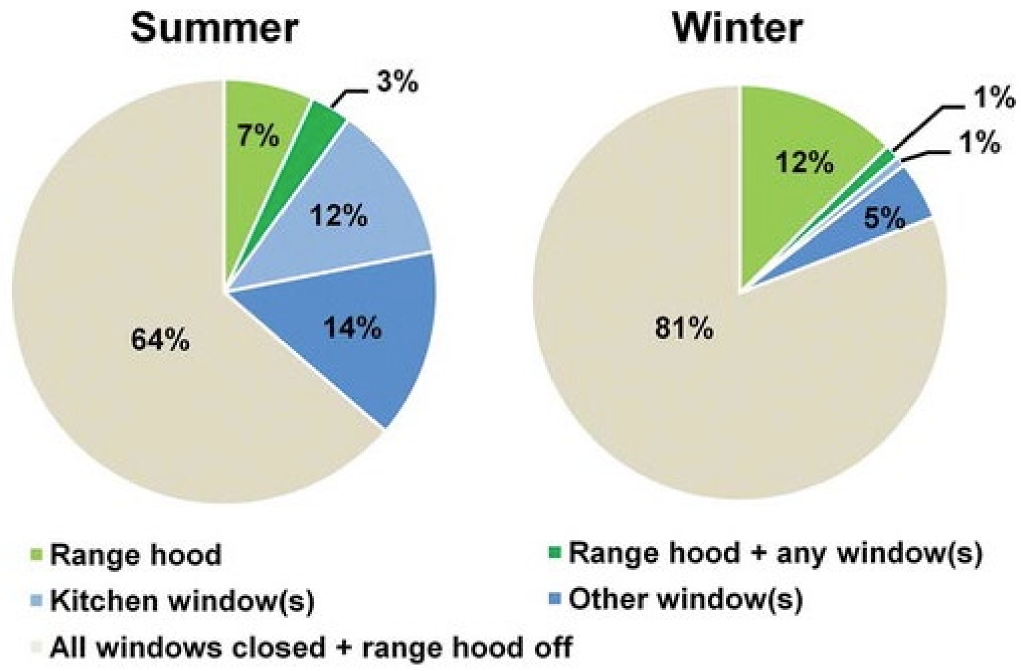
Web-based survey of mostly SoCal homes built 2003-2010
Chan et al 2019

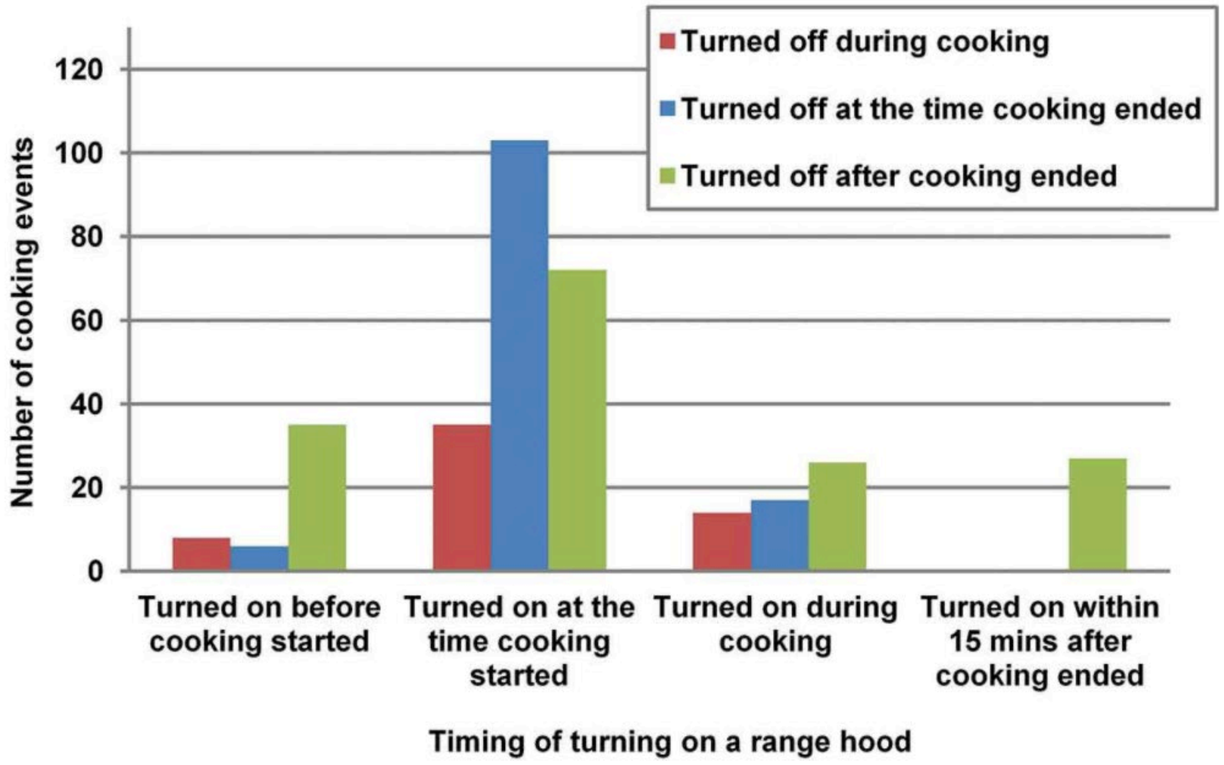
Daily activity log gives different answer

132 homes in Halifax and Edmonton (Canada)

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

Cooking by daily log; write down range hood, windows use time

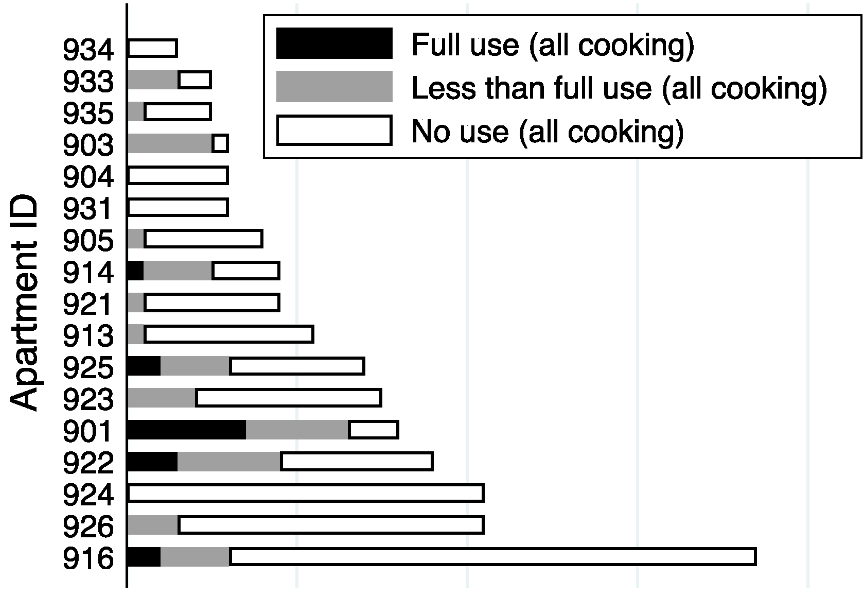




Sun and Wallace, 2021

In home measurement shows range hood use more often in single family houses, but <40%

Cooking Type	Houses		Apartments		p-Value [1]
	Cooking Events	Any Hood Use n (%)	Cooking Events	Any Hood Use n (%)	
CT only	487	182 (37%)	190	50 (26%)	0.006
OV only	48	12 (25%)	15	5 (33%)	0.53
CTOV	39	11 (25%)	5	3 (60%)	0.76
Total	574	205 (36%)	210	58 (28%)	0.03
p-value [2]	0.09		0.56		

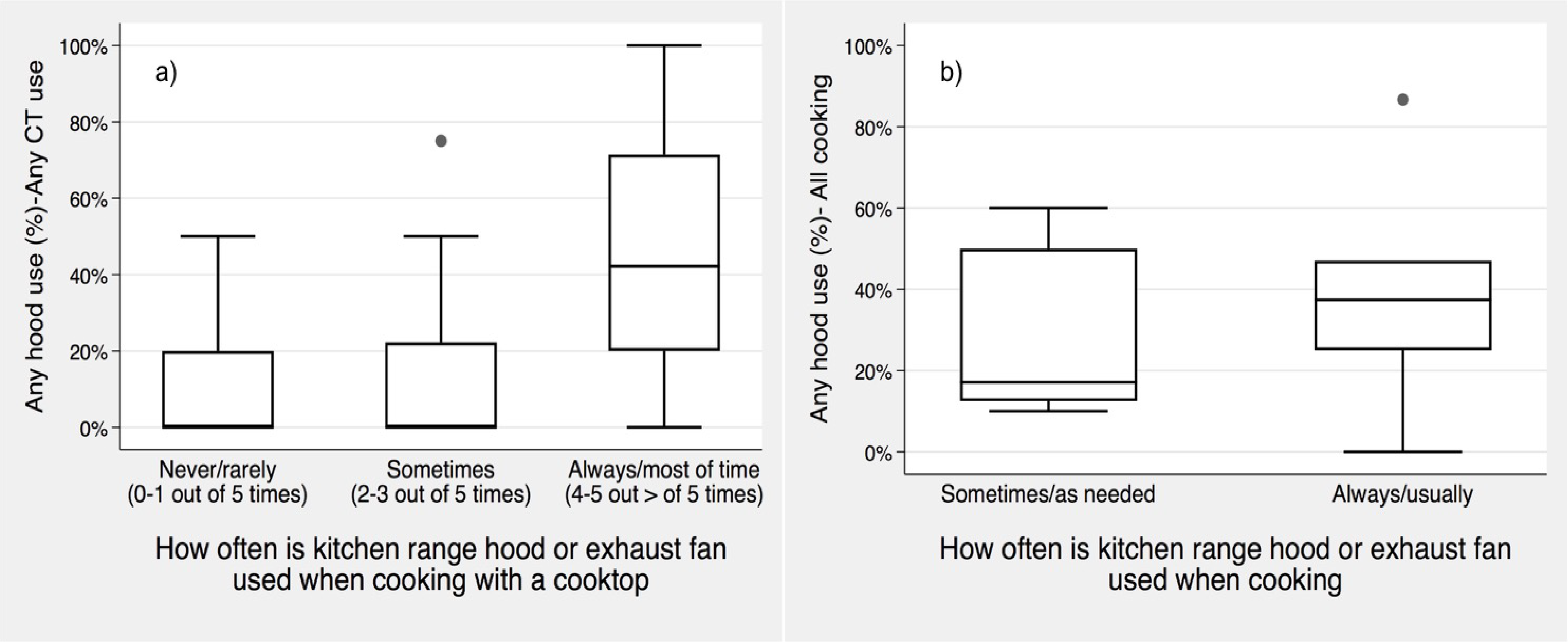


Most homes used a hood for fewer than half of events.

- Most relevant reason for not use: forget, Do not think RH is effective
- Longer cooking event, more likely to use a hood
- Cooking with more PM emitted, more likely to use a hood

Zhao et al, IJERPH, 2020

Self-reported range hood use overestimated



In both houses and apartments, actual hood use was higher in homes of participants that self-reported more frequent use, but actual use was much lower than self-reported use.

Zhao et al, IJERPH, 2020

Summary

- Installed airflow of a range hood is often lower than certificated, leading to the actual flow below the ASHRAE 62.2 minimum requirement
- Capture efficiency is rarely measured in US homes or in the lab, due to difficulty to conduct the test
- Range hood usage is overestimated by self-report

Questions

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