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Document Title:	LBNL Kitchen Ventilation Panel Presentation
Description:	This file contains the presentation given by Brett Singer of Lawrence Berkeley National Laboratory at the September 30, 2020 hearing and panel discussion on kitchen ventilation, indoor cooking, and indoor air quality.
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Gas Burners, Cooking and Kitchen Ventilation

Presentation to CEC Indoor Cooking and Air Quality Workshop

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Research presented here was supported by the following institutions:

Relevant CEC Studies

Natural Gas Variability in California: Environmental Impacts and Device Performance, CEC-500-05-026

Residential Energy Savings from Airtightness and Ventilation Excellence Program, CEC-500-05-061

Energy and Indoor Environmental Quality (IEQ) Retrofits In Low-Income Apartments, CEC-500-09-022

Healthy Homes: Exposure to Unvented Combustion Gases, CEC-500-09-042

Effective Kitchen Ventilation for Healthy ZNE Homes with Natural Gas, PIR-16-012

Partner for Field Study:

ASSOCIATION FOR ENERGY AFFORDABILITY INC.

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Summary Points - 1

- Gas burners and cooking each generate pollutants that degrade IAQ
  - Using gas burners w/o venting can cause indoor 1h NO_2 to exceed thresholds for outdoor standards
  - Cooking w/o venting can cause 24h $PM_{2.5}$ to exceed ambient standards & guidelines
- Pollutant levels increase with cooking and higher in smaller homes
- Venting range hoods can effectively control cooking pollutants
- Over the range microwaves perform similarly to common range hoods

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Summary Points - 2

- Capture efficiency varies by airflow & front vs. back burners
- Venting at the 100 cfm as currently required by Title24 is inadequate
- Use of hoods with CE up to 65-75% needed to protect IAQ in all new homes, particularly in those <1000 sf
- Range hoods not used routinely and much less than people claim

Cooking & burners are important sources

CO_2 & H_2O

NO,NO_2, HONO, Formaldehyde

Ultrafine particles

Ultrafine particles, $PM_{2.5}$

Formaldehyde, Acetaldehyde

Acrolein, PAH

Ultrafine particles

Induction burners appear to emit many fewer ultrafine particles[1] and no NO_X

[1]Less et al. 2015

Simulations using cooking data from homes and measured emission rates indicate possible widespread NO_2 problems

- Physics based simulations of 6634 SoCal homes from 2003 RASS
- Self-reported cooking frequencies by meal
- Cooking durations from web-based survey
- Emissions measured from 10 used ranges
- Winter week including NO_2 from outdoors
- Compare to acute ambient AQ standards
  - NO_2: 100 ppb for 1 h
  - CO: 20 ppm for 1 h
    9 ppm for 8h

	% of homes above acute standard – No RH use	Estimated # of CA homes affected
CO	**7-8%**	**1.7M**
NO_2	**55-70%**	**12M**

Note: cooktop CO emissions much lower with modern burner designs with higher grills, better air supply. Ovens likely still susceptible to higher CO as spreader plates degrade

Logue et al., 2014, Environ. Health Perspectives.

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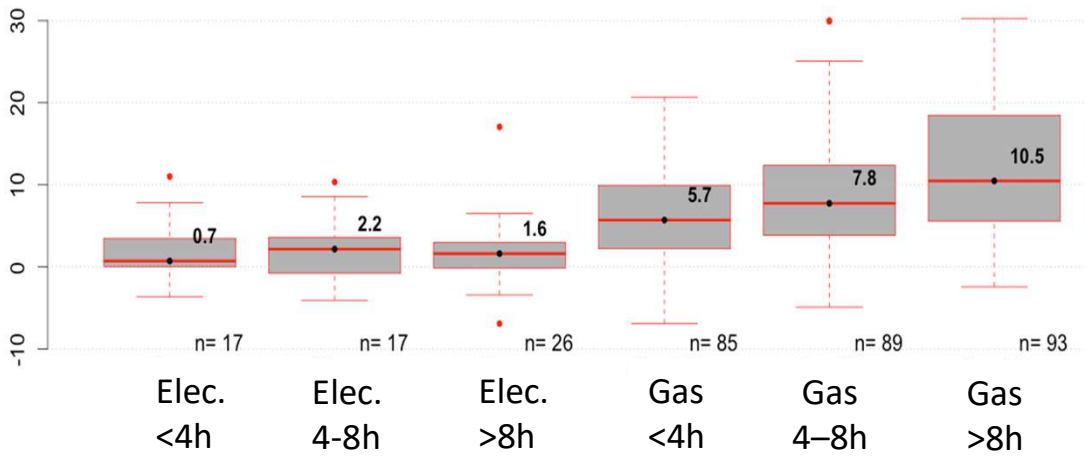
Measurements in homes support simulations

1-week integrated measurements in 350 California homes; heating season

Indoor source contribution to Bedroom NO_2



Burner fuel and total amount of cooking in a week

Kitchens were ~50% higher
Median areas for gas homes: 105-128 m^2
These are higher than NO_2 increments in simulations

Mullen et al., 2015, Indoor Air

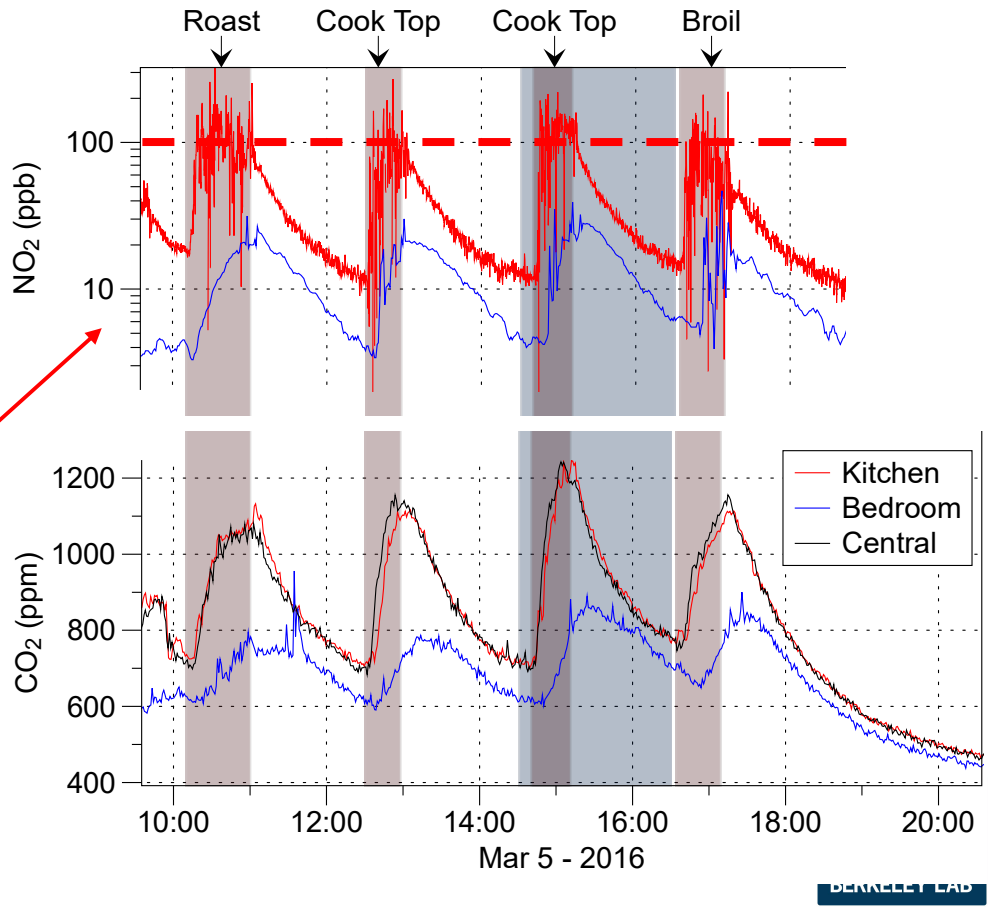
Measurements in homes support simulation results for acute concentrations

Simulate cooking of modest meal for 4

Example: 1400 sf house with continuous ventilation of 0.5 ach by ERV

- NO_2 in kitchen exceeds ambient AQ threshold value

4 of 9 homes had kitchen NO_2 exceed 100 ppb over 1h



Singer et al., 2017, Building Environment

Lab studies of range hood performance

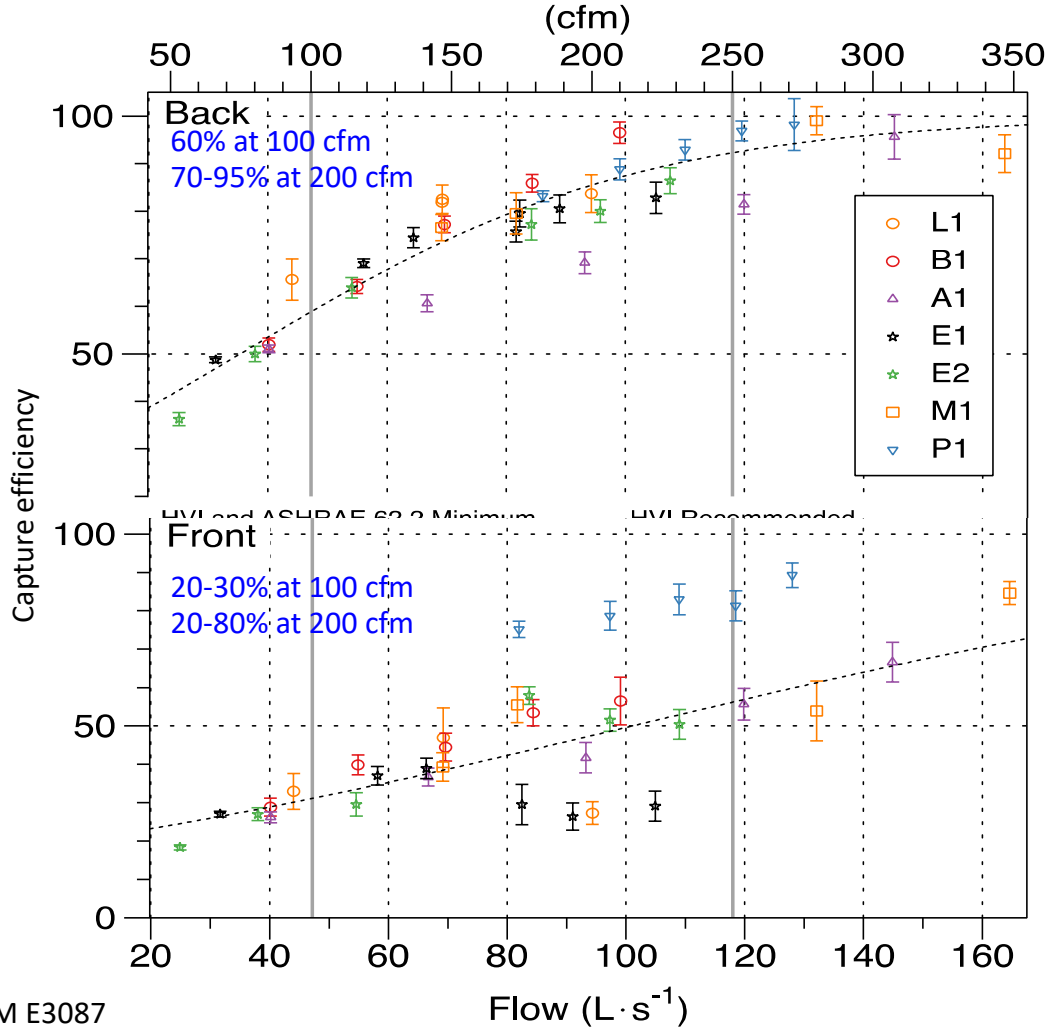
Capture efficiency is the fraction of emitted pollutants removed by the range hood.

Delp and Singer, 2014;
Lunden et al., 2015

Lab study results

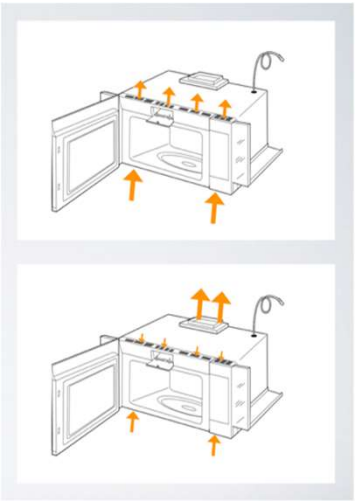
Delp and Singer, 2014

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



Based on LBNL dynamic method used for research, not ASTM E3087

Do over the range microwaves perform similarly to conventional range hoods?



OTR microwave range hood tested:

Whirlpool (HVI listed)

WMH31017
(WH1)
$238
300cfm blower

WMH32519HV-4
(WH3)
$298
300cfm blower

WMH53520CB
(WH2)
$377
400cfm blower

GE

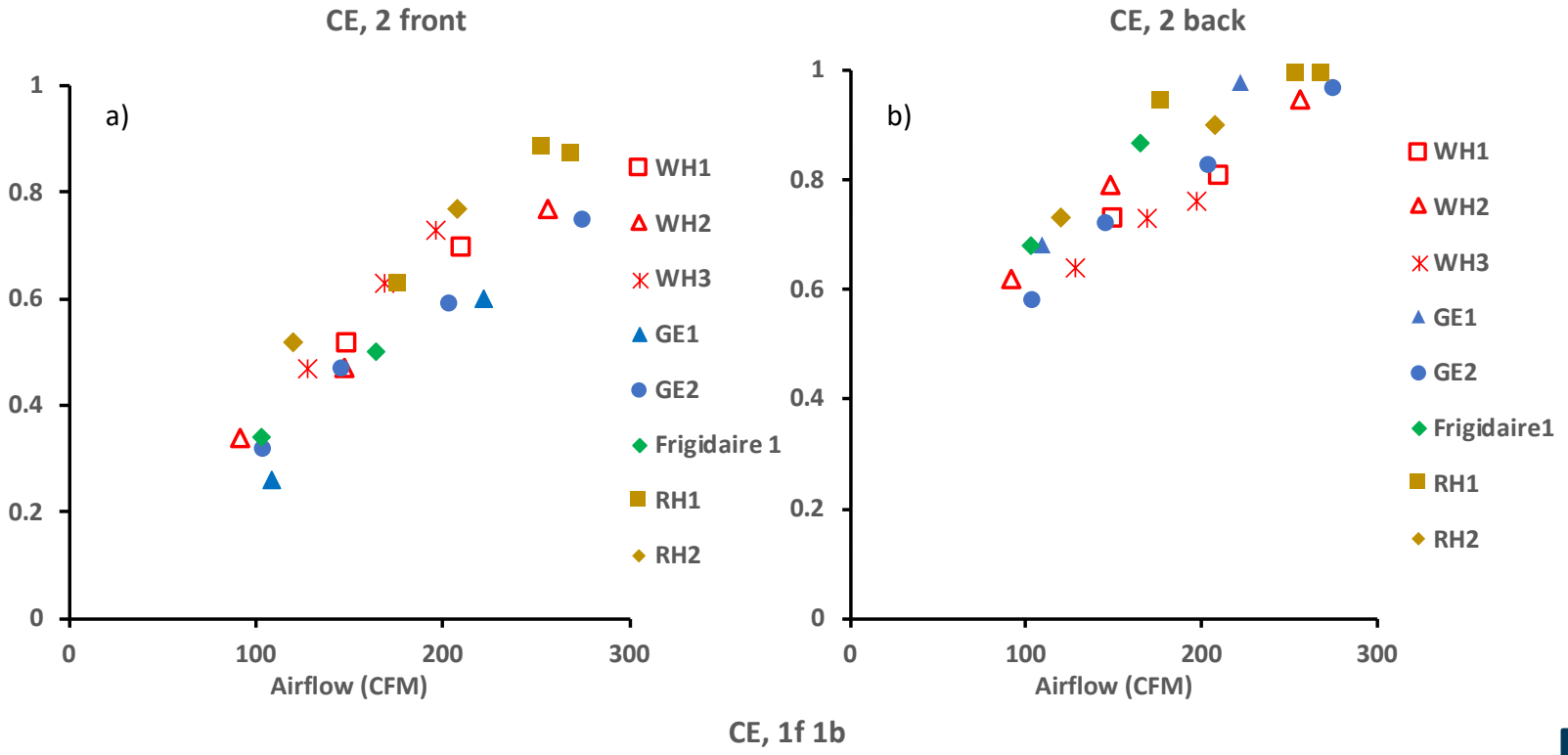
JVM3160RFSS (GE1)
$208 300cfm blower

JVM7195SKSS (GE2)
$357 400cfm blower

Frigidaire

FFMV1645TS
$228 220cfm blower

OTR microwaves have similar trend with airflow



Note: results based on LBNL dynamic method used for research, not ASTM E3087, see Zhao et al. 2020

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Simulation analysis suggested that using even an average range hood could help a lot

- Ran SoCal simulations assuming range hood use during all cooking events
- Assumed CE = 55%
  - Mean from Singer et al. 2012 field study
  - Higher than CE for front burner with base hood at 100 cfm
- Compared to acute ambient air quality standards

	% of homes above acute standard – No RH use	% of homes above acute standard – WITH RH use
CO	**7–8%**	**2%**
NO_2	**55–70%**	**18–30%**

Logue et al., 2014, Environ. Health Perspectives

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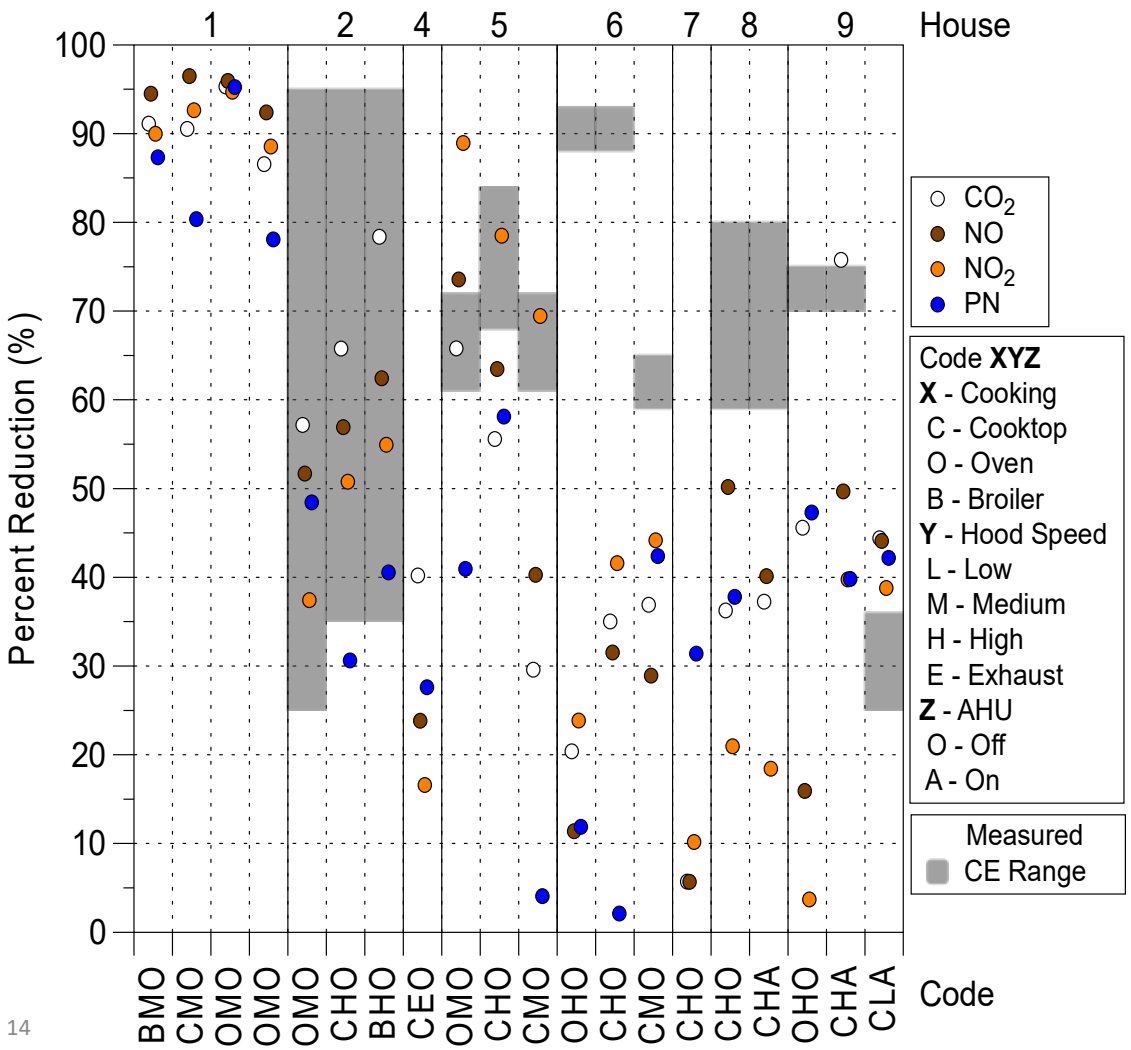

Range hoods showed range of performance in 9 homes with scripted cooking

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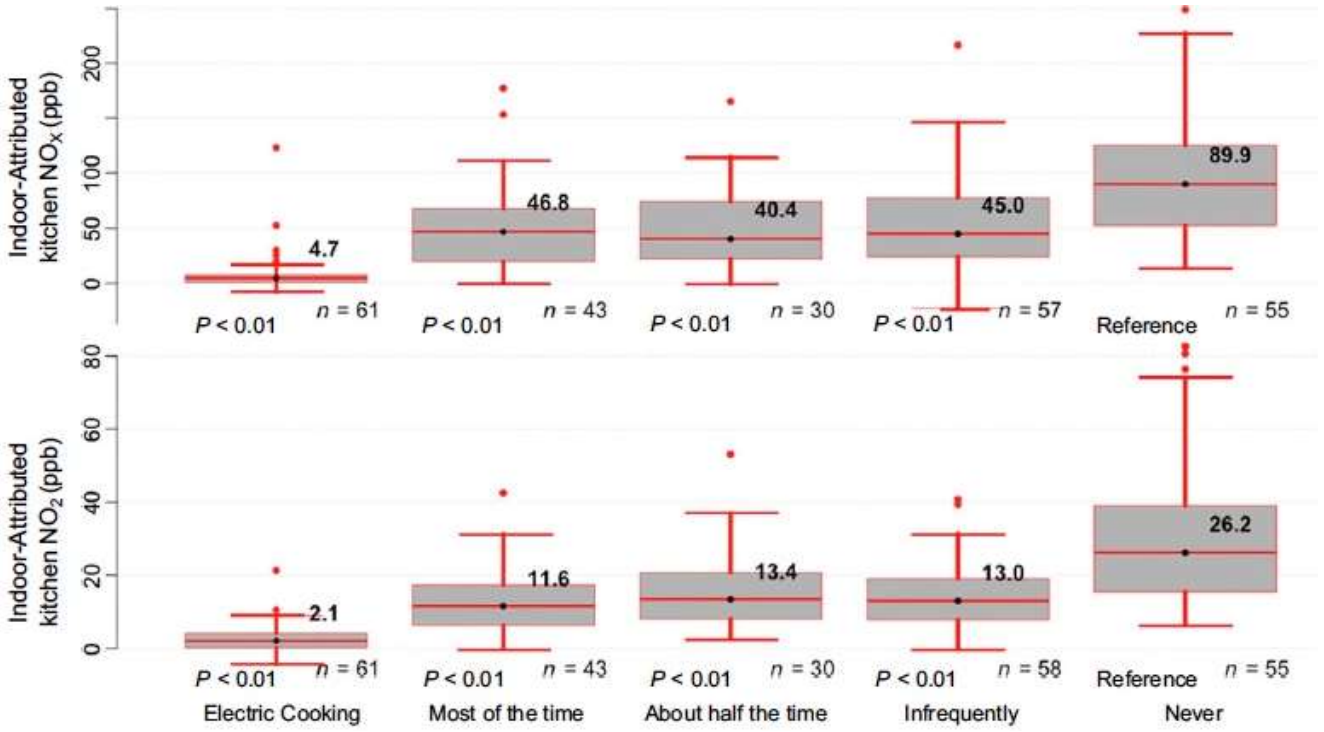
Participants that reported ever using hoods had lower NO_2 and NO_X in 350-home study

But did **not** scale with self-reported ***frequency***!



Mullen et al., 2015, Indoor Air

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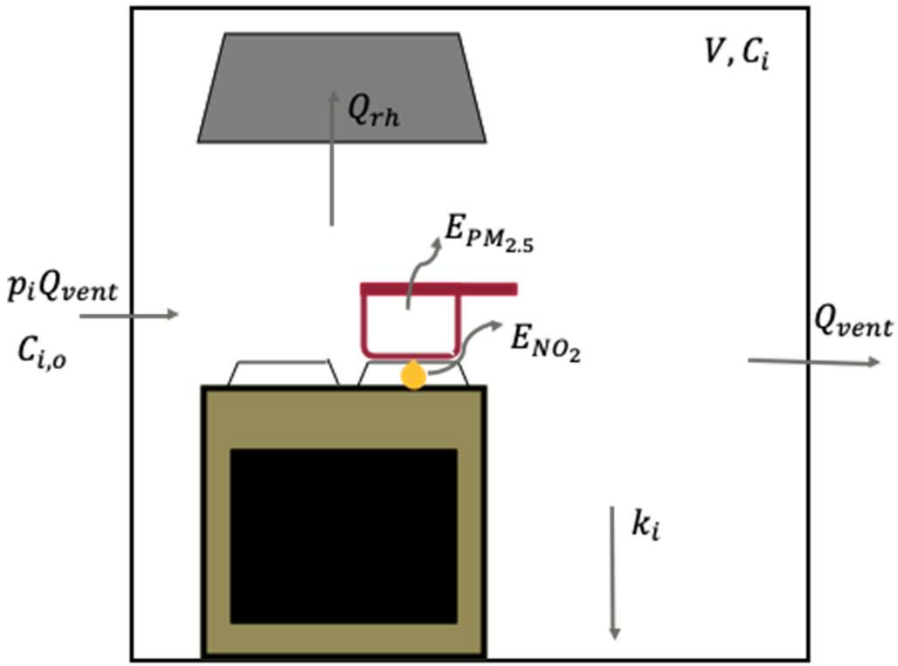
How high does capture efficiency need to be?

Simulations to calculate concentrations from cooking with various CE levels



$$V\frac{dC_i}{dt} = (p_i C_{i,o} - C_i)Q + (1 - CE)E_i - k_i V C_i$$

Variable	Description	Units
V	Volume of Home	1/hr
p_i	Penetration Factor	unitless
Q_vent	Mechanical Ventilation Flow Rate	m^3/hr
CE	Capture Efficiency	unitless
Q_rh	Range Hood Flow Rate	cfm
k	NO_2 Deposition Rate	1/hr
C_(i,o)	Outdoor Concentration	ppb or µg/m^3
E_i	Cooking Emission Rate	µg/hr

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How high does capture efficiency need to be?

Framework:
Every, or almost every, new California home should have ventilation equipment that, if used, enables occupants to cook routinely without being exposed to hazardous air pollutant levels inside.

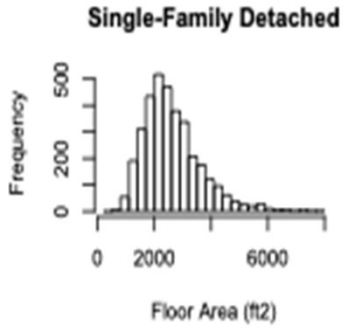
Pollutants* of Focus:
Nitrogen dioxide from gas burners -> target is 1-h NAAQS of 100 ppb
$PM_{2.5}$ from cooking -> target is 24-h WHO guideline of 25 $\mu g/m^3$

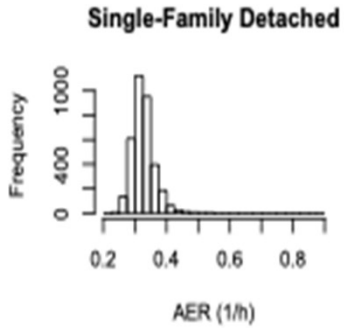
Outdoor contributions:
Distributions from California monitoring sites
NO_2 from 5-9 pm in winter
$PM_{2.5}$ 24-h data over course of year

*Acrolein relevant but problematic

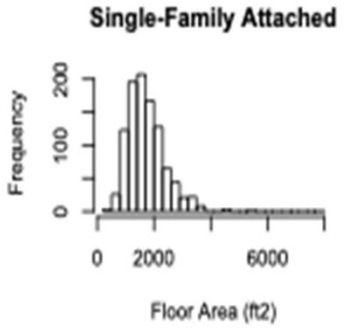
Inputs: California new homes

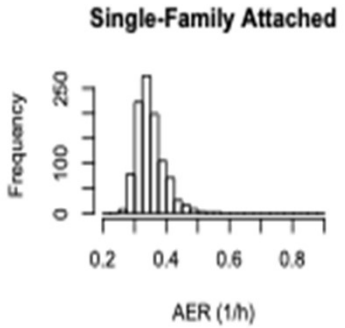
35%



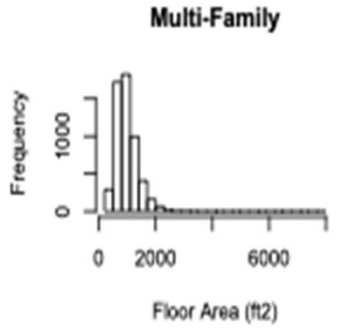


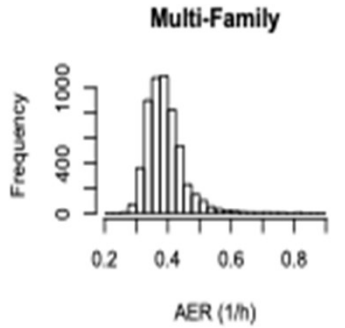
10%

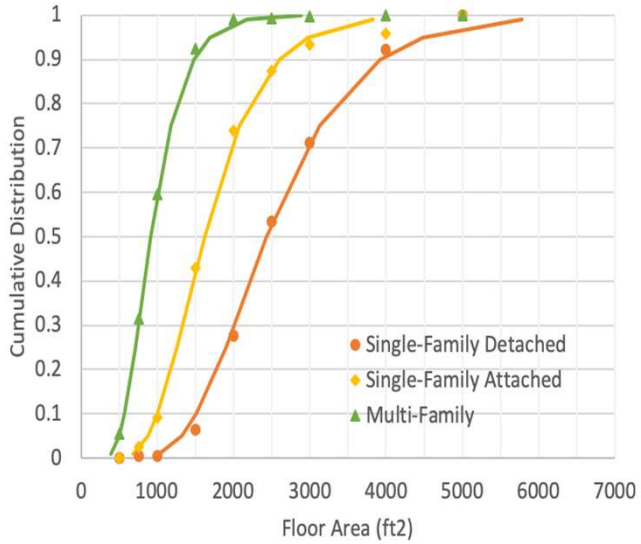




55%

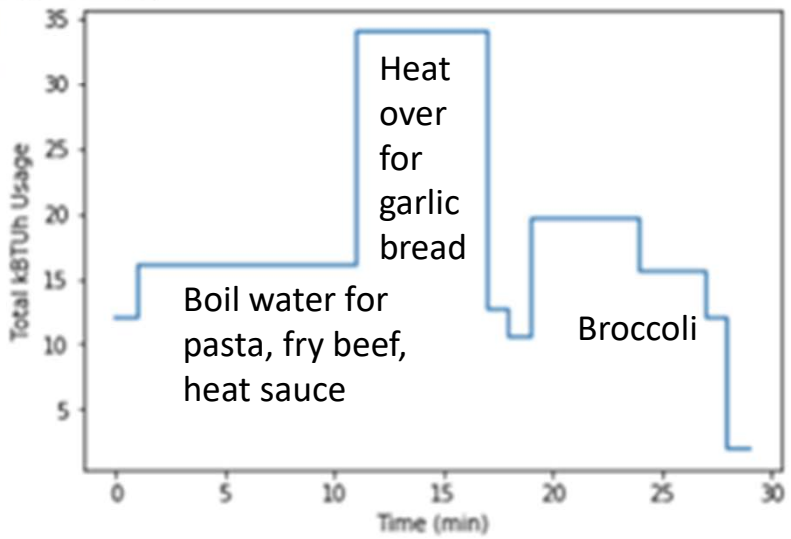


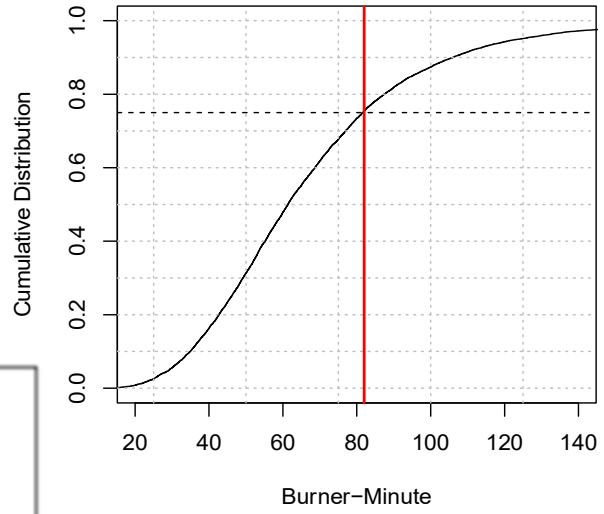




Inputs: NO2 emissions from a typical dinner with gas burner

Pasta with meat sauce, garlic bread, broccoli



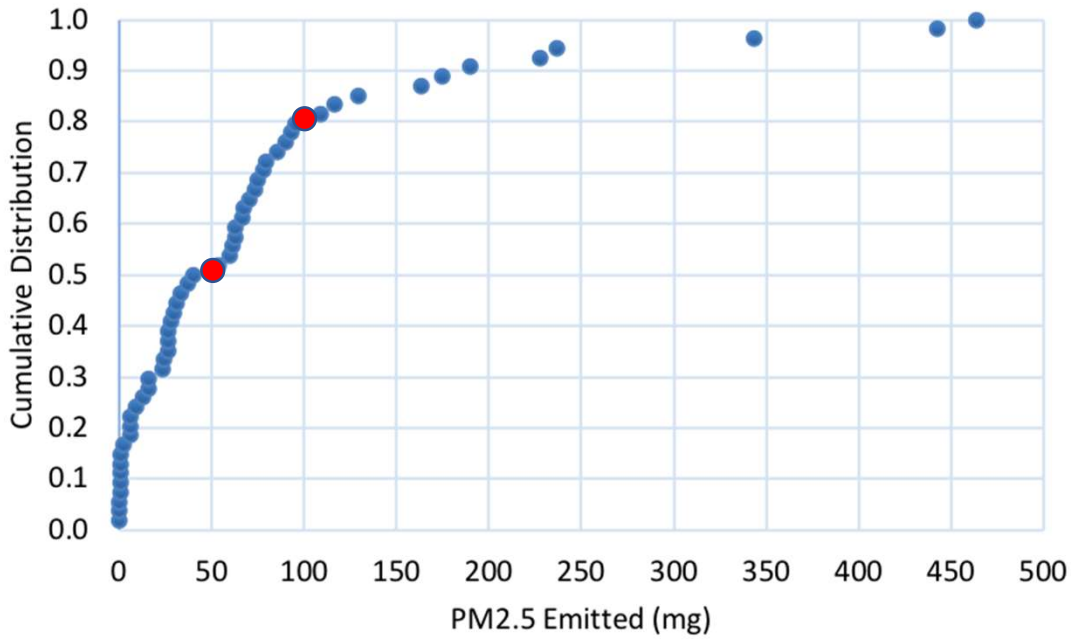


Burner use at 75th percentile of estimates from Logue 2014

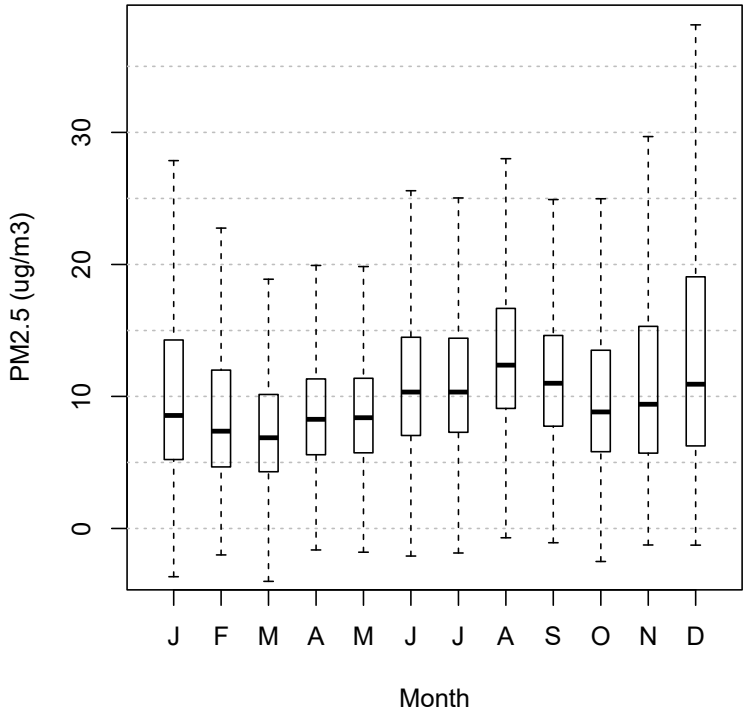
Inputs: 3 meals with particle emissions (24h standard)

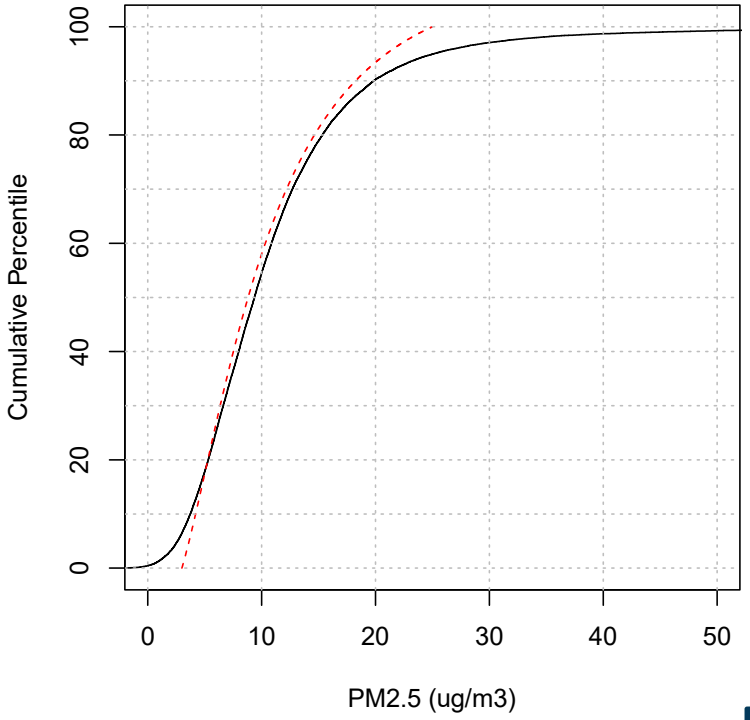
Breakfast: bacon, eggs and hash browns, 19 min, 100 mg (80th);
Lunch: stir-fry of chicken and vegetables, 17 min, 50 mg (50th);
Dinner: pasta Bolognese, 20 min, 50 mg (50th).

Compilation of published data on PM emissions for dishes and meals

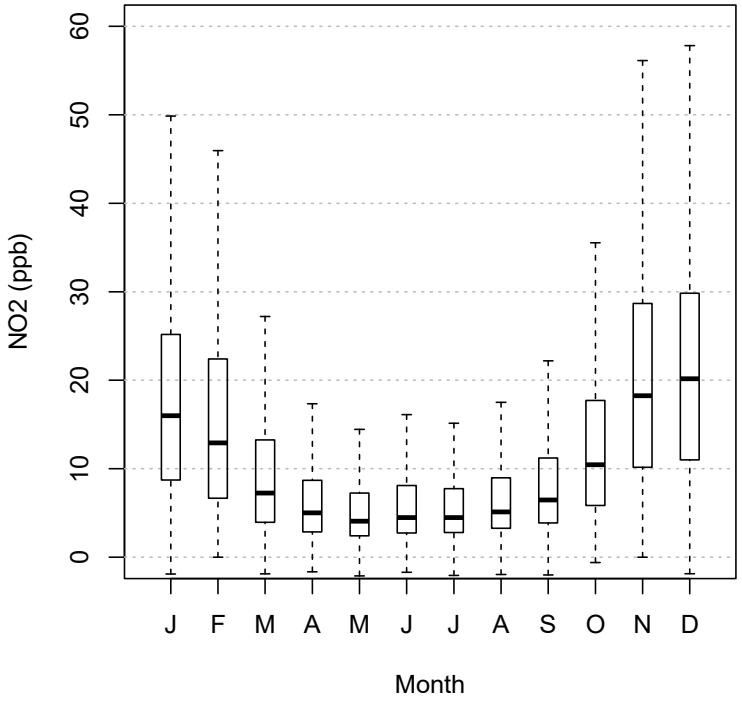


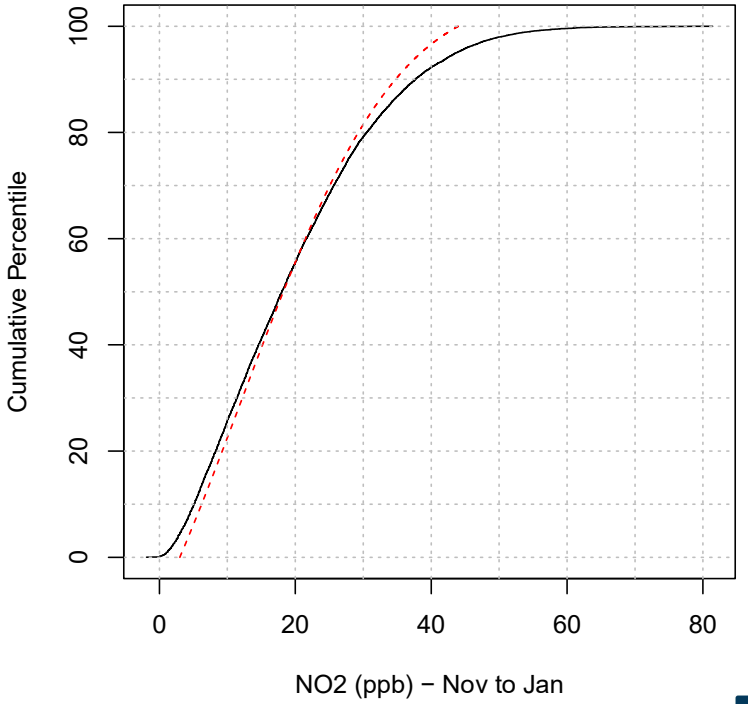
Outdoor PM2.5





Outdoor NO2


NO2 (ppb)
0
10
20
30
40
50
60
J
F
M
A
M
J
J
A
S
O
N
D
Month


Cumulative Percentile
0
20
40
60
80
100
0
20
40
60
80
NO2 (ppb) − Nov to Jan

Other Parameters

- PM2.5 penetration: Uniform, 0.4–0.6
- PM2.5 deposition: Triangular, Mode=0.6/h, Range: 0.3–1.2/h
- NO2 penetration: 1.0
- NO2 deposition: Triangular, Mode=0.75/h, Range: 0.5–1.0/h

Percent exceeding 1h NO_2 of 100 ppb

CE	All Homes	<750 sf	750-1000	1000-1500	>1500 sf
0	53%	100%	100%	88%	19%
0.5	10%	57%	22%	3%	0.003%
0.55	7%	44%	13%	0.7%	0
0.6	4%	30%	5%	0.09%	0
0.65	2%	16%	0.8%	0	0
0.7	0.8%	7%	0.01%	0	0
0.75	0.2%	1%	0	0	0
0.8	0.01%	0.1%	0	0	0

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Percent exceeding 24h $PM_{2.5}$ of 25 microg/m^3

CE	All Homes	<750 sf	750-1000	1000-1500	>1500 sf
0	56%	100%	100%	76%	8%
0.50	3%	18%	1%	0.01%	0
0.55	1%	8%	0.3%	0	0
0.60	0.4%	3%	0.03%	0	0
0.65	0.08%	0.5%	0	0	0
0.70	0.007%	0.04%	0	0	0
0.75	0.001%	0.006%	0	0	0

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Percent exceeding 24h $PM_{2.5}$ of 35 microg/m^3

CE	All Homes	<750 ft2	750-1000	1000-1500	>1500 sf
0	34%	99%	71%	76%	8%
0.50	0.03%	0.2%	0	0.01%	0
0.55	0.004%	0.02%	0	0	0
0.60	0.001%	0.006%	0	0	0

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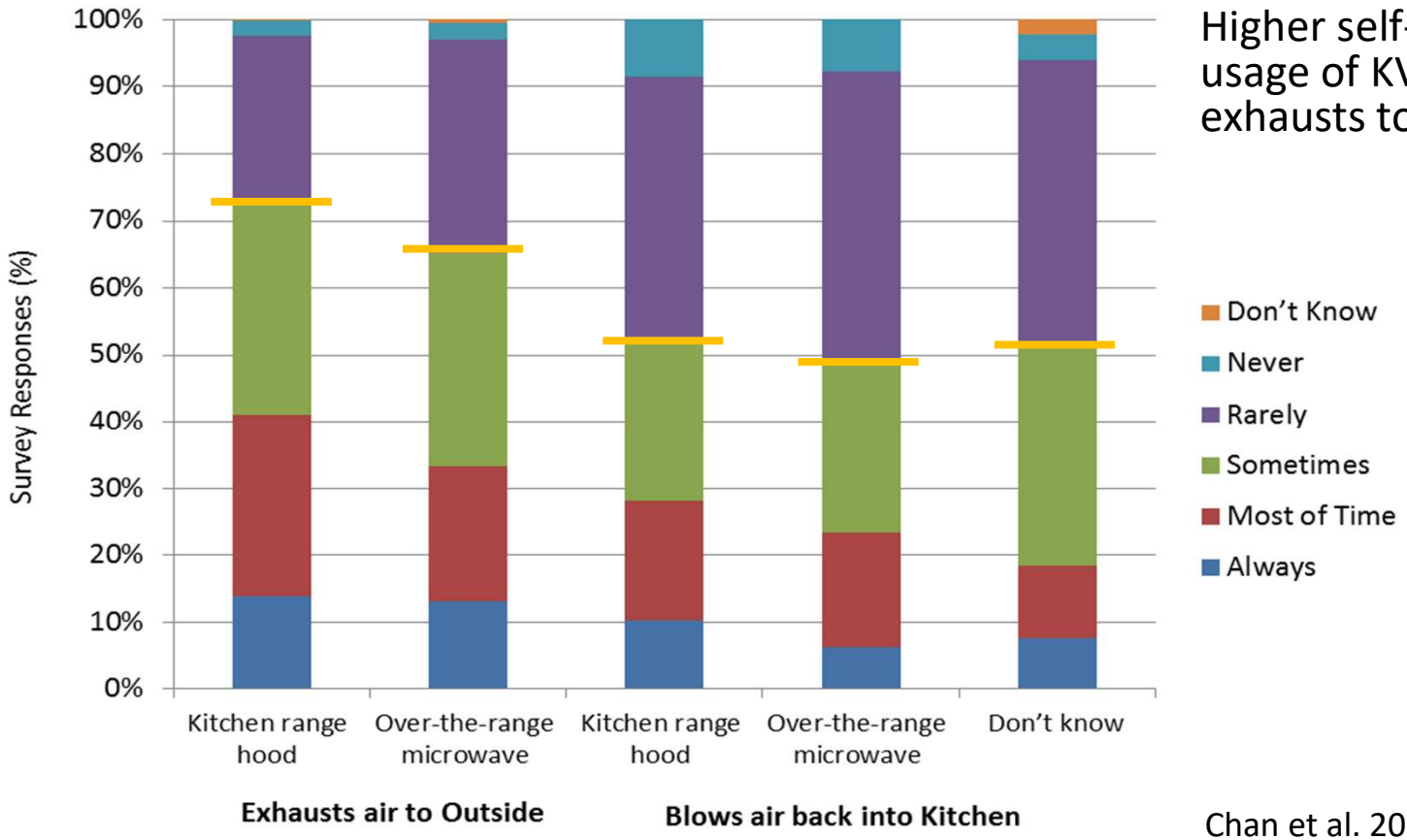
Self-reported range hood use

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

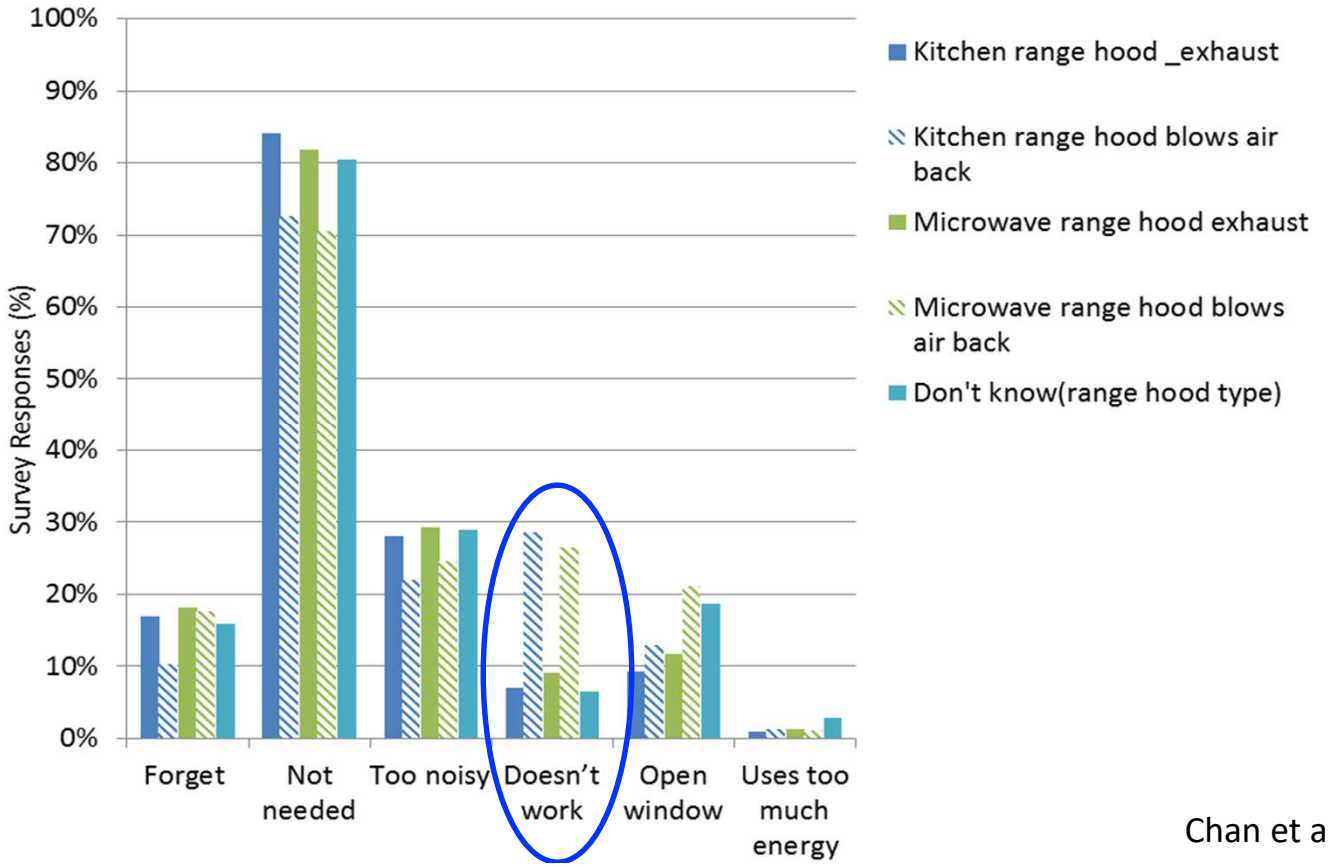


Higher self-reported usage of KV that exhausts to outside

Chan et al. 2019

Why do people not use their range hoods?

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



Chan et al. 2019

Range hoods used less often than self-reported

Single detached houses

Survey response[1]	# houses	CT events	Any hood use N (%)
Always/most of time (4–5 out of 5 times)	26	349	158 (**45%**)
Sometimes (2–3 out of 5 times)	13	97	20 (**21%**)
Rarely/never (0–1 out of 5 times)	13	70	11 (**16%**)
Don't know	0	0	0
No response	2	10	4 (40%)
p-value[2]		<0.01	

Zhao et al. Submitted

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Don't know	0	0	0
No response	2	10	4 (40%)
p-value[2]		<0.01	

Income-qualifying apartments

Survey response[1]	# apts	CT events	Any hood use N (%)
Usually or always	6	83	32 (**39%**)
Sometimes / as needed	6	51	10 (**20%**)
Rarely or never	0	0	0
Don't know	3	46	6 (13%)
No response	2	15	5 (**33%**)
p-value[2]		0.02	

Zhao et al. Submitted

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- Zhao H, Delp WW, Chan WR, Walker IS, Singer BC. 2020. Measured Performance of Over the Range Microwave Range Hoods. Lawrence Berkeley National Laboratory, Berkeley, CA. LBNL-2001351.
- Zhao H, Chan WR, Singer BC, Delp WW, Tang H, Walker IS. Factors impacting range hood use in California houses and low-income apartments. *International Journal of Environmental Research in Public Health. Submitted 05-Sep-2020.*

Extra Slides

Field experiments of burners and range hoods

- **Controlled experiments with cooking burners**
  - Cooktop: boil/simmer pot (4L water) and heat/simmer pan (1L water)
  - Oven: preheat to 425ºF + 30 min (pot w/1L water)
  - Broiler: preheat 20 min, 15 min (pot w/1L water)
  - No food preparation
- **9 homes in Northern California**
  - 8 houses/flats 108–226 m^2 + 26 m^2 apt; 1-2 stories; Built 1904–1991
  - 6 with venting hood, 1 bath fan, 1 recirc hood

 Singer et al., 2017, Building Environment