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U.S. DEPARTMENT OF ENERGY

In-Situ Effectiveness of Cooker Hoods

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Three measures of effectiveness

1. **Air flow**
2. **Capture Efficiency**
3. **Cooker hood use**

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Airflow measurement

Cardboard flowhood

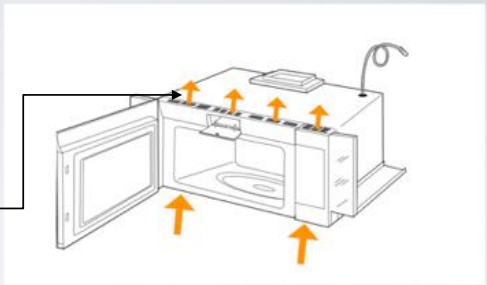
Use fan/flowmeter to zero pressure different across the cardboard box – or match static pressure in duct system

Fan/flowmeter

Issues with microwave hoods

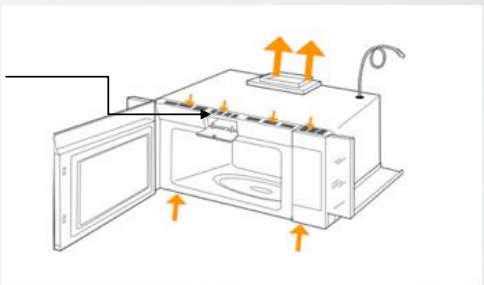
Recirc. Mode (default)

Air returned to room via vents in the top of the hood

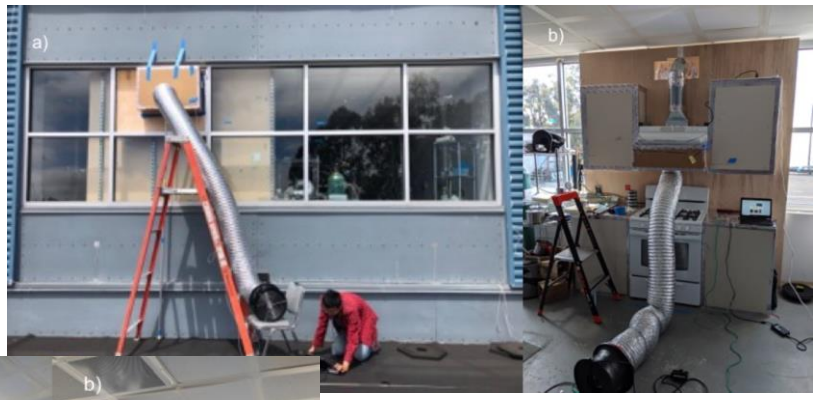


Not all the air enters the bottom of the hood

Venting Mode



Simultaneous inlet & outlet measurements to determine correct microwave hood flows



About 15% of flow missed if measurements are made for the bottom inlet only

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Older Home Performance Study

		Measured Flows [L/s] (% of rated flow)		
Home ID	Type	Low	Medium	High
H1	Hood	66	108	148 (59%)
H2	Microwave	66 (78%)		76 (54%)
H5	Hood	135 (98%)		153
H6	Microwave	43		49 (45%)
H8	Hood	20 (40%)	n/a	30 (40%)
H9	Hood	39 (79%)	n/a	19 (64%)

In these older homes – air flows not meeting specifications and not always minimum (in the US ASHRAE 62.2) requirement of 50 L/s

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Air Flow Measurements in NEW California homes

72 New homes in California built since 2008

Higher flows than in older homes

Big range: 16-380 L/s

Microwaves - much lower flow

Fan Speed Setting	Median (5th–95th %tile) (L/s)	
	Range Hood	Microwave
Low	65 (28–138)	36 (16–67)
Medium	106 (38–295)	57 (37–89)
High	121 (65–380)	59 (17–102)

Other recent studies in California:

- 4 homes built in 2012 in California averaged 72 L/s – all met the 50 L/s requirement in California
- 23 apartments in California averaged 43 L/s on low speed and 70 L/s on high. 32% met the 50 L/s requirement in California on low speed and 77% on high speed

Primary effectiveness metric: Capture Efficiency

The fraction of cooking contaminants are exhausted by the cooker hood

Measuring Capture Efficiency in the field using gas burners

- Turn on burner and use gas meter to determine gas use rate. Convert this to CO_2 emission rate using standard combustion calculations (E [mL/min])
- Measure air flow through cooker hood (Q [m^3/min])
- Measure CO_2 concentration [mL/m^3] in the room (C_0) and the exhaust duct (C_v)

$$CE = Q * (C_v - C_0) * 10^6 / E$$

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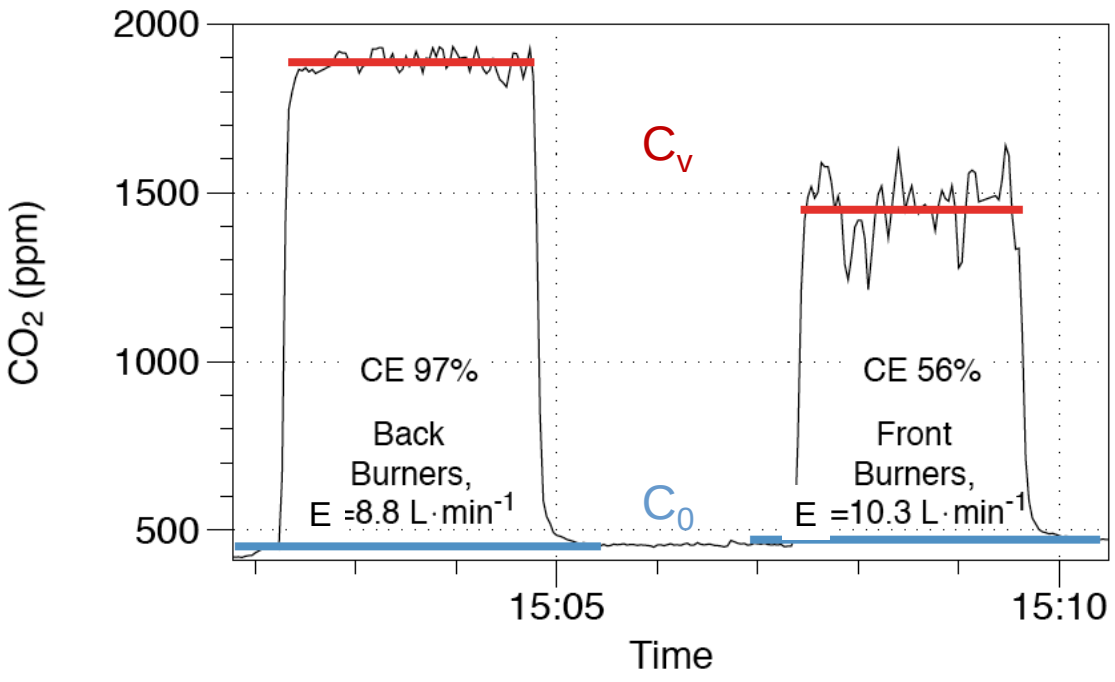


In-Home Performance Study

15 devices

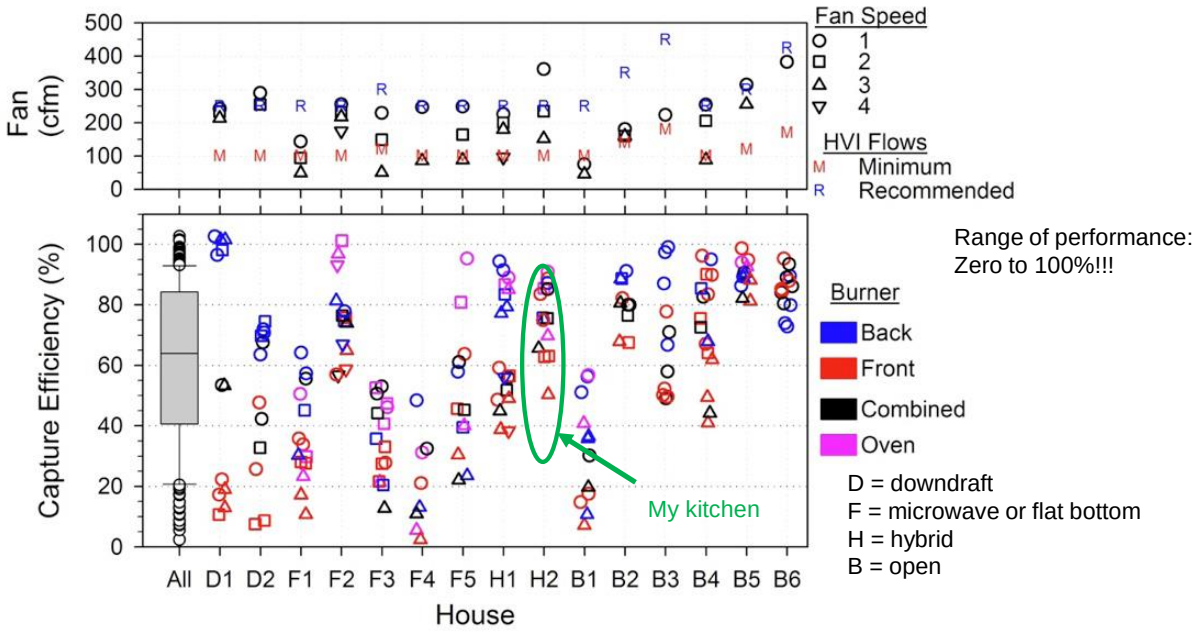
- 2 downdraft
- 2 microwaves
- 3 flat-bottom hoods
- 2 hybrid
- 6 open hoods

Cooktop tests

- Pots with water
- Front, back, diagonal

Oven tests

- (245 C) 425 F, door closed
- Cool between tests



Delp, W. W., and B. C. Singer. 2012. "Performance Assessment of US Residential Cooking Exhaust Hoods." *Environmental Science & Technology* 46 (11): 6167–6173.

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Multifamily field study: gas burners with pots of water in new and renovated dwellings

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Collected field data from 23 apartments in 4 buildings built since 2013

- All low-income residences
- All have gas cooking and self-reported to cook daily
- Six units had Capture Efficiency measurements

3. Chula Vista (Sep, 2019)

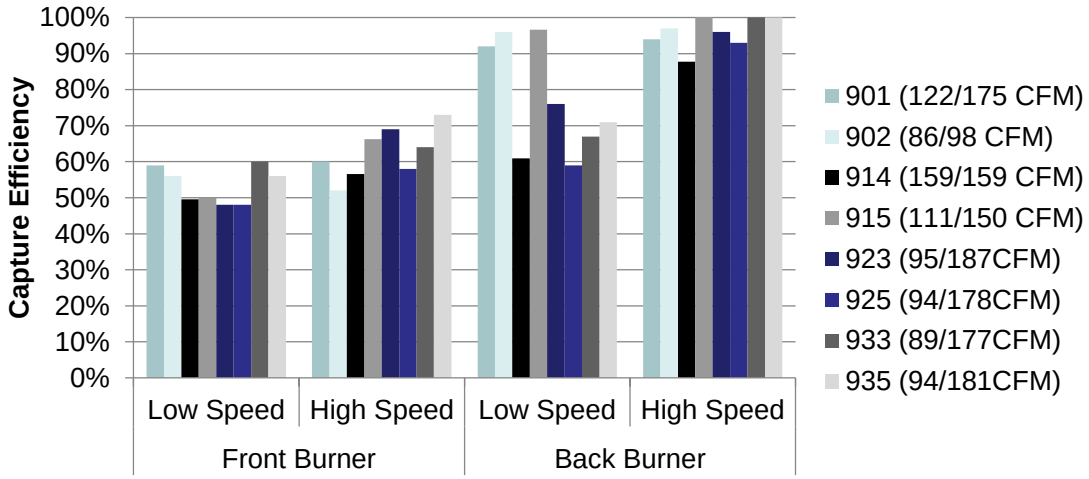
4. Los Angeles (Nov, 2019)

1. Hayward (Feb, 2019)

2. San Francisco (Apr, 2019)

Range Hood Capture Efficiency

Much more consistent and no very low flows or CE compared to older home study



Measuring Capture Efficiency for any burner – gas or electric: the foil curtain

Shroud the cooktop with temporary foil curtain – theoretical 100% capture

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Measuring Capture Efficiency for any burner – the foil curtain

- Measure background CO_2 with no burners or CO_2 injection (C_0)
- Use either gas burner* or inject tracer gas into pot above burner as source for CO_2
- Measure CO_2 concentration in the exhaust duct (C_{100}) with shroud in place
- Remove shroud and repeat CO_2 measurement in exhaust duct (C_N)

$$CE = \frac{(C_N - C_0)}{(C_{100} - C_0)}$$

*Note: all data in this presentation for gas burners

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Measured CE using foil curtain approach

		Low speed		High speed	
Home ID	Hood type	Front burners	Back burners	Front burners	Back burners
H1	Hood	NM[1]	NM[1]	NM[1]	NM[1]
H2	Microwave	25%	>95%	35%	>95%
H5	Hood	61%	68%	72%	84%
H6	Microwave	31%	88%	31%	93%
H8[1]	Hood	59%	68%	65%	80%
H9[1]	Hood	25%	74%	36%	75%

[1]Not measured; there was no way to access the range hood exhaust duct without aesthetic damage.

Like other studies/approaches: higher CE on back burner and at higher air flow

Singer BC, Pass RZ, Delp WW, Lorenzetti DM, Maddalena RL. 2017. Pollutant concentrations and emission rates from natural gas cooking burners without and with range hood use in nine California homes. *Building and Environment* 122: 215-229

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Cooking and Cooker Hood Monitoring

Monitor cooktop and oven use with iButton temperature sensors

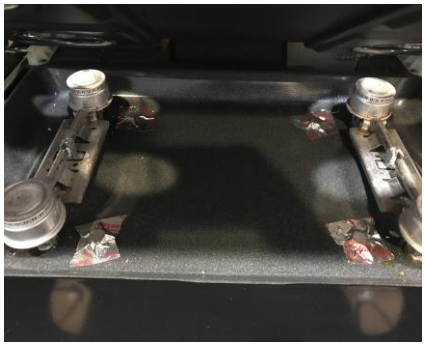
Monitor cooker hood use with anemometer

Identify Cooking Events

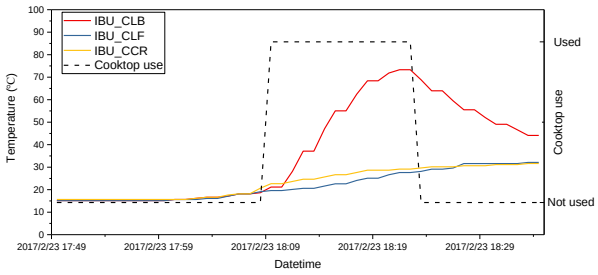
Algorithm to process iButton temperature sensor data

Cooking start identified by a rapid increase in temperature measured by iButton

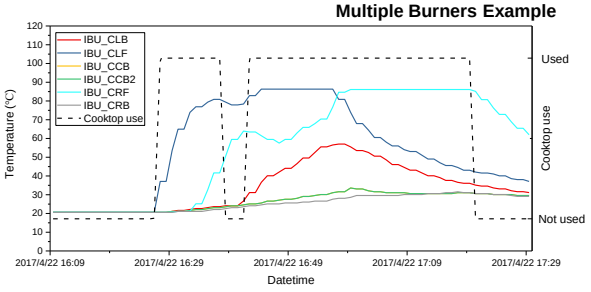
Cooking end when the main burner iButton temperature started to drop



Single Burner Example



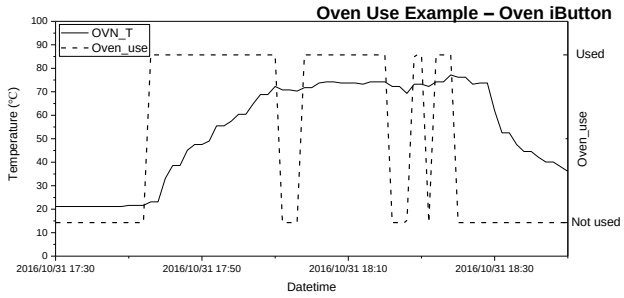
Multiple Burners Example

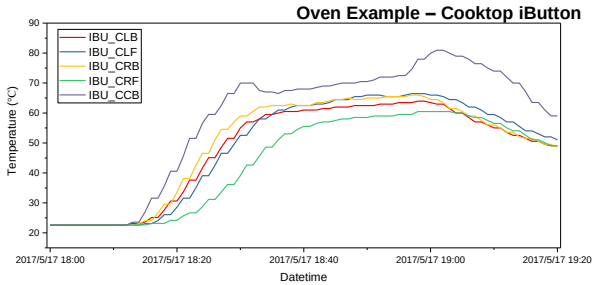


Identify Oven Use

Similar algorithm as cooktop, but more challenging:

- Placement of iButton varied from home to home – near oven vent
- Fluctuations in oven temperature (burner cycling)





Identifying cooktop/oven use

- **The start and ends of cooking events were identified by temperature changes measured by an iButton**
  - Start of event:
    - Cooktops: Threshold temperature rise of 0.6 to 1°C/minute
    - Ovens: Threshold temperature rise of 0.6 to 2°C/minute
  - End of event:
    - Cooktops: temperature drop by a minimum of 0.2 to 0.5°C/minute
    - Ovens: temperature drop of 0.3 to 0.5°C/minute
- **Selection of the threshold value for each home was done by visual inspection with the goal of having all cooking events identified.**
- **No single threshold value was suitable for all homes.**
  - Above limits worked in 86% of homes for cooktop and 78% of homes for oven use

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Results of cooktop/oven use monitoring

A cooker hood was used during 29% of events that involved a cooktop burner and 22% of events with oven use.

Longer events with more burners had more cooker hood use.

People are not good predictors of their own cooking behavior:

- **In households that reported no cooker hood use generally, they were actually used during 12% of cooktop events.**
- **In households that said cooker hoods are used 80–100% of the time generally, they were actually used during only 33-38% of cooktop use.**

Summary of in-field cooker hood effectiveness evaluation methods

Air flow measurement

- Needs temporary flow capture fabrication
- Microwave hoods need to capture all vents (or add about 15%0
- Older homes and installations have generally poor flows, newer homes and remodels are better

Capture Efficiency

- Gas cooktops: use gas consumption rate of burner and measured CO_2
- Gas and electric cooktops: use burner or other CO_2 source and a foil shroud for 100% capture reference
- Vert large performance range zero to 100% capture.
- Better on back burners and at higher flow

Over and Burner operation

- Use small temperature sensors + visual inspection using temperature change metric
- Not perfect, but OK for assessing use patterns

Acknowledgements

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