Healthy Kitchen Ventilation: Best Practices in Low E Homes

Tom Phillips
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Reducing Outdoor Contaminants in Indoor Spaces (ROCIS.org)

North American Passive House Network 18
October 19, 2018, Pittsburgh, PA, https://naphnconference.com/program-2/

Topics

- **Background: who, what, why, when**
- **ROCIS Best Practices for *Ducted* Range Hoods**
  - **Reduce emissions at the source**
  - **Determine hood flow requirements**
  - **Hood with high Capture Efficiency**
  - **Hood with low noise rating**
  - **Good duct design, installation, and testing**
- **Special concerns for low E, airtight homes**
  - **Use ducted hood, and not a recirculating hood**
  - **Use makeup air with split delivery**
  - **Consider side shields**
  - **Oven venting**

What is right (and/or wrong) with these?

1

2

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4

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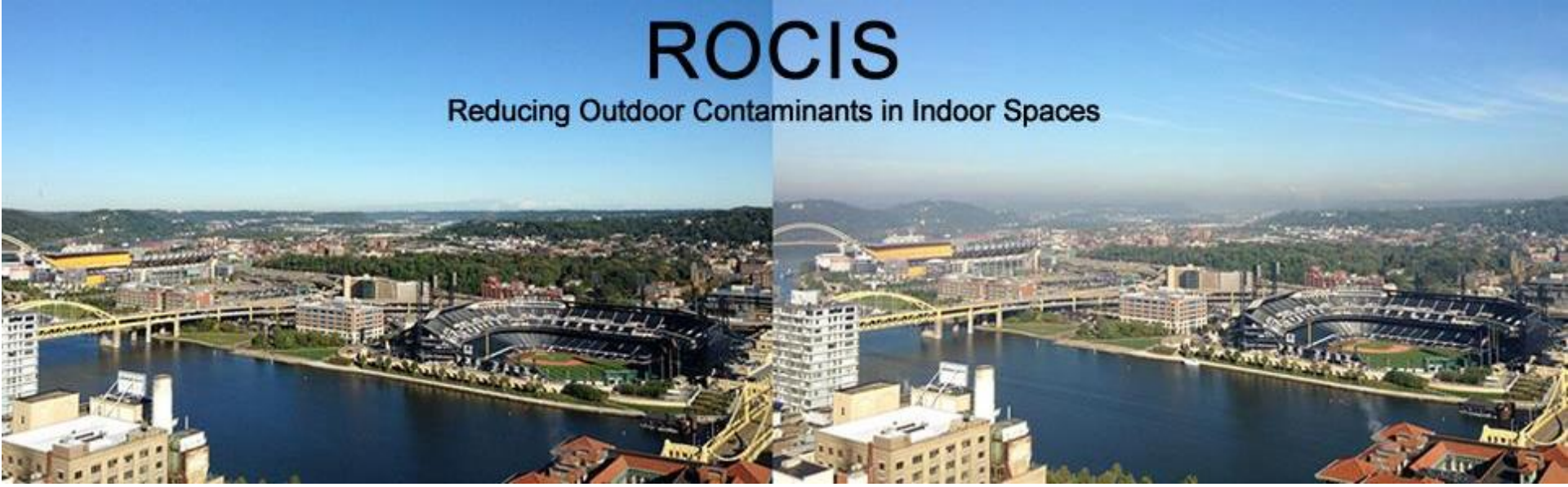


OBJECTIVES

Support and broaden the ROCIS stakeholder network in SW PA

Begin to establish a baseline (indoor/outdoor pollutants) and data to support the feasibility of interventions

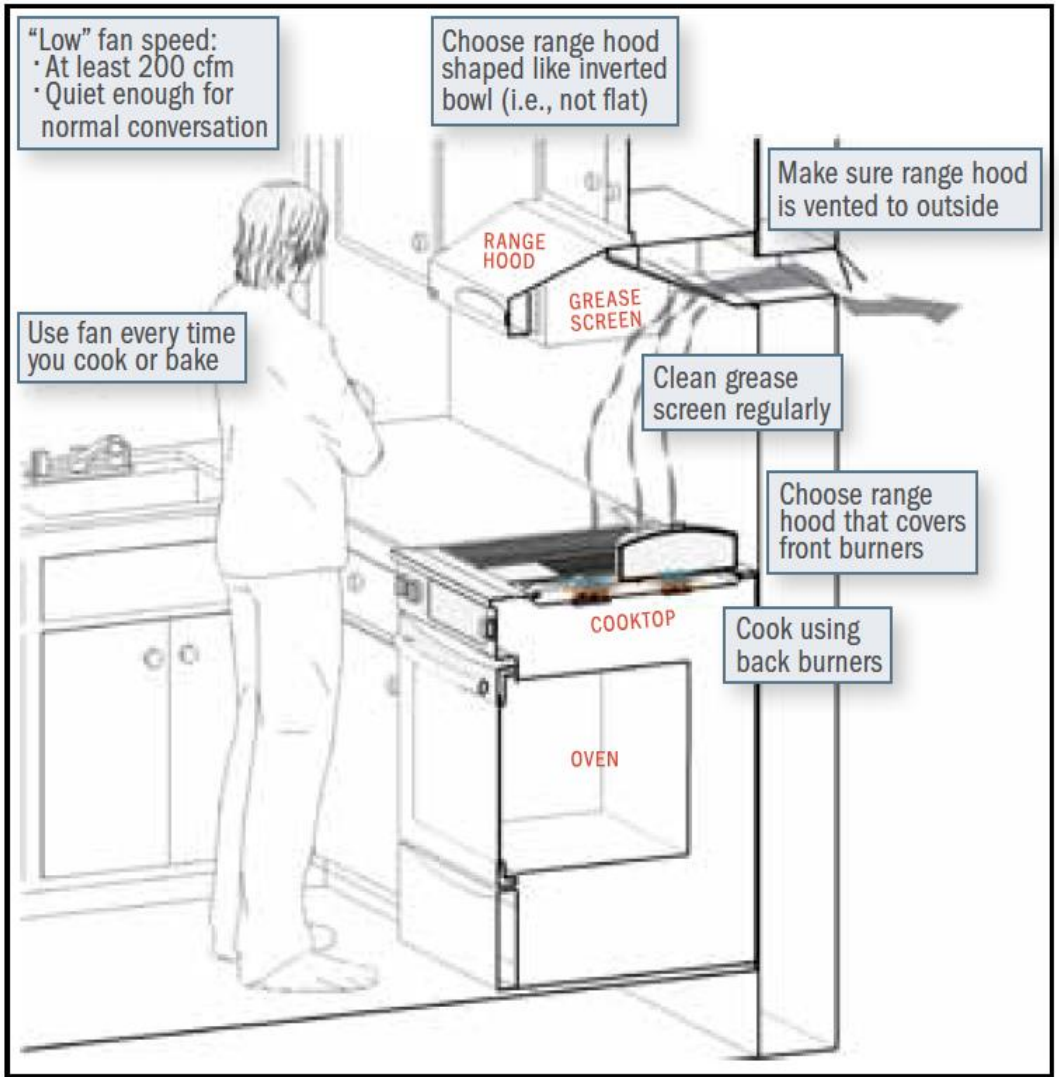
Address barriers to implementation, particularly regarding the lack of tested protocols for interventions

ROCIS Best Practice Guidance

Ducted Range Hoods:

Recommendations for New and Existing Homes

January 2018, ROCIS.org/kitchen-range-hoods



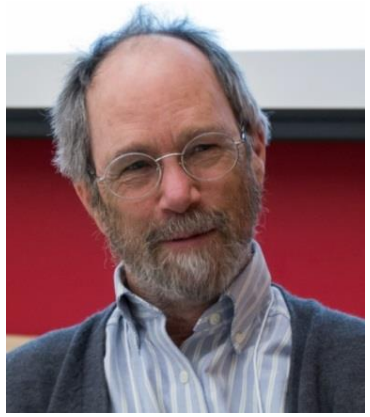
AND

- ✓ **Put lids on pots and pans**
- ✓ **Cook at lower temperatures**
- ✓ **Provide make-up air and split delivery in cold climates**
- ✓ **Good duct design**
- ✓ **Inspect and test**

Image: Chris Stratton, Feb. 2015.
Kitchen Ventilation, Home Energy Magazine.

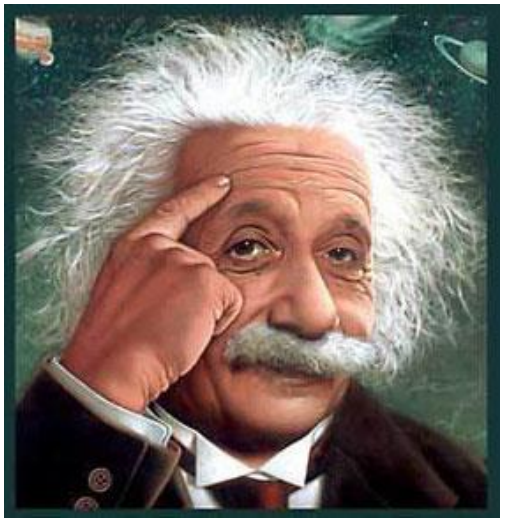
Acknowledgements

- **ROCIS Team:**
  - **Linda Wigington**
  - **Don Fugler**
  - **Rob Busher**



- **Over a dozen expert reviewers from US and Canada**
- **Numerous IAQ and ventilation researchers**

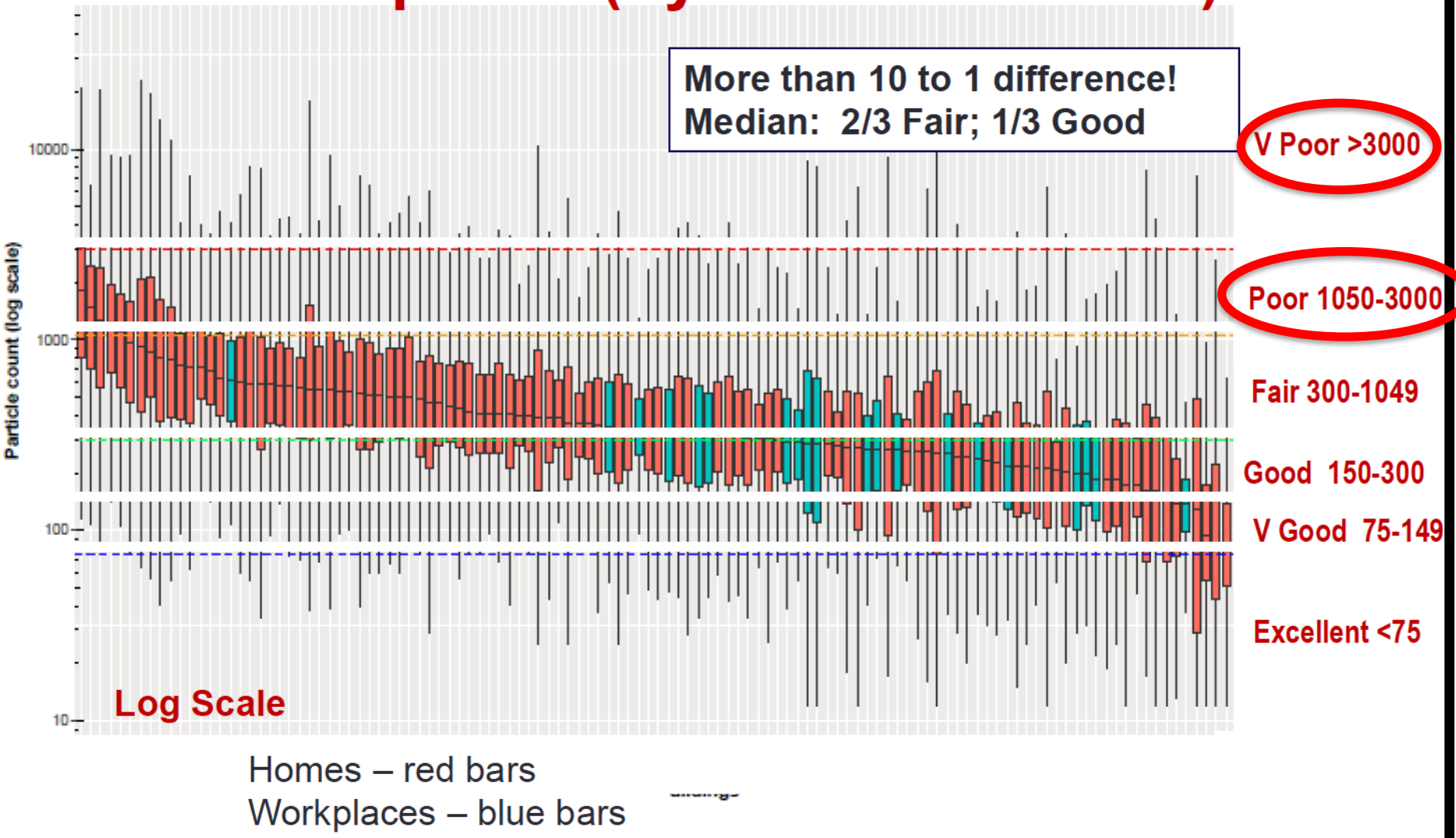
- **Heinz Endowments (partial funding)**



Particle Counts in ROCIS Low Cost Monitoring Project

Indoor Median & Distribution

137 Participants (Dylos Total 0.5+ um)



Wigington, L., Nov. 2-4, 2017. Healthy Building Summit 2017, Seven Springs, PA.

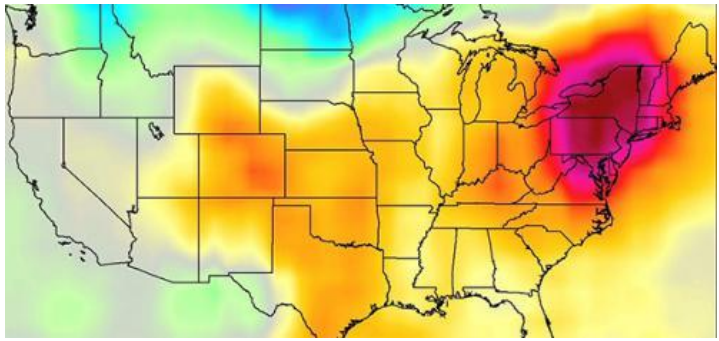
WHO needs a ducted range hood?

- Anybody who cooks indoors
- Anyone retrofitting or building a home, or replacing a hood
- Sensitive populations
  - Children or pregnant women
  - Respiratory disease patients
  - Elderly
  - Persons sensitive to odors or noise
- Especially
  - With high emission cooking such as frying, grilling, roasting, broiling, multiple burners
  - In smaller homes and airtight homes

Top image : Bradman, A., 2012. Early Childhood Environments study. CARB seminar.
Bottom image : Allegheny County has some of PA's highest asthma rates. "What We Breathe." H Magazine, Vol. 3, 2015. http://www.heinz.org/news-and-media/library?PublicationTypeID=1.

WHY update range hood guidance NOW?

- Growing recognition of indoor pollution from cooking and its health impacts
- Homes are getting more airtight: easier to pollute and depressurize
  - Building standards and guidelines to achieve low energy and low carbon goals
  - Home weatherization to help reduce C emissions, power plant emissions, and energy poverty
- Remodeling boom: a golden opportunity
- New test method and HVI rating for hood capture efficiency is coming in 2019



HOME VENTILATING INSTITUTE

Certified Home Ventilating Products Directory, https://www.hvi.org/proddirectory/index.cfm

Top image: NASA JPL, at Baltodano et al. 2018, Climate Change, Heat Waves, and Air Quality. https://www.arec.umd.edu/news/climate-change-heat-waves-and-air-quality.
Center: BC Public Interest Advocacy Centre. http://bcpiac.com/about/our-work/energy-poverty/.

WHY is cooking pollution a concern?

- Odors

- Moisture
  - Increased risk of mold bacteria & dust mite growth
  - Electric stove, 3 meals: over 2 pints/day
  - Gas stove: about 5 pints/day

Table 1. Moisture released from cooking sources

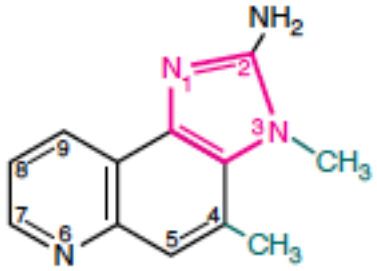
Cooking Activity	Moisture Released: Electric	Moisture Released: Gas
Breakfast for 4 people	0.35 pints	0.93 pints
Lunch for 4 people	0.52 pints	1.23 pints
Dinner for 4 people	1.22 pints	2.80 pints
Simmer, 6-inch pan (10 minutes)	0.1 pints covered 0.13 pints uncovered	
Boil, 6 inch pan (10 minutes)	0.48 pints covered 0.57 pints uncovered	

Top image: http://aqualifeforyou.blogspot.com/2012/09/soak-fish-in-milk-for-odor-free-cooking.html
Bottom image: Angell & Olson, 1988. University of Minnesota. https://www.aivc.org/resource/moisture-sources-associated-potential-damage-cold-climate-housing.

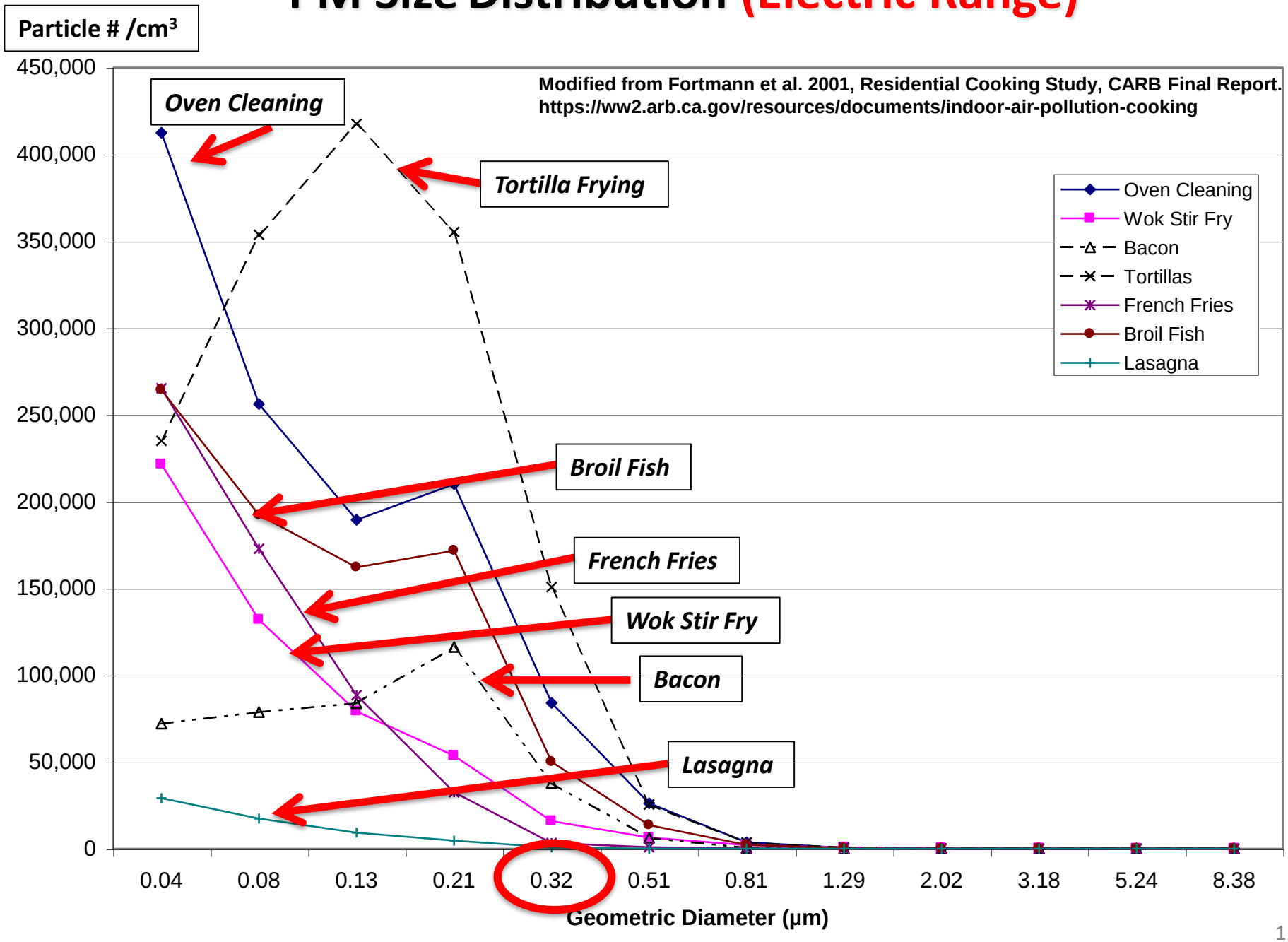
WHY is cooking pollution a concern? (contd.)

- **Cooking pollutants increase the risk of health impacts**
  - Respiratory effects in children (short term)
  - Cancer risks (long term)
  - Cooking can contribute significantly to personal exposure (breathing zone) and dose to the lung
- **Indoor pollutant levels from cooking can exceed health guidelines for air pollution**
  - Gas stove: Combustion pollutants from gas burners (particles, NO_2, aldehydes, CO)
  - Electric stoves: particles, aldehydes

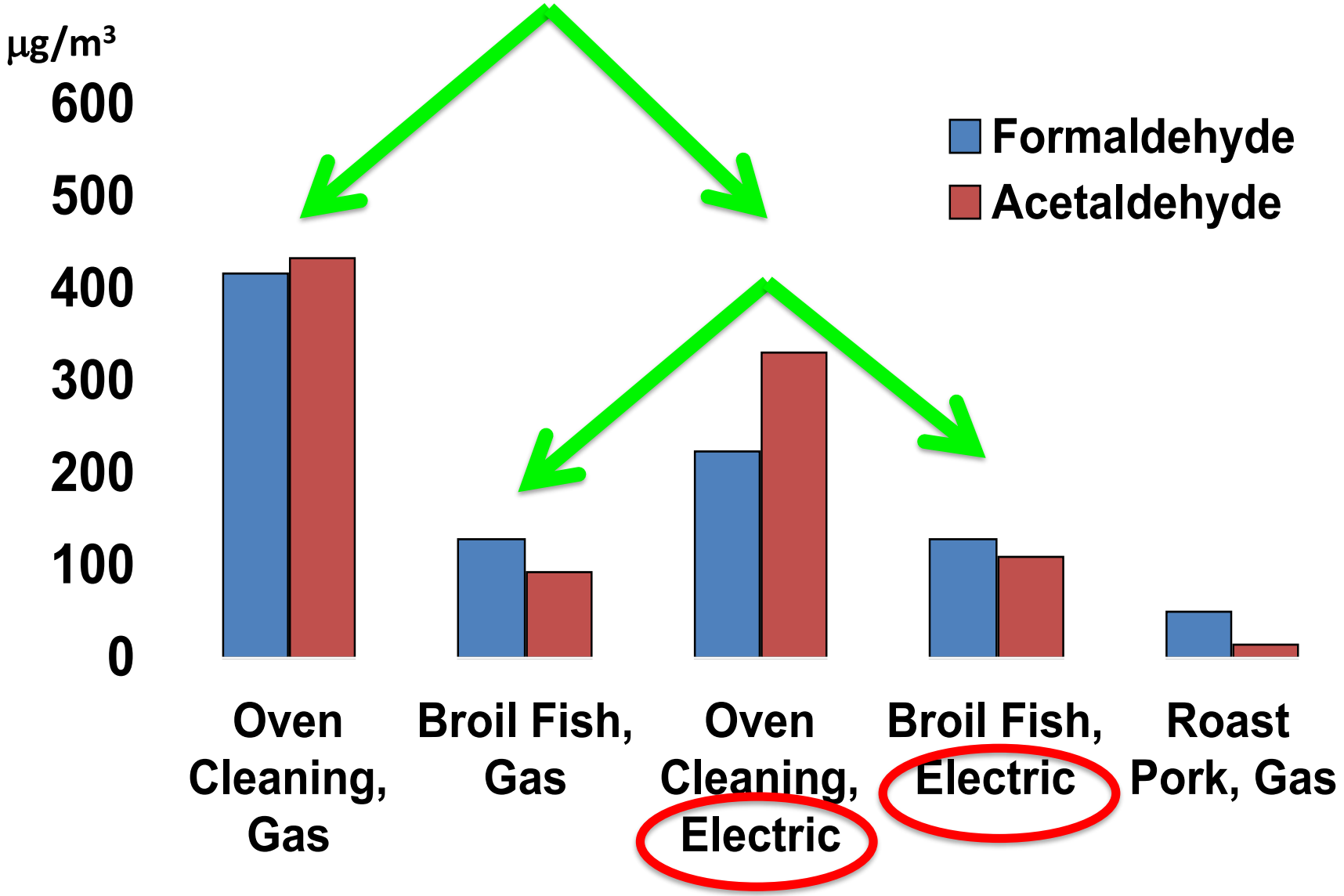
(c) The food mutagen 4-MeIQ



PM Size Distribution (Electric Range)



Formaldehyde and Acetaldehyde in Kitchen



Phillips et al., ISEA 2000. From Fortmann et al. 2001, CARB Final Report. Test # 9.
https://ww2.arb.ca.gov/resources/documents/indoor-air-pollution-cooking

Personal Exposure to Cooking PM: *5 Countries* *

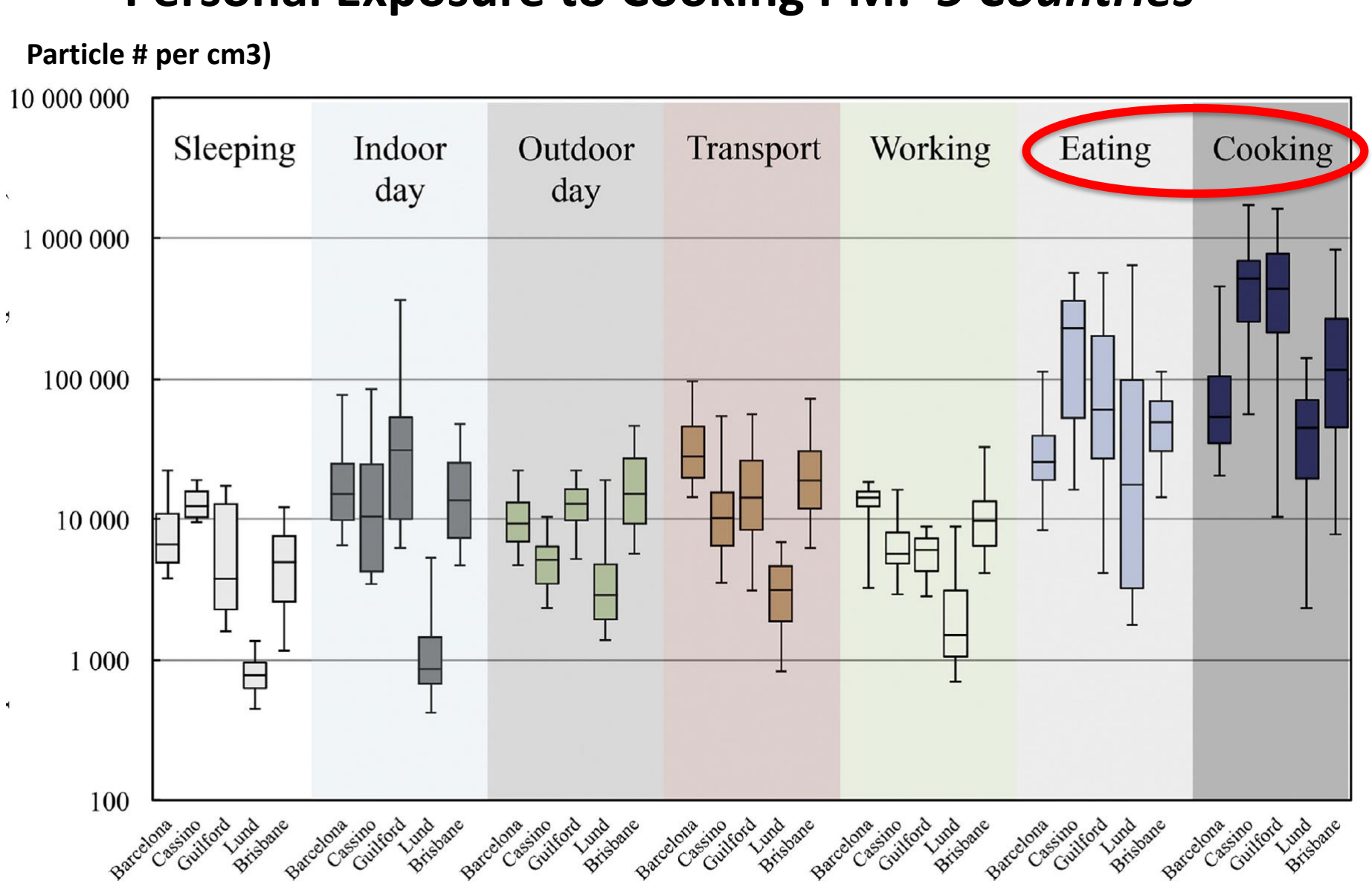


Fig. 1. A box plot of particles number concentrations in the investigated cities as a function of the microenvironments.

*** Pacitto et al., 2018. https://doi.org/10.1016/j.envpol.2017.09.023.**

Topics

- **Best Practices for *Ducted* Range Hoods**
  - **Reduce emissions at the source**
  - **Determine hood flow requirements**
  - **Hood with high Capture Efficiency**
  - **Hood with low noise rating**
  - **Good duct design and installation**

Best Practices: *Easy Ways to Reduce Exposures*

- **Cook on back burners**
- **Cover pots & lids**

Image: Jacobs et al., AIVC Alexandria 2016.

- **Use electric induction stove**
- **Pre-cook with microwave**

- **Cook at lower temperatures**
- **Keep burners clean**

Images: B. Singer, LBNL

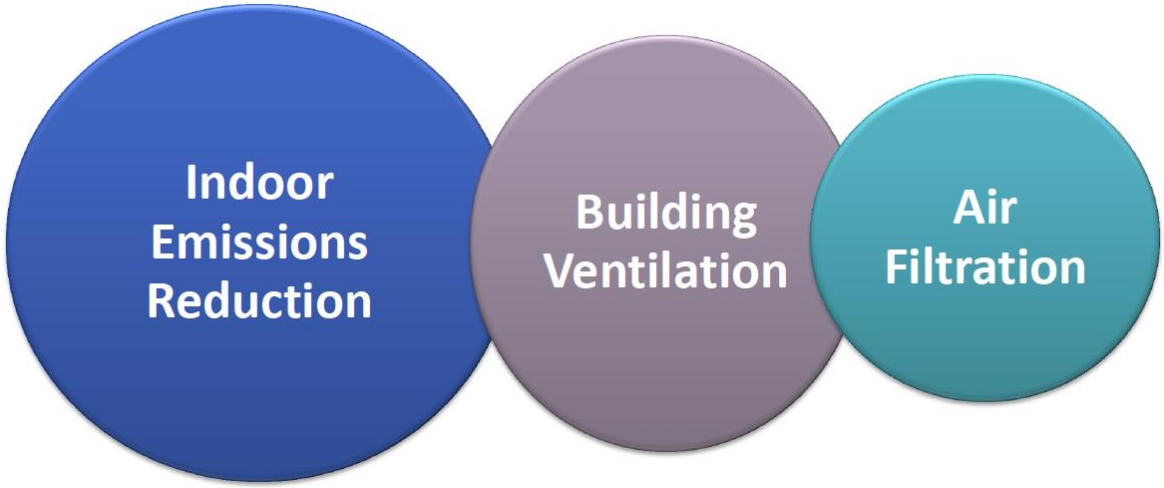
- **Close up kitchen area**

- **Cook outside: BBQ, solar oven**

Image: Wikipedia

Why Do We Need a *Ducted (Vented)* Range Hood?

- They help remove cooking pollution at the source, reducing their spread into the rest of the house
- Some cooking pollutants also soil interior surfaces
- Open windows and exhaust fans are not as effective as a good range hood system [1,2]

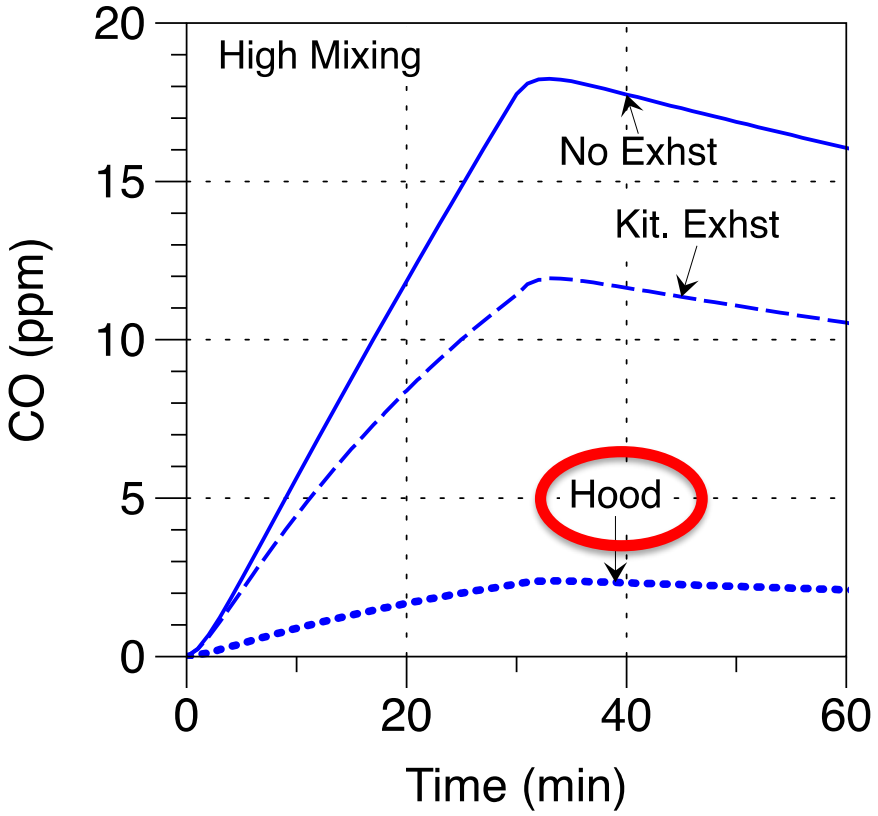


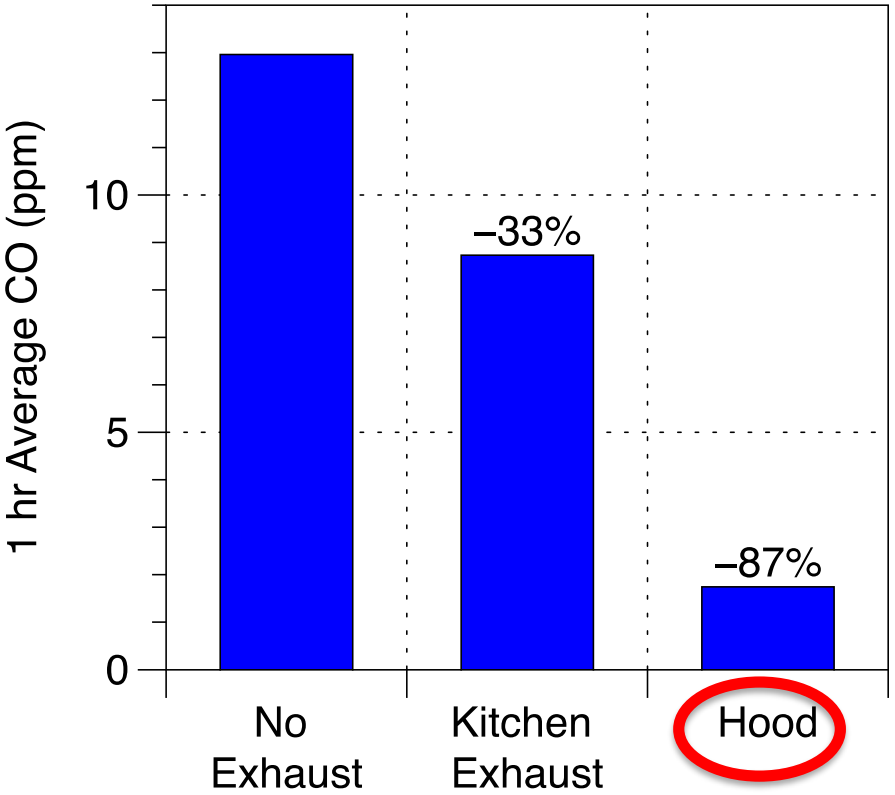
1. Singer & Stratton, 2014. ACEEE Summer Study.
2. O'Leary et al., AIVC 2015. https://www.researchgate.net/publication/281861195_Mitigating_Occupant_Exposure_to_PM_25_s_Emitted_by_Cooking_in_High_Occupancy_Dwellings_Using_Natural_Ventilation_Strategies.

Range hoods better than general kitchen exhaust

Simulations of 200 cfm range hood or kitchen exhaust (80%)

CO concentration throughout the **home**: **OPEN FLOOR PLAN**





Singer & Stratton, 2014. ACEEE Summer Study.

15,000 btu/h
800 ng/J CO

Best Practices: *Low Noise*

- Check Home Ventilating Institute (HVI) Range Hood listings for Noise Ratings
- Select a hood with a noise rating of less than 3 sones at 200 cfm
  - Normal conversations take place at ~ 4 sones
  - Get the quietest hood at the airflow rate you need
  - Warning: non-HVI ratings may not be accurate
- Consider a remote fan (in-line or roof) or an in-line silencer

Best Practices: *Hood Design*

Images: B. Singer, LBNL.

- Pick a deep hood (large internal volume) with an open bottom
- Airflow rate, maximum: 200-350 cubic feet per minute (cfm), depending on installation and stove type
- Multiple speeds for lower noise levels

Best Practices: *High Capture Efficiency (CE)*

- **By early 2019: Home Ventilating Institute (HVI) Range Hood ratings for CE**
- **Standard Test Method for Measuring CE of Domestic Range Hoods, ASTM E3087-17 ***
- **Select a hood with a CE of 75-80%, or more if possible**

CE test setup
(LBNL BTO Peer Review, 2017)

HOME VENTILATING INSTITUTE

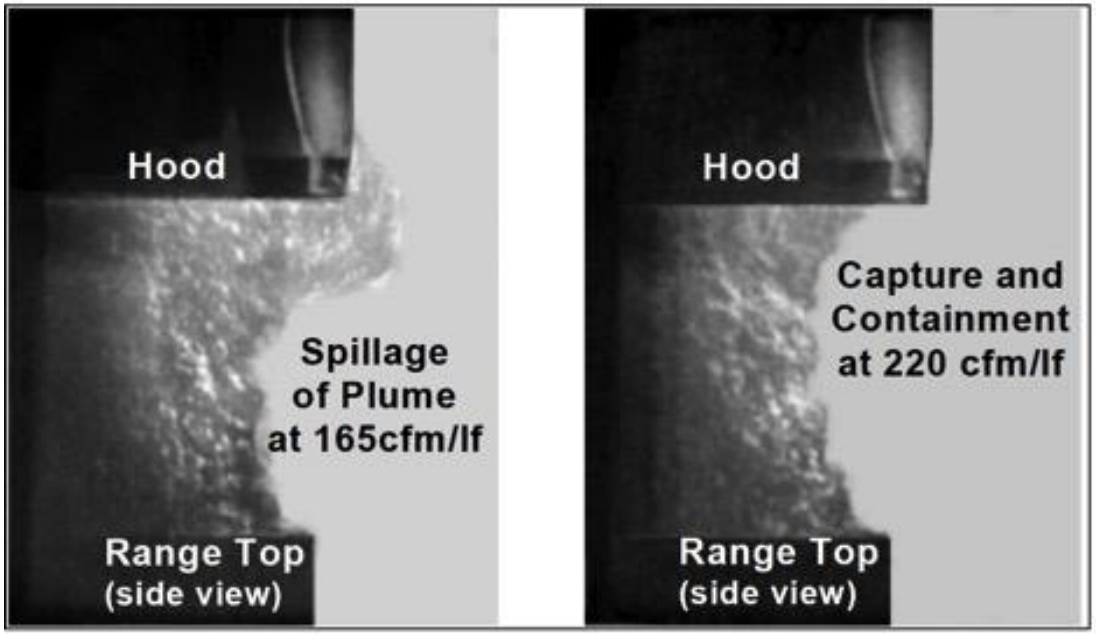
Certified Home Ventilating Products Directory, https://www.hvi.org/proddirectory/index.cfm

* ASTM, 2017. ASTM E3087 – 17, Standard Test Method for Measuring Capture Efficiency of Domestic Range Hoods. https://www.astm.org/Standards/E3087.htm.

Best Practices: *Hood Design*

- **Cover the entire cooking surface**
- **Install 24-32” from stove top**
- **Install in corner or between cabinets, flush with cabinets**
- **Do not have separate ovens and cooktops (ovens need to be vented too)**

Tips for Successful Operation. Best Range Hood LLC.



Ventilation Lab, Food Service Technology Center.

Best Practices:
Not Microwave Over the Range Exhausts

- **Microwave exhaust systems are less effective**
  (less coverage of burners)
- **They are very noisy at high airflows needed to capture pollutants**

Singer and Stratton, 2014. ACEEE Summer Study

Side Shields Can Improve Capture Efficiency (CE)

- "Damp barrier" (extensions, left image)
- "Side barrier" (rear taper, right image)
- PM1 decay periods reduced substantially (by about half and half again, respectively) in lab tests. Potential energy savings

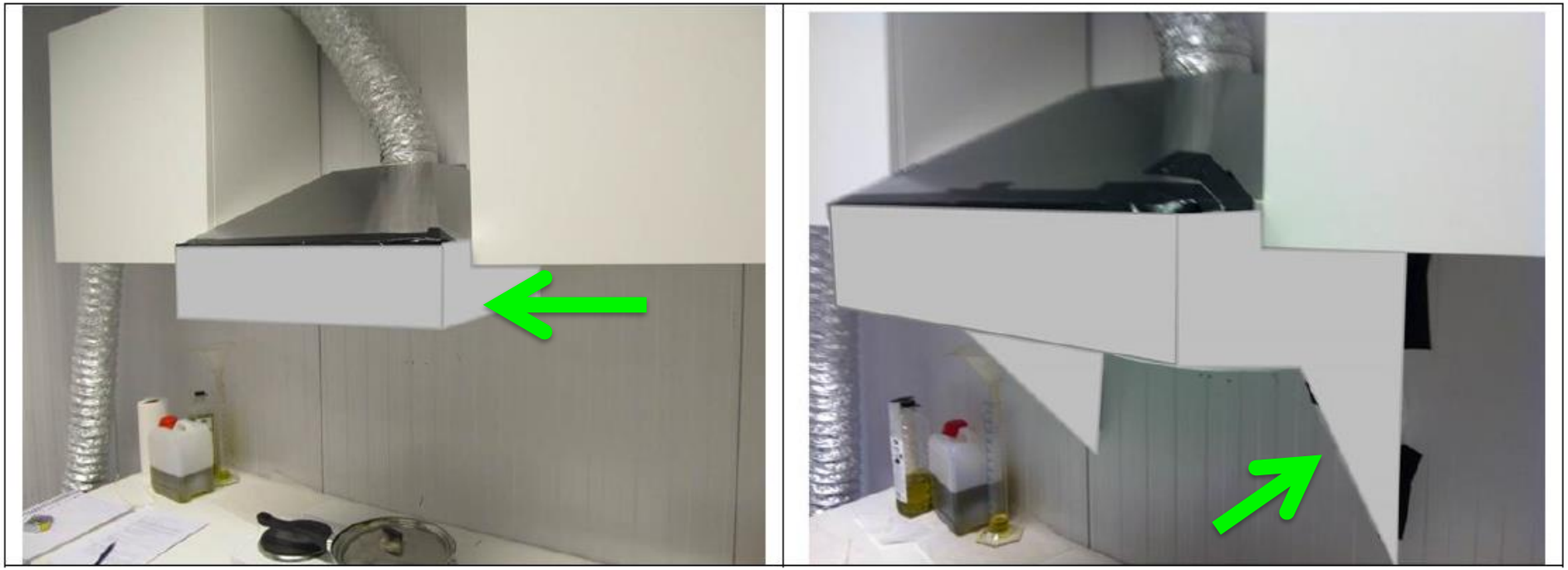
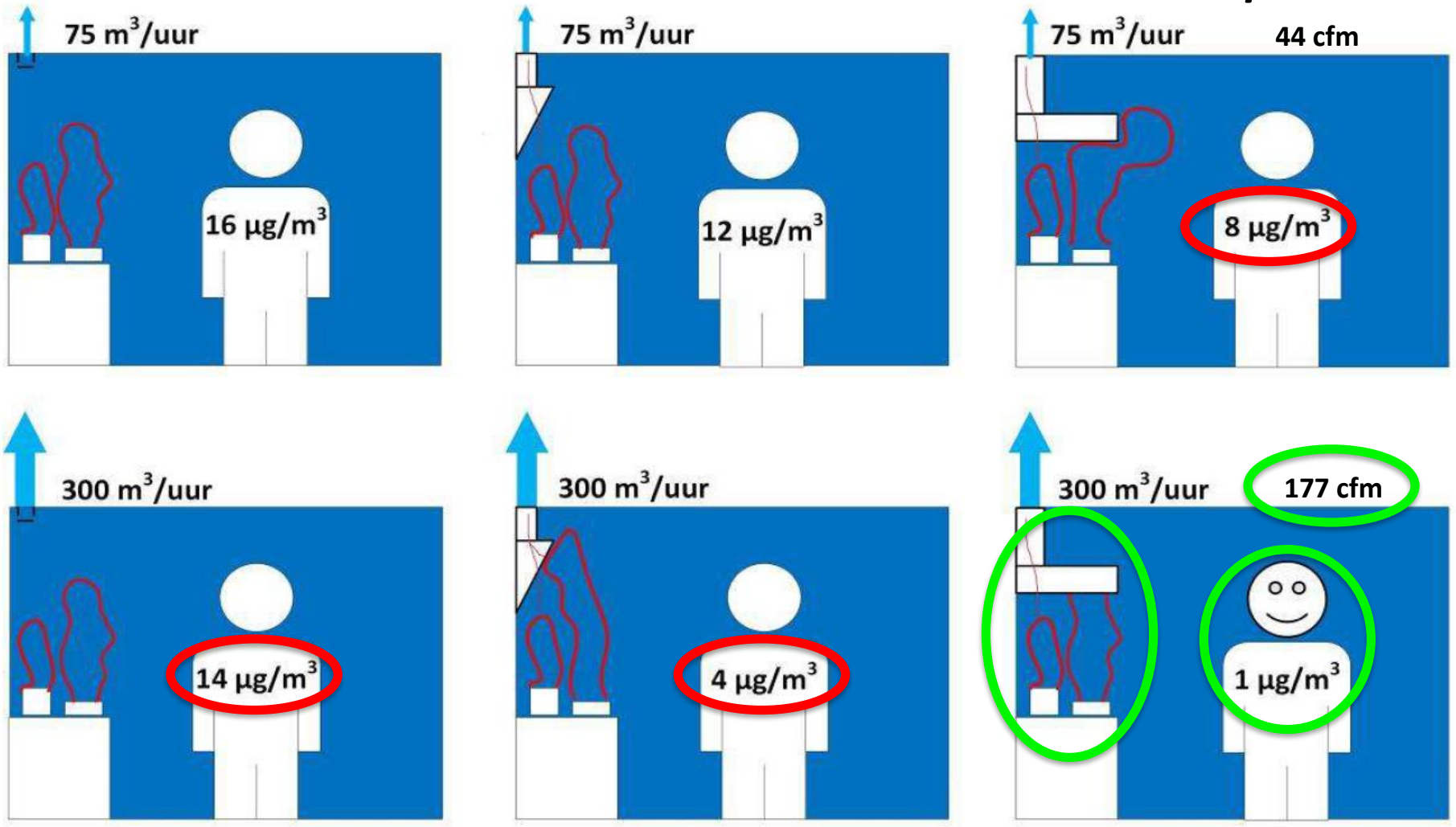


Figure 2. Left: damp buffer applied in experiment G, Right: damp buffer with side barrier in experiment H and I.

Jacobs et al., 2016. Energy efficient measures to reduce PM2,5 emissions due to cooking. Indoor Air 2016. Paper 781-2.

Different Hood Geometries and Flow Rates: *Personal Exposure*

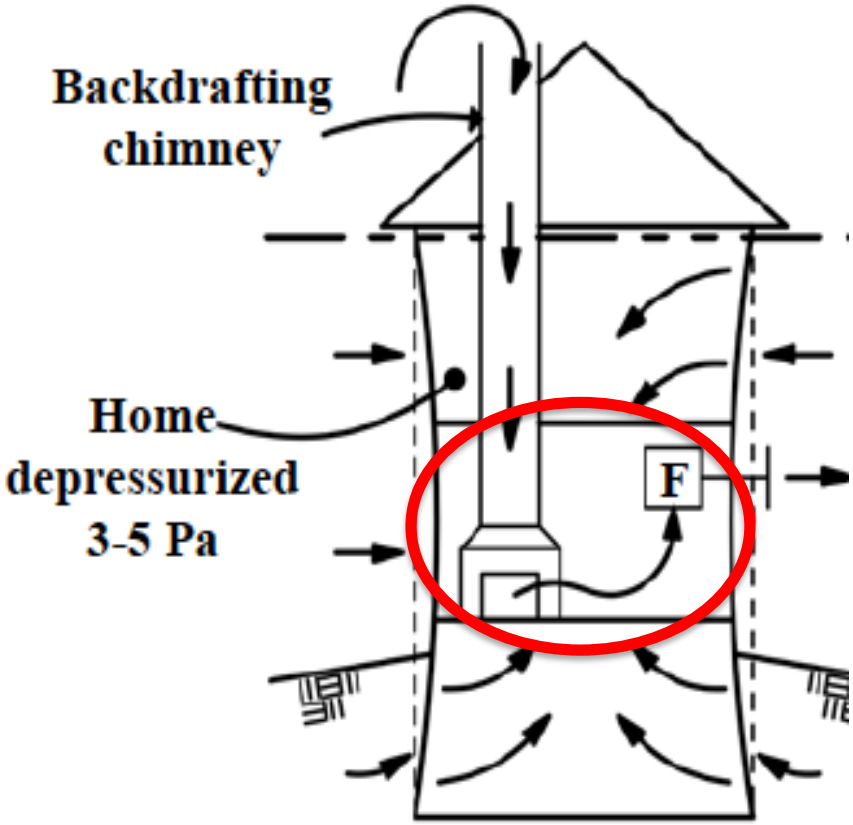


- **Annual avg. personal PM exposure (modeled: reduced by higher CE and higher flow rate**
- **Approximate 10 X reduction vs. ceiling exhaust and/or lower flow rate**

Borsboom et al., 2018. Assessment of range hoods based on exposure. AIVC 2018 conference. http://aivc2018conference.org/.

Best Practices: *Caveats and Cautions*

- **High flow hoods (> 400 cfm)** hoods can cause depressurization and backdrafting
  - Requires mechanical make-up air systems (not passive)
  - Interlink the hood and make up air damper
  - Filtered, tempered make up air recommended
  - Naturally vented combustion appliances and fireplaces are not appropriate
- Consult building officials and building experts



Best Practices: *Installation*

- Double check duct layout
- Low resistance, sealed ducting through the roof or wall
- Clean old duct work or replace
- Avoid cross-contamination of air intakes
- Inspect and test the entire fan, duct, and control system BEFORE closing up the wall or installing attic insulation

Debris found in ducting of range hood

Singer & Stratton, 2014 ACEEE Sumer Study.

Why We Commission Building Systems

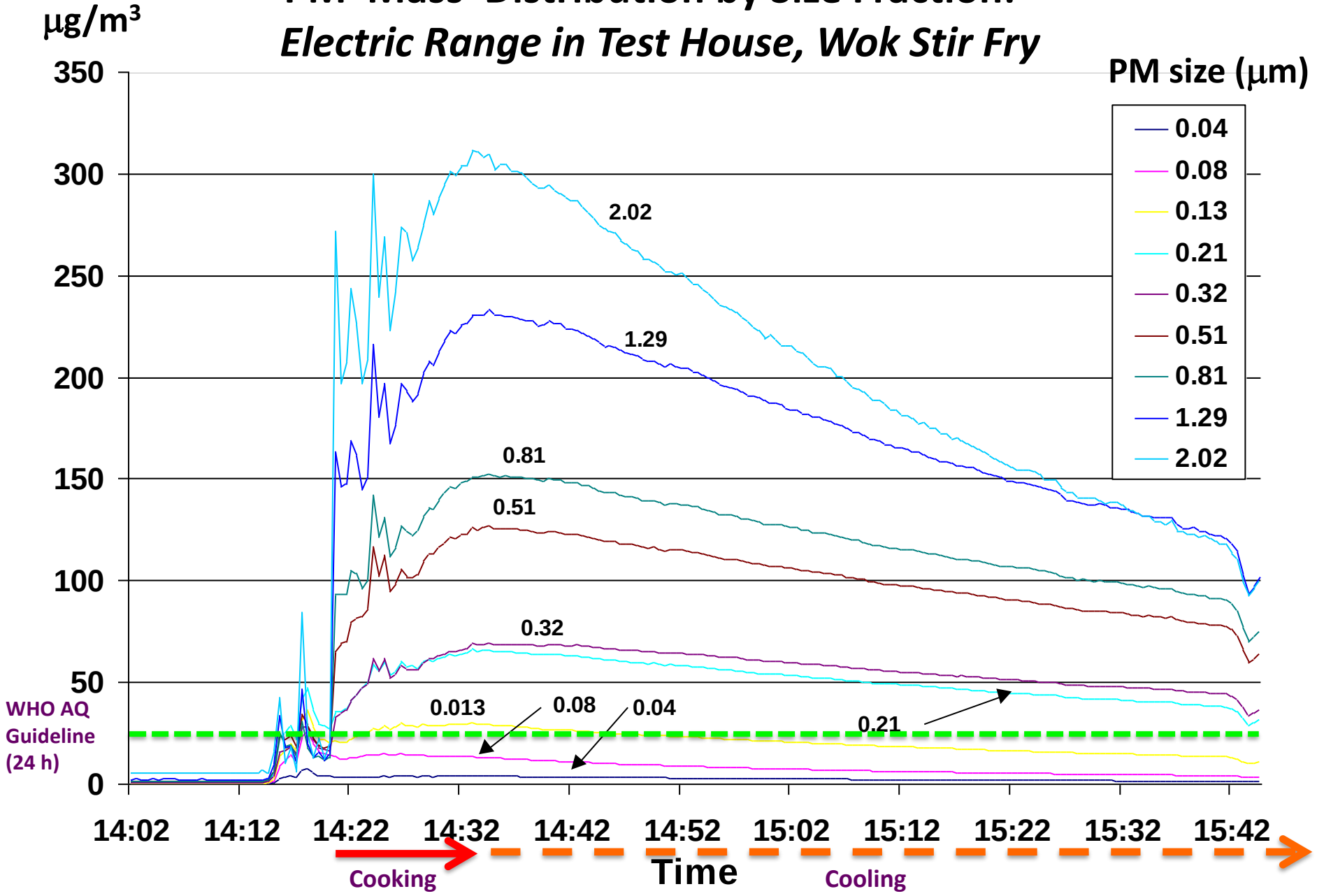
http://angelicapinto.com/tag/diy-disaster/

Best Practices: *Operation & Maintenance*

- Operate at highest fan speed at highest tolerable noise level
- Leave the fan on for at least 10-20 minutes after the cooking
  - Until the cooking surfaces have cooled, or
  - Until odors and smoke have cleared throughout the house

- Clean grease filters at least quarterly
- Oven cleaning cycle
  - Evacuate house
  - Close up kitchen and run hood at maximum speed
  - Clean grease filters afterward

PM Mass Distribution by Size Fraction:
Electric Range in Test House, Wok Stir Fry



Phillips et al., ISEA 2000. From Fortmann et al. 2001, CARB Final Report. Test # 9.
https://ww2.arb.ca.gov/resources/documents/indoor-air-pollution-cooking

Special concerns for low E, air tight homes

- **Use ducted hood, not a recirculating hood**
- **Use makeup air**
- **Consider side shields**
- **Oven venting**

What is good & bad about this design?

Image: Passive House Retrofit, Highland Park, Pittsburgh, PA. http://thoughtfulbalance.com/projects/HighlandParkRetrofit

WHAT ABOUT a *recirculating (ductless)* range hood?

- **Recirculating (ductless) range hoods are not effective [1]**
  - **Moisture is not removed**
  - **Gas filter effectiveness declines quickly**
  - **Particles are not removed**
  - **Expensive filters; occupant often do not replace filters**
- **Building ventilation and air mixing may not be sufficient without exhaust venting**

Image: B. Singer, LBNL.

1. **Jacobs and Cornelissen, Healthy Buildings 2017. Efficiency of recirculation hoods with regard to PM2.5 and NO2. More supporting information on hood performance at the ROCIS Range Hood page.**

Recirculating (Non-ducted) Hoods AKA:

- ***… A recirculating toilet.***
  The stuff just goes round and round and never leaves.
  (John Straube, Bldg. Sci. Corp.)

- ***Forehead Greasers*** **(Brett Singer, LBNL)**

- ***The most screwed-up, badly designed, inappropriately used appliance in your home***
  (Lloyd Alter, Mother Nature Network, TreeHugger)

- ***Another "stupid human trick"*** **(Tom Phillips)**

WHAT ABOUT "Plasma" Recirculating Hoods?

- **Some "plasma" models produce air pollution**
  - **400 ppb ozone in lab test; NO2 levels also high [1]**
  - **Would exceed outdoor air quality standards and CARB emission limits for portable air cleaners**
- **Regeneration of filter may also release toxic pollutants.**
- **Examples:**
  - **Evowall cooker hood, Spain. [2]**
  - **PlasmaMade cooker extractor insert, Netherlands. [3]**
  - **NikolaTesla Elica, Aspiration Hob. Ceramic filter can be regenerated in oven. [4]**

1. Jacobs and Cornelissen, Healthy Buildings 2017. Efficiency of recirculation hoods with regard to PM2.5 and NO2.
2. Evowall. Cooker hoods in a passive house or Passivhaushttps://evowall.com/en/cooker-hoods-passive-house-passivhaus/
3. PlasmaMade. https://www.plasmamade.com/movies/. Video on ionizing air cleaner. https://www.youtube.com/watch?v=vyr8tM9fvAk.
4. NikolaTesla Elica, Aspiration Hob. Hood and hob in one. https://elica.com/PT-en/aspiration-hob.

Best Practices: *Makeup Air System*

- **Automatic mechanical damper (motorized)**
- **Air filter**
- **Check depressurization and flows**

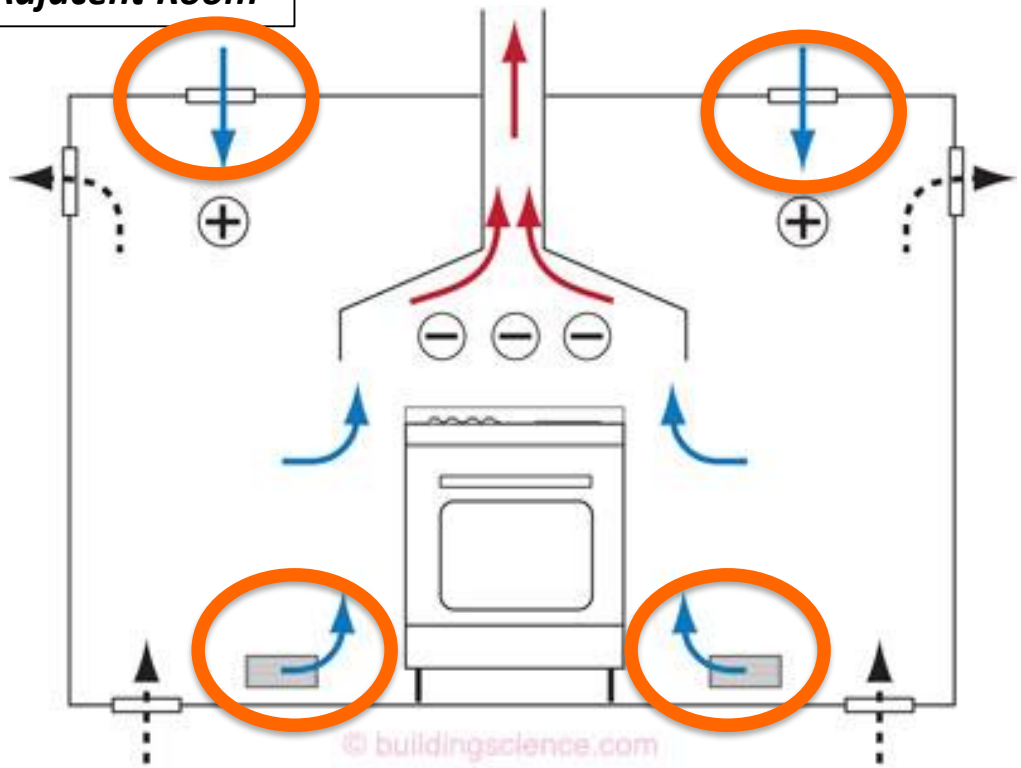
M. Guertin, 5/12/17.
Makeup Air for the Range Hood.
https://www.finehomebuilding.com/2017/05/12/make-air-range-hood.

Make Up Air in Very Airtight Homes

- **Practitioners have installed ducted range hoods with make up air**
  - **N. CA coast, near Passive House tightness: delivered above or below the stove; minimal energy or thermal comfort impact (B. Barry)**
  - **Eastern & Northern US: make up delivery is split between stove area (30%) and common area (70%) to minimize drafts in cold climates (J. Lstiburek)**

Make Up Air: *Examples*

60-70% of Makeup Air from Adjacent Room

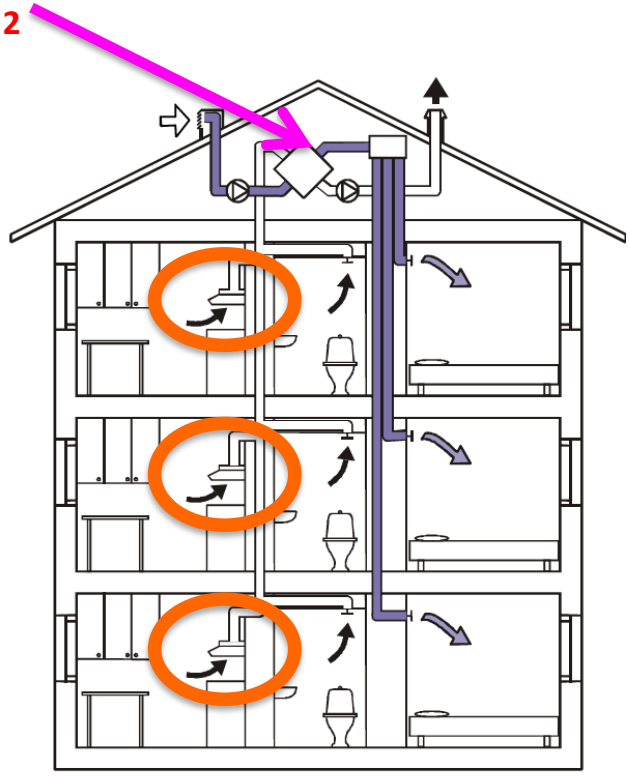


30-40% of Makeup Air Near Stove Base

Lstiburek, 2014. BSI-070:
First Deal with the Manure and Then Don't Suck.
https://buildingscience.com/documents/insights/bsi-070-first-deal-with-the-manure.

Make Up Air in Very Airtight Homes (Part 3)

- **European research and recommendations for low E homes [1]**
  - **A motorless range hood, with a high quality grease filter, connected to a common exhaust system using a balanced ventilation system,**
  - **OR a *ducted* exhaust vent used with a supply ventilation system at specific design pressures, such as an *HRV* with low noise range hood**
  - **≤ 30 dBA noise limit for kitchen & living room [2]**
  - **- 10 Pa depressurization limit [3]**
- **Evolving area – proceed with caution**
  - **Large personal exposure study of cooking and IAQ in progress (TNO, Netherlands) [3]**



https://www.rehva.eu/fileadmin/events/eventspdf/ISH_Frankfurt.../3_Kurnitski.pdf

1. Jacobs and Borsboom, June 2017. Cooking exhaust systems for low energy dwellings. REHVA HVAC Journal.
2. J. Kurnitski, 2018. Personal communication. REHVA and Eurovent Residential Guide. https://eurovent.eu/?q=articles/new-rehva-and-eurovent-residential-ventilation-guidebook-gen-91200. See also: Kurnitski, 2017. Appropriate design of mechanical heat recovery ventilation systems for residential buildings. https://www.rehva.eu/fileadmin/events/eventspdf/ISH_Frankfurt.../3_Kurnitski.pdf
3. P. Jacobs, TNO. Personal communication, 2018.

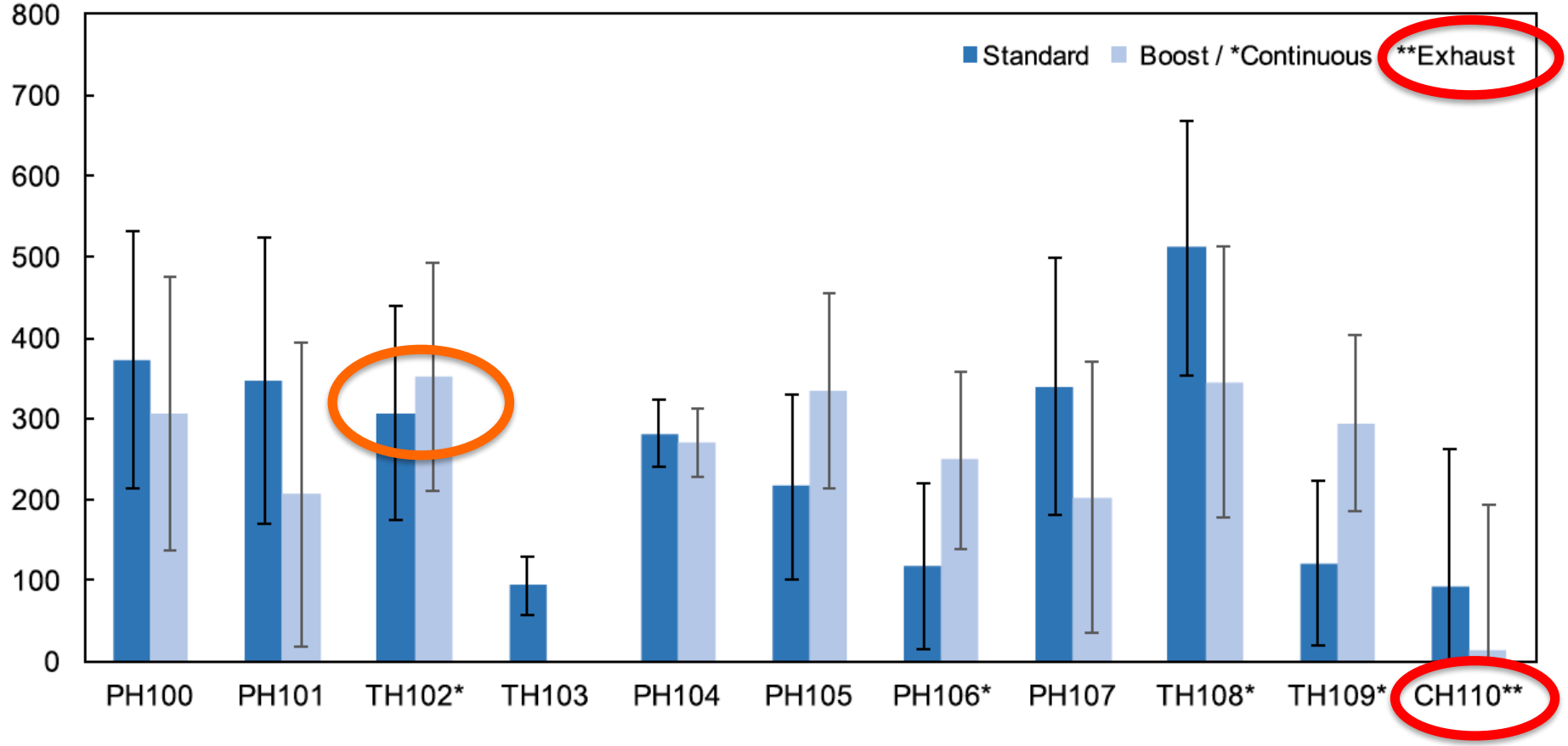
IAQ in Colorado Passive and Airtight Homes: *Methods*

- **9 Passive or Low E Homes and 1 conventional home; Fall-Spring**
- **HRV, ERV, or CRV (+ heat pump) running, with and without boost function**
- **Egg fried 6 minutes on induction hot plate; splatter screen; no occupant activities**
- **PM > 2.5 um (Dylos counts, calibrated) over 20-30 minutes**

Militello-Hourigan &Miller, 2018. https://doi.org/10.1016/j.buildenv.2018.08.044.

IAQ in Colorado Passive Houses: *Results*

PM2.5+, 20-30 min mean (ug/m^3)



- **Cooking event drastically increased PM.**
- **Temporary boost in ventilator did not have significant effect.**
- **Directly-exhausting (ducted) range hood reduced peak PM by 85%.**
- **PM2.5 levels were slow to decay unless exhaust hood was used at high flow.**

Militello-Hourigan and Miller, 2018. https://doi.org/10.1016/j.buildenv.2018.08.044.

Modeling Results: *Ventilator and Hood Modes*

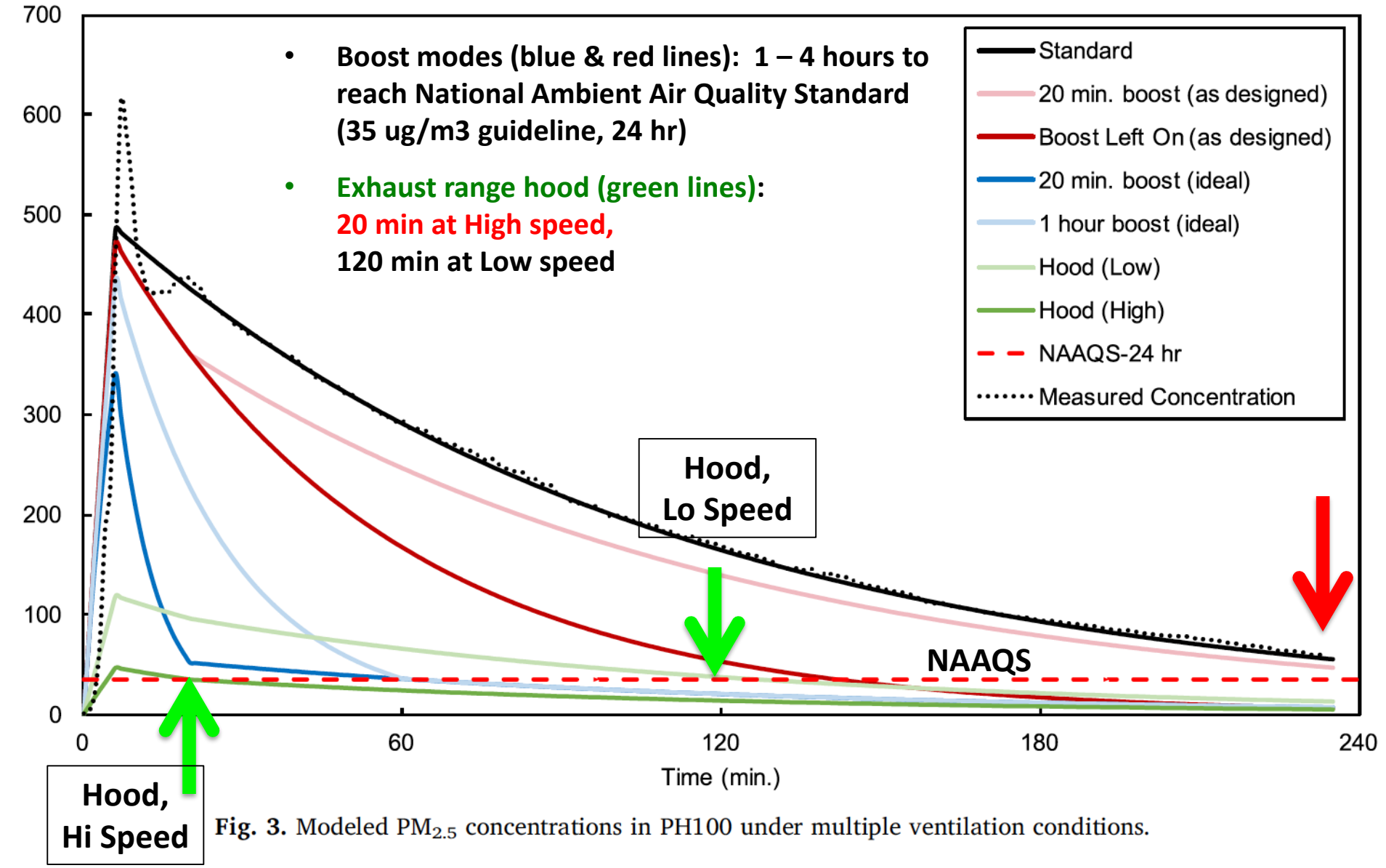


Fig. 3. Modeled $PM_{2.5}$ concentrations in PH100 under multiple ventilation conditions.

Militello-Hourigan and Miller, 2018. https://doi.org/10.1016/j.buildenv.2018.08.044.

Venting a Wall-mounted Oven

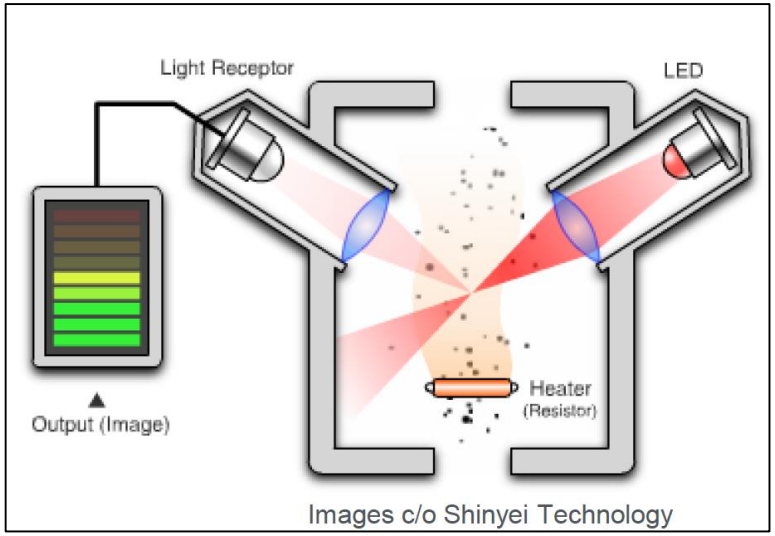
- **Some brands were vented in the past** [1]
- **Suggested solution**
  - **Large exhaust vent under a soffit overhanging the oven**
  - **Ducted exhaust fan, variable speed**
  - **Grease filter**

1. Goedekers Home Life, 2018. Wall Oven Venting: Indoor Vents for Wall Ovens. https://www.goedekers.com/blog/wall-oven-venting/.
   Examples at https://www.houzz.com/discussions/2271087/wall-ovens-and-venting.

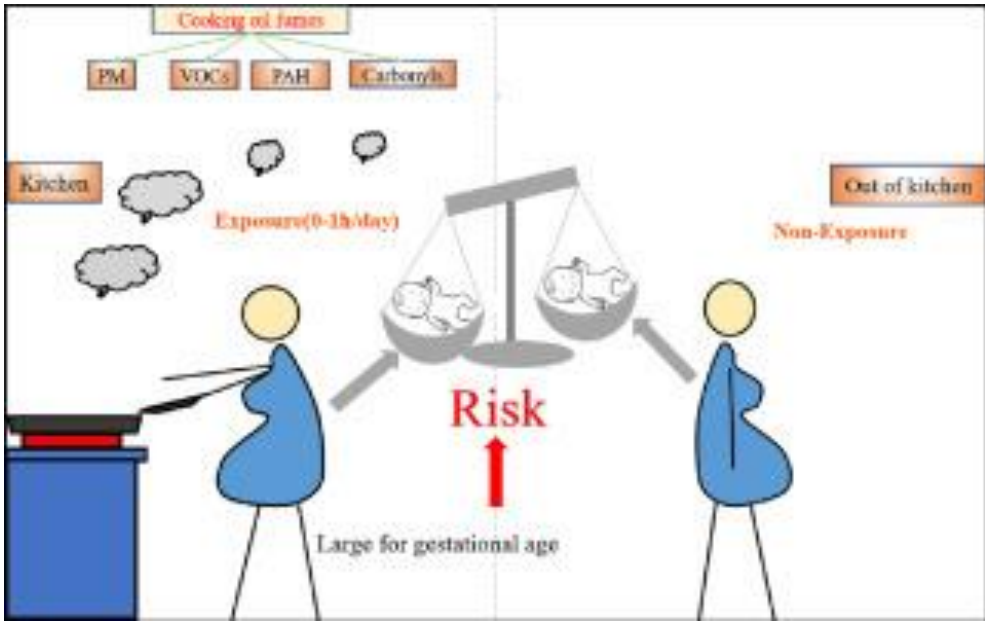
Next Steps

- **Consumer, professional, and trades education & training**
- **Automatic range hood [1]**
- **Health effects of cooking fumes**
  - **Immune response (Vogel, 2010. CARB final report and seminar)**
  - **Developmental effects [2]**
  - **Carcinogens, Mutagens**

Low-cost, accurate sensors for automatic range hood



Increased infant weight in exposed Chinese mothers

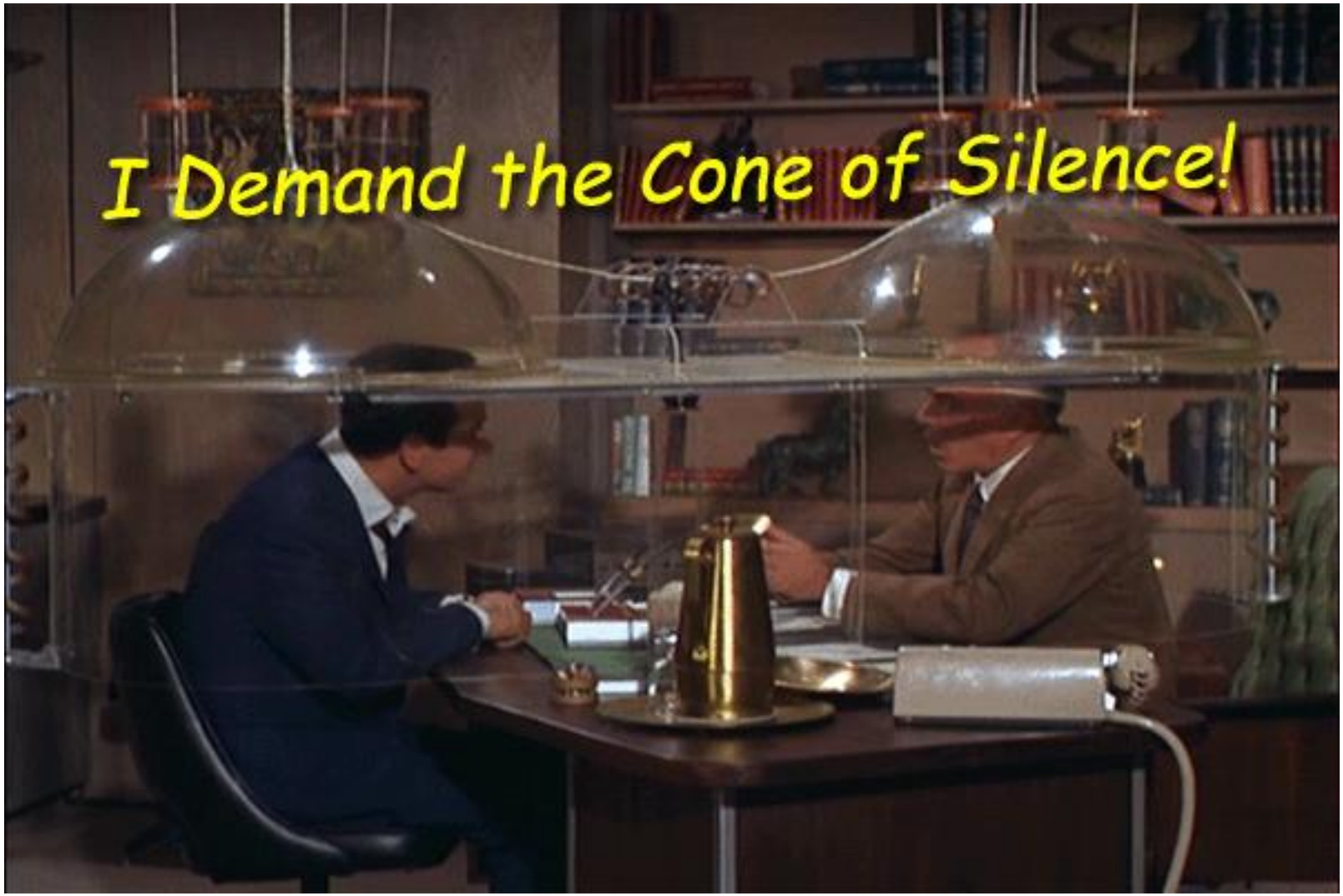


1. Moore, 2017. DOE BTO Peer Review Presentation. Development of the Industry's First Smart Range Hood.

2. Wang et al., 2018. https://www.sciencedirect.com/science/article/pii/S0048969717320296.

CONCLUSION:

PUT A LID ON IT and A GOOD, QUIET HOOD ON IT !



Get Smart TV show, Episode 1.
https://www.youtube.com/watch?v=tu5piMRY1fU
Music theme: https://www.youtube.com/watch?v=c3UQL_Vu0H4

More Information

- **Guidance Posted at rocis.org/kitchen-range-hoods**
  - **Detailed Supplements**
  - **Tools and Resources; References; Presentations**
  - **Living document on the web; will be updated**

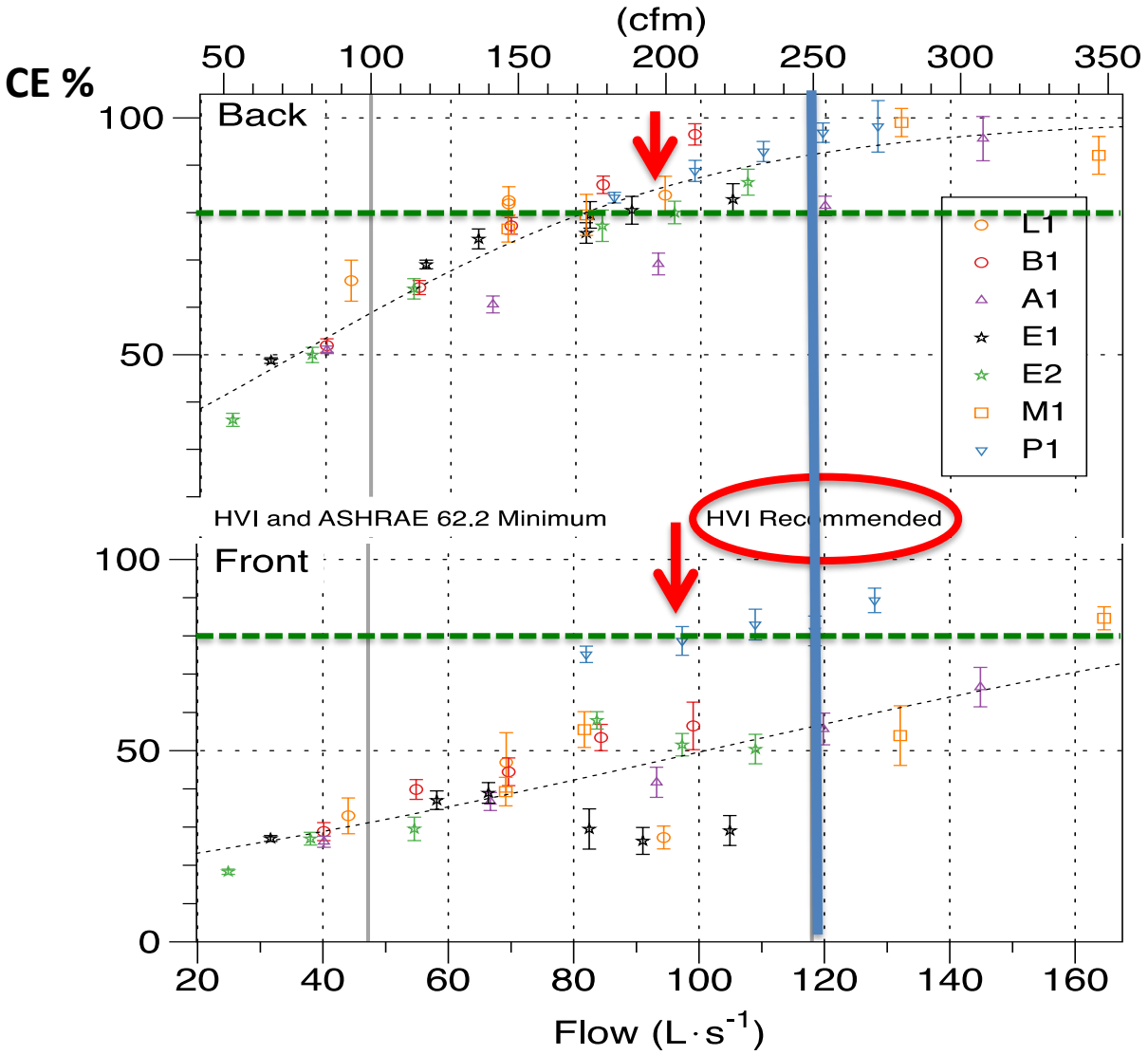
- **User Feedback Needed: send to Linda Wigington lwigington1@outlook.com**

- **Kitchen Ventilation discussion group and resources at Home Energy Pros Forum**

- **Contact Information:**
  Tom Phillips
  Healthy Building Research, Davis, CA
  tjp835@sbcglobal.net

Extra Slides

Capture Efficiency (CE)—Lab Results



Reference Flows:

100 cfm

- 60% back
- 30% oven, front

200 cfm

- ~80% back
- 40-80% oven
- 25-80% front

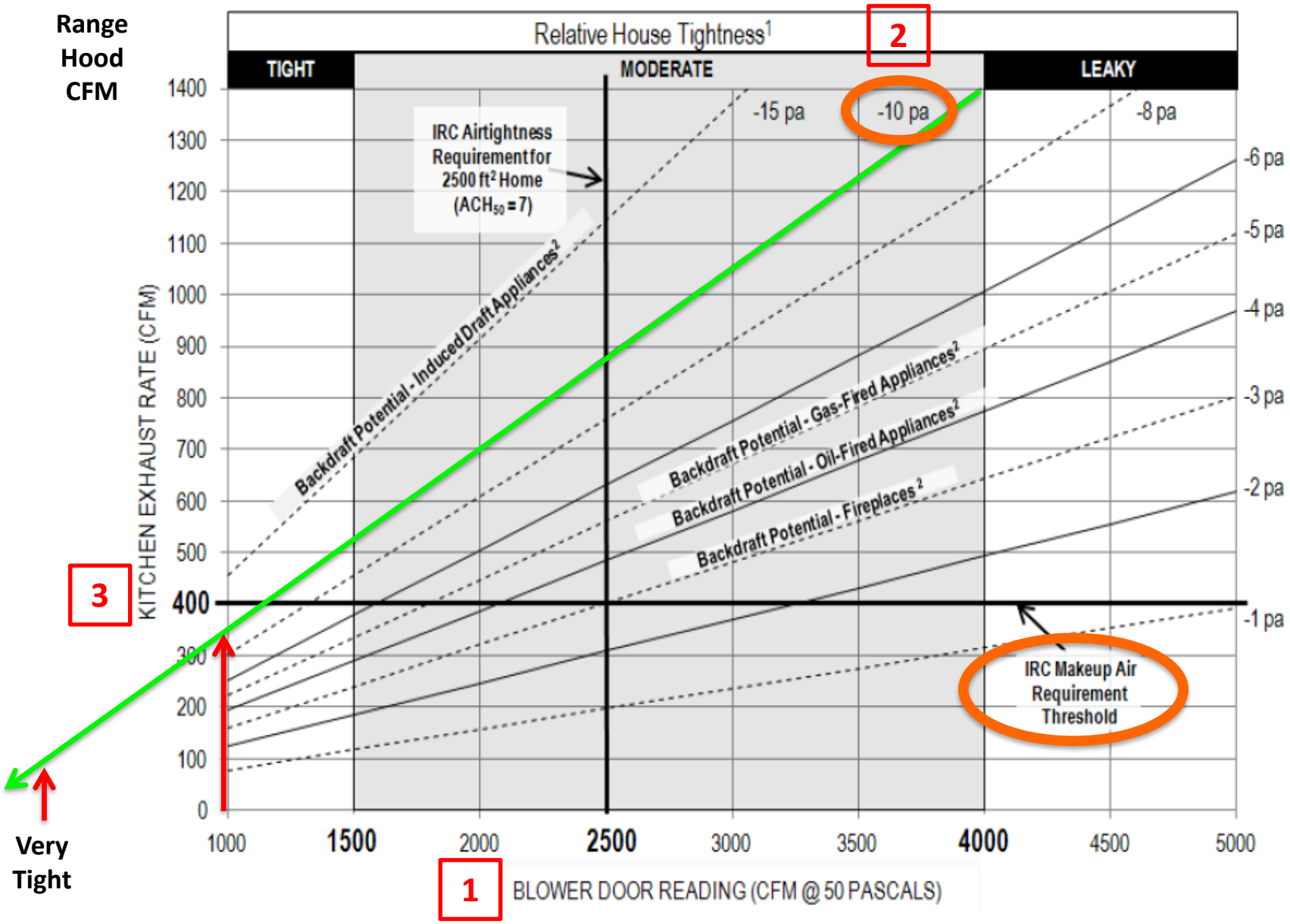
Adapted from Walker and Singer, 2017. IAQ, ventilation and air tightness in high performance new and existing Homes. National Home Performance Conference.

Best Practices: *Determine Exhaust Flow Limits*

1. **Test house airtightness with blower door**
2. **Determine depressurization limit, e.g., - 10 Pa**
3. **Estimate allowable airflow rate for the range hood at that limit**

Image: Energy Conservatory, at https://www.greenbuildingadvisor.com/article/blower-door-basics.

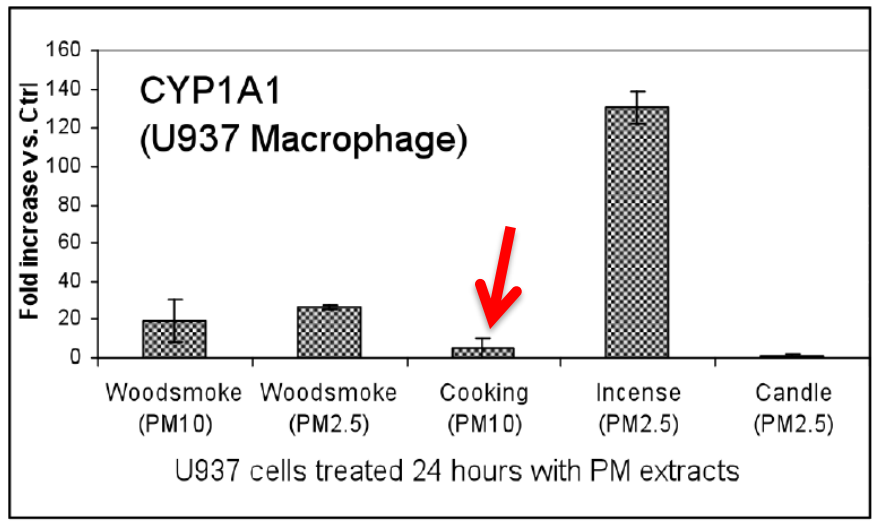
Estimating Allowable Range Hood Flow Rate

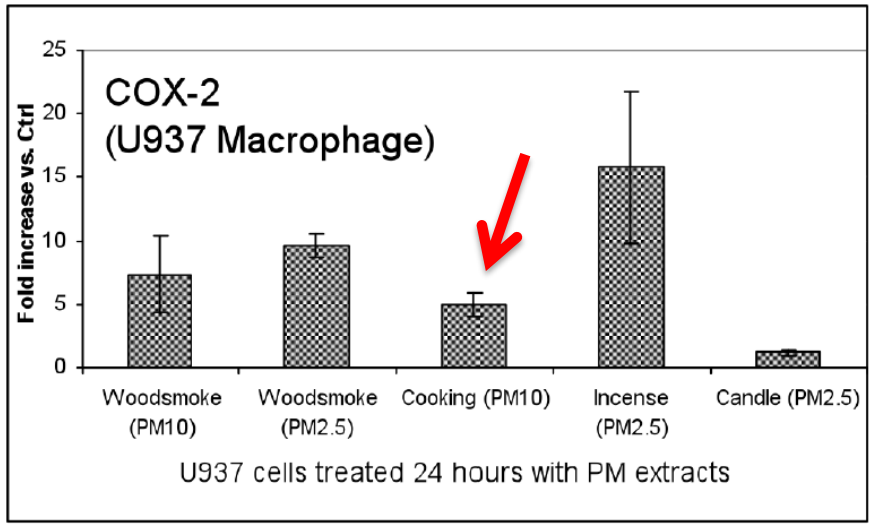


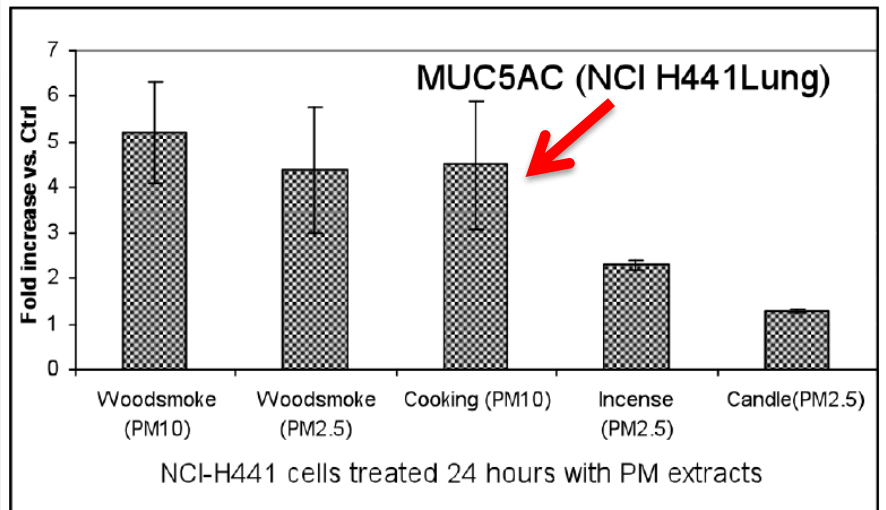
Jellen et al., 2012 (modified). Kitchen Ventilation Systems: Part 2. Providing Adequate Makeup Air. Penn. Housing Research Center, Builder Brief 0312. http://www.phrc.psu.edu/assets/docs/Publications/BB0312.pdf. Adapted from Neal Moyer, Florida Solar Energy Center.

Indoor PM: Animal Immunotoxicity

- Cells tested with air PM samples from various source types
- PM10 from residential cooking had substantial effect on 2 of 3 cell responses (COX-2 inflammation pathway; MUC5AC asthma & COPD pathway)



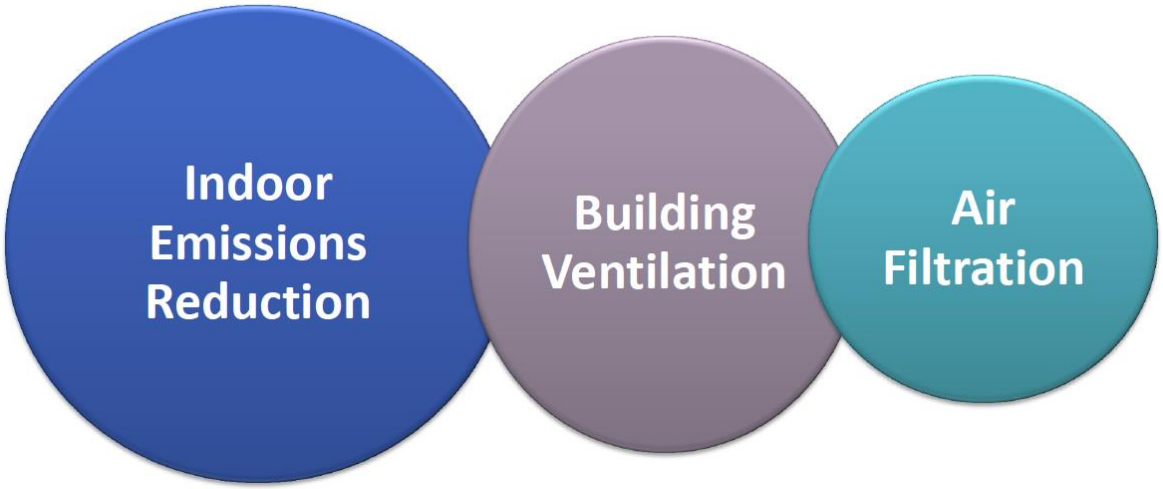




Vogel, 2010 CARB seminar. Cellular Inflammatory Responses to Indoor-Source Particulate Matter. UC Davis. https://www.arb.ca.gov/research/seminars/vogel/vogel.htm.

Effectiveness of Mitigation Strategies: *IEQ Perspective*

- **Emission reduction is the most effective and reliable strategy for reducing indoor air pollution.**
- **Ventilation has much less impact, and it requires energy and maintenance**
- **Air filtration or cleaning can be effective, especially for PM, but it requires energy and maintenance**



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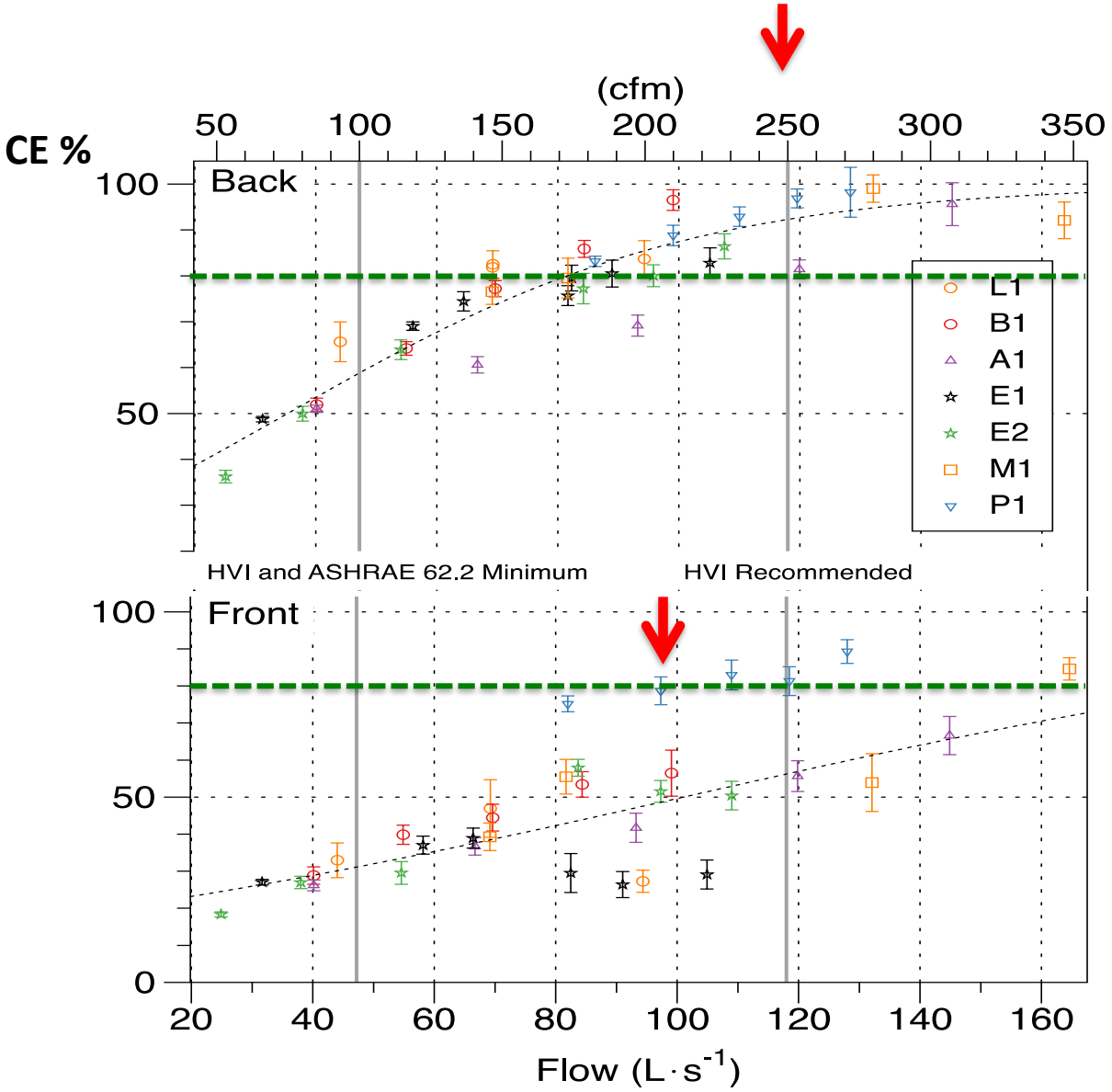

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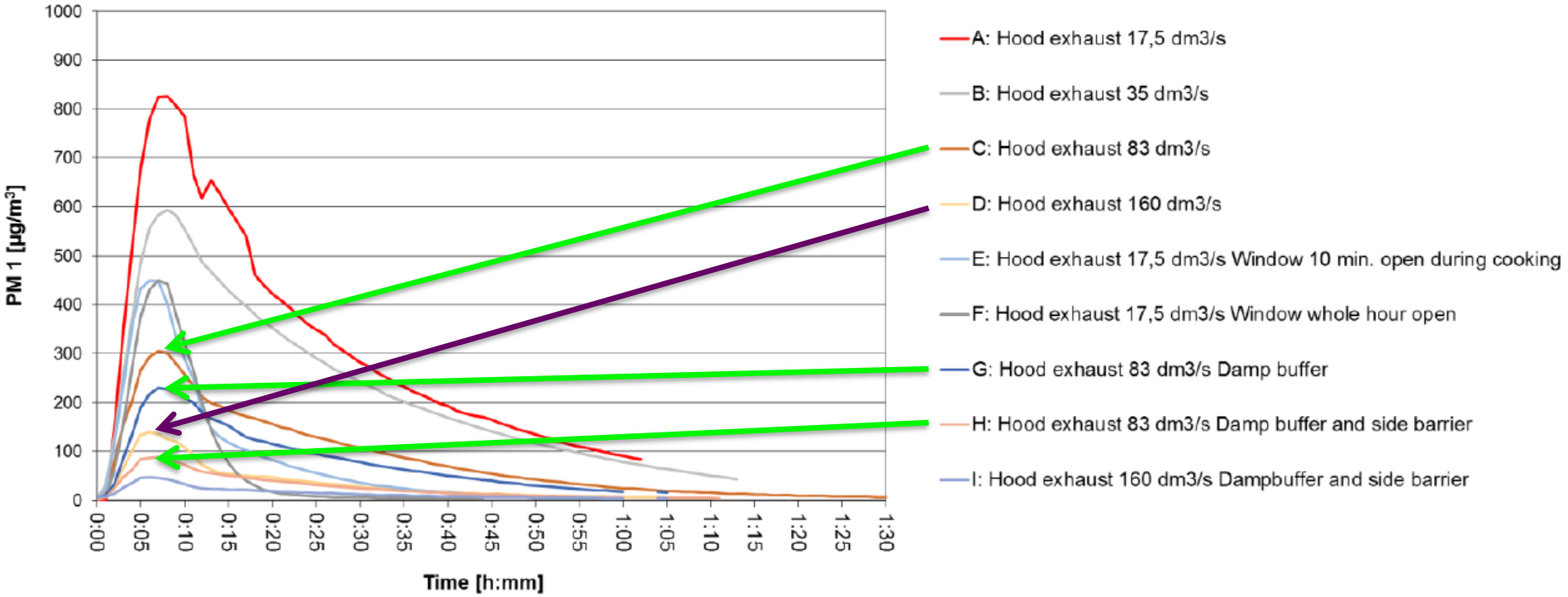
Side Barriers (Shields) and Front Buffers: *Results*



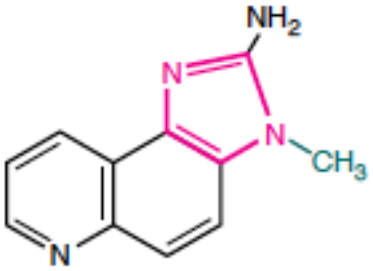
- **PM1 peaks and decay periods: decreased as airflow rates increased, from 17.5 (37 cfm) to 160 dm³/s (339 cfm)**
- **Shields at 83 dm³/s (176 cfm): Damp buffer (front) reduced PM1 and decay periods substantially (by about half)**
- **Adding Side Barriers reduced them by about half again**
- **Combined buffer and shields – PM1 reduced more than 2x vs. doubling of airflow rate to 160 dm³/s**

Jacobs et al., 2016. Energy efficient measures to reduce PM2,5 emissions due to cooking. Indoor Air 2016. Paper 781-2.

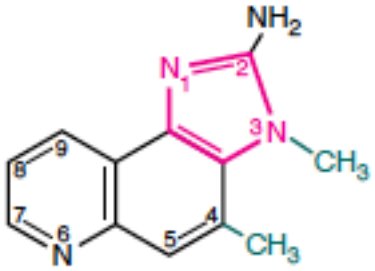
Carcinogens and Mutagens: How to Reduce Emissions and Intake

- Reduce cooking temperatures
- Pre-cook meats in microwave
- Marinate meats
- Avoid charring and burning
- Avoid fried beef

(b) The food mutagen IQ



(c) The food mutagen 4-MeIQ



Student chefs using superheated woks. National Geographic Magazine, Jan. 2018.

Felton, July 1995. Cooking Makes the Difference. S&TR, LLNL.
Image: Felton, Sept. 1995. Food Mutagens. S&TR, LLNL.