Healthy Kitchen Ventilation: Best Practices in Low E Homes

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Reducing Outdoor Contaminants in Indoor Spaces (ROCIS.org)

North American Passive House Network 18
Topics

• **Background:** Who, What, Why, How, 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?
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

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)

More than 10 to 1 difference!
Median: 2/3 Fair; 1/3 Good

V Poor >3000
Poor 1050-3000
Fair 300-1049
Good 150-300
V Good 75-149
Excellent <75

Log Scale

Homes – red bars
Workplaces – blue bars

Modified from 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**

• **Health - 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**

WHY update range hood guidance NOW?

• Growing recognition of indoor pollution from cooking and its health impacts
  – 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

• Homes are getting more airtight: easier to pollute and depressurize

• Remodeling boom: a golden opportunity

• New test method and HVI rating for hood capture efficiency is coming in 2019


WHY is cooking pollution a concern?

• Odors are a common complaint

• Moisture
  – Increased risk of mold bacteria & dust mite growth
  – Total emissions per day, 3 meals: Electric stove: > 2 pints/day  
    Gas stove: ~ 5 pints/day
  – Covering pans helps some

Table 1. Moisture released from cooking sources

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

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, NO₂, aldehydes, CO)
  – Electric stoves: particles, aldehydes
  – Emerging health risks
Formaldehyde and Acetaldehyde in Kitchen

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.

BEST PRACTICES

• Reduce emissions at the source
• Determine hood flow requirements
• Hood with high Capture Efficiency
• Hood with low noise rating
• Good duct design, installation, and commissioning
Best Practices: *Easy Ways to Reduce Exposures*

- Cook on back burners
- Cover pots & lids
- Use electric induction stove
- Pre-cook with microwave
- Cook at lower temperatures
- Keep burners clean
- Close up kitchen area
- Cook outside: BBQ, solar oven

Images: B. Singer, LBNL

Image: Jacobs et al., AIVC Alexandria 2016.

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 \(^1,^2\)

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2. O’Leary et al., AIVC 2015.

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

Modified from Singer & Stratton, 2014. ACEEE Summer Study.
Best Practices: *Low Noise*

• Check [Home Ventilating Institute](http://www.hvi.org) (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*

• 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 2019: CE ratings of hoods by Home Ventilating Institute (HVI)
- 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)

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

Best Practices: *Hood Design*

- Cover the entire cooking surface (B X C)
- Install 24-32” from stove top (A)
- 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.
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)
- Reduce PM1 decay periods 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.

Different Hood Geometries and Flow Rates: Personal Exposure

- Annual average of personal PM exposure (modeled)
- Reduced by higher CE and higher flow rate; potential energy savings
- Approximate 10 X exposure reduction vs. ceiling exhaust and/or lower flow rate

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*

- Clean old duct work or replace
- Double check duct layout
- **Low resistance, sealed ducting through the roof or wall**
- 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**

*Why We Commission (Cx) 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*

Special concerns for low E, air tight homes

- Use ducted hood, not a recirculating hood or E/HRV boost
- Use makeup air
- Consider extensions and/or side taper
- Consider exhaust for oven


What is good or bad about this system design in a Passive House?
WHAT ABOUT a recirculating (ductless) range hood?

• Recirculating (ductless) range hoods are not effective
  – 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

Pet Names for Recirculating (Non-ducted) Hoods

•  
  ... 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” on the list for IEQ and Building Energy Myths
  (Tom Phillips, apologies to Dave Letterman)
WHAT ABOUT “Plasma” Recirculating Hoods?

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

1. Jacobs and Cornelissen, Healthy Buildings 2017. Efficiency of recirculation hoods with regard to PM2.5 and NO2.
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.
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.
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

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

• 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.

• Cooking event drastically increased PM2.5 levels; levels are slow to decay.
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Boost modes (blue & red lines): 1 – 4 hours to reach National Ambient Air Quality Standard (35 ug/m³ guideline, 24 hr)

Exhaust range hood (green lines):
  20 min at High speed,
  120 min at Low speed

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

Venting a Wall-mounted Oven

• Some brands were vented in the past

• Suggested solution
  – Large exhaust vent under a soffit overhanging the oven
  – Ducted exhaust fan, variable speed
  – Grease filter

Next Steps

• Consumer, professional, and trades education & training

• Automatic range hood

• Health effects of cooking fumes
  – Immune response (Vogel, 2010. CARB final report and seminar)
  – Developmental effects
  – Carcinogens, Mutagens

Low-cost, accurate sensors for automatic range hood


Increased infant weight in exposed Chinese mothers
CONCLUSION:
PUT A (Big, Deep, Quiet) LID 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
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.
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

Student chefs using superheated woks.


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.
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.
PM1 results: 

- PM1 peaks (and decay periods): decreased from 800 to 130 ug/m³ as airflow rates increased, from 17.5 dm³/s (37 cfm) to 160 (339 cfm)
- Front Damp buffer reduced PM1 peak and decay periods substantially
- Adding Side Barriers reduced PM1 peak about 2X again
- Combined buffer and shields: PM1 reduced 2-3 X:
  - From 300 to 130 ug/m³ at 83 dm³/s,
  - From 130 to 40 ug/m³ at 160 dm³/s

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

Estimating Allowable Range Hood Flow Rate