Cooking, Health and Decarbonization

Iain Walker
Critical contaminants related to health are emitted by cooking.

DALY = Disability Adjusted Life Year

Increased by cooking
Both food and heat sources generate pollutants

**Gas**
- CO$_2$ & H$_2$O
- Particles, NO$_2$ (and NO), CO, Formaldehyde,

**Electric**
- Ultrafine particles

**Food**
- Particles, Formaldehyde, Acetaldehyde, Acrolein, H$_2$O, Odors
Measurements in homes
Cooking and range hood monitoring

Monitor cooktop and oven use with iButton temperature sensors

Monitor range hood (RH) use with anemometer
IAQ Monitoring

Time-resolved IAQ

- Formaldehyde
- PM$_{2.5}$
- PM$_{2.5}$, CO$_2$, T, RH*
- NO$_2$
- UFP

Time-integrated

- PM$_{2.5}$
- NO$_x$
- Formaldehyde

Concurrent Outdoor Monitoring

* Monitored at two locations: central area, bedroom
Scripted cooking with gas

NO₂ in kitchen exceeds ambient Air Quality threshold value

4 of 9 homes had kitchen NO₂ exceed 100 ppb over 1h

NO₂ >100 ppb in kitchen

Singer et al., 2017, Building Environment
Does NO$_2$ just stay in the kitchen?

No it does not.....

In this example: bedrooms about 20% lower than central location
Apartments & smaller homes more critical

LIA = Low Income Apartments
SFD = Single Family Detached

Low Income:
About twice as much cooking
More cooking for longer = Bigger Health Risk
Apartments are more critical

Apartments more likely to be:
- Low Income
- Disadvantaged communities

Improvements in kitchen venting and switching to electric cooking are helping those that need it most
Kitchen Venting
Capture efficiency (CE):
The fraction of pollutants emitted at the cooktop or in the oven that are removed before mixing into the air of the home.

Standardized test method for rating about to become international = ratings coming soon.

ASM International
Designation: E3087 – 17

Standard Test Method for Measuring Capture Efficiency of Domestic Range Hoods
Lab Testing
Field Testing
Capture Efficiency

Two front burners

Current minimum in US stds = 100 cfm

Two back burners

OTR = Microwave with Exhaust
Some Impractical Solutions
Laboratory Testing for Contaminants
Gas Range in a unit of FlexLab at LBNL

Hood exhaust balanced with MERV13 filtered supply
Reference Instruments

- GRIMM Particle Spectrometer - PM, PN, distributions
- MetOne - PM
- API Gas analyzer - NO, NO2, NOx
- RAE VOC analyzer - tVOC
- Miran IR gas analyzer - R124 tracer for ventilation rate

Consumer Instruments

- eLichens - PM, CO2, tVOC, NO2, T, RH
- LaserEgg2 - PM, T, RH
- PurpleAir - PM, T, RH

Measurements are near the center of the room away from the cooking

Mixing fans
### Breakfast Cooking Details - PARALLEL

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Activity</th>
<th>Gas (lpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Start front left burner on medium (2 lpm) for hash browns</td>
<td>-&gt;</td>
</tr>
<tr>
<td>0:15</td>
<td>Start front right burner on medium (+2 lpm; Total 4 lpm) - bacon in pan (cook 12 min); remain to watch oil</td>
<td>-&gt;4.04</td>
</tr>
<tr>
<td>1.5</td>
<td>Add 2 hash browns to small skillet (cook 9 min); remain</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Flip bacon and adjust in pan; remain</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>Press hash browns 5s each; remain</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Flip bacon and adjust in pan; remain</td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>Flip hash browns; press 5s each; remain</td>
<td>3.99</td>
</tr>
<tr>
<td>6</td>
<td>Flip bacon and adjust in pan; remain</td>
<td>3.97</td>
</tr>
<tr>
<td>7</td>
<td>Flip bacon and adjust in pan; remain</td>
<td>3.96</td>
</tr>
<tr>
<td>8-12</td>
<td>Flip bacon every 30s</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Return; flip hash browns; press</td>
<td>3.94</td>
</tr>
<tr>
<td>10:30</td>
<td>Stop front left burner; remove hash browns to plate with paper towel; place skillet on back left burner.</td>
<td>-&gt;2.02</td>
</tr>
<tr>
<td>12</td>
<td>Stop front right burner; remove bacon to plate; move pan to rear burner; leave uncovered</td>
<td>0</td>
</tr>
<tr>
<td>12.5</td>
<td>Place non-stick pan with butter on front left burner, start and adjust to medium (2 lpm)</td>
<td>-&gt;2.04</td>
</tr>
<tr>
<td>14</td>
<td>Add eggs to non-stick pan (cook 4 min); remain</td>
<td>2.05</td>
</tr>
<tr>
<td>17</td>
<td>Flip eggs</td>
<td>2.05</td>
</tr>
<tr>
<td>18</td>
<td>Stop front left burner; remove eggs to plate; place pan on front right burner</td>
<td>-&gt;0</td>
</tr>
<tr>
<td>48</td>
<td>Remove skillets and fry pan from cooktop</td>
<td></td>
</tr>
</tbody>
</table>
Breakfast

Some variability even with scripted cooking

More variability in particle emissions

NO₂ 1 hour
100 ppb threshold

PM₂.₅ 24 hour
25 ug/m³ threshold
Off
Auto

PM2.5 ($\mu$g·m$^{-3}$)

0
100
200

PN (#·cm$^{-3}$)

0
20,000
40,000

NOx (ppb)

0
50
100
150
200

0:00 0:15 0:30 0:45 1:00 1:15 1:30

Breakfast - Induction

Induction = no NOx

NO$_2$ 1 hour
100 ppb threshold

PM2.5 24 hour
25 ug/m$^3$ threshold
What next?
Different code requirements: proposed CA T24

- Key health contaminants are PM2.5 (gas and electric cooking) and NO₂ (only from gas)
- To meet health guidelines more/better kitchen ventilation is required for NO₂, i.e., gas cooking

<table>
<thead>
<tr>
<th>Cooking Fuel</th>
<th>Floor Area (ft²)</th>
<th>Capture Efficiency</th>
<th>Airflow as installed (cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;1500 ft²</td>
<td>0.50</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>1000 - 1500 ft²</td>
<td>0.50</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>750 - 1000 ft²</td>
<td>0.55</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>&lt;750 ft²</td>
<td>0.65</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td><strong>Gas</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;1500 ft²</td>
<td>0.70</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>1000 - 1500 ft²</td>
<td>0.80</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>750 - 1000 ft²</td>
<td>0.85</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>&lt;750 ft²</td>
<td>0.85</td>
<td>280</td>
<td></td>
</tr>
</tbody>
</table>
New studies

• Health studies, e.g., California Energy Commission & Asthmatic Children intervention study
• More focus on ultrafine particles
• Specifically investigate induction c/w electric resistance
• Is non-stick better?
• Work internationally – much more induction cooking in other countries
• Assessing safety advantages
• Assessing energy use: preliminary studies for commercial cooking show savings from efficiency (heat the pot not the cooktop/element/room) and shorter heat up time
Thanks to my colleagues:
Brett Singer
Woody Delp
Haoran Zhao
Brennan Less
and to USDOE and California Energy Commission for funding
Question/Comments?


# Scripted Pasta Meal

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Activity</th>
<th>Gas (lpn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><strong>Start front right burner on high (6 lpm)</strong> for pasta. Pasta lid is on; walk away</td>
<td>6.03</td>
</tr>
<tr>
<td>1:30</td>
<td>Return; <strong>start front left burner; adjust to medium (+2 lpm, 8 lpm total)</strong>; remain</td>
<td>8.06</td>
</tr>
<tr>
<td>3</td>
<td>Spread oil with wood spoon; <strong>add onions (cook 6 min)</strong>; stir 15s; walk away</td>
<td>7.99</td>
</tr>
<tr>
<td>5</td>
<td>Return; stir onions 5s; Walk away</td>
<td>7.87</td>
</tr>
<tr>
<td>6</td>
<td><strong>Adjust flow of FRONT LEFT burner to 8 lpm total</strong>; stay as far as possible from range hood</td>
<td>7.9</td>
</tr>
<tr>
<td>7</td>
<td>Return; stir onions 5s; remain</td>
<td>7.91</td>
</tr>
<tr>
<td>8</td>
<td>Stir onions 5s; remain</td>
<td>7.87</td>
</tr>
<tr>
<td>9</td>
<td><strong>Add beef (cook 8 min)</strong>; stir and break chunks for 30s</td>
<td></td>
</tr>
<tr>
<td>9:30</td>
<td>Walk away</td>
<td>7.81</td>
</tr>
<tr>
<td>11:30</td>
<td>Walk away</td>
<td>7.75</td>
</tr>
<tr>
<td>14</td>
<td>Return; stir beef for 15s; lift pot lid to check water, replace lid; remain</td>
<td>7.70</td>
</tr>
<tr>
<td>15</td>
<td>Stir beef 15s; remain</td>
<td>7.68</td>
</tr>
<tr>
<td>16</td>
<td>Remove pot lid to confirm rolling boil; <strong>add pasta (cook 13 min)</strong>; stir 5s; remain</td>
<td>7.66</td>
</tr>
<tr>
<td>17</td>
<td><strong>Add jar of sauce to saute pan</strong>; stir 15s; place lid on saute; remain</td>
<td>7.65</td>
</tr>
<tr>
<td>18</td>
<td>Stir pasta 5s; adjust <strong>front right burner to medium (+2.5 lpm, 4.5 lpm total)</strong>; remain</td>
<td>4.46</td>
</tr>
<tr>
<td>19</td>
<td>Stir sauce; <strong>Adjust front left burner to medium-low (+1.0 lpm, 3.5 lpm total)</strong>; place lid on saute</td>
<td>3.46</td>
</tr>
<tr>
<td>19:30</td>
<td>Walk away</td>
<td>3.5</td>
</tr>
<tr>
<td>21</td>
<td>Return; stir pasta 5s; stir sauce 5s and replace lid; walk away</td>
<td>3.49</td>
</tr>
<tr>
<td>24</td>
<td>Return; stir pasta 5s; stir sauce 5s and replace lid; walk away</td>
<td>3.46</td>
</tr>
<tr>
<td>27</td>
<td>Return; remove one piece of pasta from pot, dip in water and taste; remain</td>
<td>3.46</td>
</tr>
<tr>
<td>29</td>
<td>Taste another piece of pasta; <strong>turn off front right burner</strong>; <strong>drain pasta</strong>; put pasta back into pot and place on stove</td>
<td>1.52</td>
</tr>
<tr>
<td>30</td>
<td><strong>Turn off front left burner</strong> (sauce); pour meat sauce into pasta pot or another bowl on cooktop; cover saute pan; remove pasta and meat sauce; leave pots on back burners.</td>
<td>1.52</td>
</tr>
<tr>
<td>60</td>
<td>Remove pots from chamber</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td><strong>Start venting chamber</strong></td>
<td></td>
</tr>
</tbody>
</table>
Scripted Oven Meal (Orange Chicken)

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Activity</th>
<th>Gas (lpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Preheat oven to 400 dF for 10 minutes (start timer when gas valve opens)</td>
<td>9.05</td>
</tr>
<tr>
<td>10:00</td>
<td>Place chicken nuggets on cookie sheet and insert in oven</td>
<td>8.55</td>
</tr>
<tr>
<td>29:00</td>
<td>Turn oven off. Remove cookie sheet from oven, place cookie sheet on cooktop, transfer nuggets to a pot, cover, and move to separate table</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Start purge</td>
<td></td>
</tr>
</tbody>
</table>
Some variability even with scripted cooking

More variability in particle emissions

PM2.5 (μg·m⁻³)

NOx (ppb)

PN (#·cm⁻³)

PM2.5 24 hour
100 ppb threshold

25 ug/m³ threshold

Pasta

Some variability even with scripted cooking

More variability in particle emissions
PM2.5 (μg·m⁻³)

0 100 200

PN (#·cm⁻³)

0 1×10⁵ 2×10⁵

NOx (ppb)

0 200 400

0:00 0:15 0:30 0:45 1:00 1:15 1:30

Orange Chicken

PM2.5 24 hour
25 ug/m³ threshold

NO₂ 1 hour
100 ppb threshold

Off

Auto

PM2.5 24 hour
25 ug/m³ threshold