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Kitchen Ventilation for IAQ and Zero Energy in Residential Applications

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GTI ENERGY
solutions that transform

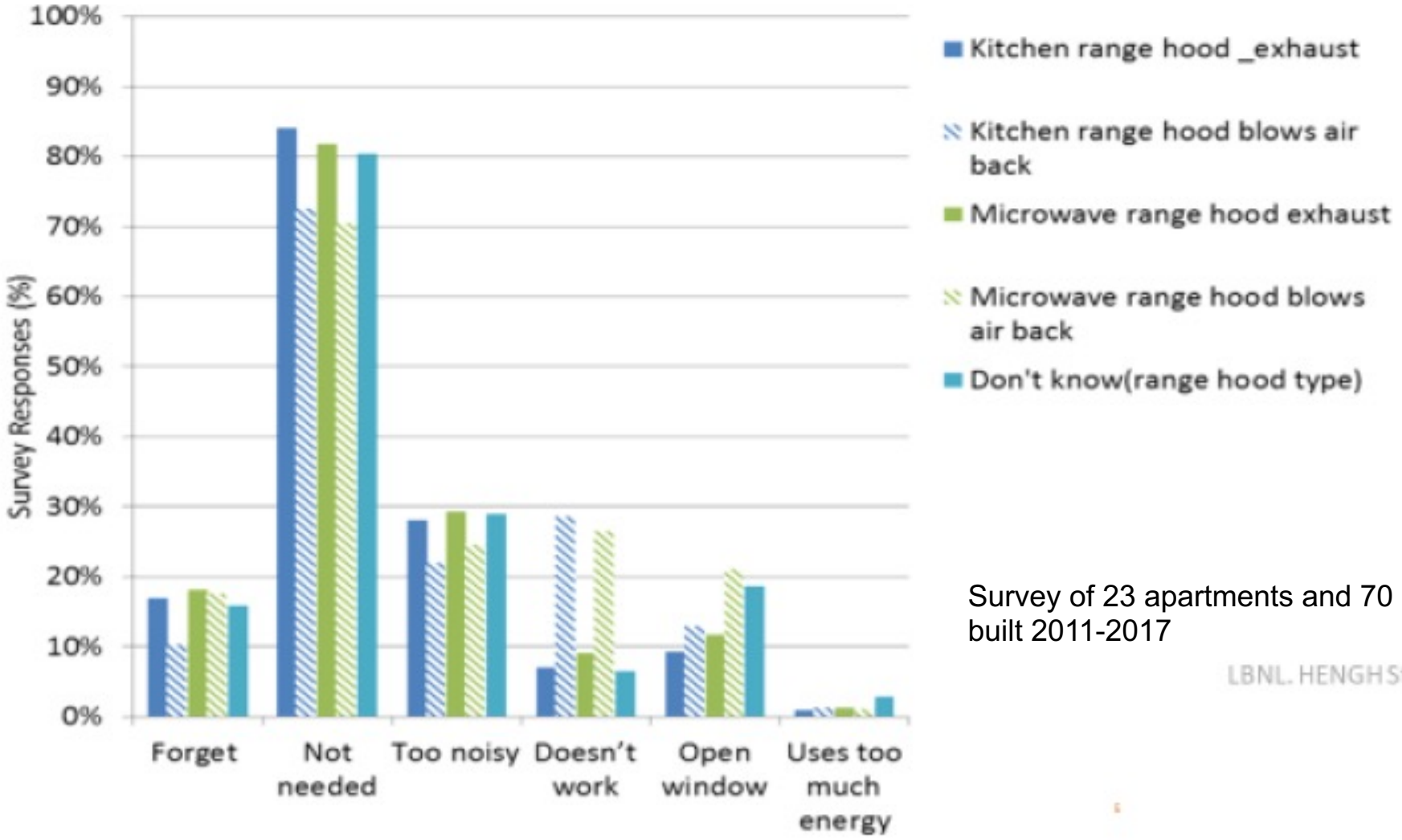
CERV®
SMART VENTILATION

October 27, 2022

Agenda

- IAQ Background in Kitchens
- IAQ/Demand Control in Commercial Kitchens
- IAQ in Residential Kitchens
  - Tierra Linda Project
- Smart Kitchen Exhaust

Why don’t people use kitchen ventilation?



Survey of 23 apartments and 70 detached homes built 2011-2017

LBNL. HENGH Study. Appendix A

More than 3 Billion CFM…

…exhausted from Commercial Kitchens in the U.S.

The Potential…

Estimated installed base of 20,000 DCV systems as this technology has slowly emerged over the last 30 years.

There are 1,000,000 Commercial Foodservice Establishments in the U.S. with CKV systems.

This represents a market penetration of only 2%.

The potential for DCKV is huge!

Design Approach:

- Reduced exhaust and makeup air (from 34,000 cfm to 12,000 cfm)
- Side panels and glass back wall for single island canopy
- Filter blanks in sections not over appliances
- Air-to-air heat recovery to preheat makeup
- Two-speed system (3000 ft/min duct velocity on high speed).

Demand Controlled Kitchen Ventilation (DCKV) Strategies

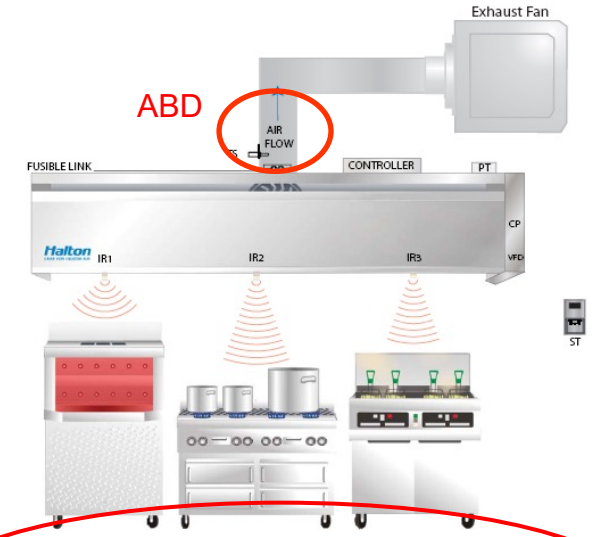
- controlled on a time-of-day basis
- controlled by exhaust temperature
- controlled by sensing smoke or steam produced by cooking process
- controlled by measuring cooking surface temperature or activity
- controlled by direct feedback from cooking equipment
- proportional to **appliance energy use**
- controlled by combinations of the above

Appliance Control

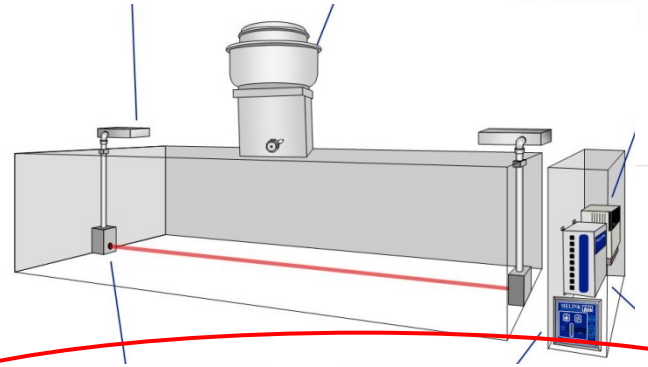
No Load - Low Speed!

2-Speed Fan Interlocked with 2-Sided Griddle

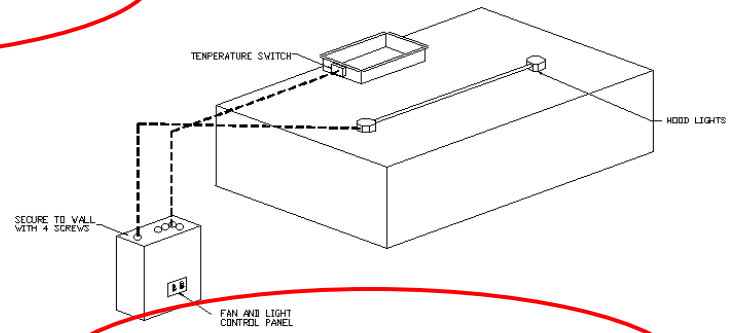
Demand Ventilation Control Technologies



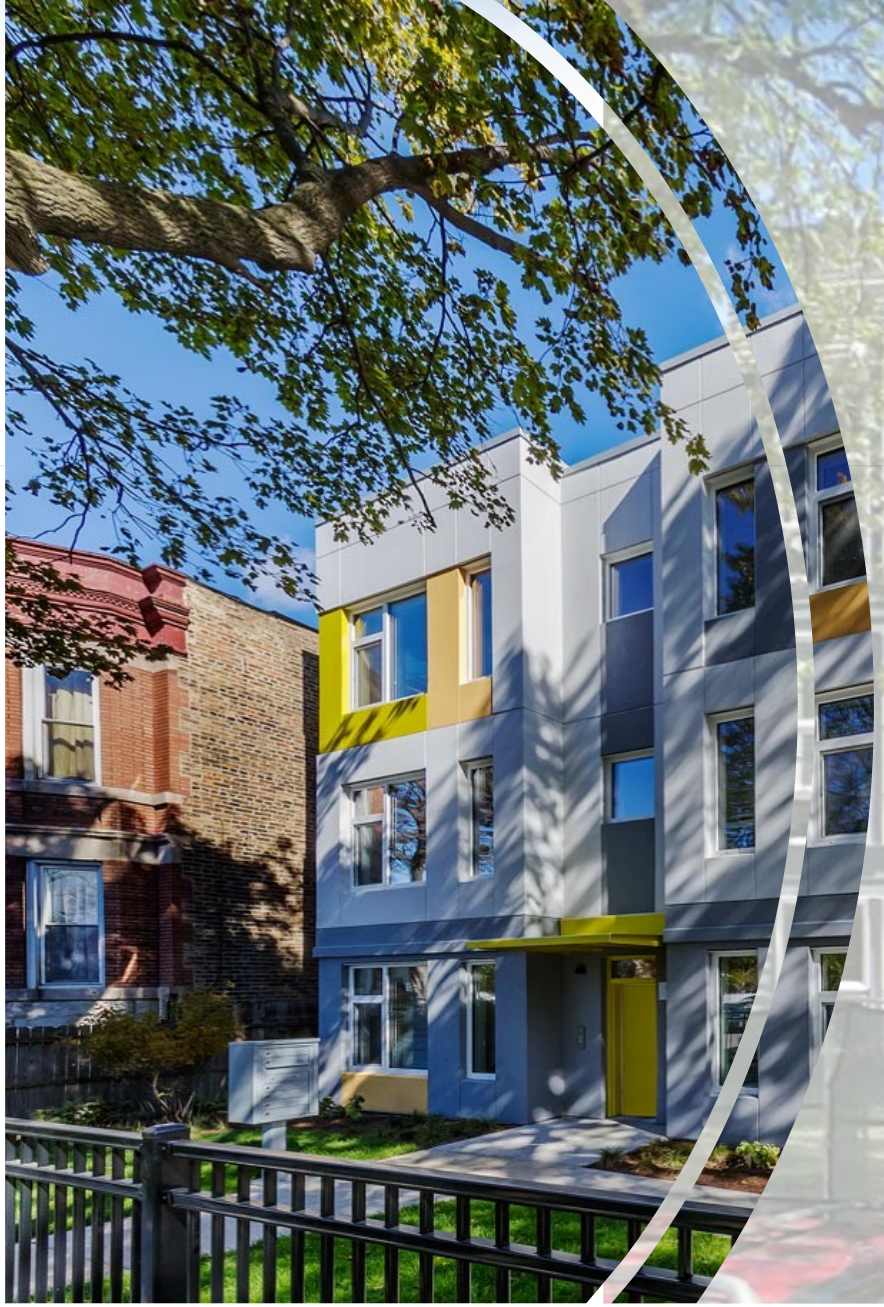
Duct Temperature Sensor & Infrared Sensors



Duct Temperature Sensor & Smoke Detection



Duct Temperature Sensor



Tierra Linda Project
Kitchen IAQ Study

GTI, LUCHA and Slipstream

Project Objectives and Goals

Objective:

- The objective of this project is to determine the effect of cooking emissions on residential Indoor Air Quality

Scope:

- Generate data to differentiate emissions from cooking processes versus emissions from appliance (gas and electric)
- Compare cooking emissions field data from multi family units
- Compare IAQ between direct vent range hoods versus recirculating hoods (with energy recovery device)

The Opportunity
Chicago, IL

Two new, 6-unit properties from affordable housing developer LUCHA

Same layout, same orientation, same location (2.5 blocks apart) built 2017-18

Constructed to two different standards

ENERGY STAR for New Construction (v3.1)

PHIUS 2015

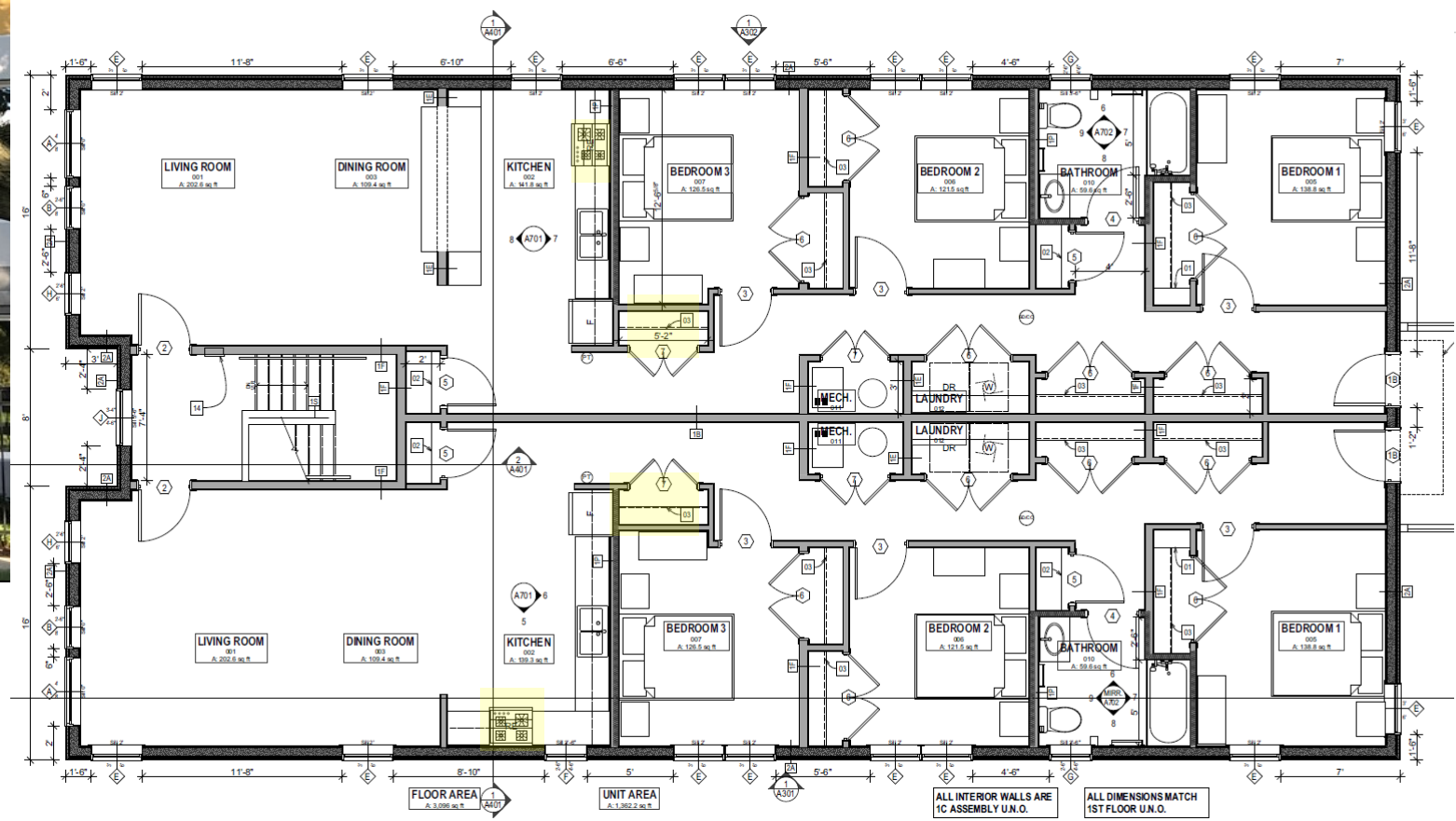
How do they compare?

Energy performance

Construction / operating costs

Indoor air quality (IAQ)

Tierra Linda Layout



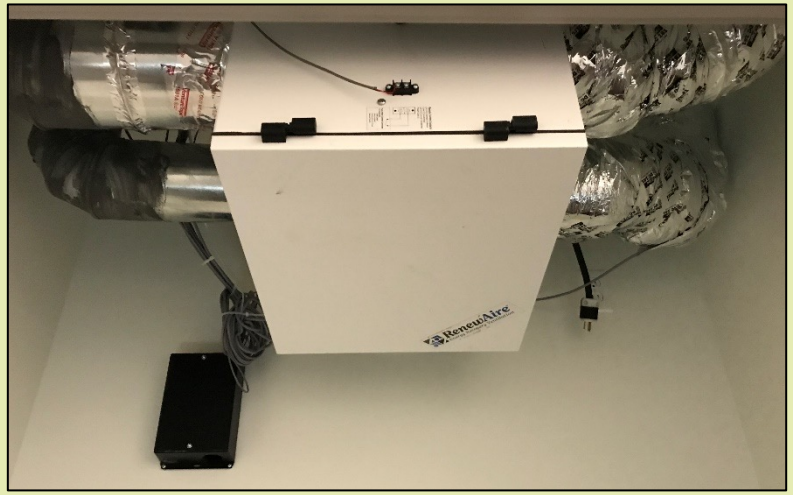
Comparison of Building Features

Feature	ENERGY STAR property	PHIUS+ property
Measured air leakage (ACH50)	1.90	0.52
Ceiling insulation	R-50	R-60
Wall insulation	R-14.5 assembly	R-29.4 assembly
Windows	Triple-pane U-value: 0.26 – 0.29 SHGC: 0.28 – 0.33	Triple-pane U-value: 0.15 – 0.17 SHGC: 0.31 – 0.37
Heating	High efficiency gas furnace G	Variable-speed ducted heat pump E
Cooling	SEER 16 central A/C	
Ventilation	Continuous bath exhaust (~40 cfm)	Energy recovery ventilator (~100 cfm)
Domestic hot water	Power-vented, 40-gal. gas water heater G	
Cooking	Gas range w/ vented exhaust G	Gas range w/ unvented exhaust (but ERV exhaust pickup in kitchen) G
Laundry	Vented dryer w/ booster fan G	Unvented compact dryer E
	$178 / ft^2 construction	$214 / ft^2 construction

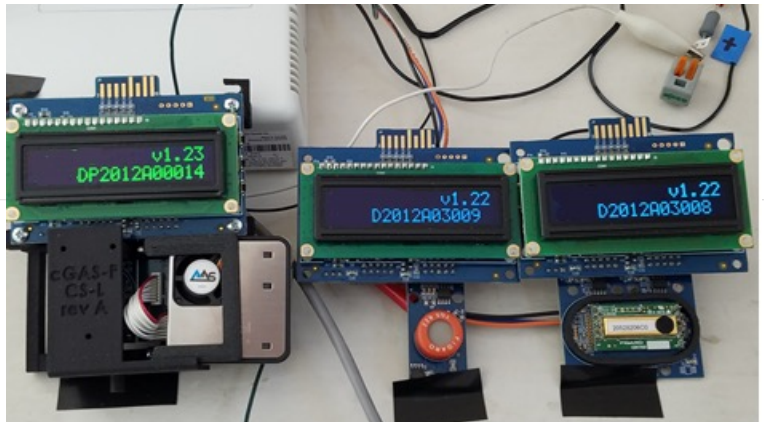
Two Approaches to Kitchen Ventilation

Baseline Ventilation:
ENERGY STAR Building
Ducted exhaust to outside

Passive House Ventilation:
Recirculating hood
Exhaust air intake in kitchen near hallway through ERV



IAQ Sensor Enclosure

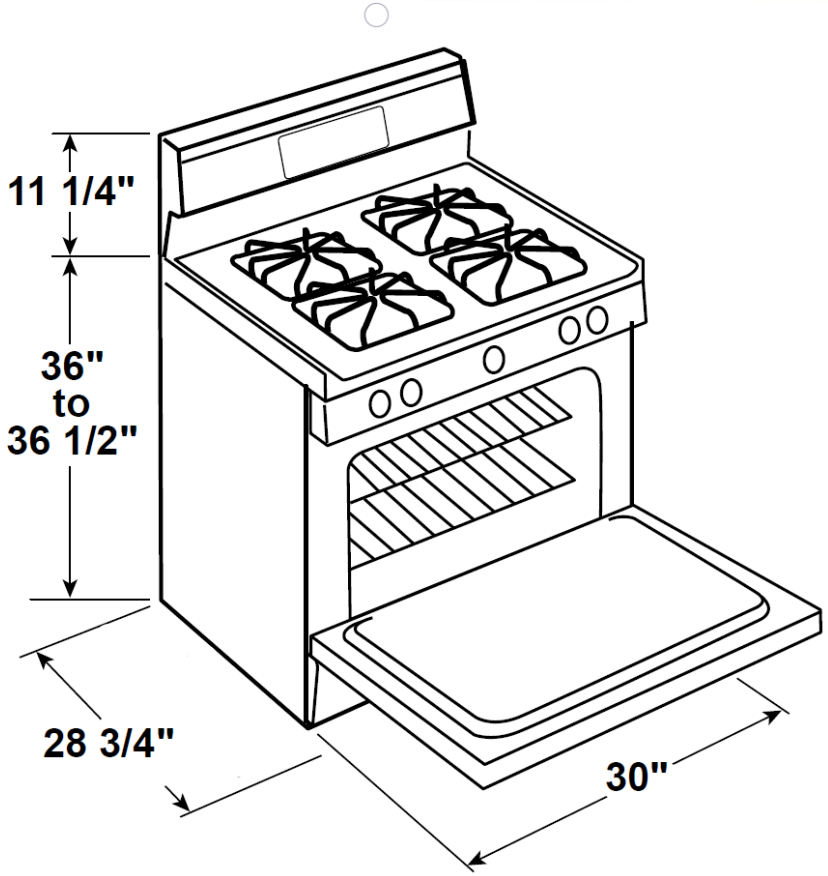


Sensor	Range	Accuracy
NO2	0-1 ppm	0-0.2 ppm +/- 0.02 ppm; 0.2-1 ppm +/- 10%
CO2	0-5000 ppm	± 50 ppm + 3% of reading
CO	0-200 ppm	< 0.5 ppm
PM	2.5 ug/m3	< 100 µg/m3 ±15 µg/m3 >100 µg/m3 ±15%
TVOC	0-5000 ppm	+/- 10% of range
Formalde-hyde	0-5ppm	+/- 5% of range
RH	15-90%	+/- 2%
TEMP	32-122°F	+/- 0.5 °C

Field Installations

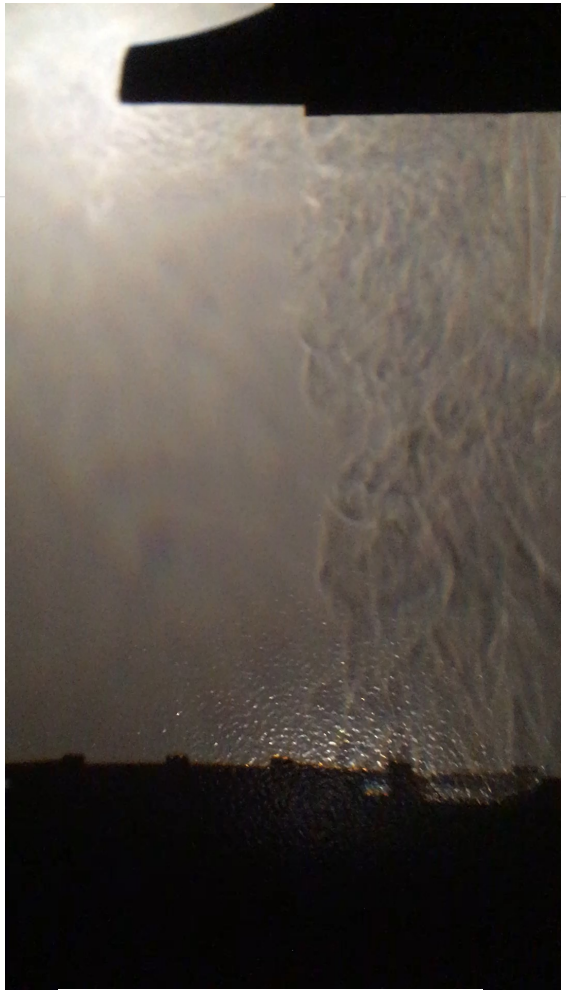
- Installation of sensor enclosures:
  - CO2, NO2, CO, RH, TEMP; VOC, PM2.5 and Formaldehyde
- Analyzing 1-minute data
  - IAQ / Power
- Controlled-cooking events
  - Boiling
  - Baking
  - Frying

Hood Design and Setback

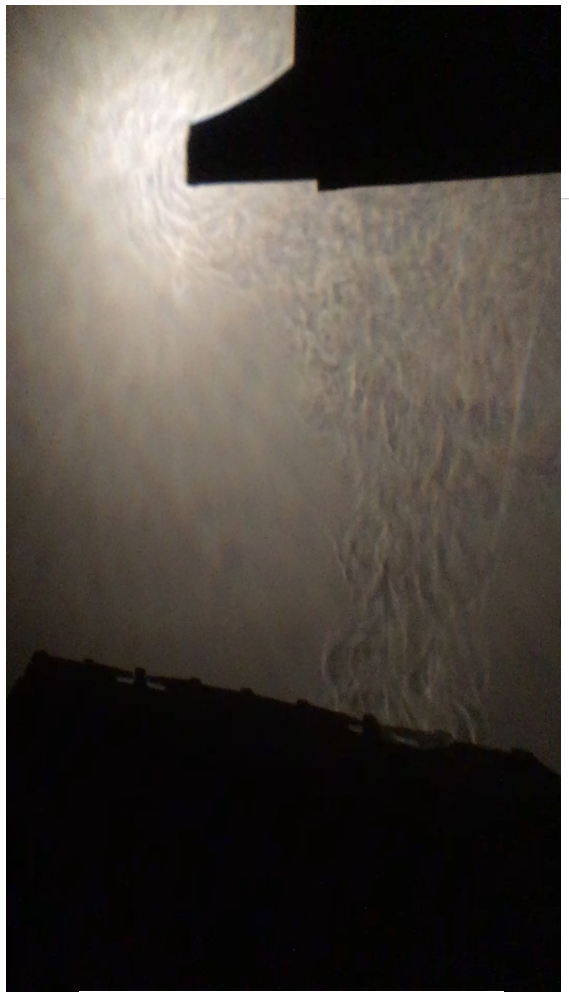


Typical = 10” setback

Field Evaluation of Indoor Air Quality



Rear Burners On
Hood on High

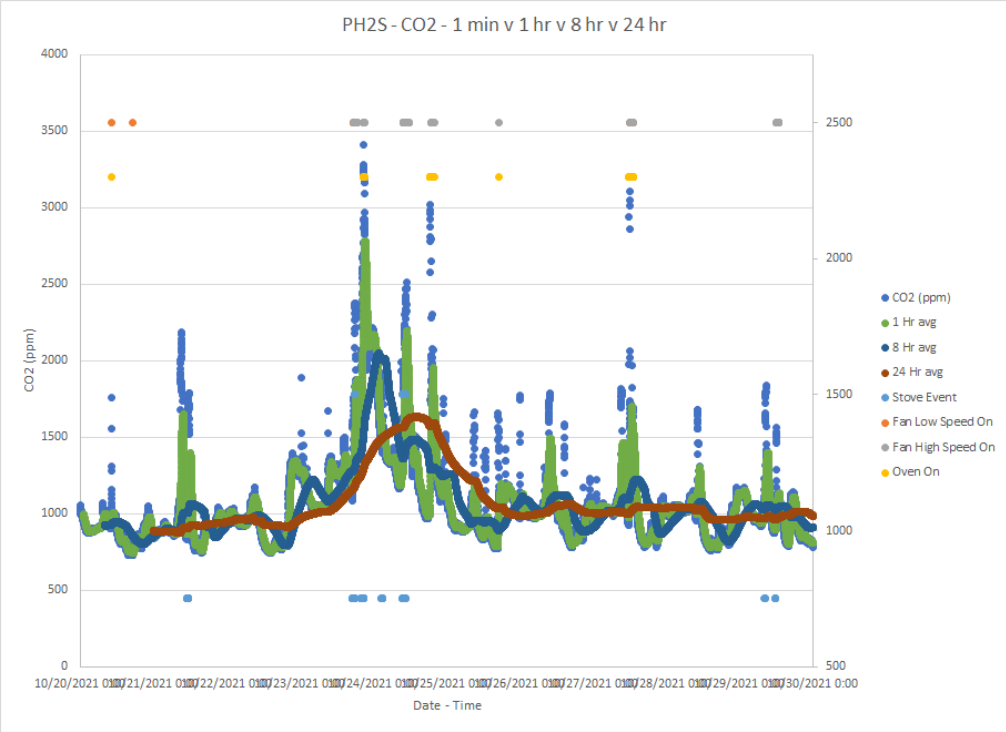


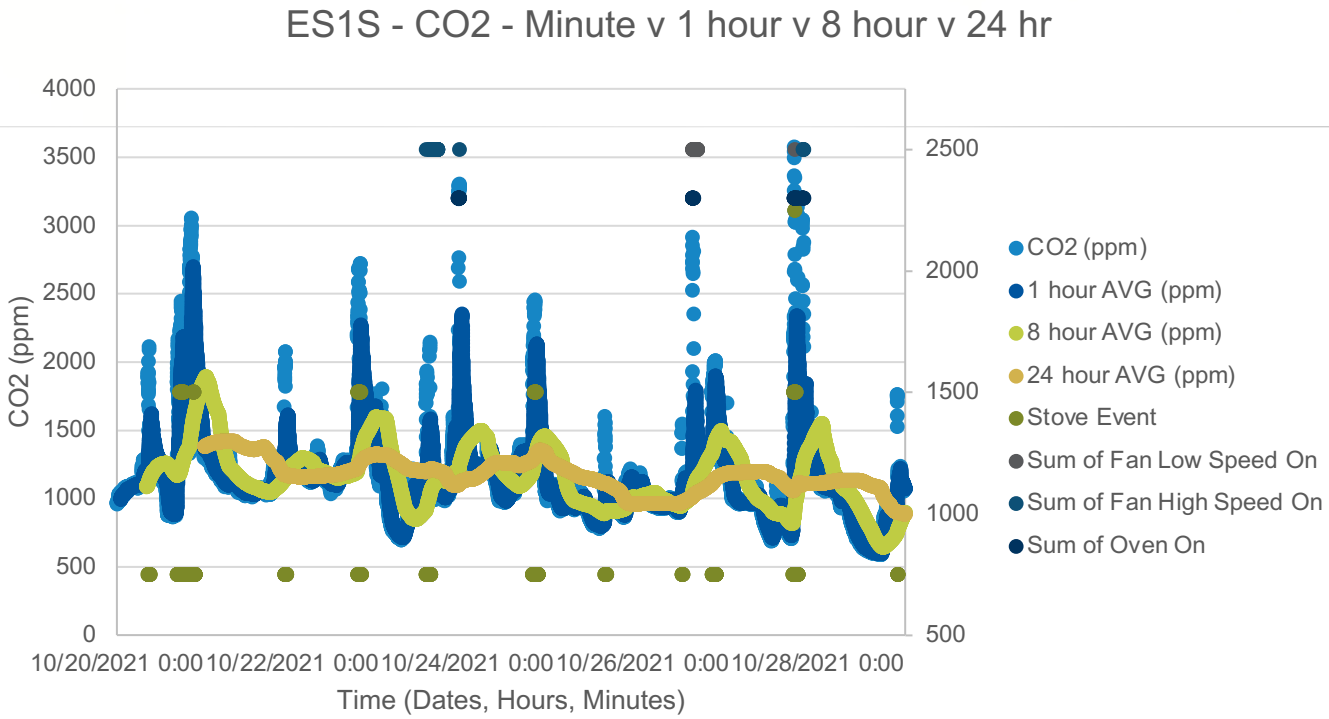
Rear Burners On
Hood on Low

Preliminary Findings

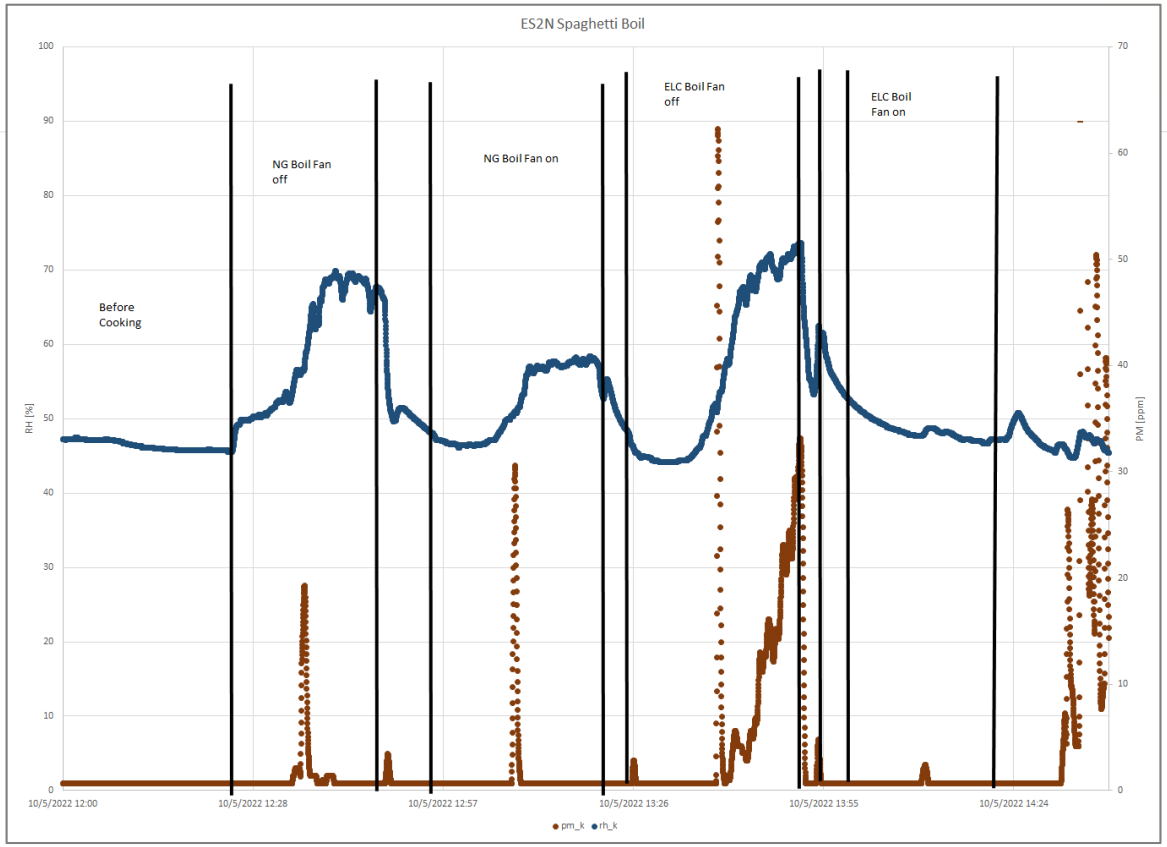
- Data Analyses of daily IAQ measurements
- Analyze IAQ measurements during cooking events that take into account
  - Cooking locations
  - Ventilation strategies

CO2 – 1 Minute/1 Hour/8 Hour/24 Hour Averages

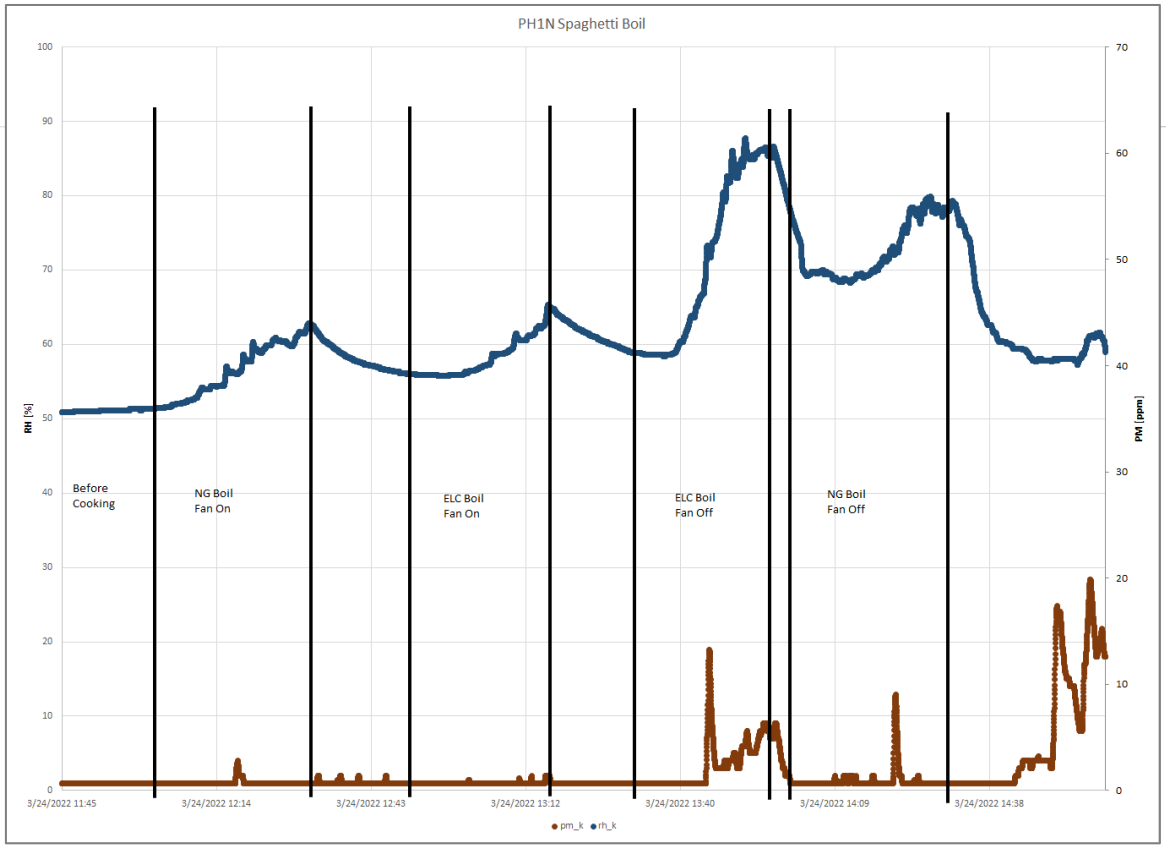




Cooking Events Boiling

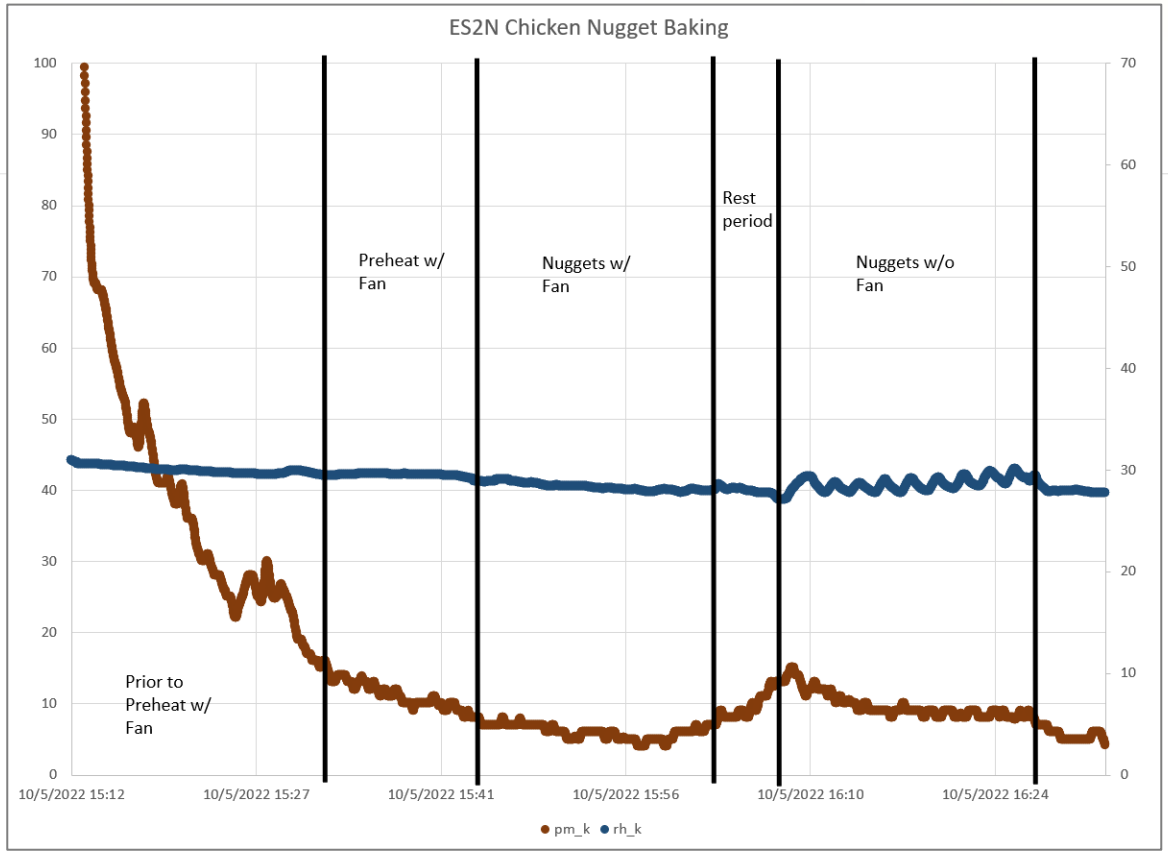


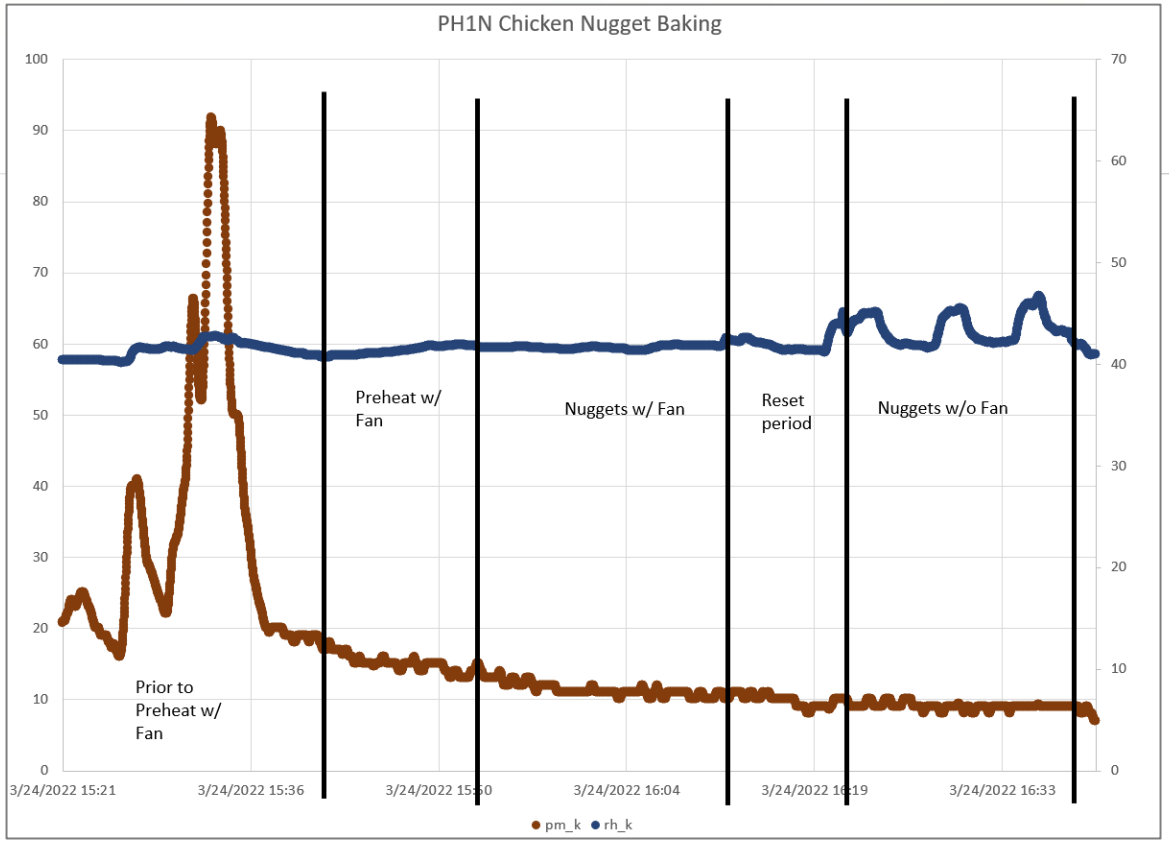
Energy Star-Direct Vent



PHIUS-ERV

Cooking Events
Baking





Next Steps for this Research

- Analyze IAQ measurements during cooking events that take into account
  - Cooking locations
  - Ventilation strategies
- Analyze cooking data with gas range and with electric induction hobs
- Global results: emissions from a variety of menus and behaviors
- Local results: emissions from specific cooking processes

Ventilation Design Recommendations

- Design configurations with wall-mount, not island hoods
- Utilize cabinetry as “side panels”
- Deeper and higher hoods perform better
- Investigating recirculating vs. vent out

Future Research Needs

- Consider modifying residential hood design:
  - Larger reservoir
  - Streamlined geometry
  - Optimized fans and filters
  - Demand controlled system (e.g., temp triggers, PM triggers, opacity)

Kitchen Ventilation - Protect the Cook and Minimize Particulates & Odor

- Recirculating hood pulls aerosols away from cook
- Grease screen in recirculating hood removes larger particles (wash grease screens in dishwasher)
- Smart ventilation system triggered to “vent mode” to exhaust particulates & fumes
  - Manual - Wireless wall switch

Kitchen Exhaust Considerations:

- Cooking Type (gas versus electric)
- Range Hood size (< or > 400cfm)
- Kitchen Volume (open/closed floorplan)

Smart Kitchen Exhaust

Four Strategies:

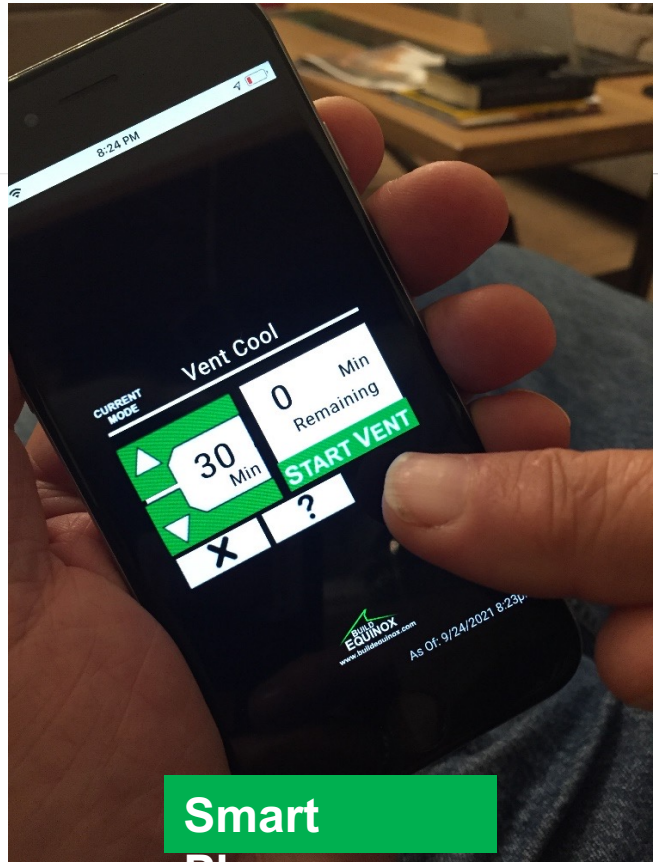
1) Basic all-electric Smart kitchen exhaust (smaller homes, ~2,400sqft or less)
    - Smart ventilation air flow turns over house volume less than 2 hours for whole house filtration and circulating fresh air “stored” in unoccupied rooms
2) Damper enhanced, Smart kitchen exhaust
    - Emphasizes exhaust from kitchen
    - Can remove pollutants quickly without requiring high fan speeds
3) Smart kitchen exhaust with direct fresh air supply and direct exhaust from cooking appliance
    - Gas cooking or code official or personal preference
4) Smart kitchen exhaust with direct exhaust from cooking appliance (no make up air)
    - Smart kitchen ventilation offsets supply/exhaust fan speeds when direct exhaust >200cfm (100Liter/s)

Multiple Ways to Start a Vent Period

Wireless Wall switch

ACT, active circuit

Wireless Occupancy

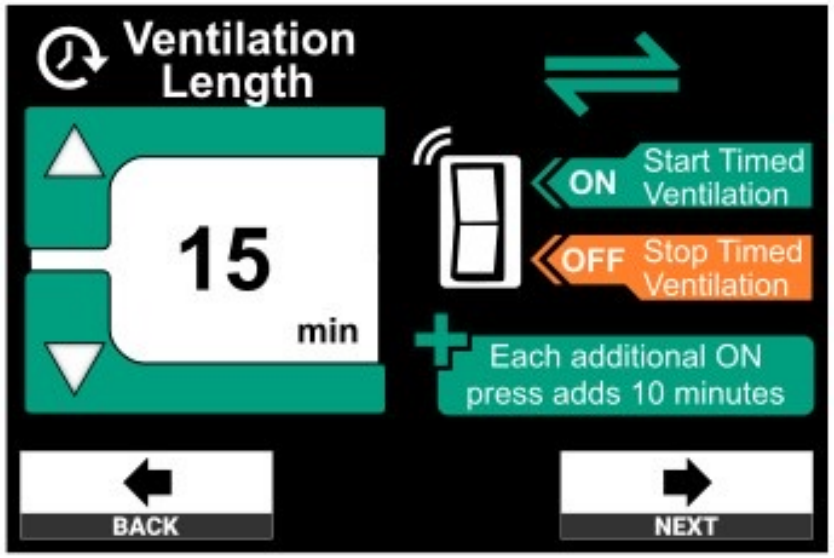


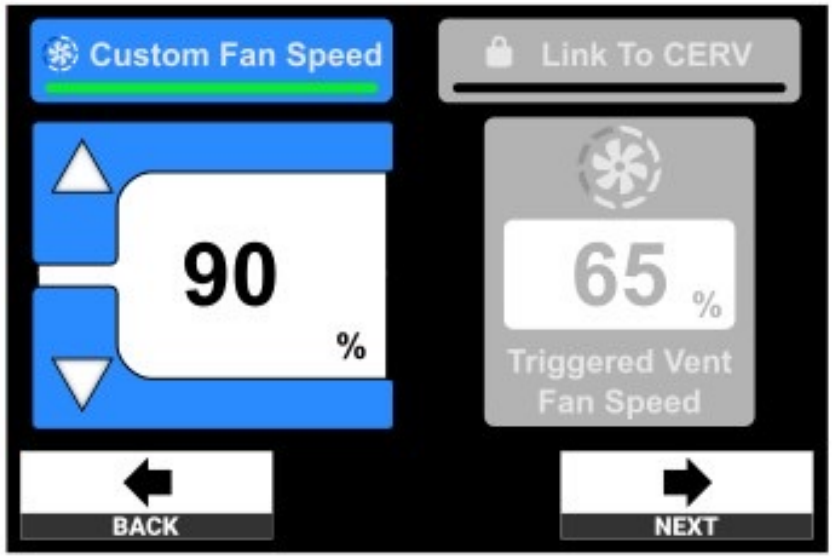
Smart

Wireless Temp/%RH

“Alexa, …. …….”

Kitchen Activity Triggers Exhaust Mode

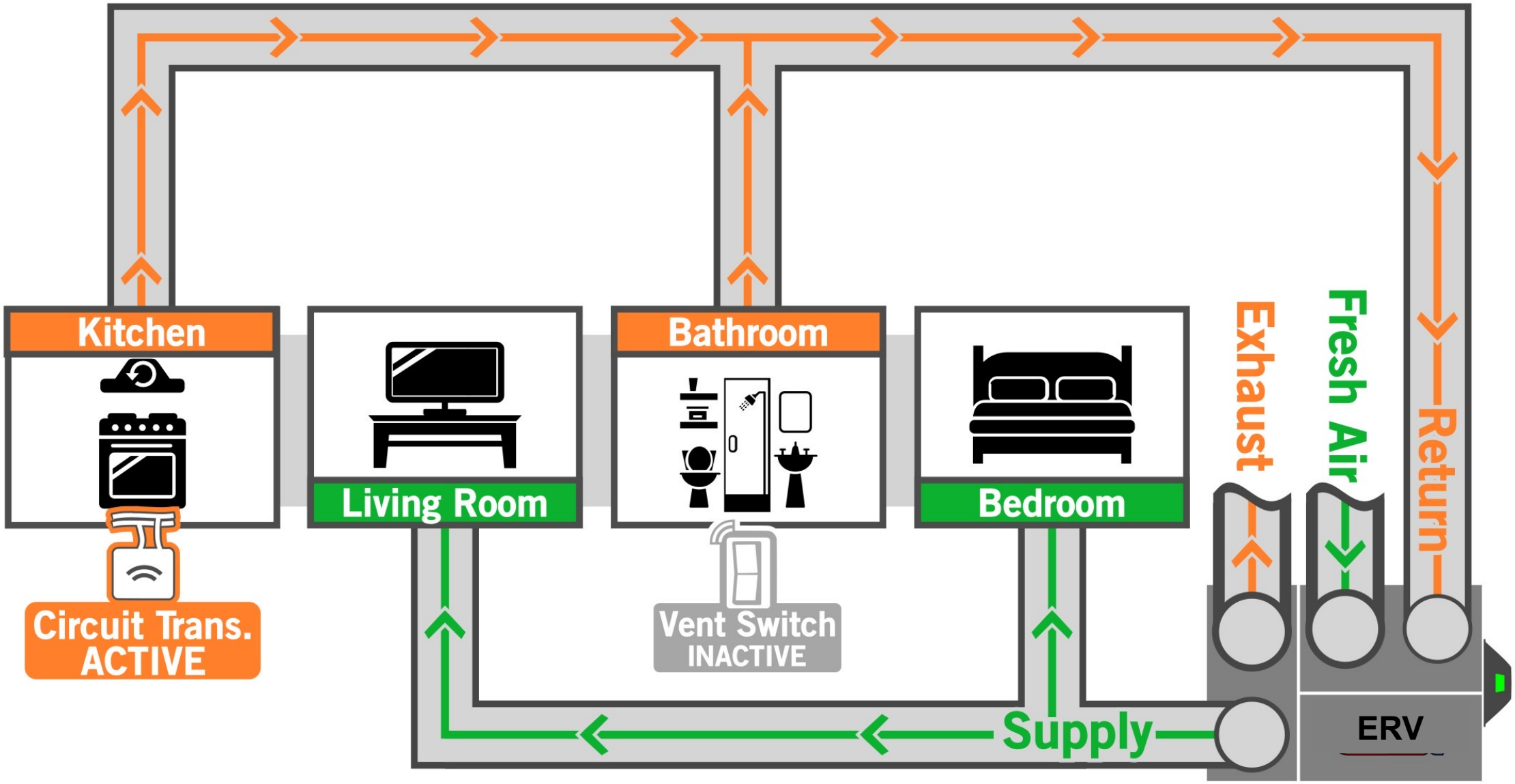




Select a vent length and fan speed for vent period

- **Can switch off or terminate vent period anytime**
- **Fresh air is never wasted with Smart Ventilation!**
  - **If vent period is longer than needed, "extra" fresh air delays need for fresh air venting at a later time**
- **Fresh Air Fan and Exhaust Air Fan speeds can be offset for kitchens with direct exhaust hoods**

Kitchen Ventilation Without Zone Dampers



Exhaust mode triggers fan speed increase for user selected time period

Exhaust mode triggers dampers to emphasize exhaust air flow

Kitchen Ventilation With Dampered Exhaust

OPEN
Zone Name
KITCHEN
Zone Type
Exhaust

CLOSED
Zone Name
BATH
Zone Type
Exhaust

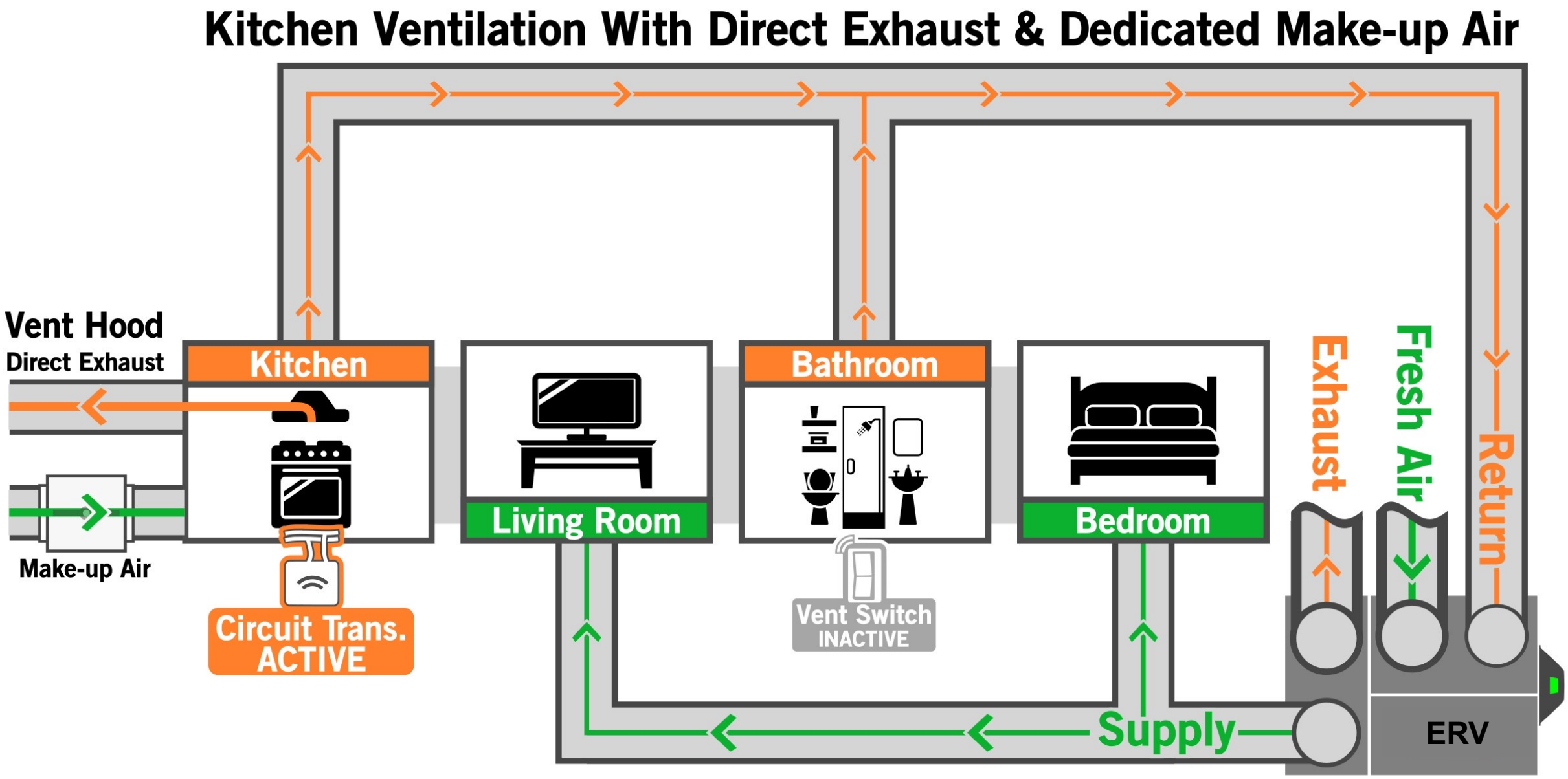
Kitchen
Living Room
Bathroom
Bedroom

Circuit Trans.
ACTIVE

Vent Switch
INACTIVE

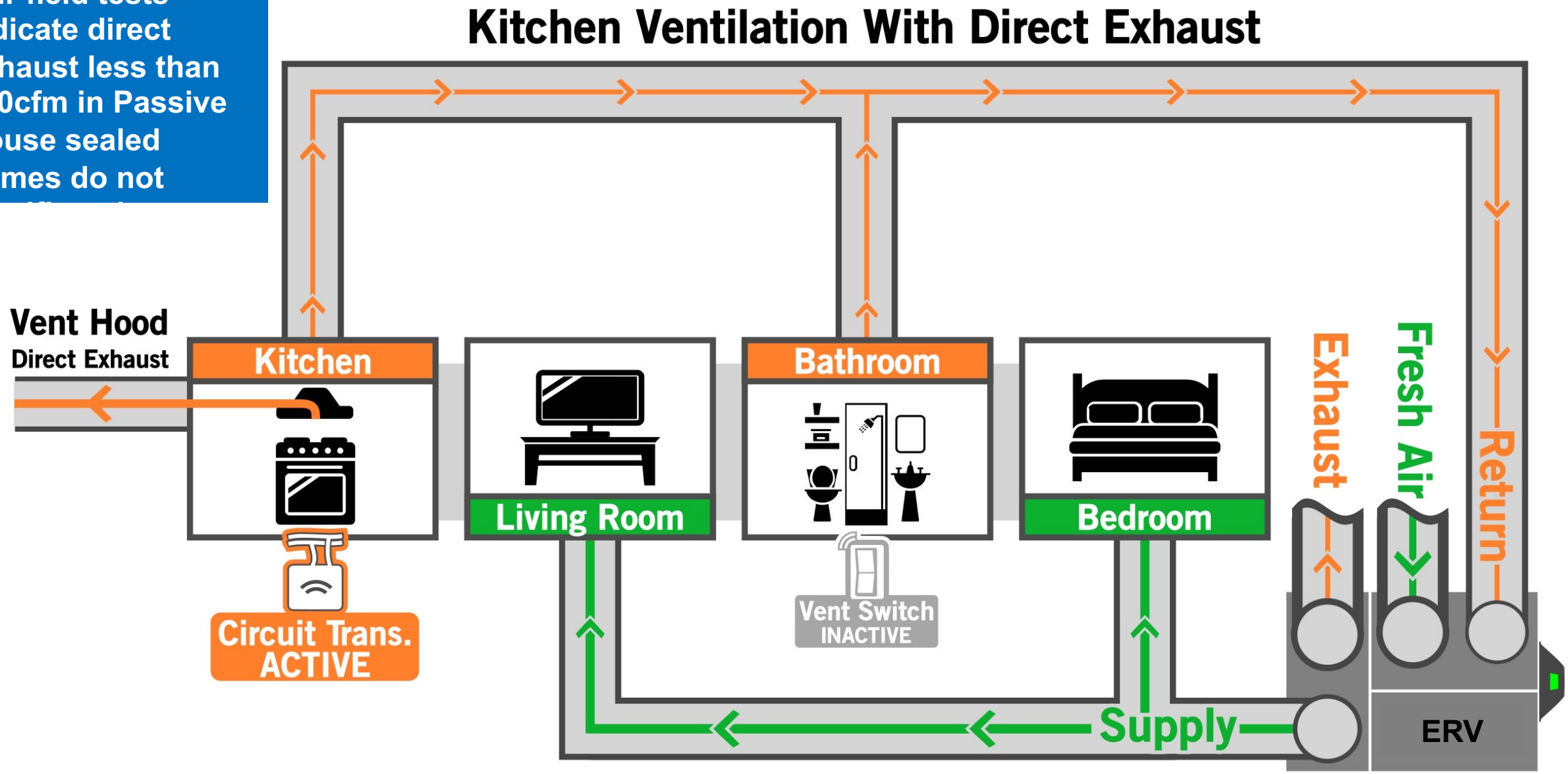
Exhaust
Fresh Air
Return
Supply
ERV

Exhaust mode triggers vent mode (and can trigger make-up air fan and



Exhaust mode triggers vent mode with supply/exhaust fan offset when direct exhaust >200cfm

Our field tests indicate direct exhaust less than 200cfm in Passive House sealed homes do not



Additional Feedback or Questions?

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