



A Tale of Two Buildings: Kitchen IAQ in PHIUS+ and ENERGY STAR Multifamily Units

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ECO ACHIEVERS

October 14, 2021

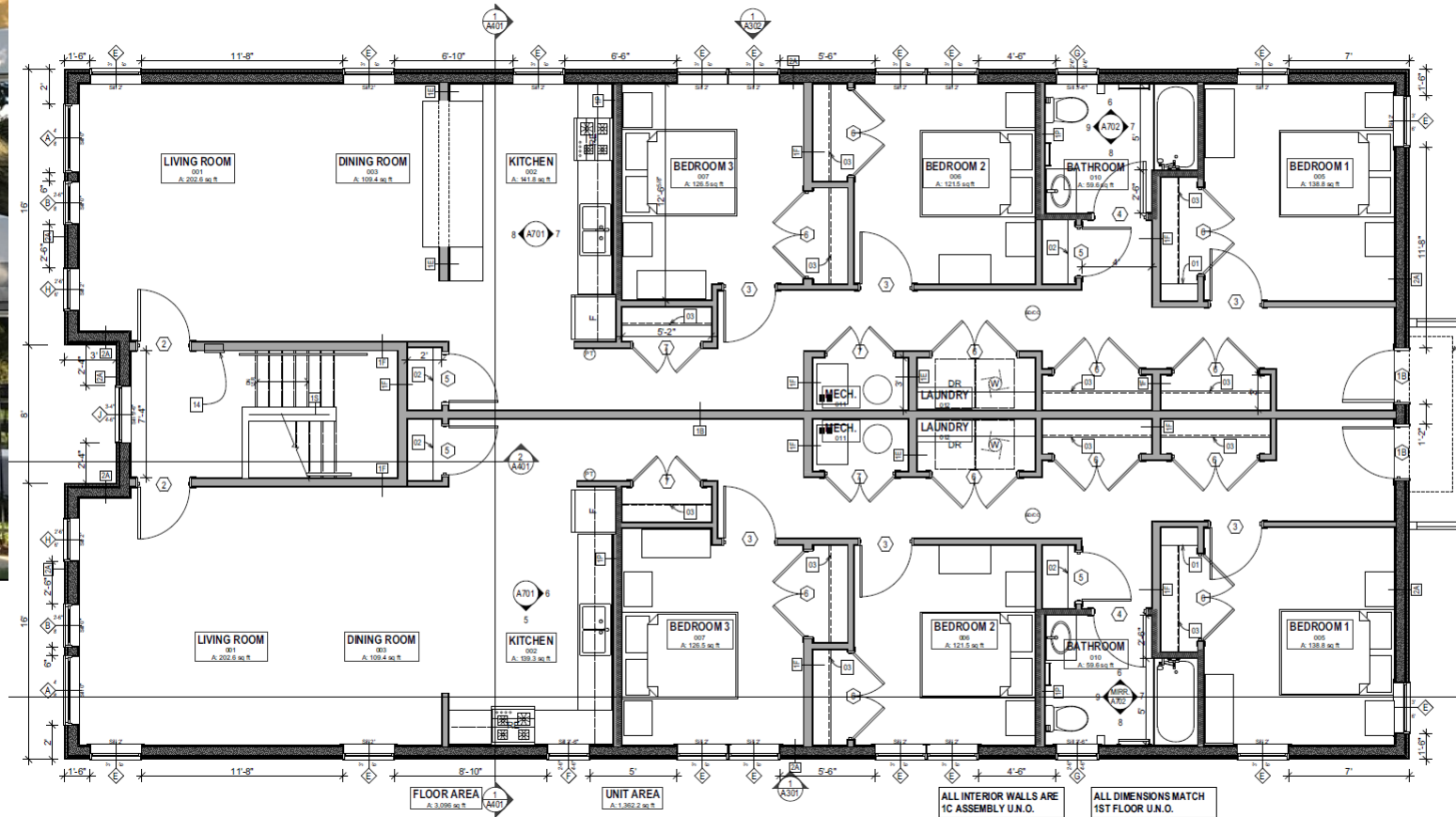
Agenda

- Background
- Tierra Linda Project and PHIUS
- Terra Linda Project and Kitchen IAQ
- Questions



Tierra Linda: Pathway to PHIUS

Tierra Linda Layout



ENERGY STAR V3/3.1



- DOE program that's the basis of many energy certifications – Now split into SFHs / MF
- Performance-based compliance
- Pass/Fail – No Optional Credits
- Primarily New Construction
- Mandatory Checklists
 - HVAC Design Report
 - HVAC Commissioning Checklist
 - Builder Water Management Checklist
 - ENERGY STAR Rater Checklist
- Critical Project Team Certifications
 - Rater – ESTAR Certified Rater
 - HVAC Contractor – HQUITO certified (depending on the mechanical system)

ZERO ENERGY READY HOME



- DOE program that builds on ENERGY STAR
- Mandatory Components
 - Envelope – meets/exceeds IECC 2012/2015
 - HVAC Location – Mainly within the thermal envelope*
 - DHW – Efficient delivery systems with temp testing OR WaterSense Option
 - Lights/Appliances – Make it ENERGY STAR
 - IAQ – Certified under indoor airPLUS
 - Renewable Ready
- Mandatory Project Team Certifications
 - Same as ENERGY STAR

INDOOR AIRPLUS



- Requires ENERGY STAR Certification
- Similar credits seen in ESTAR Builder Water Management Checklist
- Durability measures for site, building envelope, and interior
- Material Vetting: Low VOCs
 - All Composite Wood Products
 - Interior Paints and Finishes
 - Carpet/Adhesives/Cushion

New - More Comprehensive - Version (v2) Coming Soon!



PHIUS+ 2015



DESIGN CHANGES & CHALLENGES

PHIUS+ 2015 INSPECTIONS & TESTING



- Slab Insulation
- Insulation – Interior and Exterior
- Framing & Insulation
- Air Barrier / Air Sealing
- Mid-Construction Testing (Optional)
- Final Testing



Mid-Construction Inspections



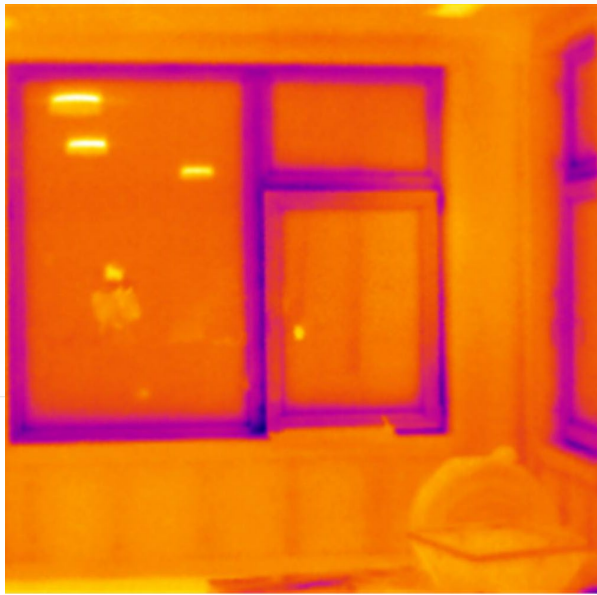
Mid Construction Blower Door

- Target CFM = 688 CFM
- Tested CFM = 1600 CFM



Final Testing





Tierra Linda Project

ComEd & Slipstream

The Opportunity Chicago, IL

Two new, 6-unit properties developed by LUCHA

Both certified under the ComEd
Affordable Housing New Construction
Program.

Same layout, same orientation, same
location.

Constructed to two different energy efficiency standards

ENERGY STAR

Passive House Institute US (PHIUS+)

How do they compare?

Energy performance

Construction and operating costs

Indoor air quality (IAQ)



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 / ft² construction

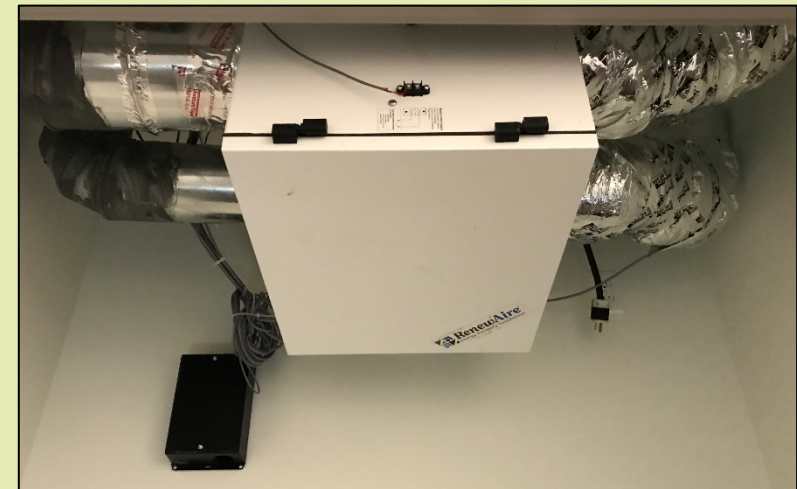
\$214 / ft² construction

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



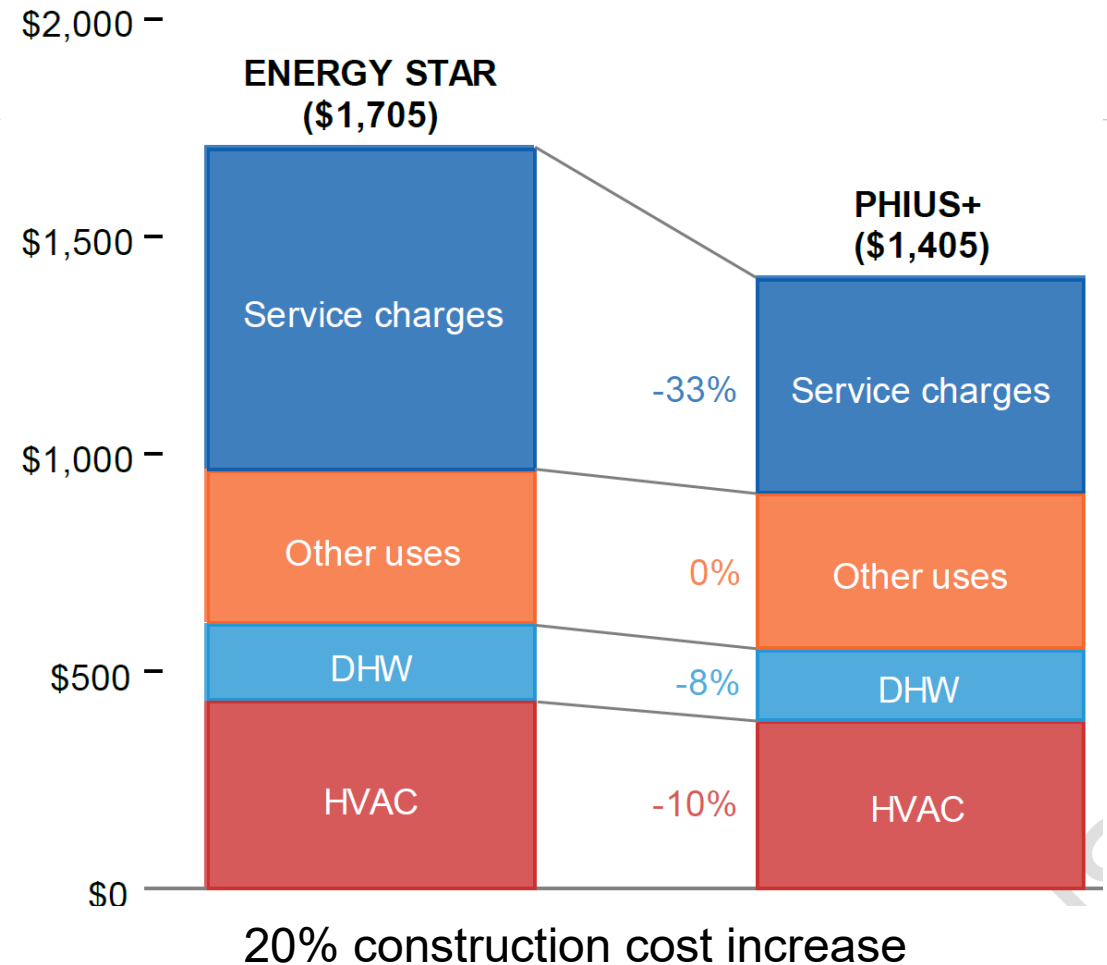
Project Results

- **Objectives**
 - Compare energy performance of the 2 buildings
 - Which PH features deliver the most bang for the buck?
 - How does IAQ compare?
- **Monitoring** (Nov 2018 – Sep 2020)
 - Circuit-level power (1-second)
 - HVAC input/output energy (1-second)
 - IAQ parameters in hallway (1-minute)
 - Temp/RH
 - CO2
 - PM2.5/PM10
 - Weather (rooftop)

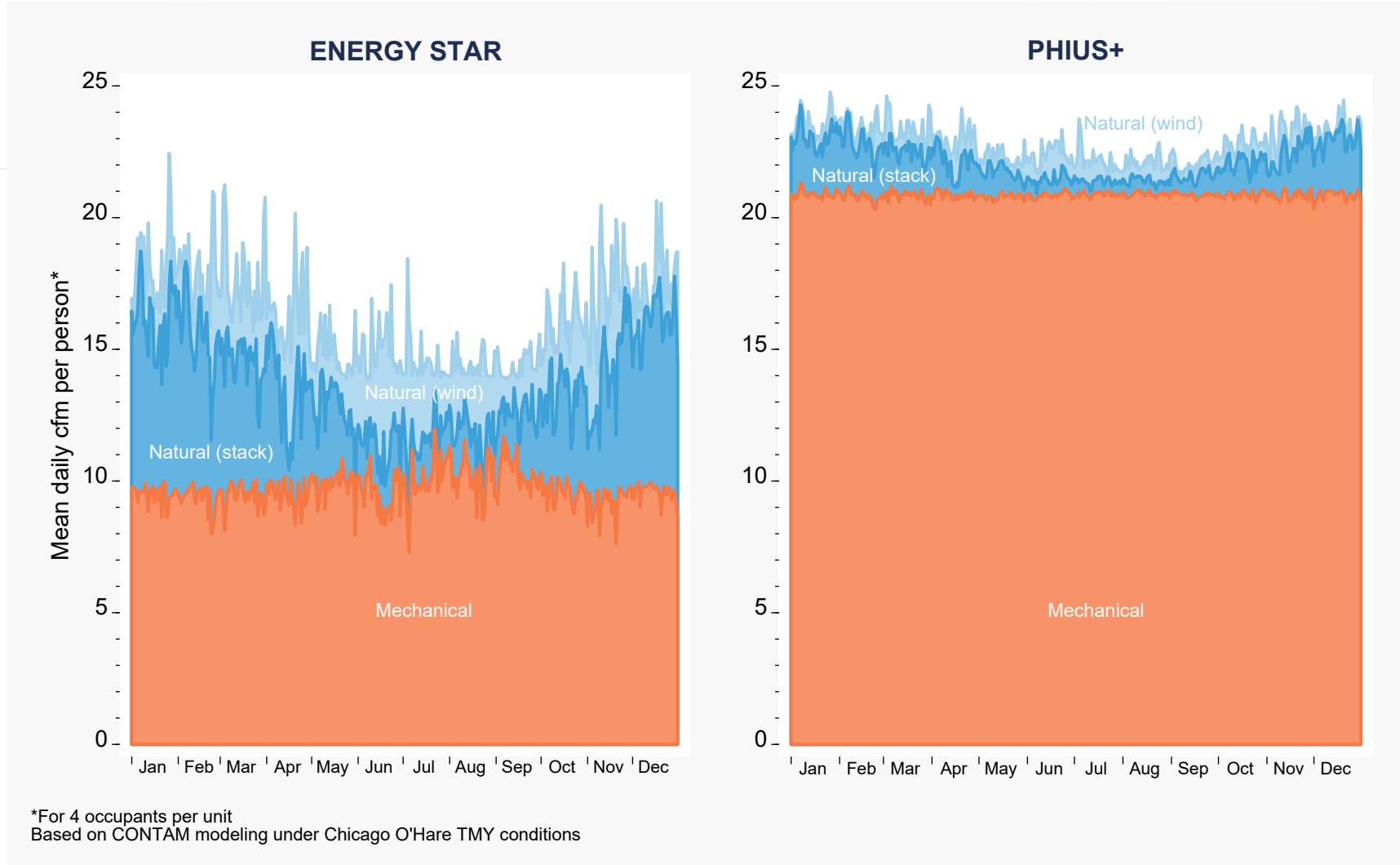


Key Energy Findings

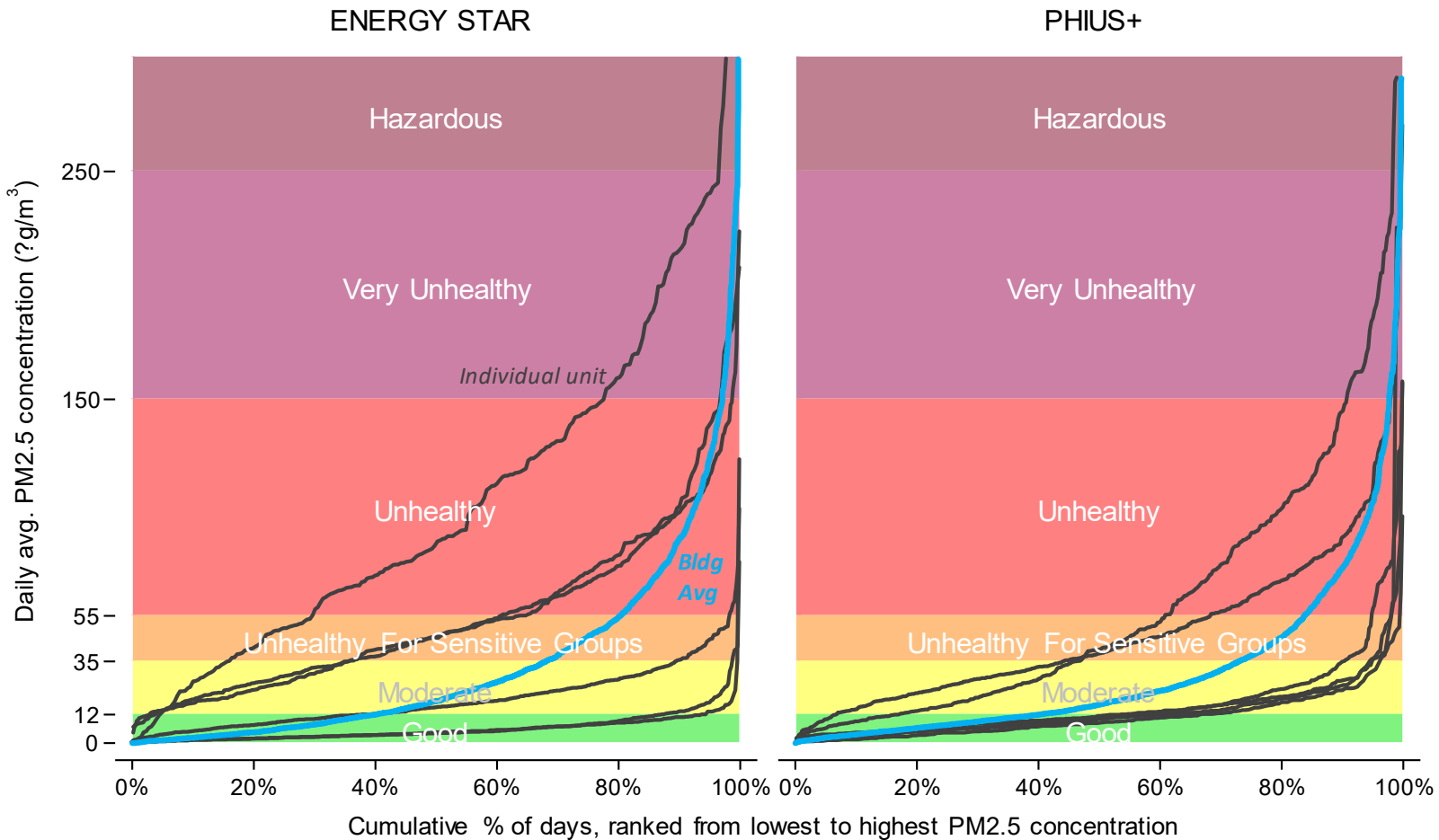
- 65% lower delivered-energy requirement for space heating (ambiguous results for cooling)
- 76% lower site-energy for heating/cooling
- 30-35% lower carbon emissions
- 19% lower tenant utility bills



Higher overall air change rate



Particulate levels



Categories are US EPA Air Quality Index breakpoints for outdoor air

Follow Up Project GTI 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)

Scope

- Measure emissions in kitchens of occupied units
 - Six direct vent outdoor hoods in ENERGY STAR building
 - Six recirculating hoods in Passive House building
- Evaluate trends in concentrations of CO₂, NO₂, CO, PM_{2.5}, VOC's, Formaldehyde, temperature, and humidity in the kitchen space during cooking with the gas range and electric counterpart
- Controlled-cook in ENERGY STAR and PHIUS units
- Compare emissions among apartments, analyzing similarities and peaks.

Instrumentation



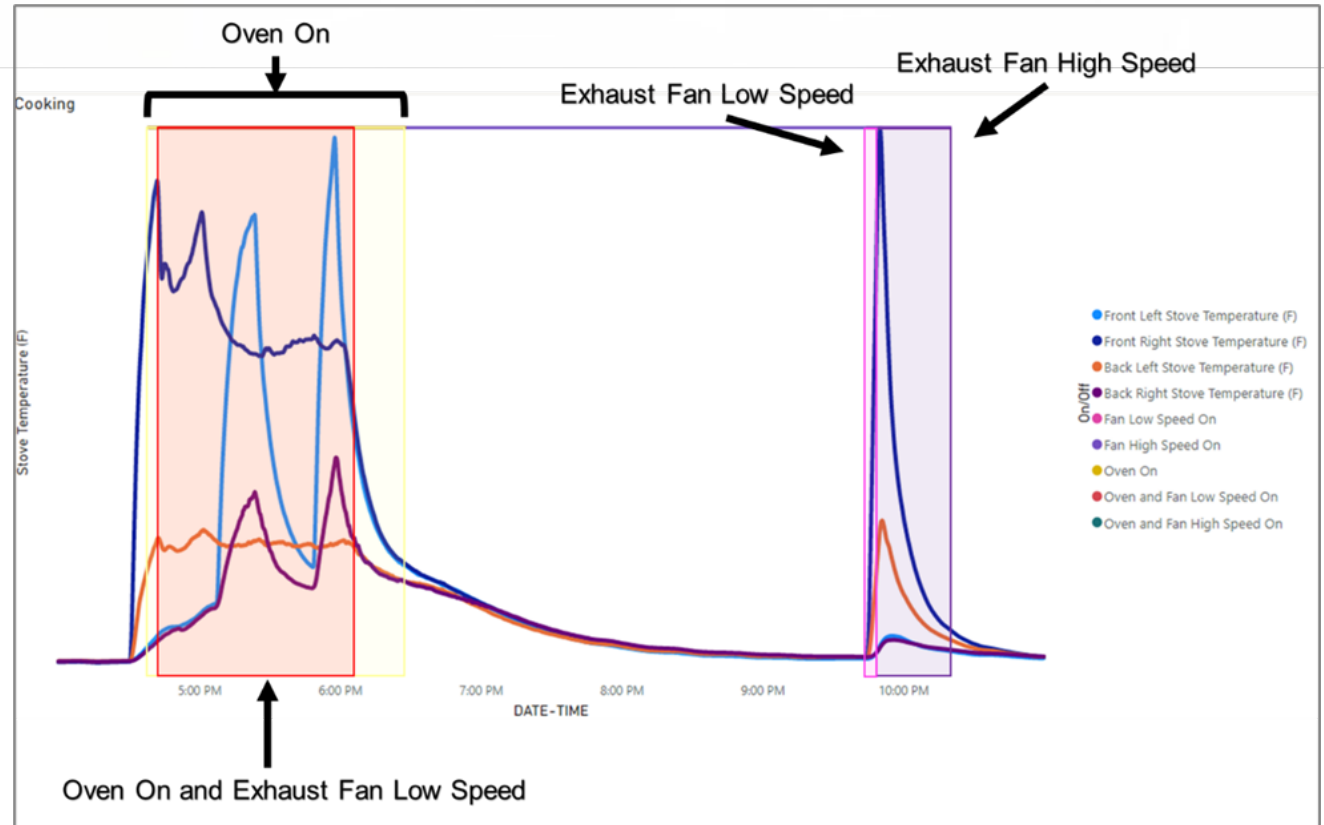
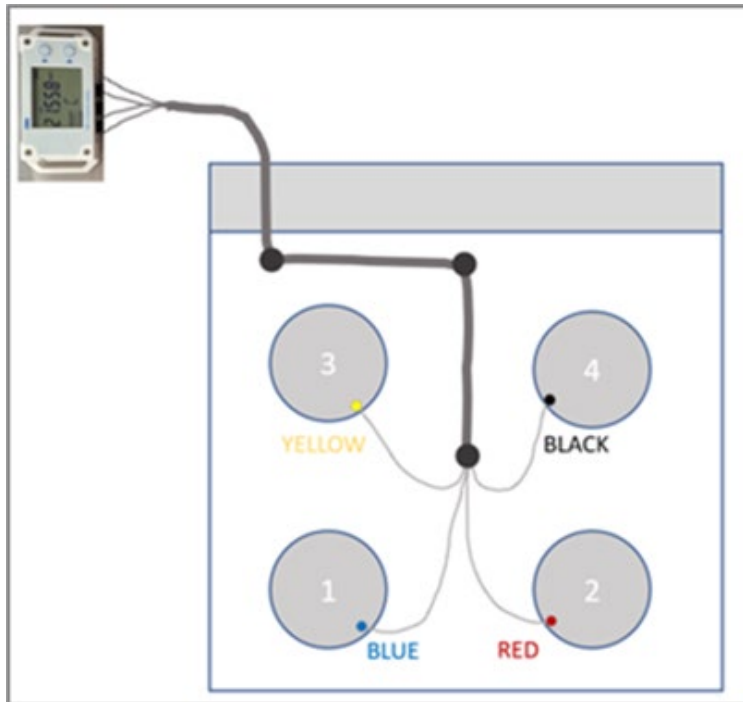
Field Installations

- Installation of sensor enclosures:
 - CO₂, NO₂, CO, RH, TEMP; VOC, PM_{2.5} and Formaldehyde



Field Measurements

- Installation of range cooking location sensors



O&M Issues

- 2+ yr post occupancy
- ERV Maintenance
 - OA intake
 - ERV Filtration
 - ERV filters in the occupied units were compared to new filters
 - loaded at 39% by weight
 - 0.07 lb/32 g



ERV Exhaust Flows – Field Evaluation Testing

			11/20/2018	6/17/2021	6/17/2021	
Area Served	Terminal Size	PHIUS Required Flow [CFM]	Certified Flow [CFM]	Post-Occupancy PHIUS 3S Flow [CFM]	Post-Occupancy PHIUS 3N Flow [CFM]	Reduction in Flow
Kitchen	8x8	35	33	24		27%
Bath	8x8	25	27	20		26%
PHIUS 3S Total		60	60	44		
Kitchen	8x8	35	38		34	11%
Bath	8x8	25	26		23	12%
PHIUS 3N Total		60	64		57	

Field Evaluation of Indoor Air Quality

- Tenant surveys
- Analyzing 1-minute data
 - IAQ / Power
- Controlled-cooking events
 - Pizza
 - Mac & cheese
 - Stir fry



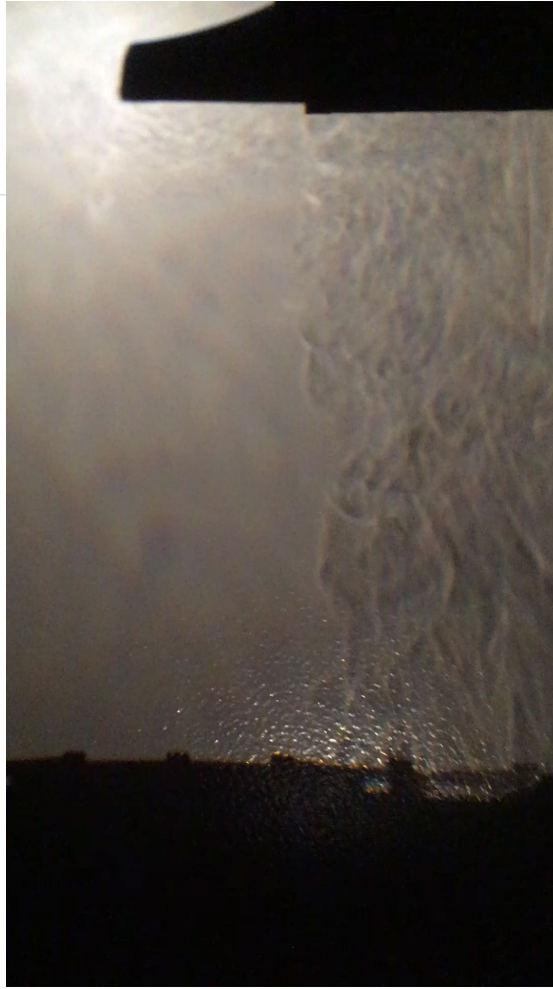
Flow Visualization



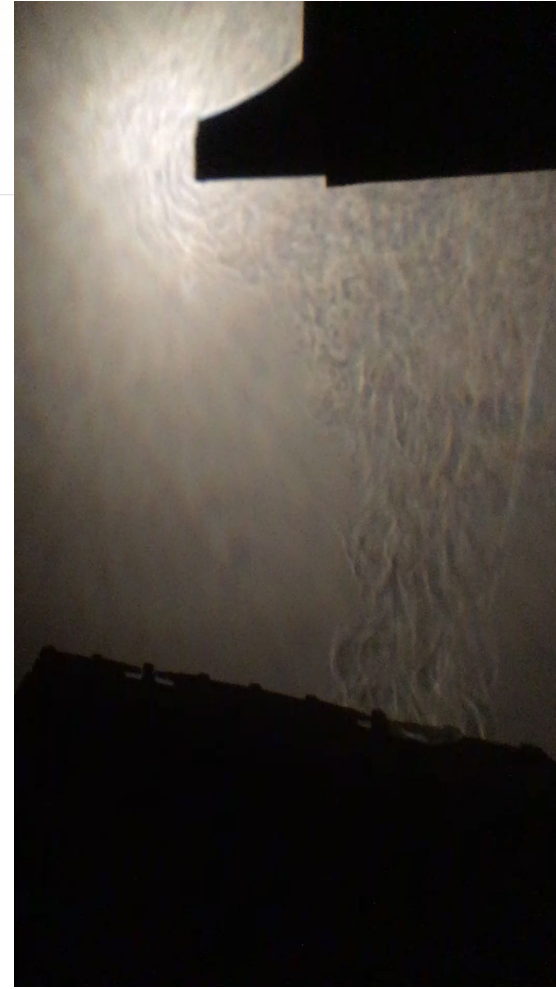
Field Evaluation of Indoor Air Quality



Field Evaluation of Indoor Air Quality



Rear Burners On
Hood on High



Rear Burners On
Hood on Low

Next Steps

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

Future Research Needs

- Consider modifying residential hood design:
 - Larger reservoir
 - Streamlined geometry
 - Optimized fans and filters
 - Demand controlled system
- BENEFIT proposal-*High Performance Residential Range Hood with Integrated Air Curtains*
 - Encouraged but Unawarded; GTI looking for collaborators
- Novel burner design with hydrogen blends

Thank you!

Questions?



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