Jiayu Li

Postdoctoral Researcher

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Indoor Environmental Quality and Ventilation in Commercial Kitchens

Rengie Chan

LBNL

Angelo Karas, Todd Bell

Frontier Energy

Stefano Schiavon

CBE

Why commercial kitchens?

Harsh working environments

- High indoor air temperature and RH
- Air pollutants from cooking and cleaning

Intensive energy usage

- Use up to 5x more energy than office buildings (per sq ft)
- Consume $10B of energy each year and emit 44 million tons of CO2e each year

Growing trends in non-restaurant sectors

- in-house kitchens

TV Show: The BEAR (Season 1)

Project overview

Objective

- Document indoor environmental quality
- Assess the ventilation performance and energy-saving potentials

Methods

- Physical measurements
- Subjective feedback from kitchen staff
- Energy audit and ventilation assessments

Funding

- U.S. Department of Energy

Generated with AI | Adobe Stock

Completed measurements in 10 restaurants

Locations

- San Francisco Bay Area (Berkeley, Lafayette, Oakland, San Francisco)

Restaurant types

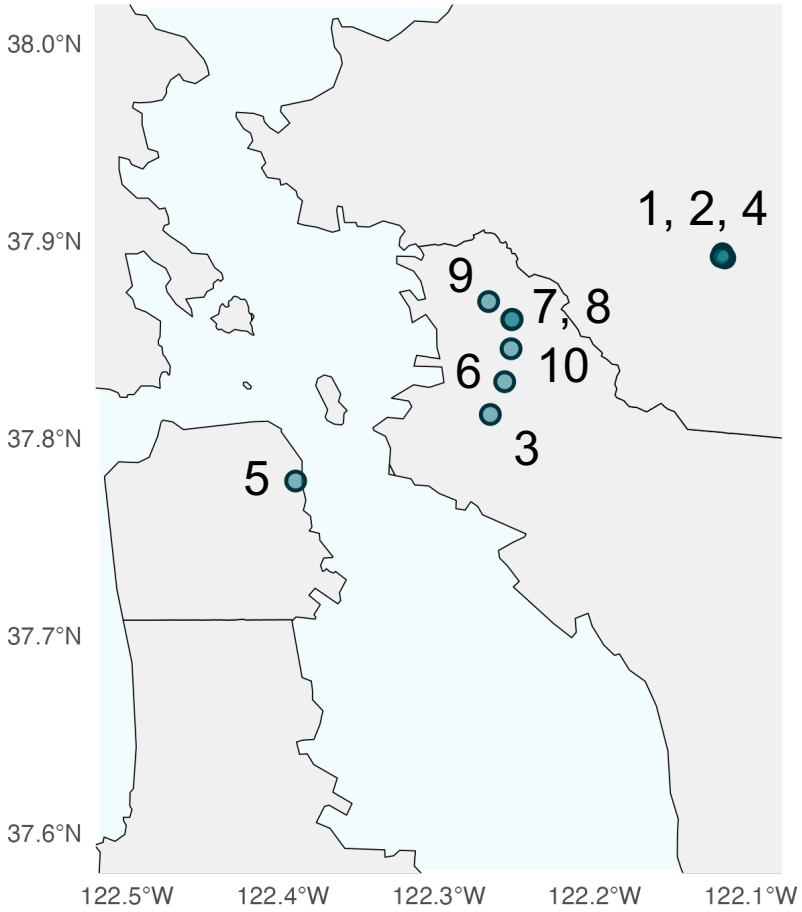
- Independent restaurants
- 6 fast casual; 4 full service
- Occupancy: 15 to 500 (median about 50)

Cooking locations

- 6 front; 3 back; 1 both front & back

Fuel types

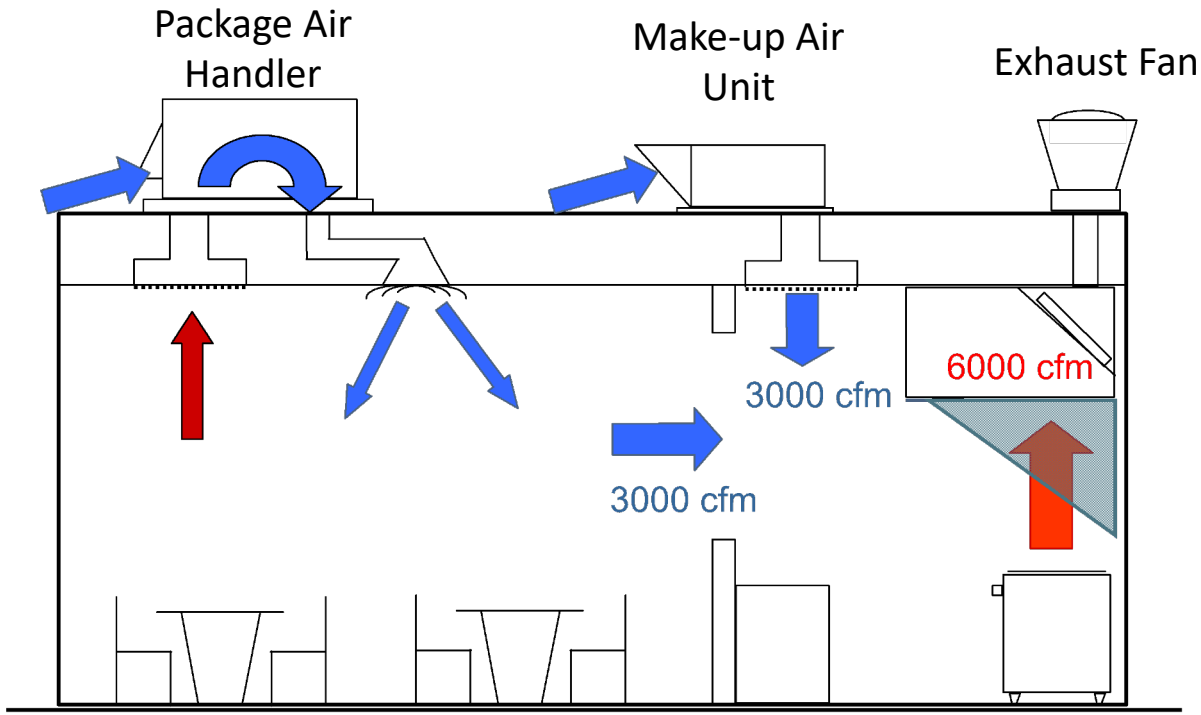
- 8 Natural gas
- 2 Natural gas and firewood

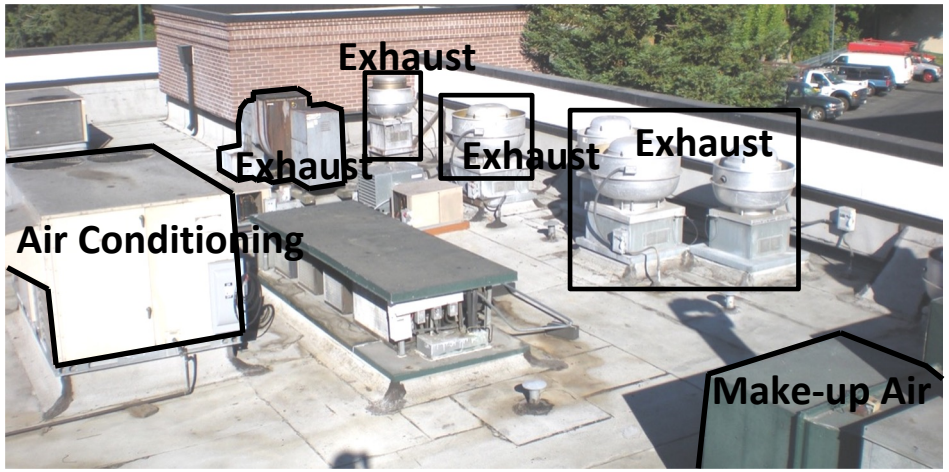


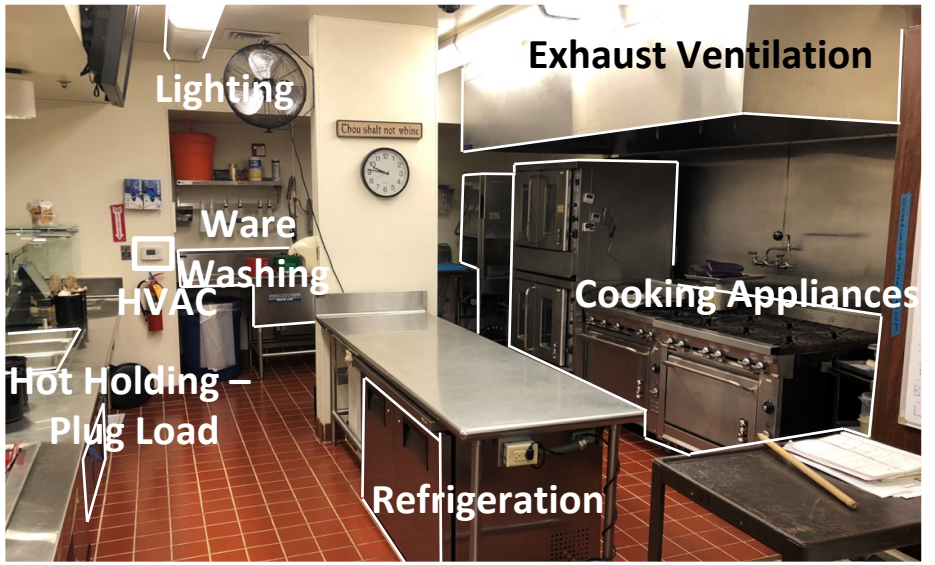
Kitchen locations (Map source: OpenStreetMap)

Energy audit and ventilation assessment

- Fundamentals of kitchen ventilation





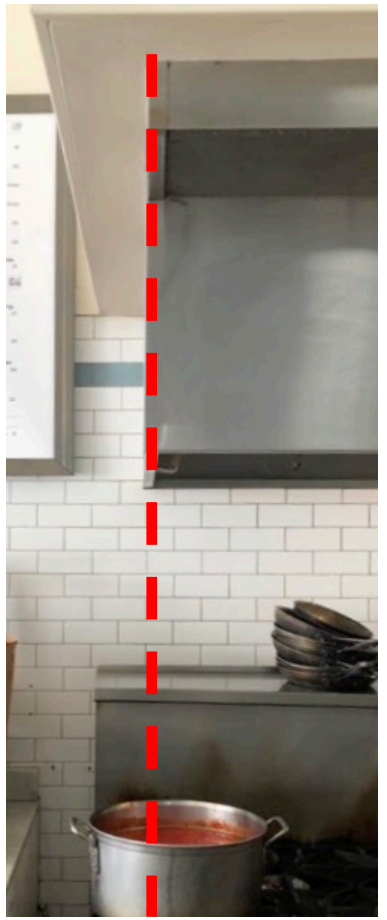


- Assessment of the exhaust system and HVAC system for kitchen and dining areas
- Documentation of the cooking appliance

Assessment of exhaust hoods

- 18 hoods were evaluated in 10 kitchens
- 14 had airflow rate within the expected range per UL requirement
- Spillage or poor capture was observed in 6 out of 10 kitchens
- Unhooded cooking appliances

UL-listed hood with demand ventilation control



Range outside hood canopy

Unhooded double-stack convection ovens

Makeup air (MUA) and air conditioning systems

- Issues in MUA systems were identified in 9 of 10 kitchens
  - 1 kitchen has no MUA
  - Evaporative coolers in 7 kitchens either had no water feed or were in poor condition
  - 3 kitchens didn’t have sufficient airflow supplied by MUA
- 5 of 10 kitchens had insufficient cooling capacity
- Dirty and crushed air filters

Evaporative cooler

Undersized ductless split system air handler

Dry evaporative media

Dirty and crushed air filters

Energy audit of cooking appliances

- ENERGY STAR fryers found in 7 of 10 kitchens
- Convection oven, pressure fryer, and thermostatic griddle each seen in one kitchen
- More utility rebates could encourage wider adoption

Examples of ENERGY STAR fryers used in the kitchens studied

Kitchen environment sampling

Indoor air quality

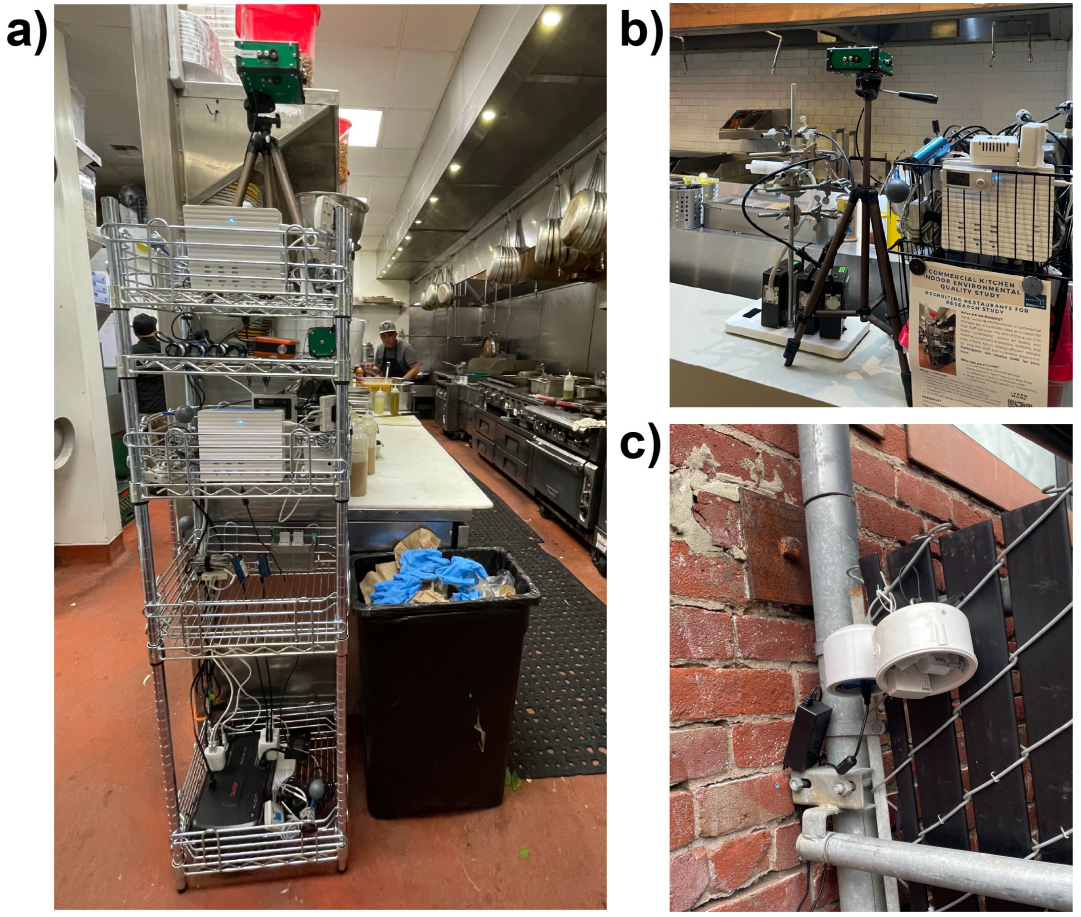
- Ultrafine particles (< 100 nm)
- PM2.5 (< 2.5 µm)
- NO_2 and CO
- Speciated VOCs and SVOCs

Thermal environment

- Air and mean radiant temperature
- Relative humidity
- Air velocity
- Radiant asymmetry

7-day sampling locations

- Indoor: near the main cooking activity on a multilayer shelving unit or in a stacked basket
- Outdoor: sheltered area near the kitchen



Setup of indoor instruments on a multi-layer shelving unit (a) or in a stacked basket (b) and outdoor instruments (c)

Indoor air quality – PM2.5

- Half of the kitchens had PM2.5 levels higher than the World Health Organization (WHO) guideline
- Cooking activities elevated the PM2.5 concentrations
- Poor ventilation and solid fuel burning potentially caused high levels of PM2.5 during cooking hours

Median and interdecile range of hourly PM2.5 concentrations under cooking (teal) and non-cooking (gray) conditions in 10 kitchens. Dots represent median values, and vertical bars represent the 10th to 90th percentile range.

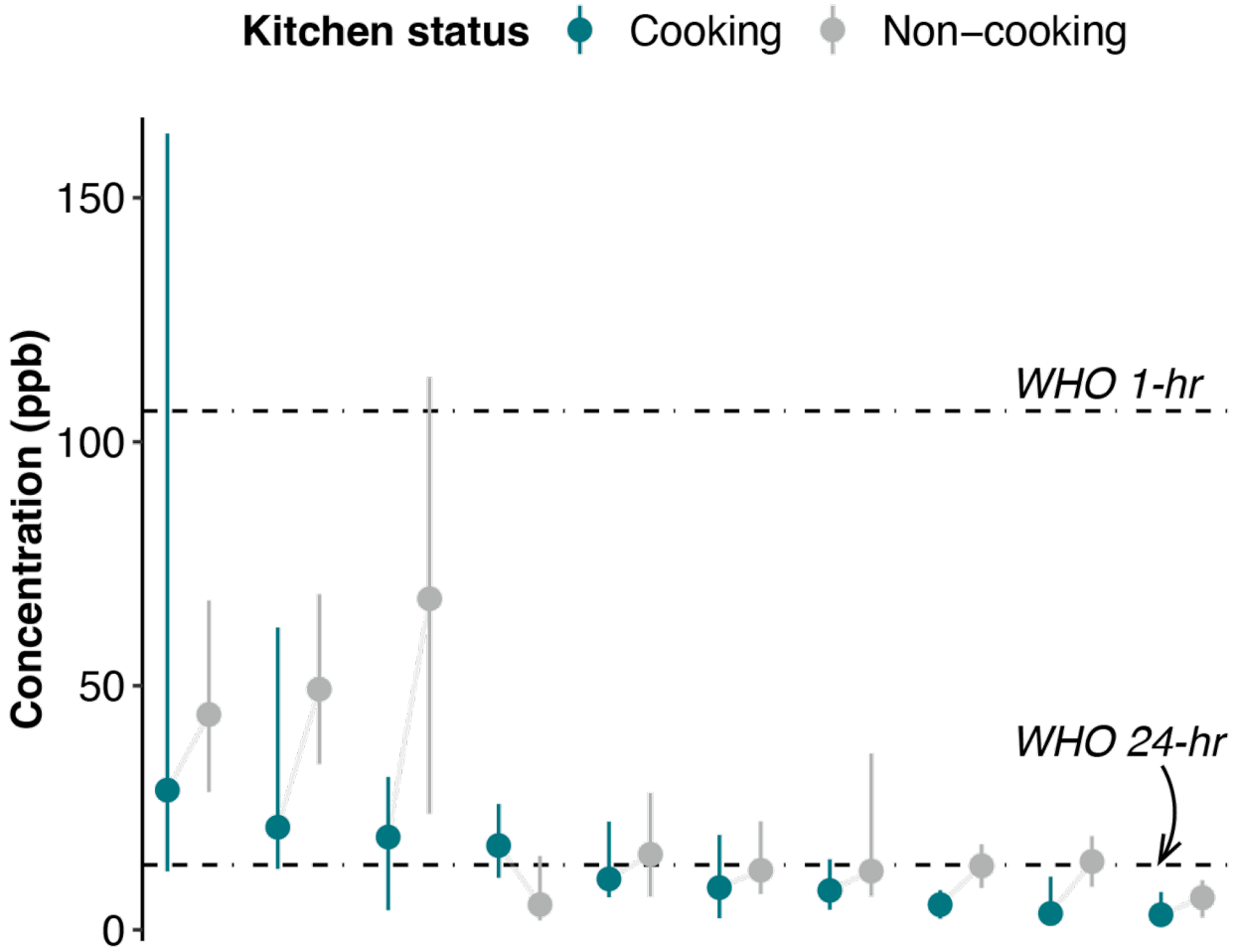
Indoor air quality – Ultrafine particles

- All kitchens had ultrafine particle concentrations higher than the WHO guideline
- The levels during cooking hours were up to 20 times higher than non-cooking

Hourly ultrafine particle concentrations under cooking and non-cooking conditions in 10 kitchens.

Indoor air quality – NO2

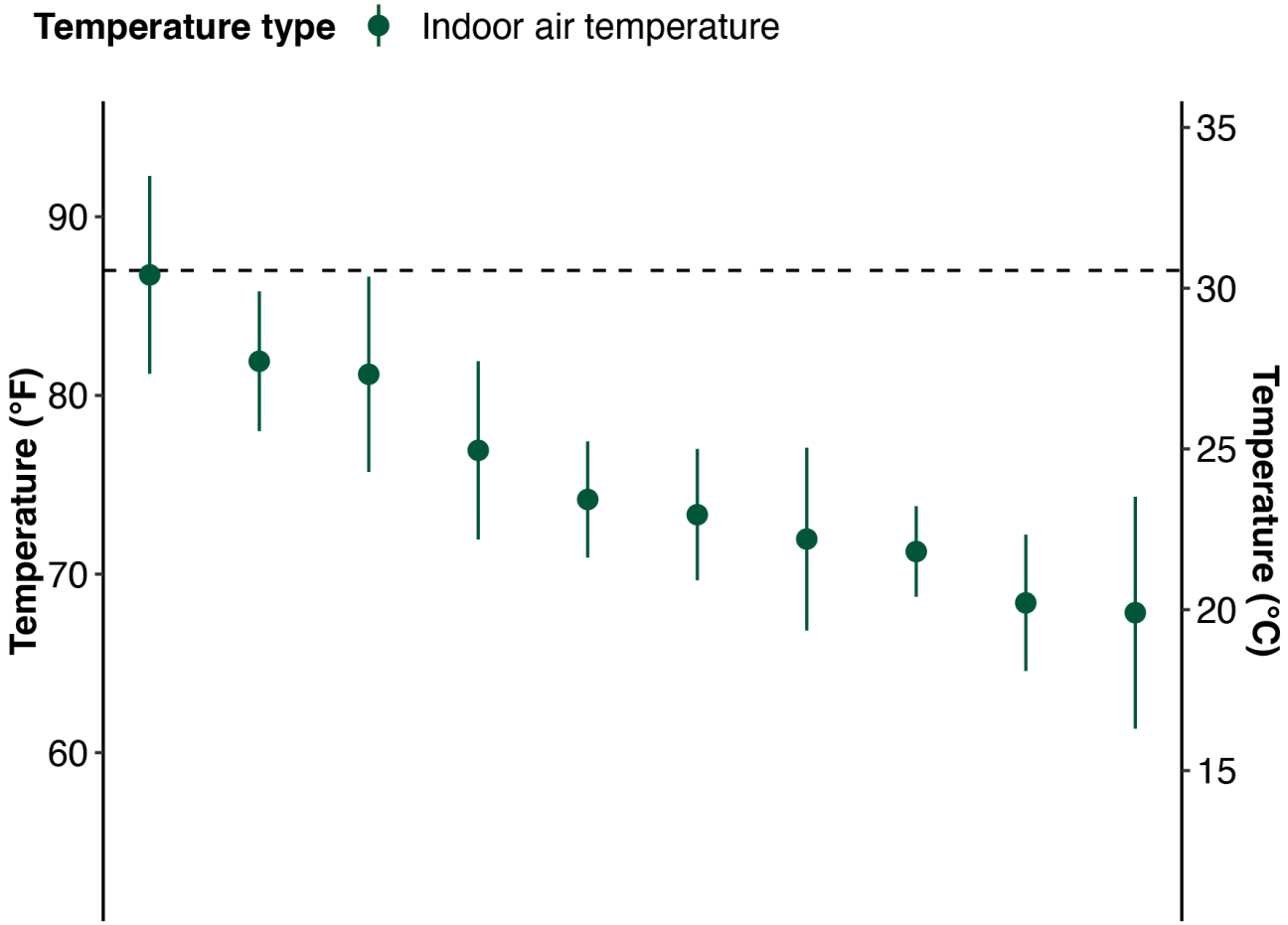
- Non-cooking NO2 concentrations higher than those during cooking hours
- In 8 kitchens, the non-cooking NO2 levels exceeded or approached the WHO 24-hr guideline



Hourly NO2 concentrations under cooking and non-cooking conditions in 10 kitchens.

Thermal environment

- High heat stress
  - Indoor air temperature > 70 °F
  - PMV > 2
- Indoor temperature higher than outdoors
  - Large cooling potentials through ventilation
- High and asymmetry radiant heat
  - 5/10 kitchens are high radiant spaces [Air and radiant temperature differences > 5 °F]
  - Difference between radiant temperatures from coolest and hottest walls was up to 25 °F

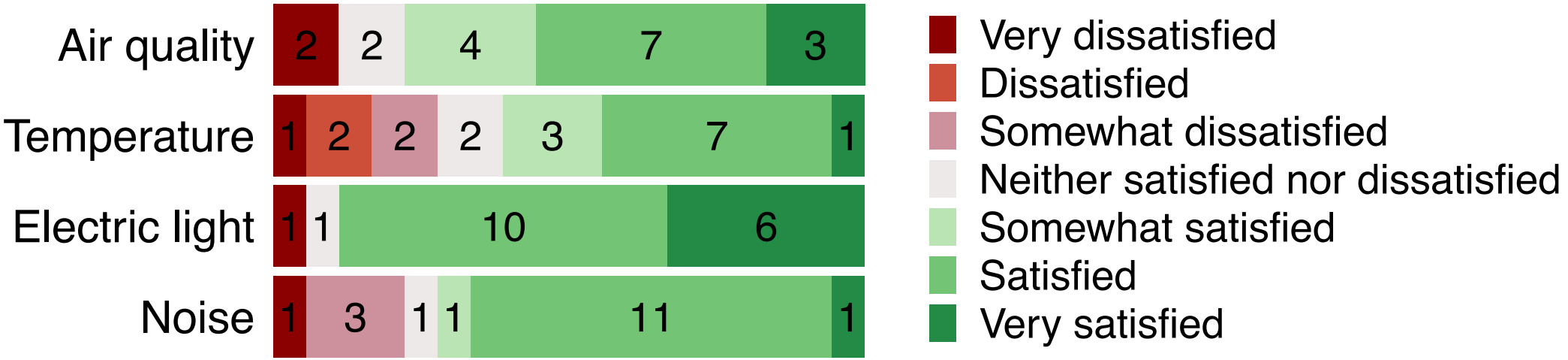


The horizontal dashed line indicates the air temperature thresholds that are subject to the provision of the Heat Illness Prevention Guidance (Cal/OSHA, 2024).

Thermal environment – subjective feedback

- Most staff reported general satisfaction with their kitchen environment
- Thermal conditions were the most cited source of dissatisfaction (5 out of 18), followed by noise (4 out of 18)

How satisfied are you with...



Summary

- **High indoor air pollution**

  During cooking hours, PM2.5 frequently and ultrafine particles consistently exceeded WHO guidelines. NO2 levels were higher during non-cooking hours.

- **Elevated heat stress**

  Kitchens experienced high indoor temperatures and radiant heat, potentially impacting worker comfort and health.

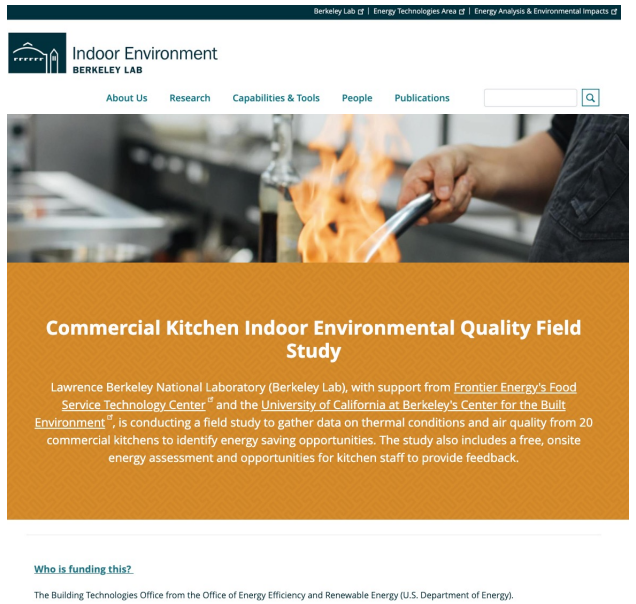
- **Inadequately maintained ventilation system**

  Most kitchens lacked adequate make-up air, contributing to poor capture of cooking pollutants and high heat stress.

- **Energy efficiency opportunities**

  Some energy-efficient equipment was found, and further adoption could reduce energy costs and emissions.

Project webpage



Please join the breakout session on

Indoor Environmental Quality in Less-Studied Building Types

Email: jiayu.li@berkerley.edu