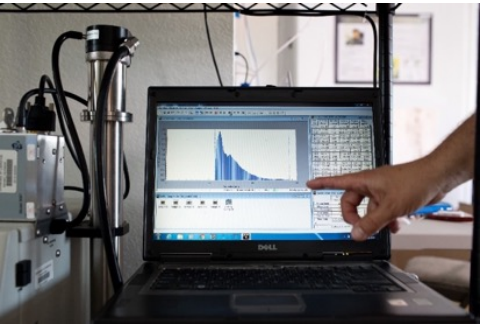


University of Colorado Boulder

Fine Particulate Matter Emissions From Cooking

Marina E. Vance

Assistant Professor,

Mechanical Engineering Department & Environmental Engineering Program

University of Colorado Boulder

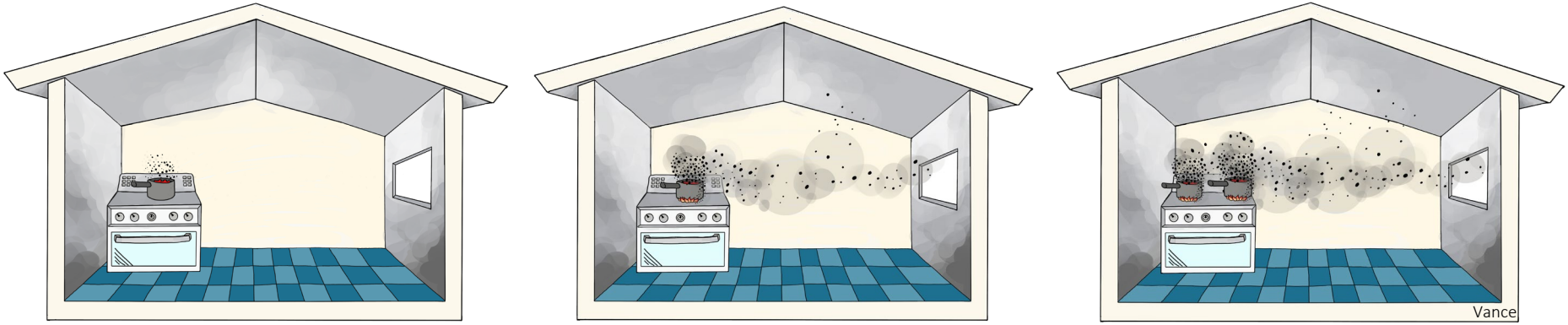
@marinavance

Indoor Exposure to Fine Particulate Matter and Practical Mitigation Approaches – A Workshop

The National Academies of Sciences, Engineering, and Medicine

April 14, 2021

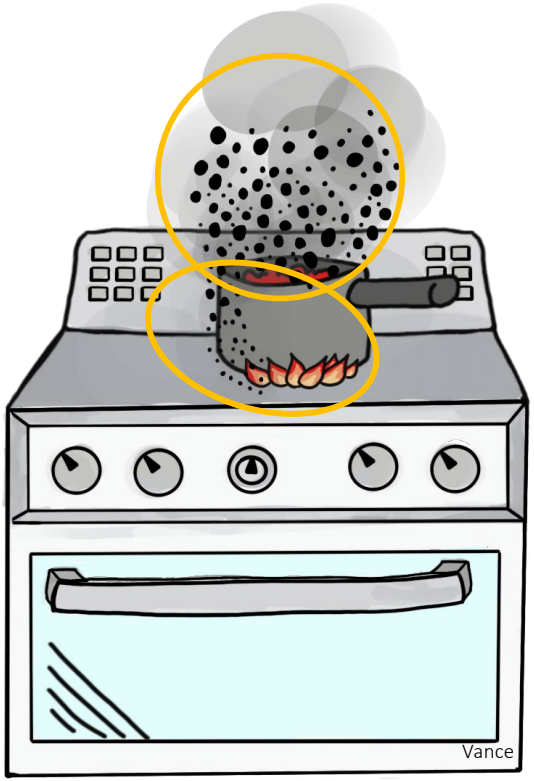
Cooking is one of many sources of indoor Particulate Matter (PM)



Cooking contributions to indoor PM can vary greatly from home home to the next

[2]

There are two air pollution components from cooking activities: heat source + food itself



Primary emissions:
Particles
VOCs
NO_X
etc.

There are two air pollution components from cooking activities: heat source + food itself

Example heat sources:

Solid (& liquid) fuels

~2.8 bi users worldwide

3.5 - 4 mi premature deaths (2010)

Smith et al. (2014) ARPH

Gaseous fuels

(propane, liquified petroleum gas, natural gas, biogas)

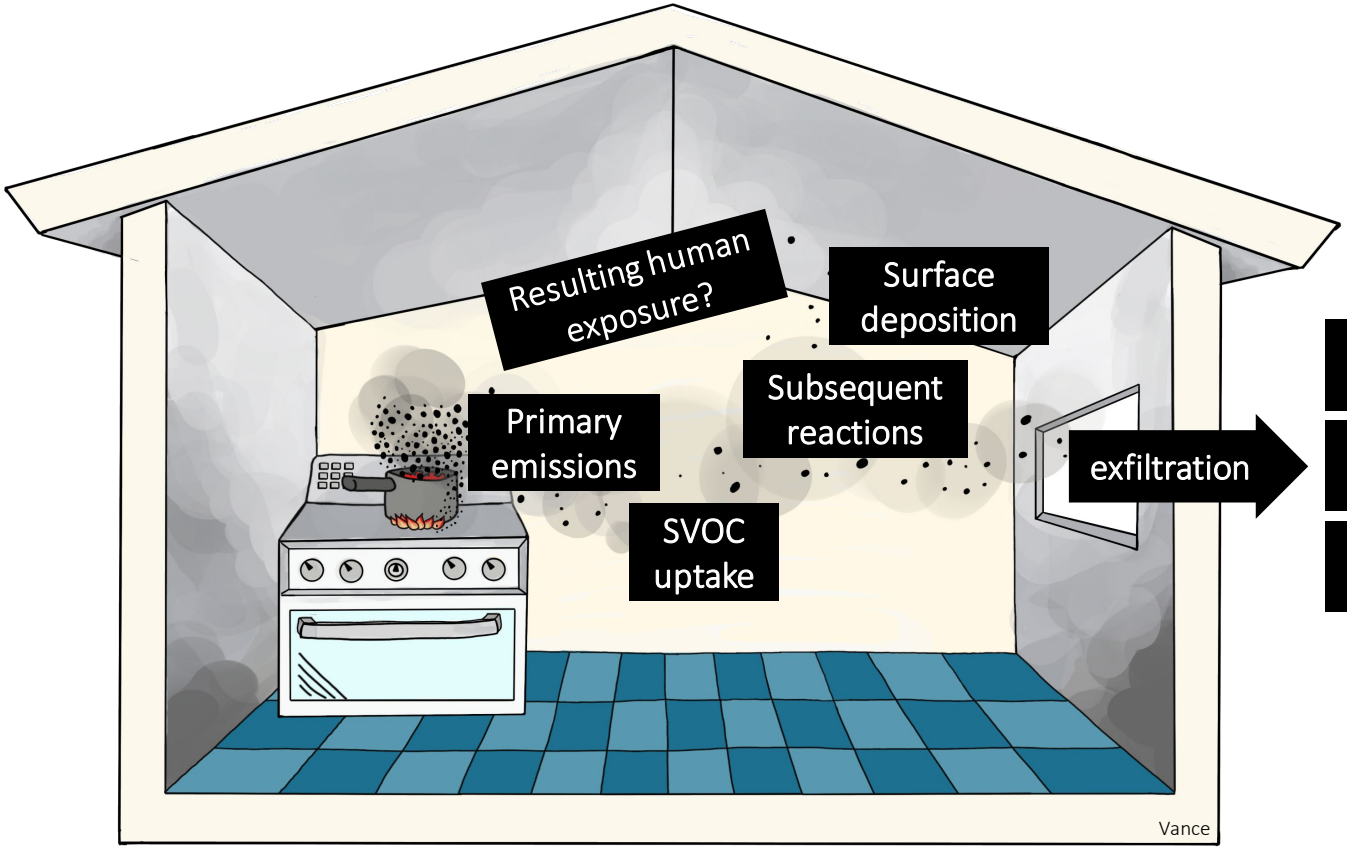
Electric

Induction

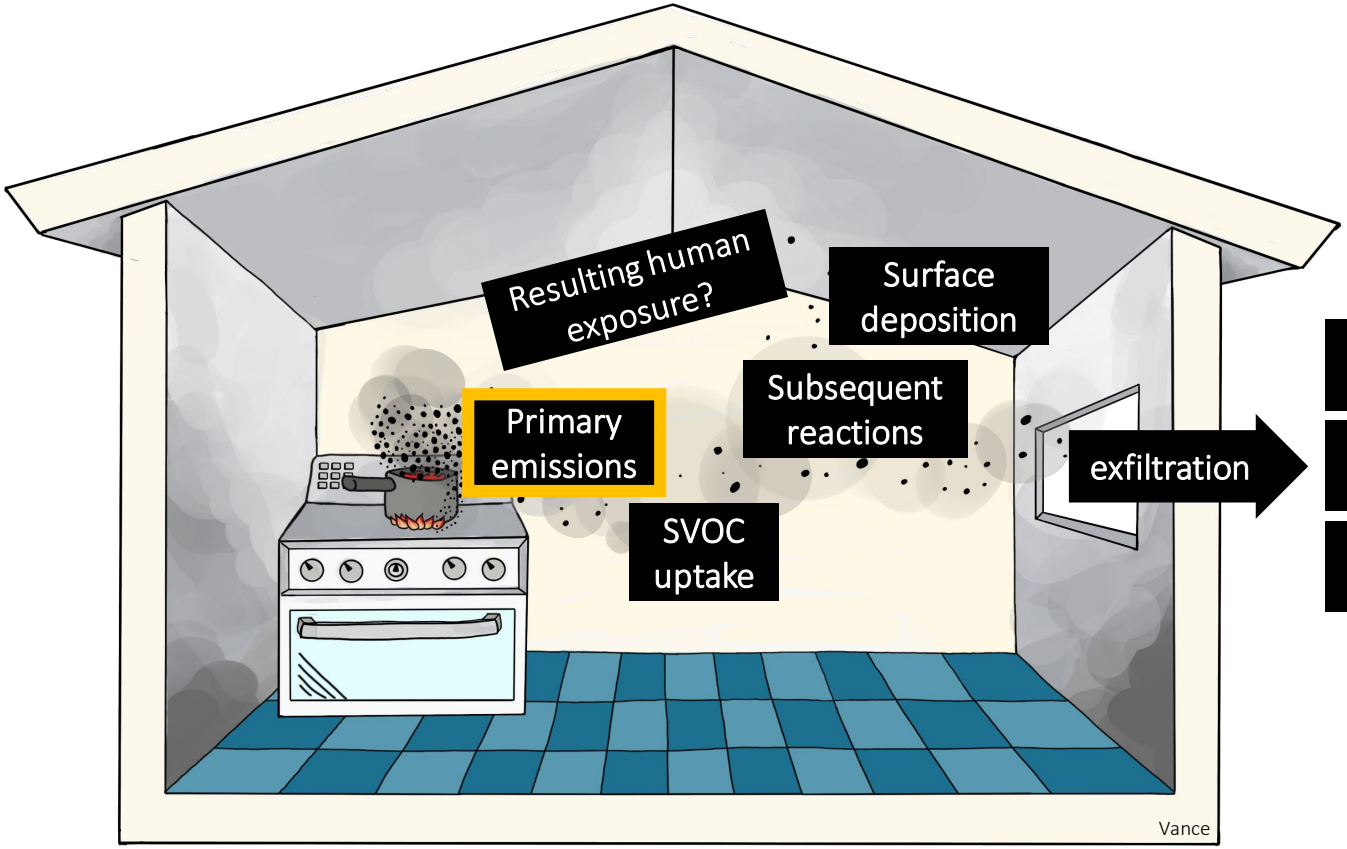
Emissions from food become important

[4]

Fate of indoor cooking emissions:

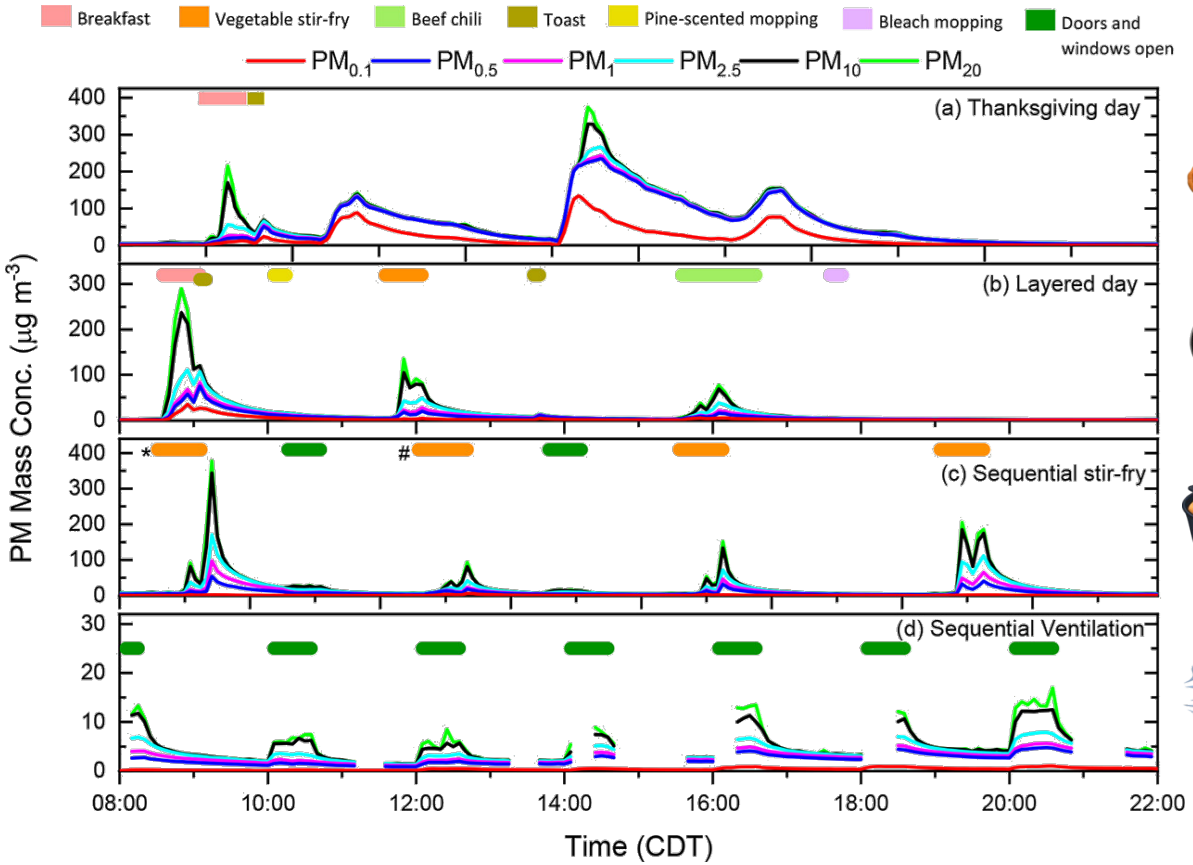


Fate of indoor cooking emissions:



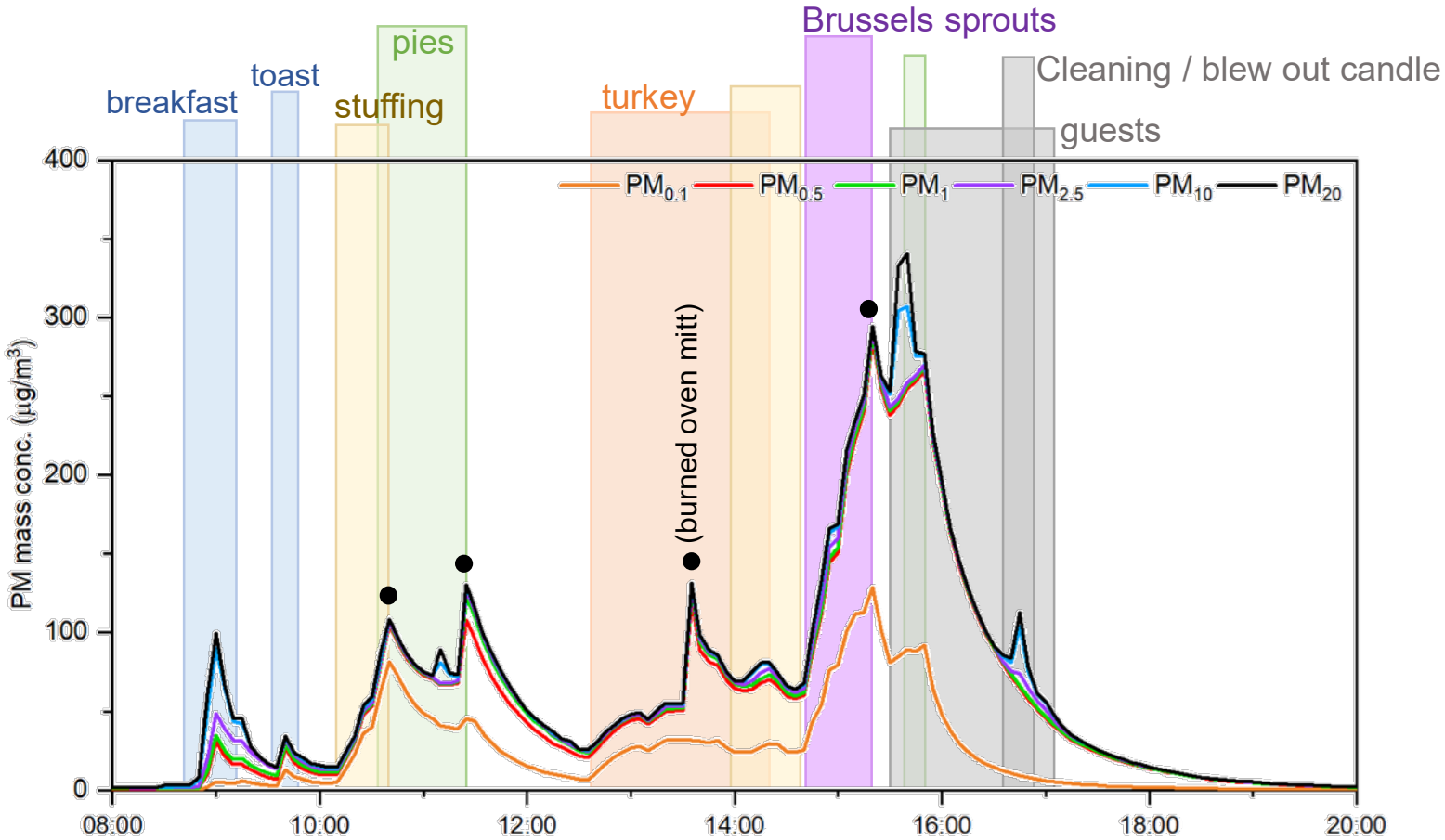
[6]

HOMEChem: High particle concentrations during cooking activities:



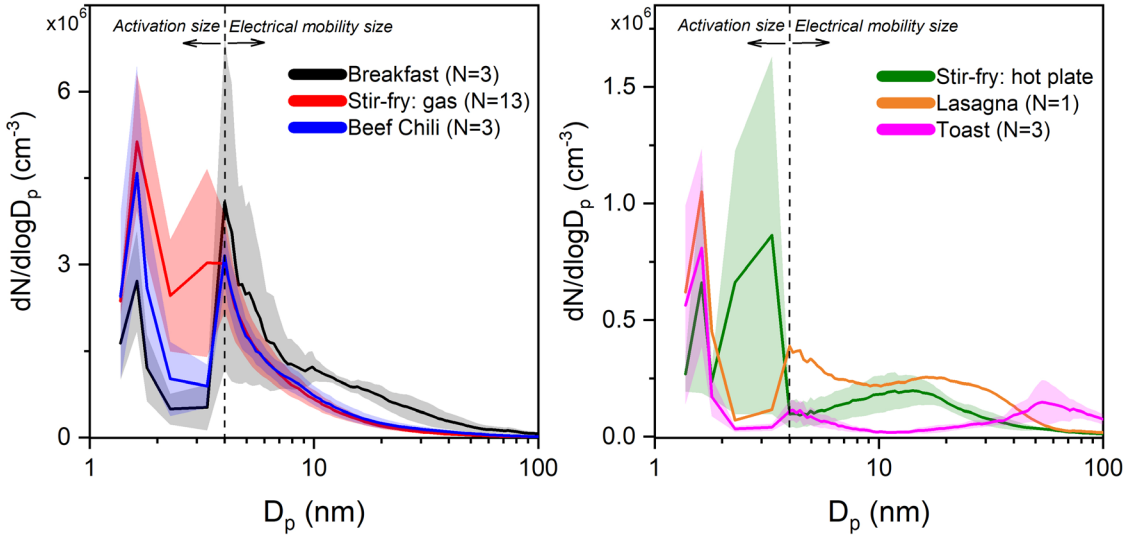
Patel et al. (2020) ES&T

Total PM mass concentrations during a Thanksgiving Day Experiment



Patel et al. (2020) ES&T

Particle number concentrations for specific meals were governed by the heat source:



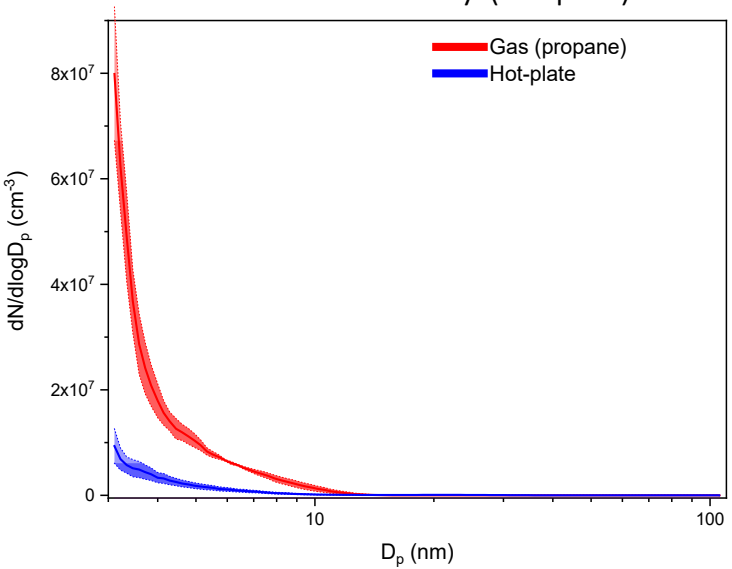
Gas stove preparations: ~4x higher PM number concentrations

Electric cooktop, oven, toaster resulted in lower PM number concentrations

Patel et al. (2020) ES&T
Also reported in Torkmahalleh et al. (20170) STOTEN

PM concentrations during stir-fry cooking: heat source vs food

Heat source only (no pan):

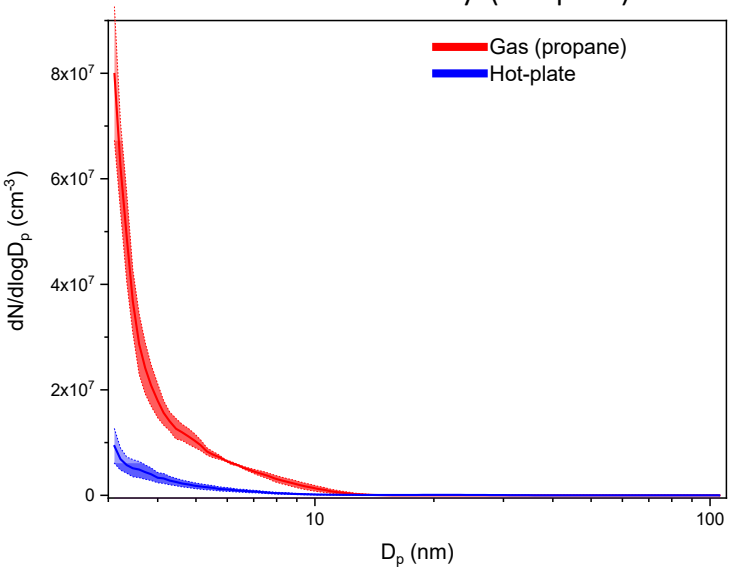


Gas stove generated 7x more particles than electric hot plate

Patel et al. (2020) ES&T

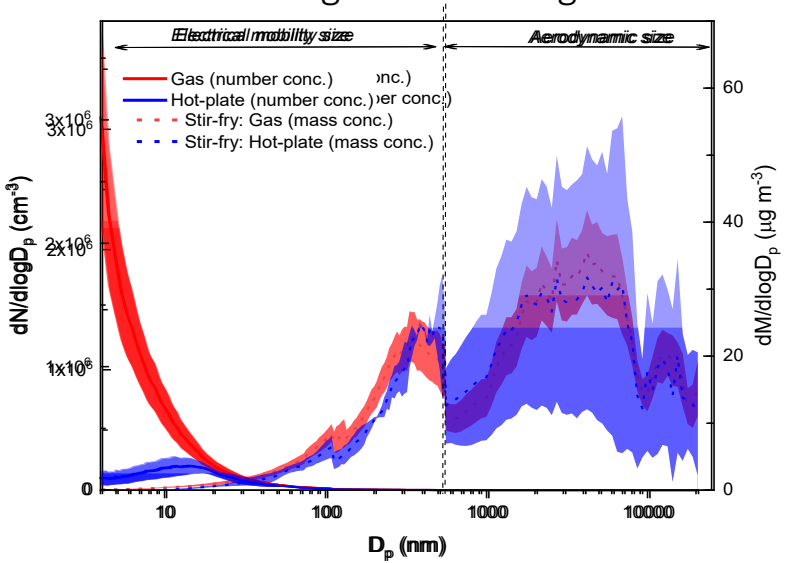
PM concentrations during stir-fry cooking: heat source vs food

Heat source only (no pan):



Gas stove generated 7x more particles than electric hot plate

During meal cooking:



During meal cooking, fewer sub-10 nm particles were emitted.

Heat source dominated particle # conc.
Food governed particle mass conc.

Patel et al. (2020) ES&T
Sub-10 nm PM also reported for natural gas by Minutolo et al. (2008) EES
Emissions from LPG combustion under investigation by Brandon Boor's group (Purdue Univ).

Cooking PM composition varies greatly

- ~>50% of the indoor cooking emissions are **organic in nature.**

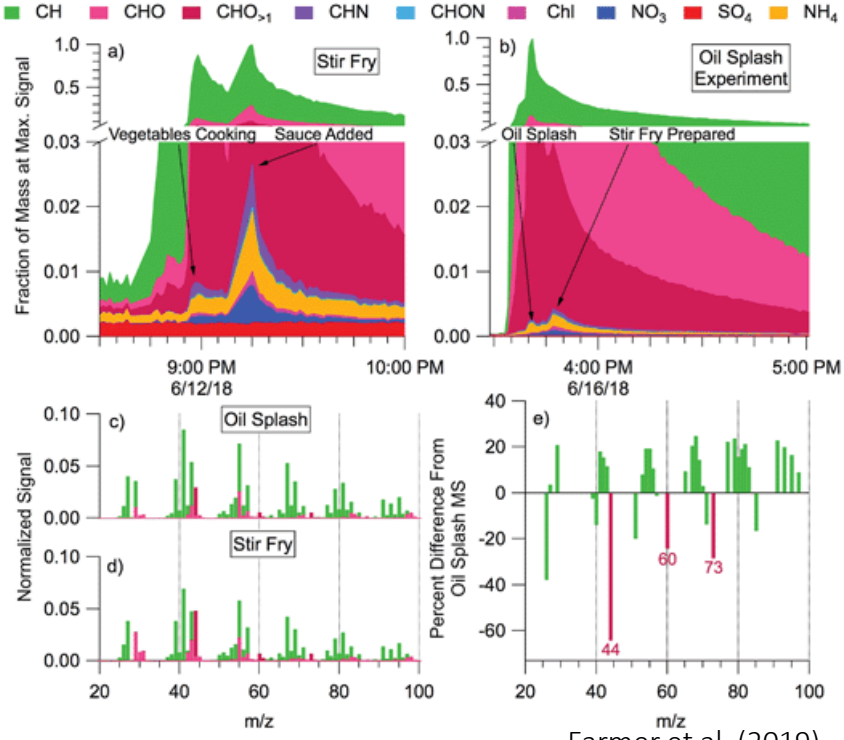
  Klein et al. (2020)
  He et al. (2004)
  Farmer et al. (2019)

- **Composition profiles and emission rates vary greatly** with ingredients, cooking style, heat source, exposed surface area, type, and temperature of oils.

  Farmer et al. (2019)
  Torkmahalleh et al. (2017)

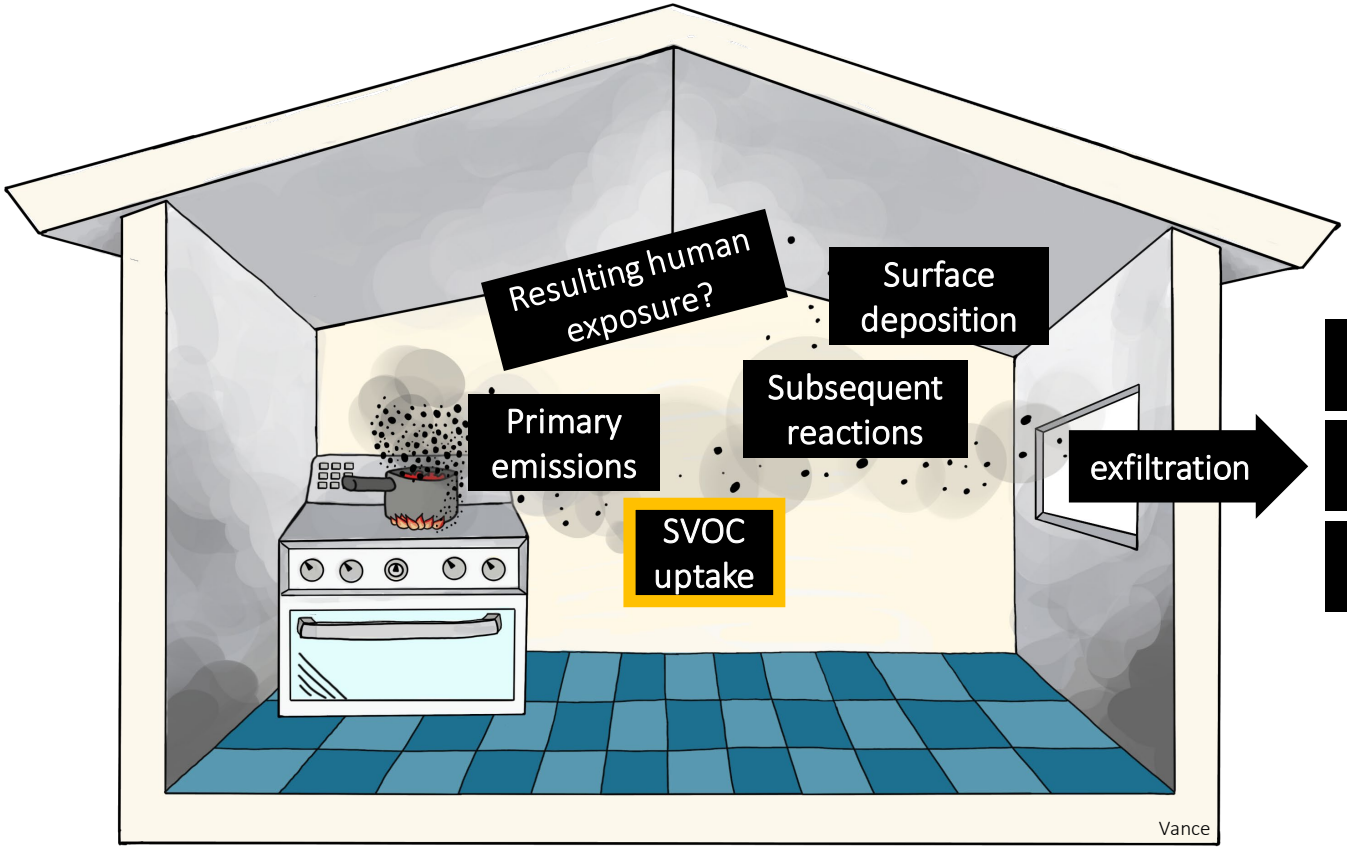
- **PAH concentrations associated with cooking PM** are highly variable

  He et al. (2004)
  Torkmahalleh et al. (2017)
  Wang et al. (2017)

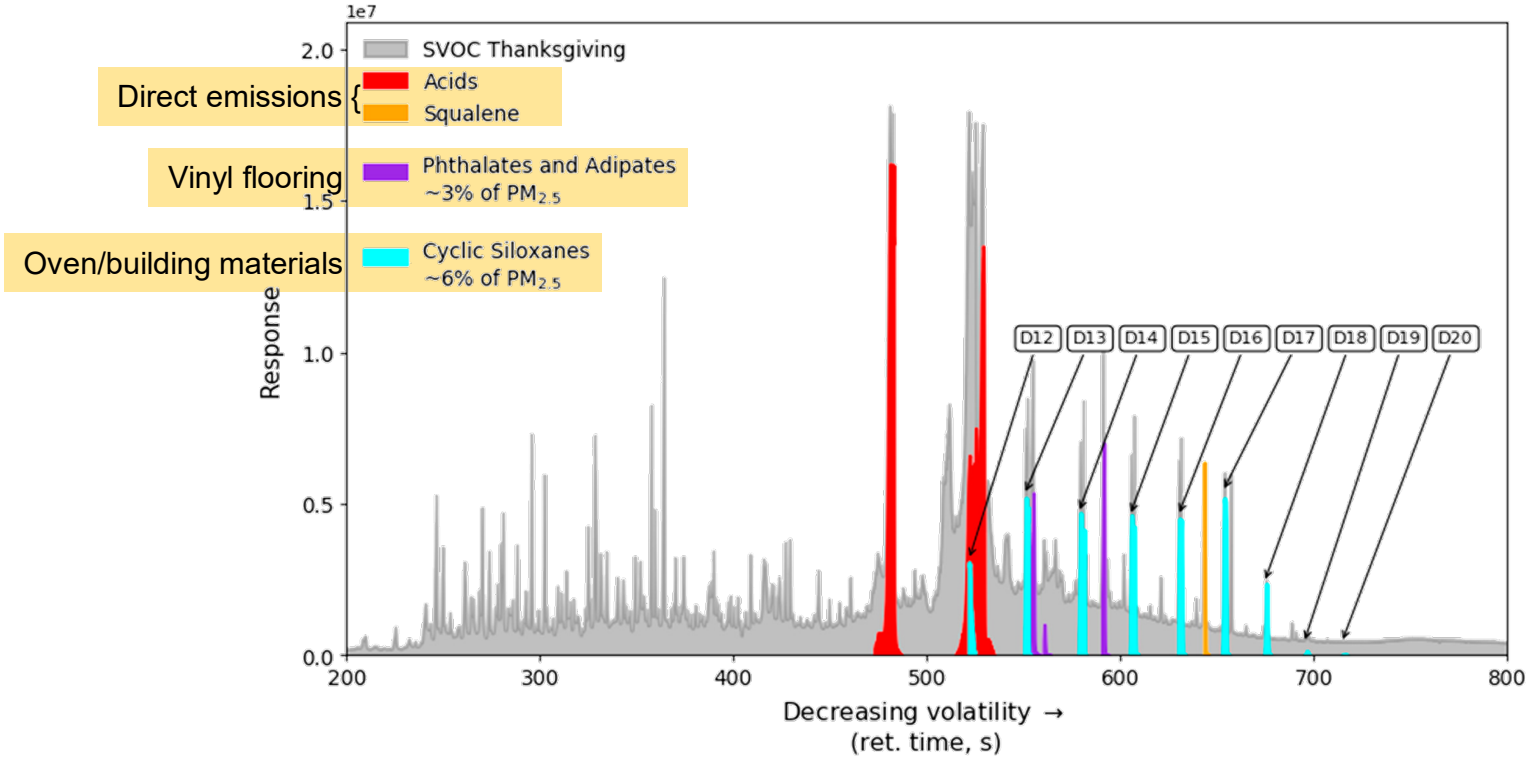


Farmer et al. (2019)

Fate of indoor cooking emissions:



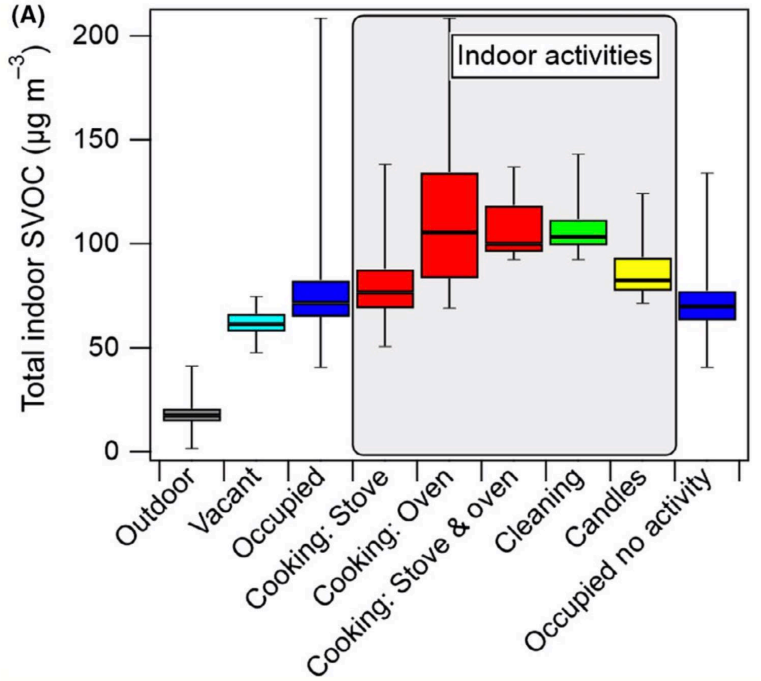
Particle-phase SVOCs enhanced during cooking

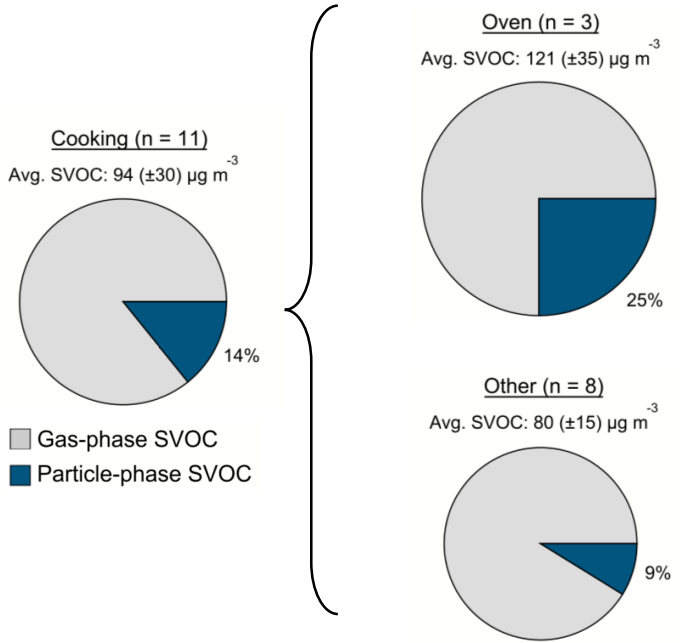


Lunderberg et al. (2020) ES&T

SVOC concentrations enhanced during indoor residential activities:

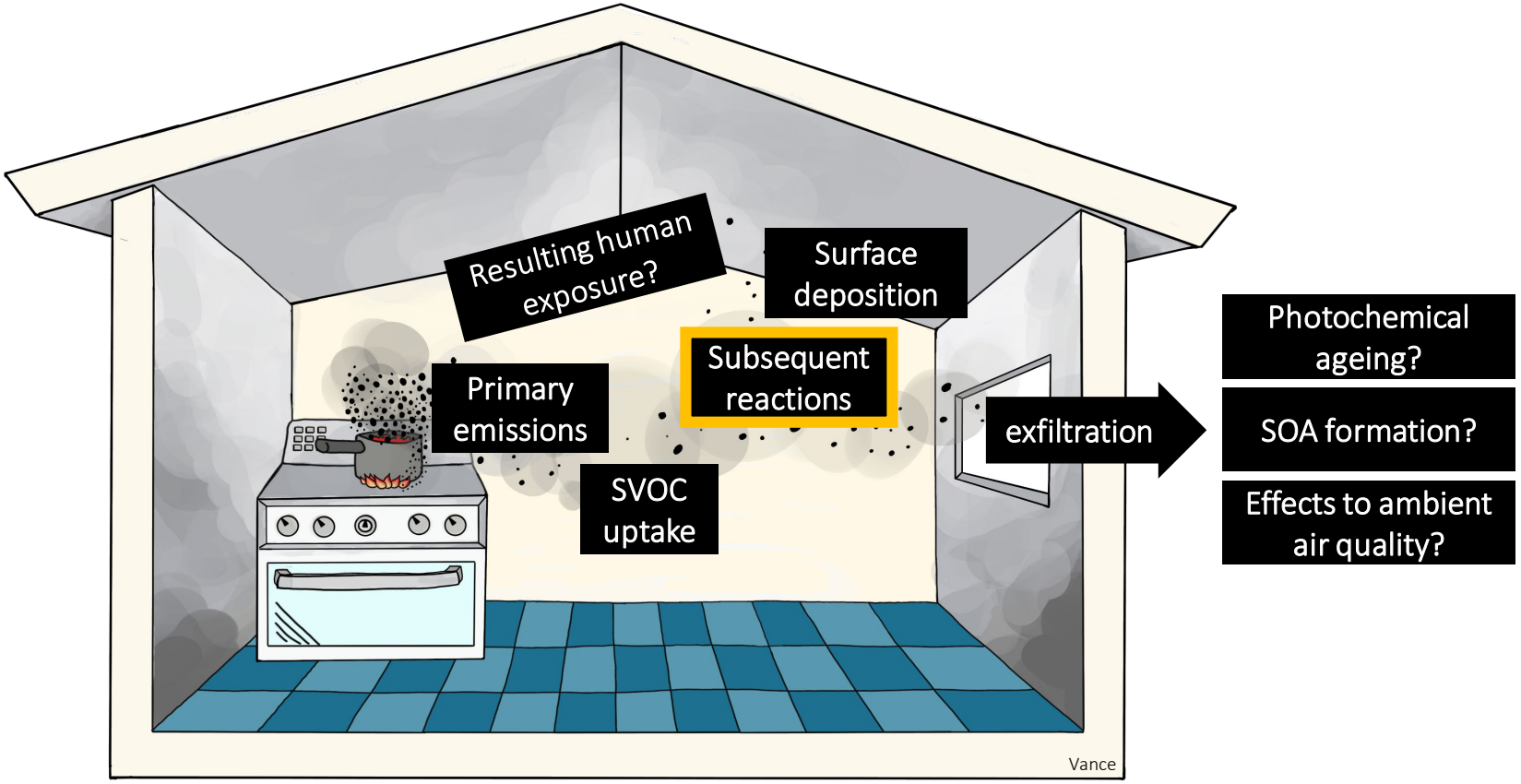
Total indoor concentration of SVOCs (gas phase + $PM_{2.5}$ particle-bound):





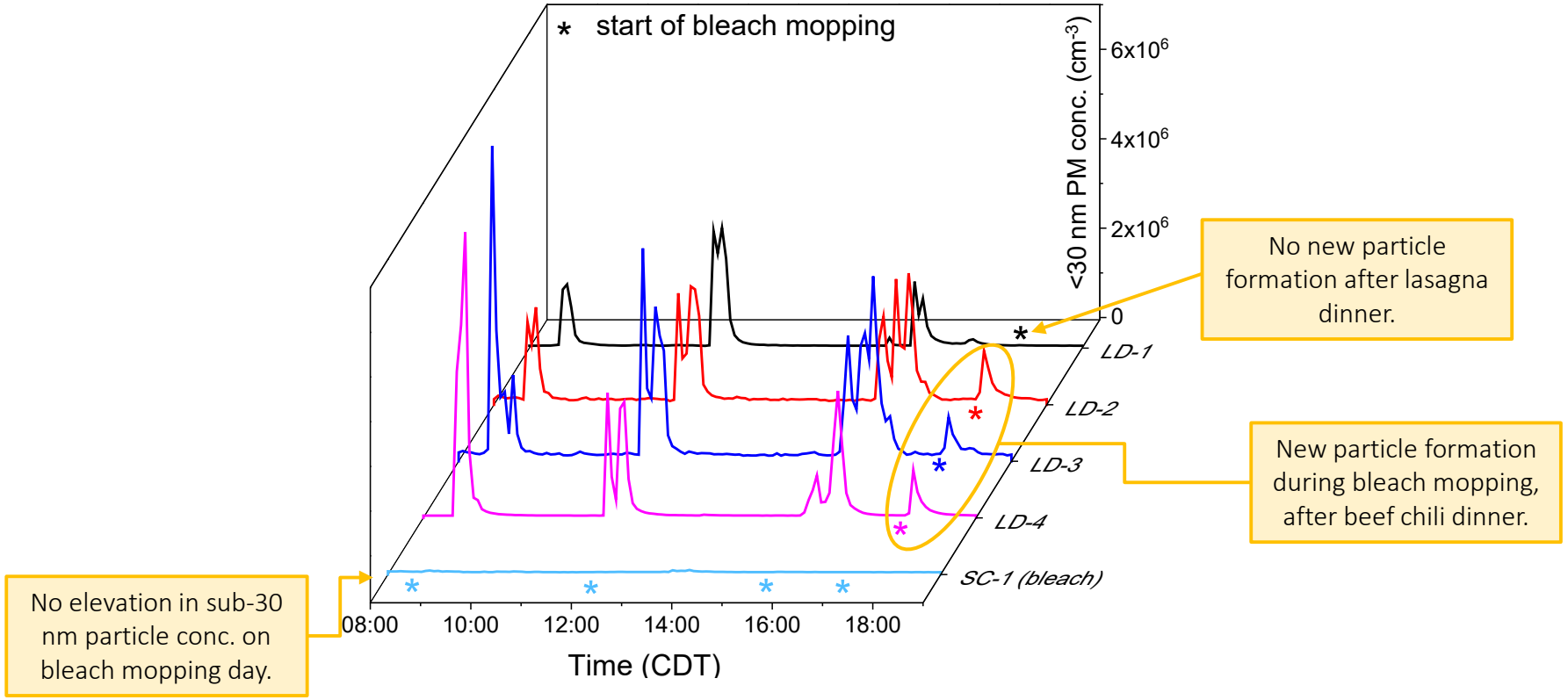
Kristensen et al. (2019) Indoor Air

Fate of indoor cooking emissions:



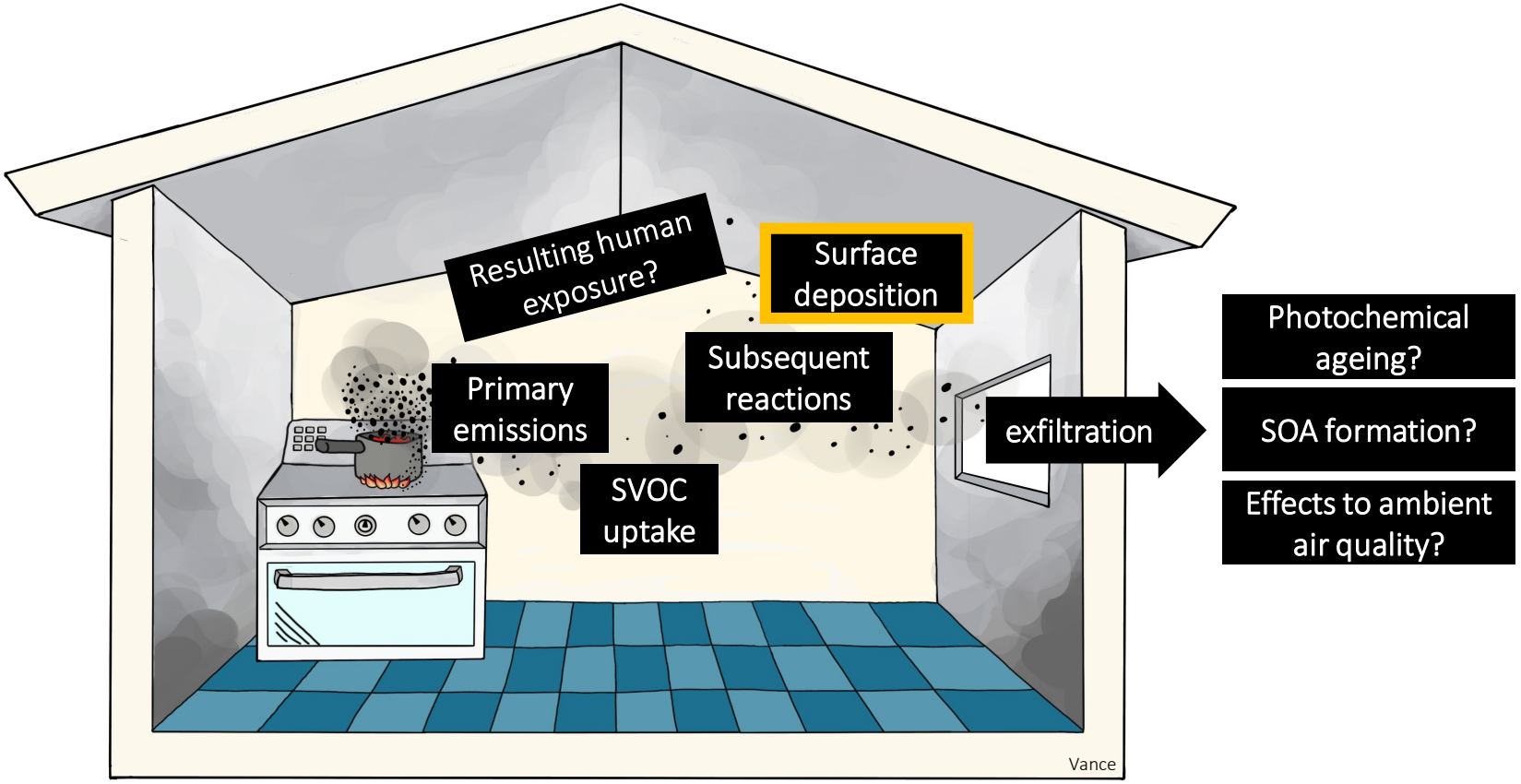
[16]

Volatile emissions from cooking activities may interact with cleaning products to spur new particle formation



Patel et al. (2020) ES&T

Fate of indoor cooking emissions:

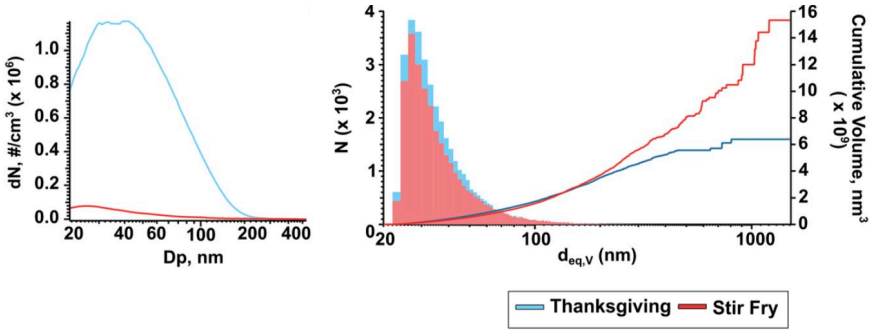


Indoor surfaces can be an important sink for organic-rich PM indoors

Although Thanksgiving produced higher PM concentrations in air, similar deposition was observed on surfaces

Cumulative particle number distributions

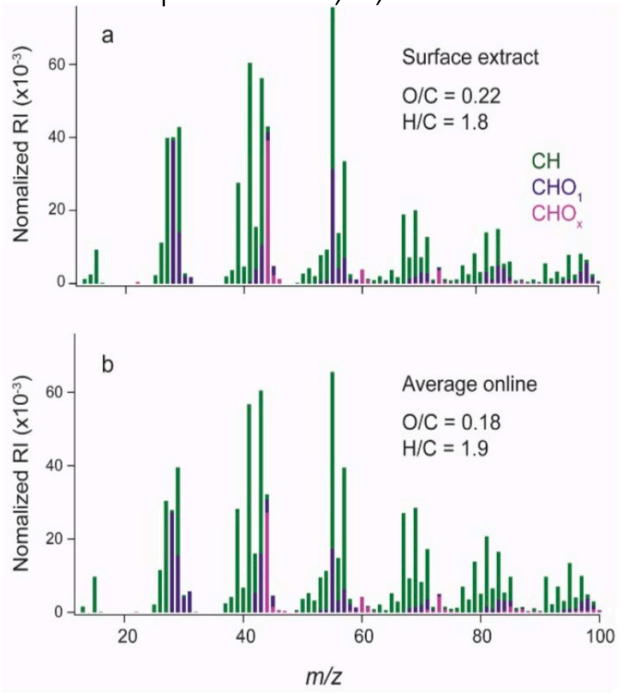
Airborne: Deposited onto glass:



Or et al. (2020) ESPI

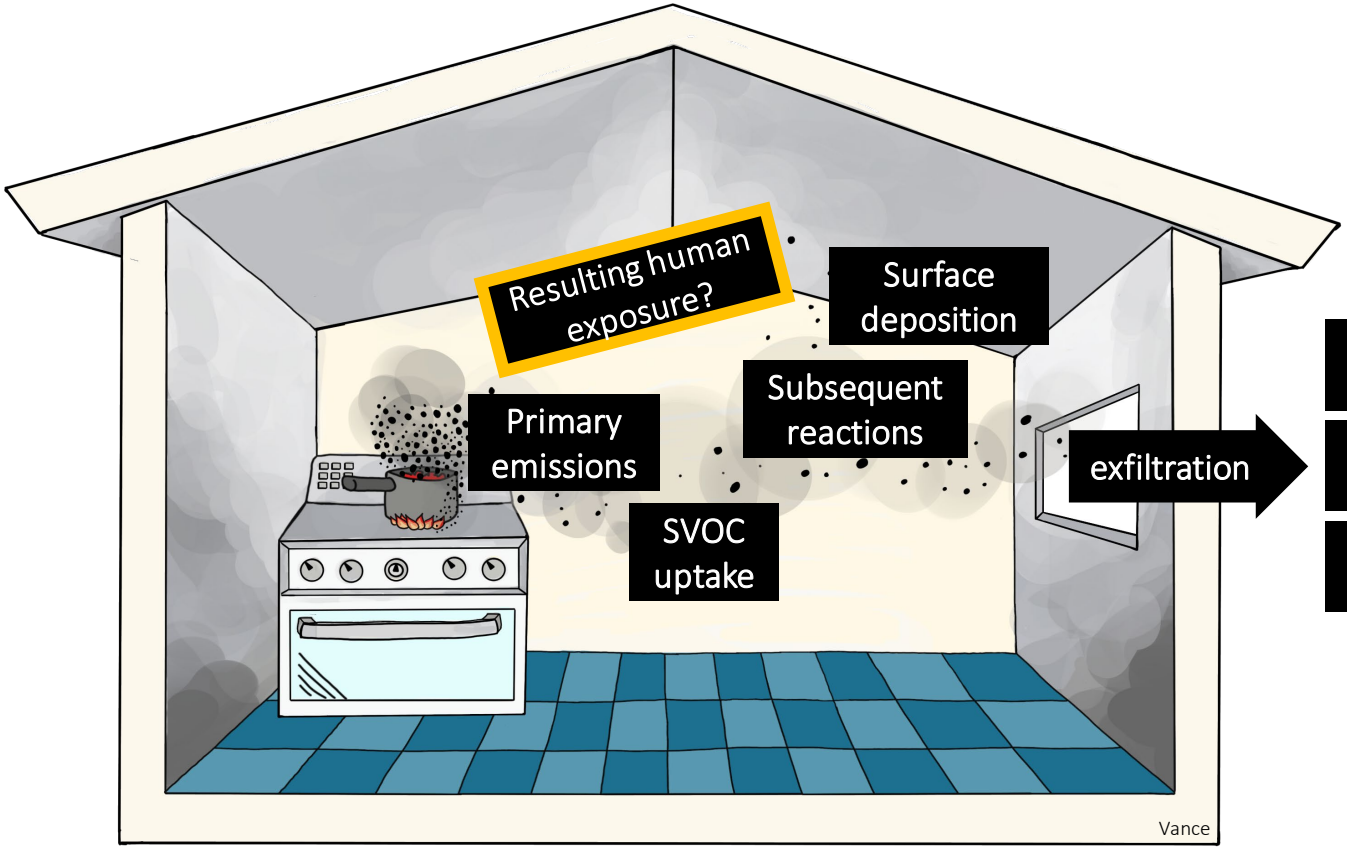
Material accumulated on glass surface had similar chemical properties to COA particles measured by online AMS

AMS mass spectra for C, H, and O containing ions

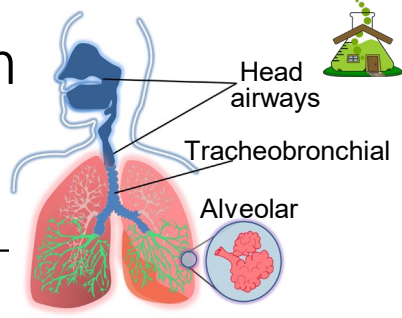


O'Brien et al. (2021) ESPI [19]

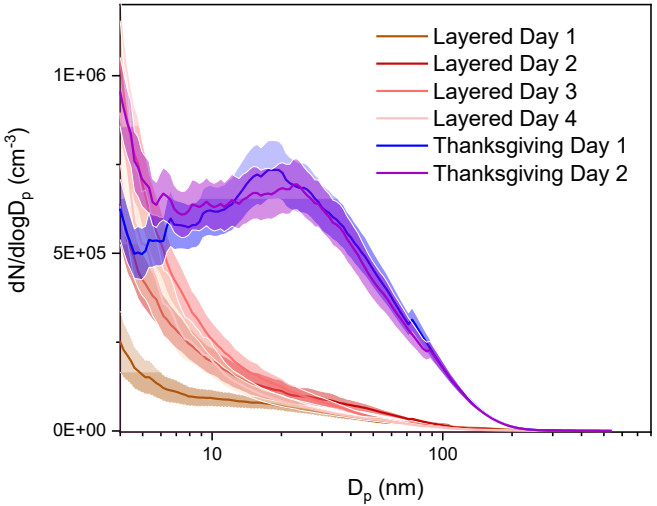
Fate of indoor cooking emissions:



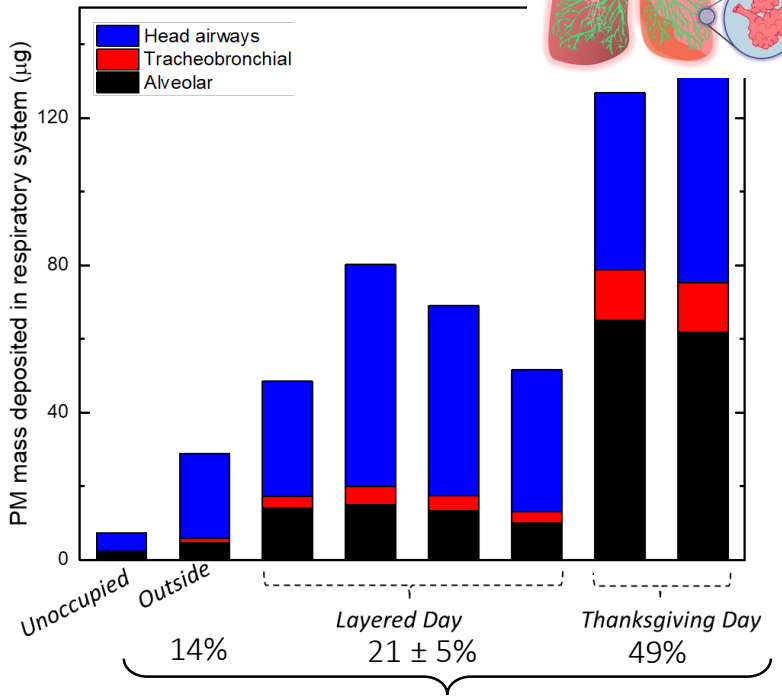
PM mass deposited in the respiratory system



Sub-10 nm and sub-100 particles dominated on 24-hr averaging basis:



24-h average particle number size distributions



Deposition in the alveolar region

Patel et al. (2020) ES&T

Toxicity can vary with cooking preparations

Cancer risk from PM_{10}-bound PAHs:

Fig. 3. Cancer risks from inhalation of PM_{10}-bound PAHs for common kitchen usage patterns (4 h a day, 350 days a year).

Bioassay toxicity of PM_{10} :

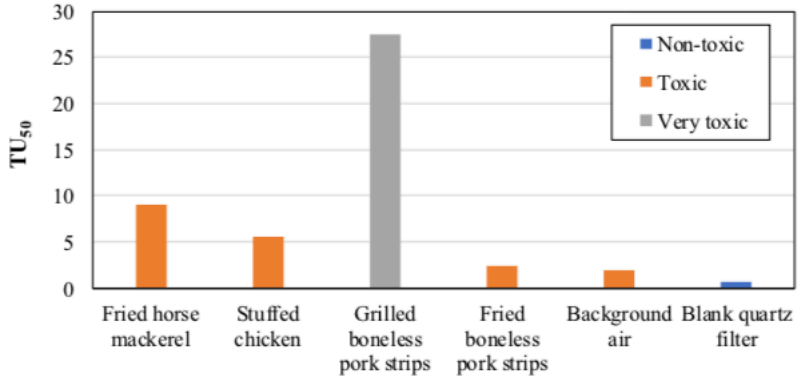


Fig. 6. Toxicity of each sample, expressed in toxic units, based on the results of the *Vibrio fischeri* bioluminescence inhibition bioassay.

(in this study, $PM_{2.5}$ comprised 86% or more of PM_{10})

Alves et al. (2021) STOTEN

Persistent knowledge gaps related to indoor cooking PM

Commonalities/differences among cooking styles/ingredients.

How does ventilation affect particle fate and exposure?

Does the chemical composition affect health?

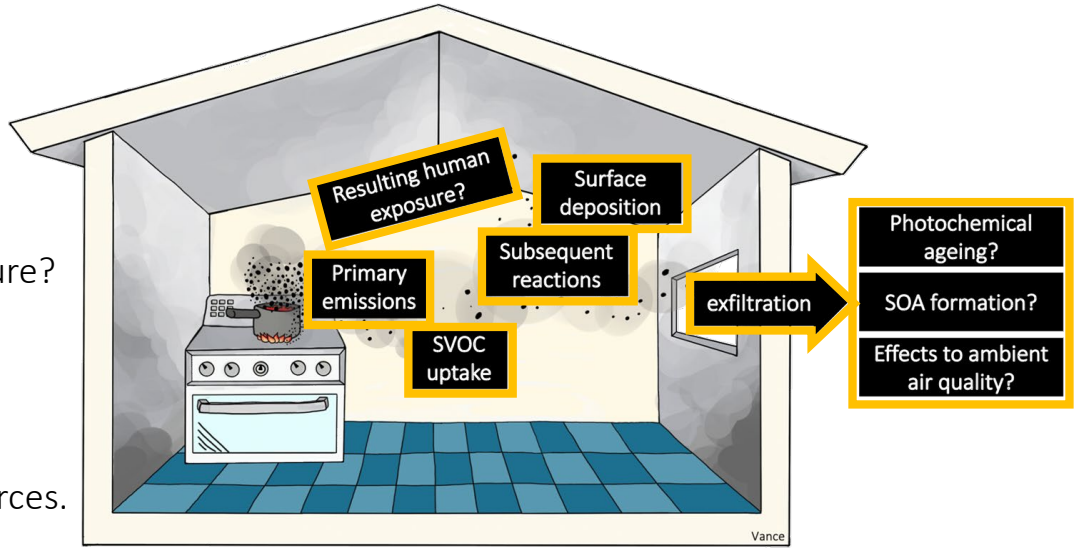
- Bulk composition from different cooking styles/ingredients.
- Influence of sorbed compounds from other sources.

Metrics for exposure and health:

- Number vs mass?
- Dose vs exposure time?

Socioeconomic disparities.

Contributions of indoor cooking activities to ambient air quality.



Broad scientific consensus:

For point sources of air pollution → Control emissions at the source

Indoor cooking emissions →
- Electrify cooking
- Use effective source control: range hood / portable air cleaner

[23]

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*Additional references of interest not included in this talk.

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Indoor Chem
www.indoorchem.org
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