An Inventory of Emissions of Organic Aerosols from Commercial Cooking in the UK

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Overview

Introduction – why emissions from commercial cooking are important

An approach for estimating emissions from commercial cooking in the UK

Independent verification of emission estimate via an alternative approach

Generating an inventory time-series

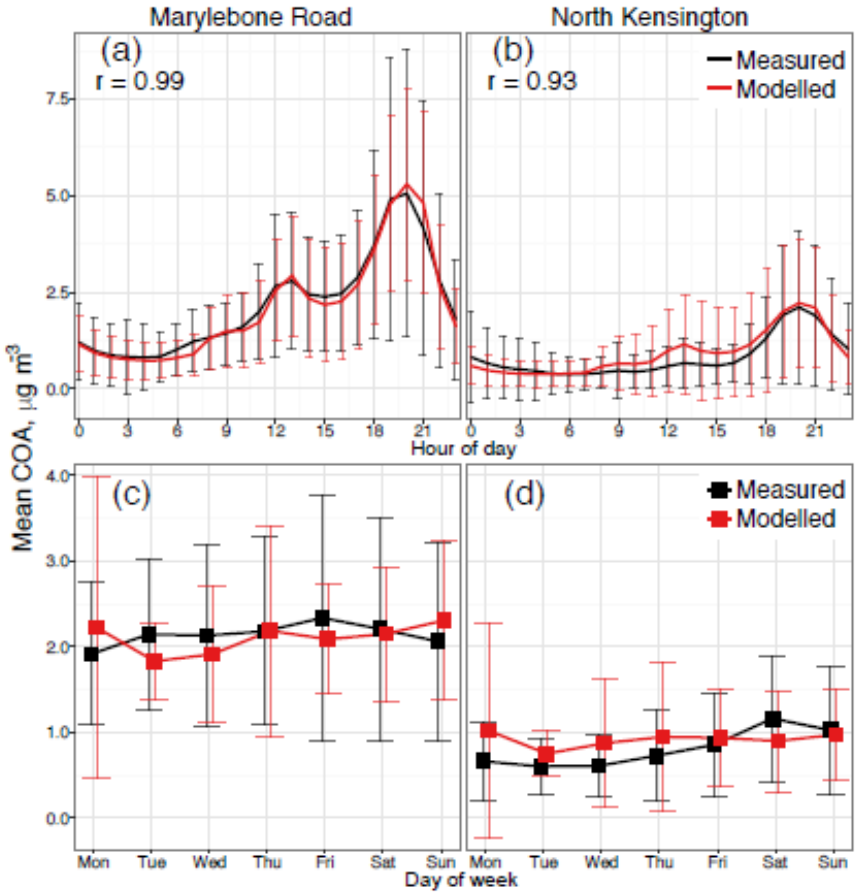
Uncertainties and limitations of approach

Summary and conclusions

Evidence for Cooking Organic Aerosols in the UK

- Evidence of cooking organic aerosols (COA) from ambient measurements at 2 sites in Central London through ClearFlo studies in 2012/13

- Analysis of Aerosol Mass Spec data by Ots et al (2016) led by UK Centre for Ecology and Hydrology shows measurements at Marylebone Rd correlate with activities associated with commercial cooking establishments, restaurants etc
  - Annual mean COA 1-2 μgm^{-3}
  - Inverse modelling approach with EMEP4UK model in conjunction with workday population data used to estimate total UK COA emissions of 7.4 kilotonnes in 2012



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Emissions of Cooking Organic Aerosols in the UK

- Emissions of cooking organic aerosols (COA) from commercial cooking establishments, restaurants etc are not included in the UK's national emissions inventory (NAEI)
  - Emissions from use of fuels in commercial cooking are captured in 1A4a

- Emissions are included in the London Atmospheric Emissions Inventory based on the same ClearFlo measurement campaign in London and similar inverse modelling approach.

- Emissions in London distributed using
  - Ordnance Survey (OS) data on commercial premises registered as preparing food in restaurants and takeaways
  - Food industry employment data for London in bars, restaurants and takeaways

$PM_{2.5}$ Emissions from the London Atmospheric Emissions Inventory (2016)

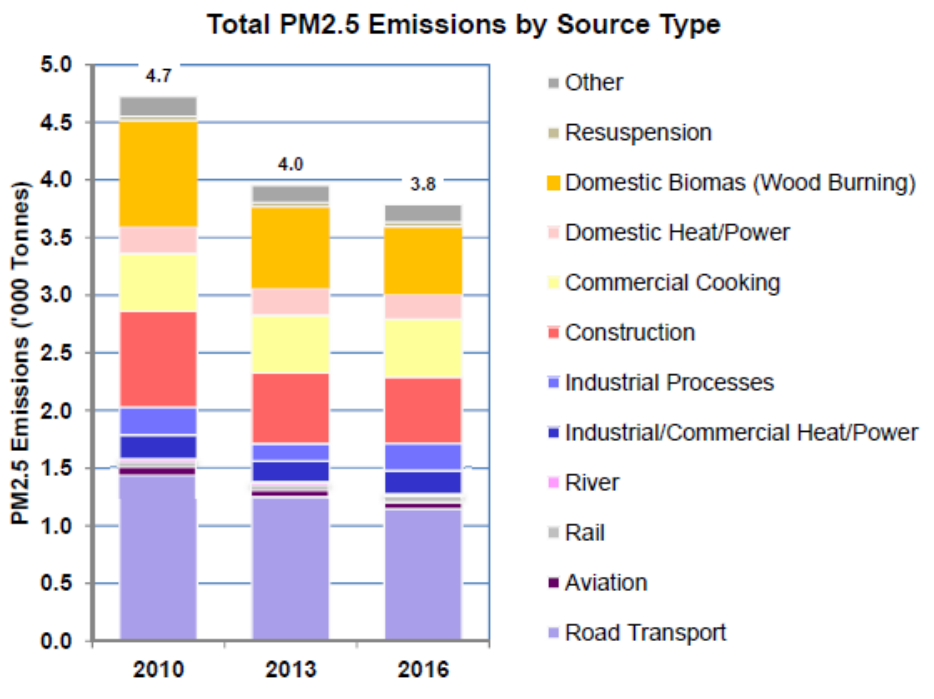
Dashboards - $PM_{2.5}$ Emissions - Greater London

Emissions (Tonnes)	2010	2013	2016
Road Transport	1,435	1,253	1,149
Aviation	72	54	56
Rail	49	50	53
River	25	23	20
Industrial/Commercial Heat/Power	210	183	201
Industrial Processes	241	150	238
Construction	829	613	574
Commercial Cooking	502	502	502
Domestic Heat/Power	234	232	215
Domestic Biomas (Wood Burning)	918	709	590
Resuspension	39	38	38
Other	171	148	152
Total	**4,726**	**3,955**	**3,789**

The summary graph represents emissions from each source stacked on top of one another, with the total stack height equalling the total emissions from all sources

The numbers in the table are those used to plot the graph and represent the tonnes of pollutant emitted into the atmosphere in that year (tonnes/year)

The emissions are combined into reasonably self explanatory "Source Types"



- LAEI 2019 data available at https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2019

Upscaling London Emission Estimates to the UK

- COA emissions in London in 2012 = 502 tonnes $PM_{2.5}$ according to LAEI

- Scaling emission estimate for London to UK using UK/London ratios in
  - ONS Workday population data (as used by CEH) → 3.7 kilotonnes $PM_{2.5}$
  - ONS detailed food service employment data (as used by LAEI) → 2.9 kilotonnes $PM_{2.5}$

- Ots et al estimate for UK = 7.4 kilotonnes:
  - Factor of 2 difference between these approaches is consistent with the view given in Ots et al that AMS "*may overestimate COA concentrations by up to a factor of 2*" (also stated in other studies)

Independent Verification of COA Emission Estimate

- Emission factors in the literature based on food consumption for different cooking styles – mostly residential
- Highest COA emission rates tend to come from charbroiling of red meat. Literature values range from 1 gPM/kg meat - frying red meat to 40 gPM/kg meat charbroiling meat with high fat content
- Siouti et al (2021) used a value of 8 gPM/kg meat to model emissions and concentrations of PM from residential cooking in Greek city of Patras.
- Combining this factor with UK consumption of red meat of 32.1 grammes per person per day in 2012 (from National Diet and Nutrition Survey) leads to UK PM emission rate of 6.0 kilotonnes in 2012 – **but refer to all types of cooking**
- Fountoukis et al (2016) implied EF 80 mgPM per person per day – ambient aerosol measurements in Paris → **1.9 kilotonnes PM in 2012**
- **Imperial College, London – PM emission estimate 5.8 – 10.4 kilotonnes assuming all meat charbroiled/fried**

Summarising Base Year Emission Estimate for 2012

- To recap:
  - Preferred value based on upscaling of London inventory estimate derived from ambient COA measurements and modelling:
    - 2.9 – 3.7 ktonnes $PM_{2.5}$
  - Range of emission estimates based on meat consumption and emission factors:
    - 1.9 – 10.4 ktonnes $PM_{2.5}$
- Reconciling the differences:
  - Meat consumption estimates tend to be higher – cover both residential and commercial cooking and not possible to separate
  - Variation in types of cooking and how these relate to the commercial cooking in the Central London area
  - Considering the differences in approach, the estimates based on London COA measurements aligns reasonably well with estimate derived from an IEF characteristic of charbroiling which is most likely to be associated with commercial cooking activities in central London
- **Proposed emission estimate for the UK = 3.3 ktonnes (range 1.5 to 5 ktonnes) in <u>2012</u>**

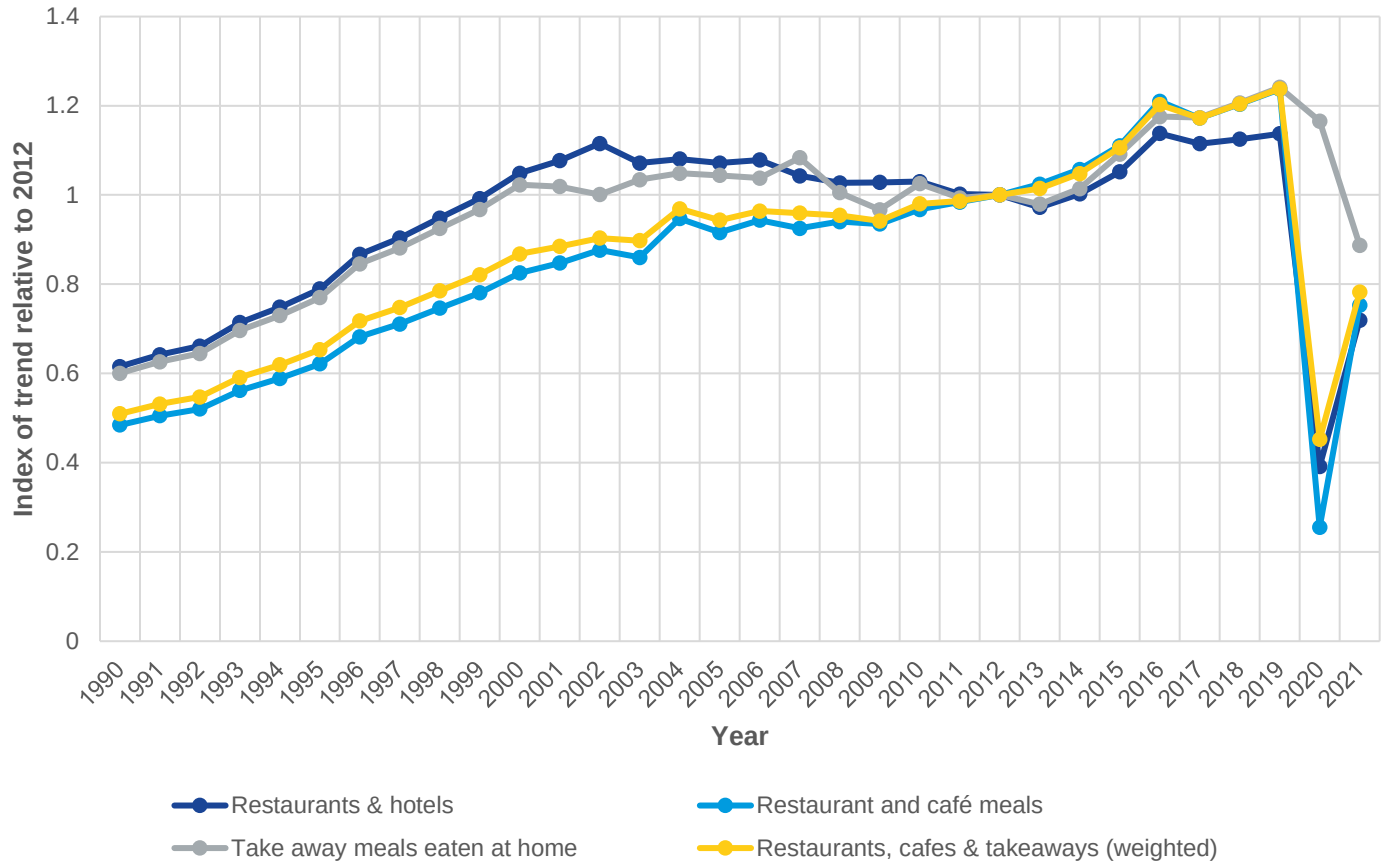
Time-Series for Emissions from Commercial Cooking

- Emission estimate derived from ambient COA measurements refer to a 2012 base year

- Time-series trend based on employment or expenditure statistics for the sector as proxies for trends in commercial cooking activities and emissions?

- Office of National Statistics (ONS) data on:
  - average weekly household expenditure on restaurants & hotels
  - average weekly household expenditure on restaurants & café
  - average weekly household expenditure on takeaway meals
  - Number of households
  - UK Consumer Price Index

Time-Series Trend in Weekly Household Expenditure in Restaurants and Cooking Establishments



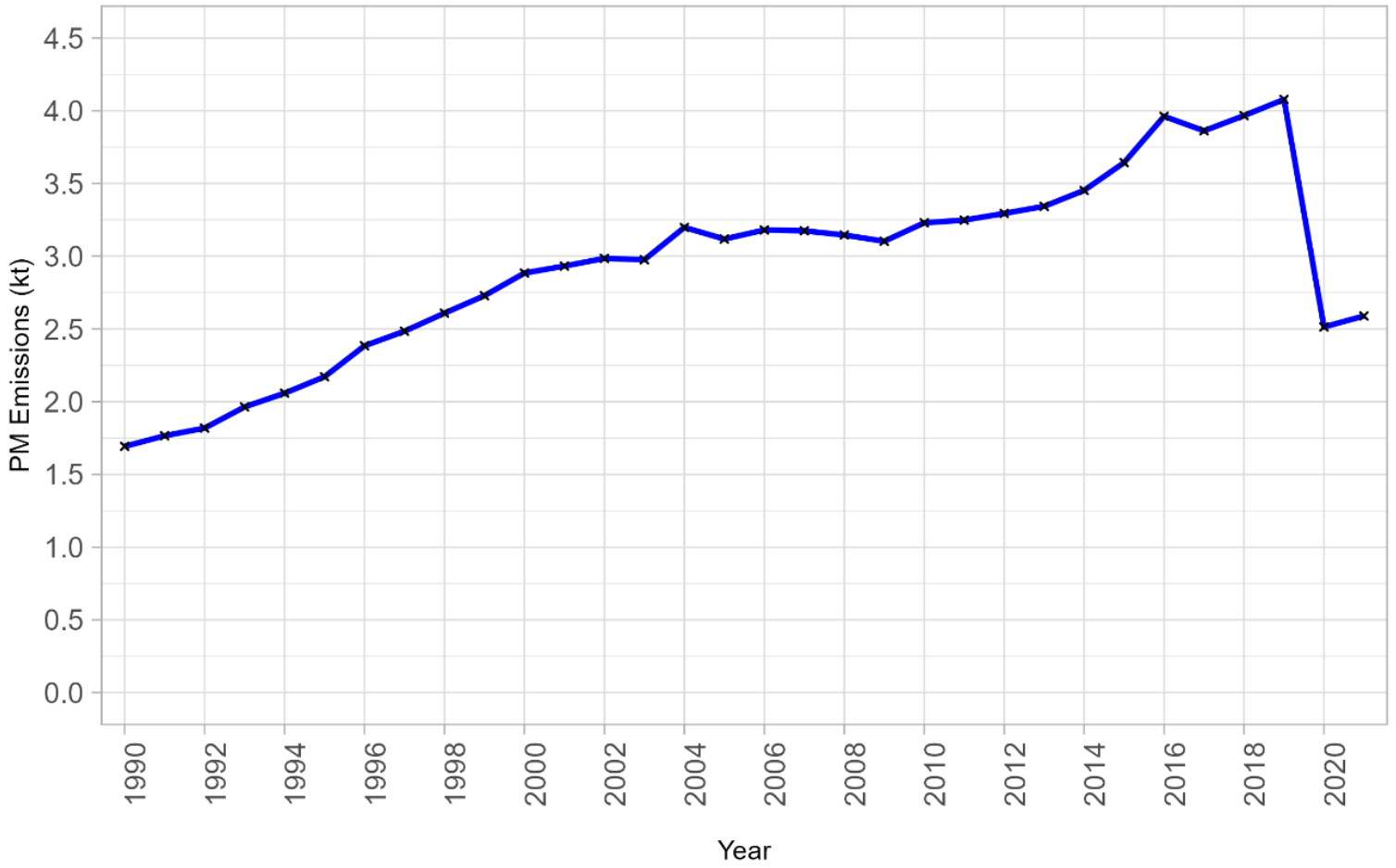
Data sourced from UK Office of National Statistics

Time-Series Trend in Red Meat Consumption

Red meat consumption data sourced from Stewart et al (2021) based on National Diet and Nutrition Survey. Downward trend may reflect changes in diet by UK population weighted by meat consumption at home.

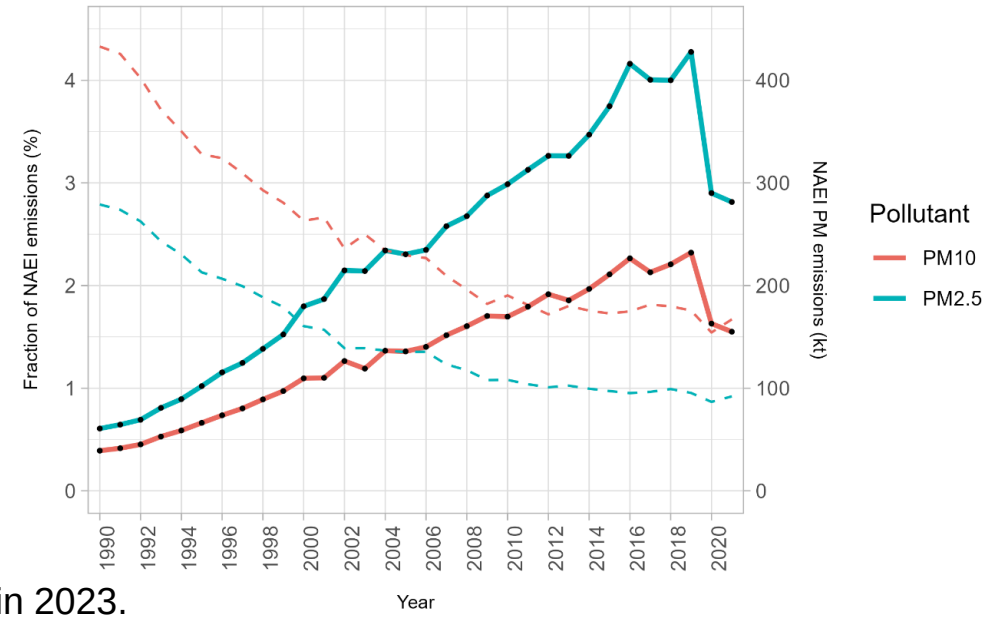
PM Emissions from Commercial Cooking in the UK

- Time-series defined by COA measurement in London in 2012, upscaled to UK
- Time-series based on trend in weighting of household expenditure in restaurants, cafes and take-aways



UK Emissions of PM from Commercial Cooking and as % of Total UK Emissions from Other Sources

Pollutant	Emission	1990	2000	2010	2015	2016	2017	2018	2019	2020	2021
PM2.5	Cooking emissions (kt)	1.7	2.9	3.2	3.6	4.0	3.9	4.0	4.1	2.5	2.6
	NAEI total (kt)	279.0	160.5	108.1	97.2	95.2	96.4	99.2	95.4	86.7	92.0
	% of total	**0.6%**	**1.8%**	**3.0%**	**3.7%**	**4.2%**	**4.0%**	**4.0%**	**4.3%**	**2.9%**	**2.8%**
PM10	Cooking emissions (kt)	1.7	2.9	3.2	3.6	4.0	3.9	4.0	4.1	2.5	2.6
	NAEI total (kt)	432.8	263.1	190.3	172.8	174.9	181.4	179.7	175.7	154.3	167.1
	% of total	**0.4%**	**1.1%**	**1.7%**	**2.1%**	**2.3%**	**2.1%**	**2.2%**	**2.3%**	**1.6%**	**1.5%**



- Total PM emissions data shown are from the 2021 NAEI - UK submission to CLRTAP in 2023. Emissions from commercial cooking were not included in that submission
- For the purpose of these comparisons, the UK totals shown here include sources reported as Memo items, not included in official national totals

Uncertainties and Limitations of Approach

- The approach is UK specific and not based on a traditional EF x AD approach due to lack of EF data, but it should help to close the gap in modelling ambient PM concentrations

- Major assumption is that emissions per unit expenditure has remained unchanged over time which is unlikely:
  - Changes in different types of cooking establishments over time, e.g. restaurant types, takeaways…
  - Changes in food preference, cooking practices and styles

- Mix of different types of cooking establishments in central London may not be representative of types in other regions, towns and cities

- Activity data may exist on trends in food consumption, restaurant, cooking types, but lack of EFs
  - increasing amount of data in the literature on Efs for different types of residential cooking may give some insight in how factors for different types of commercial cooking may vary, although subject to differences in scale and appliances used

UnderstandING the sourcEs, traNsformations and fates of IndOor air pollUtantS" (INGENIOUS)

- https://ingenious.york.ac.uk/about

The INGENIOUS project will quantify and identify:

• the composition and concentrations of air pollutants within indoor spaces, such as those from cooking and cleaning;

• how air pollutants react chemically and transform over time, including when different air pollutants mix;

• how air pollutants from indoor air sources affect outdoor air quality and vice versa;

• how different household behaviours affect the production of and exposure to air pollutants and how this affects health outcomes and inequalities;

• which behaviour change interventions are most effective at reducing exposure to indoor air pollution; and

• which recommendations to take forward as policy solutions.

Summary and Conclusions

- An emission rate of 3.3 ± 2 ktonnes PM_{10} and $PM_{2.5}$ has been estimated for commercial cooking sources in the UK in 2012 based on an emission estimate made for London derived from ambient measurements of COA at two sites in central London, upscaled using workday and food service industry employment data

- Time-series developed using trends in household expenditure on eating establishments, rising to 4.1 kt in 2019 (4.3% of UK totals $PM_{2.5}$) and reflecting a fall in 2020, 2021 due to the COVID pandemic.
  - The UK is still considering the conclusions of this work so these emissions are not yet included in UK's inventory submissions

- Further evidence from ambient monitoring is required to verify this trend → trend in IEFs?

- The approach is relatively simple to introduce to an annual inventory compilation, through use of ONS annual activity statistics, notwithstanding the above issue regarding assumptions on IEFs. Which NFR:
  - NFR 2H2 "Food & Beverages Industry"?
  - NFR 6A "Other"?

- The approach does provide a basis for applying spatial datasets to map out emissions, as required by modellers, e.g. use of data on location of restaurants, employment data

- Emission projections need consideration of trends in future activity data and IEFs

Acknowledgements

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