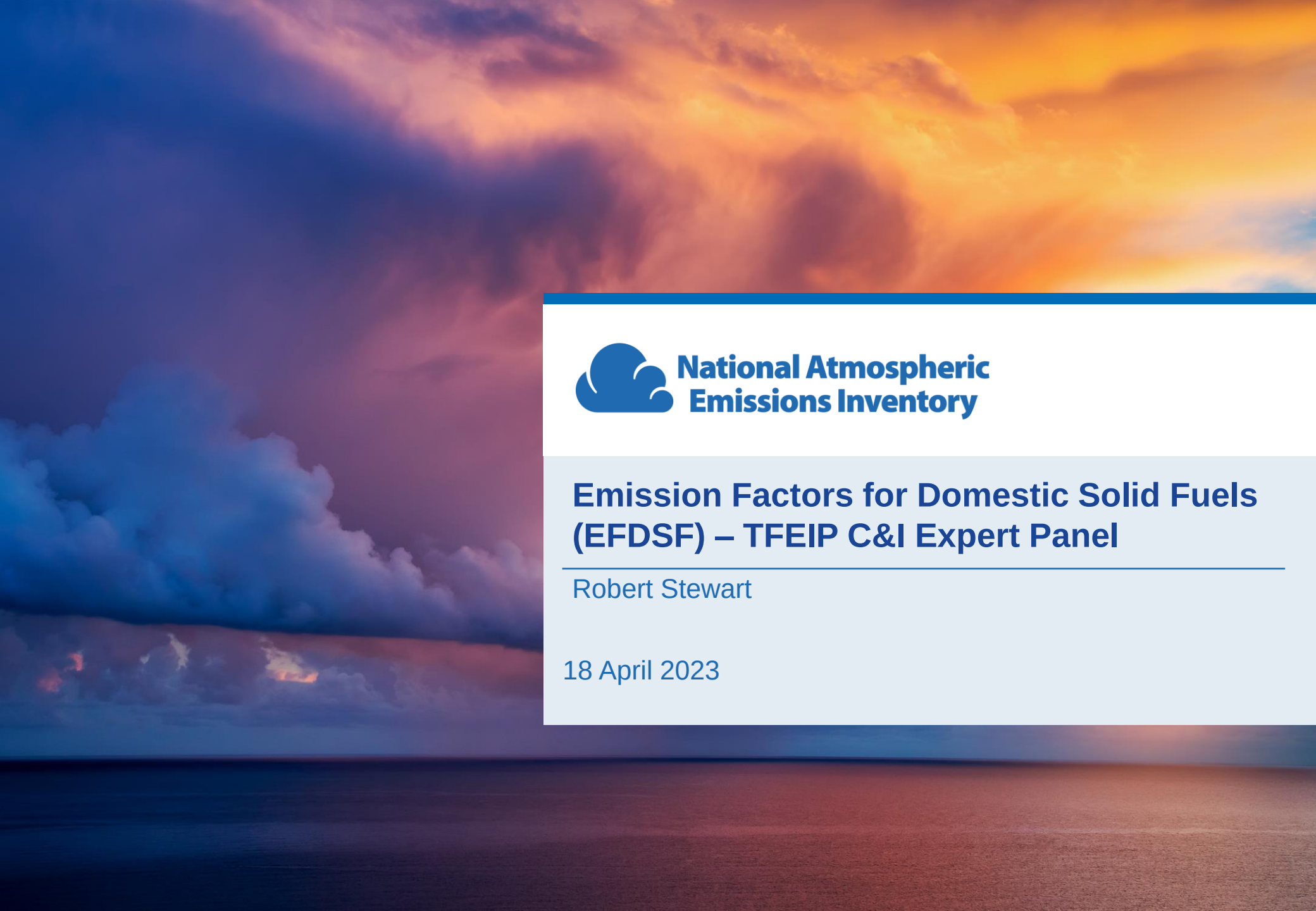


National Atmospheric Emissions Inventory

Emission Factors for Domestic Solid Fuels (EFDSF) – TFEIP C&I Expert Panel

Robert Stewart

18 April 2023

AGENDA

- Introduction to EFDSF Project
- Project team
- Objectives
- Work Programme
- Outputs to date

INTRODUCTION TO EMISSION FACTORS FOR DOMESTIC SOLID FUELS (EFDSF) PROJECT

- EFDSF project to provide emission factors for various pollutants, solid fuels and appliances for UK emission inventory (NAEI).
  Aim to extend current 'Tier 2' model for residential wood – providing emission factors for wood of varying moisture contents and a range of appliance types to enhance NAEI model and replace/enhance default (EMEP/EEA Guidebook) emission factors.
  Implement use of 'Tier 2' model for residential solid mineral fuels for wider range of pollutants and enhance emission factors for solid mineral fuels used in UK.
- Part of a suite of Defra-funded projects looking to improve evidence on residential burning.
  Domestic Burning Survey – led to the major revision to UK energy statistics for wood in 2021, repeat survey underway;
  NAEI domestic combustion model improvement (this has been designed to allow easy assimilation of EFDSF project emission factors);
  Emerging fuels study

PROJECT TEAM

Defra
Contract Manager,
Evidence and policy
teams

Stakeholders :
Project Steering Group
NAEI delivery team
NAEI Steering Group

OBJECTIVES

- Improve NAEI emission estimates for residential solid fuel use through development of emission factors (EFs) for range of pollutants with high contribution to NAEI and with high uncertainty.
- Develop a reliable test protocol for measuring EFs so that experiments are as real-world and repeatable as possible.
- Round robin tests to help develop test protocol
- Develop EFs for selected domestic solid fuels on a range of appliances :

  WP1 - Wood fuels
  WP2 - Other fuels
- WP3 extends measurements to include further appliances.

WORK PROGRAMME

To provide pollutant emission factors for residential solid fuel and appliances commonly used in UK :

- Fuels :
  - 0-10% moisture (very dry wood)
  - 11-20% moisture (seasoned wood)
  - 21-30% moisture (wet wood)

  - house coal
  - anthracite
  - manufactured solid fuels (MSFs)
  - coffee logs

WORK PROGRAMME

Appliances

Open fire
Parkray Paragon
(standard setting)

Oldest Stove
Hunter Oakwood
(released 1997)
Primary + Secondary

~ 2010 Stove
Dovre 500MFR
(~ 2008)
Primary + Secondary

Modern Stove
Charnwood C-Four
(*Blu wood version)
Primary + Secondary
+ Tertiary

WORK PROGRAMME

Emission measurements
Particulate Matter (filterable and total)
Black Carbon
Particle size ($PM_{10/2.5/1}$)
Polycyclic aromatic hydrocarbons (PAH)
Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs)
NOx, SOx, TOC, CO, CO_2
Heavy metals (WP2) – As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn, Sb, Co, Mn, Tl, V

WORK PROGRAMME

Test protocol

- How to measure ‘real-world’ emission performance.
- Consistent appliance operation.
- Pollutant Measurements.
- Methodology for Black Carbon measurements and condensables characterisation.
- Performance characterisation (Round Robin tests).
- Uncertainty and accuracy of results.
- Method for the development of final emission factors.

Test protocol (wood)

- Three sets of tests, each test 3 to 4.5 hours (based on Defra burning survey)

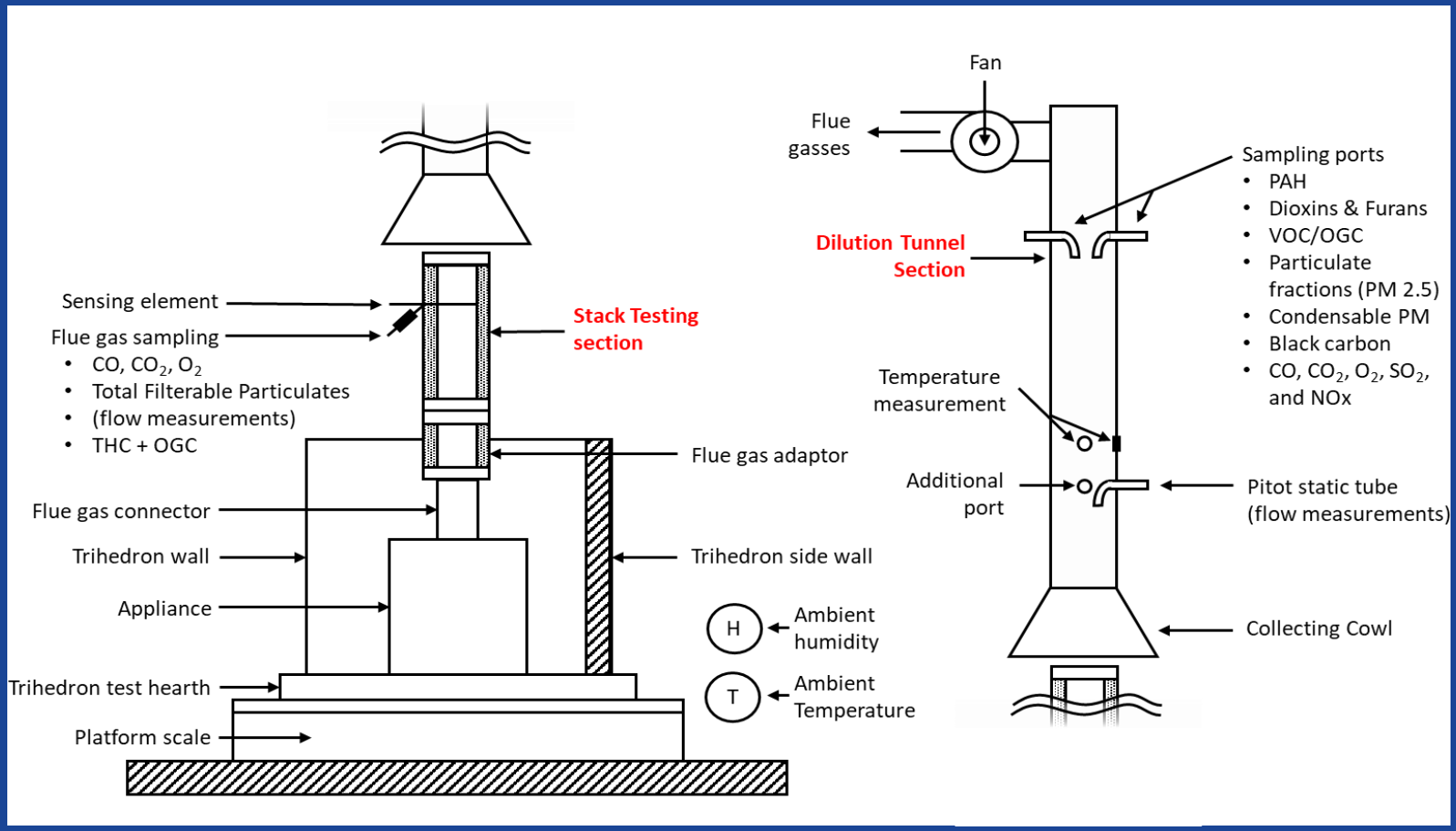
- Each test covers multiple phases of use (ignition, refuels and shutdown)
  Ignition (cold start) + 3 x refuels (Operation phase) + Shutdown/burnout

- Consistent appliance operation :
  Ignition batch 1.8kg (2 x 0.6 kg logs, 0.6 kg kindling, firelighter)
  Refuels 1.2 kg (2 x 0.6 kg logs)
  Consistent placing of logs to assure burn quality and ignition
  Wood not debarked
  Draught – 16 Pa (open fire lower).
  End-point of each batch determined by appearance (loss of flame)
  End-point of shutdown, minimum of 60 minutes then weight change but test stopped at 90 minutes

WORK PROGRAMME

Measurement approach

Mix of direct and dilution tunnel measurements



WORK PROGRAMME

Appliance test stand (front)

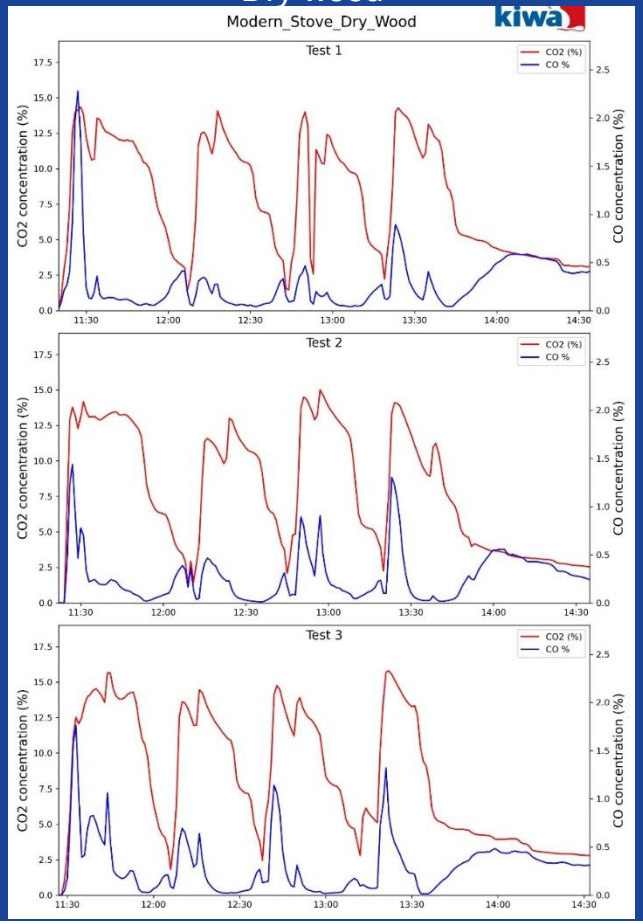
Dilution tunnel sampling platform

Appliance test stand (rear)

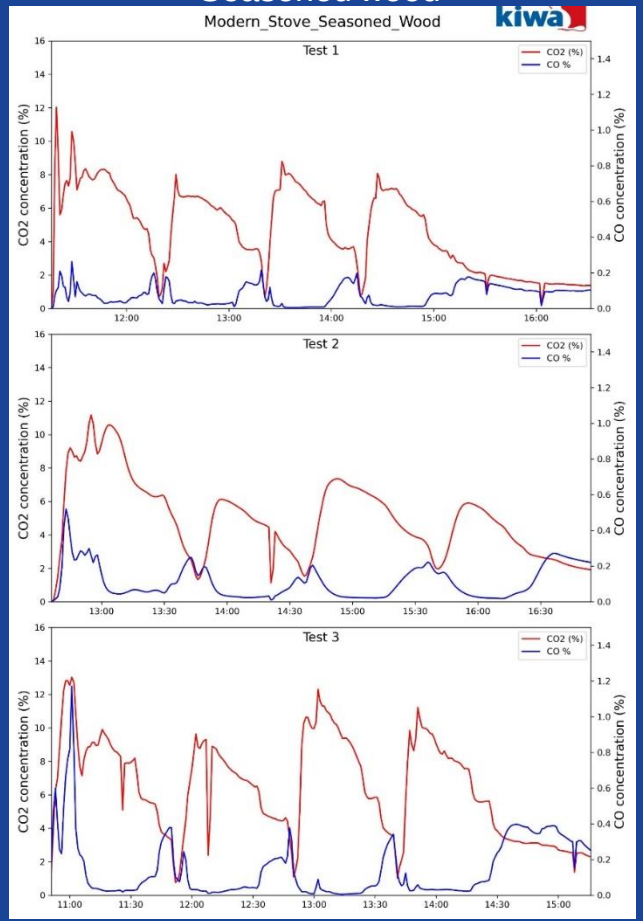
WORK PROGRAMME

- Testing Data Modern Stove CO/CO_2 Concentrations

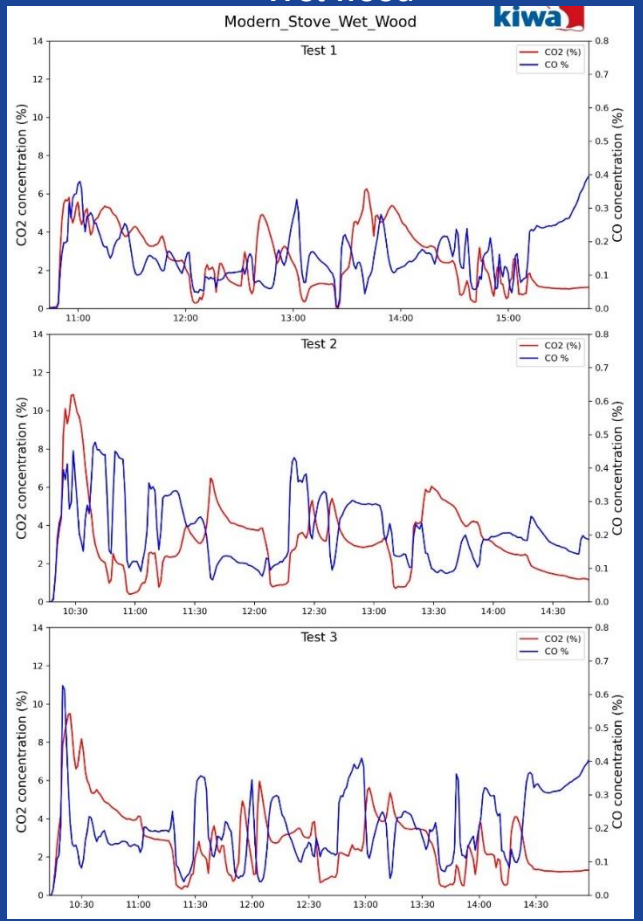
Dry wood



Seasoned wood



Wet wood



WORK PROGRAMME

WP1 Emission factors calculation

Data generally provided as a concentration at STP (0°C, 101.3kPa) and dry gas for period sampled. Conversion to Emission Factors has involved several stages :

1. Conversion to a mass concentration at STP for a dry gas (where required);
2. Correction to undiluted concentration applying ratio of CO determined at appliance outlet and dilution tunnel (where required);
3. Standardising to a reference oxygen concentration (13% O_2);
4. Converting to a g/GJ net heat input emission factor by applying a stoichiometric dry flue gas volume (adjusted to 13% O_2) for wood (Nm^3/GJ net heat input);
5. Aggregating emission factors for each phase for full burn cycle (weighted for fuel burned in each phase);
6. Averaging for each appliance+fuel combination (3 tests to single value).

Continuous data has an additional weighting to adjust for different burn rate at each 1-minute average data point.

Emission factors

All data are emission factors (**g/GJ** net heat input)

Data are grouped by appliance –

modern stove
mid age stove
older stove
open fireplace

By fuel quality :

Dry wood
Seasoned wood
Wet wood
NAEI (EMEP/EEA Guidebook 2019 Tier 2 emission factors)

Data included in 2023 inventory submission except PMx emission factors – PMx should be included, subject to steering group approval, in next submission.

OUTPUTS

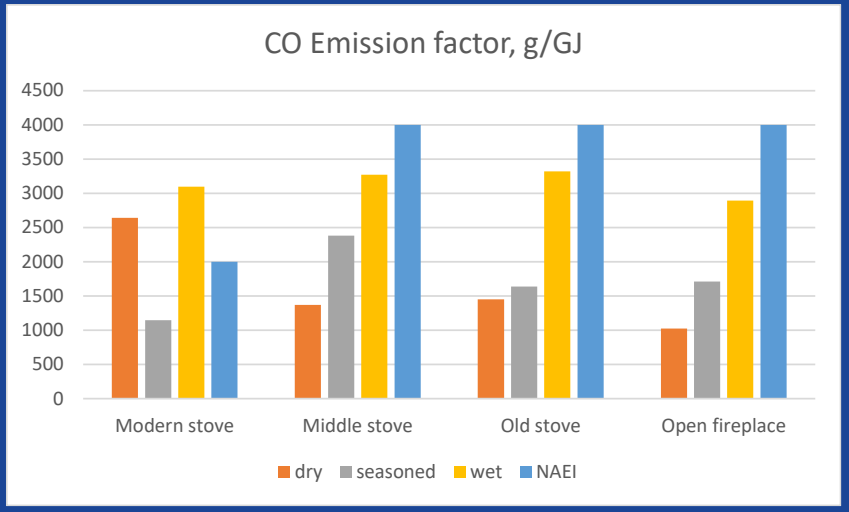
CO, $PM_{2.5}$

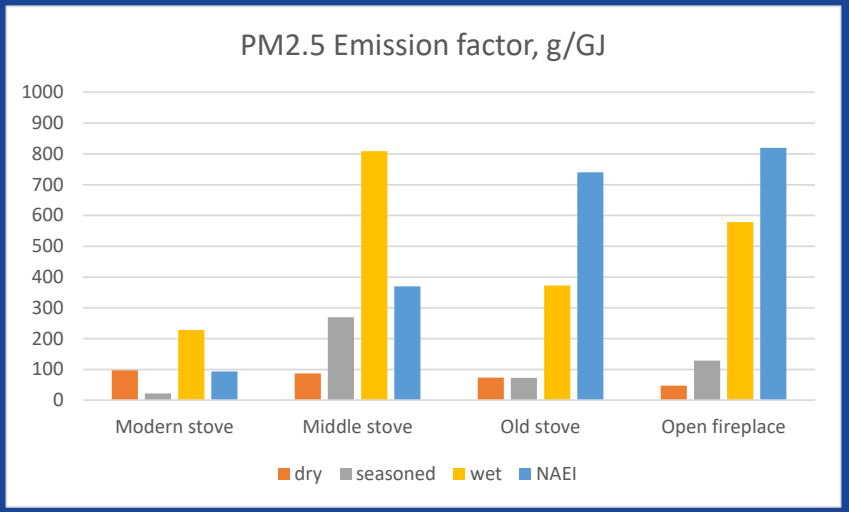
Emission factors increase with fuel moisture on two older stoves and the open fire. These appliances have limited air control.

Different on modern stove – wet fuel worse but dry fuel also has increased emissions for CO and $PM_{2.5}$. Perhaps more constrained air management optimised for seasoned wood.

Emission factors used in NAEI for CO and $PM_{2.5}$ all higher than for seasoned wood operation but may underestimate emissions for wet wood on modern and middle stove.

$PM_{2.5}$ not included in 2023 submission – propose to include in 2024 submission.





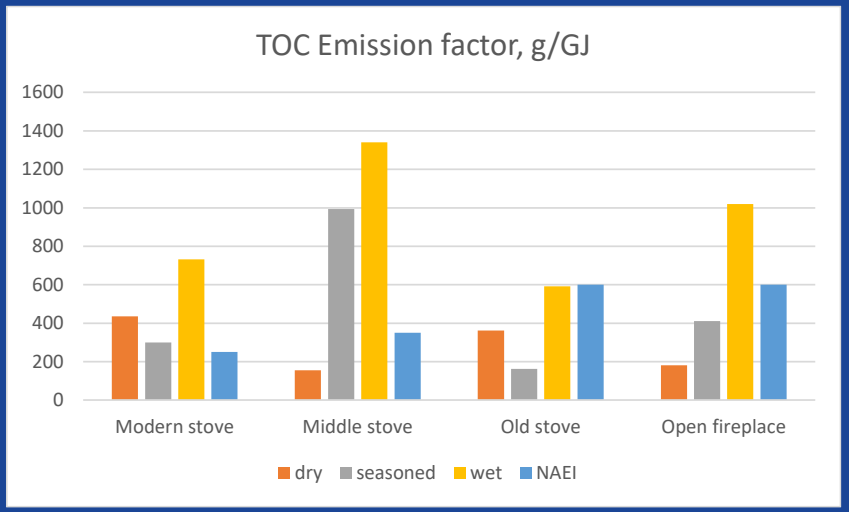
OUTPUTS

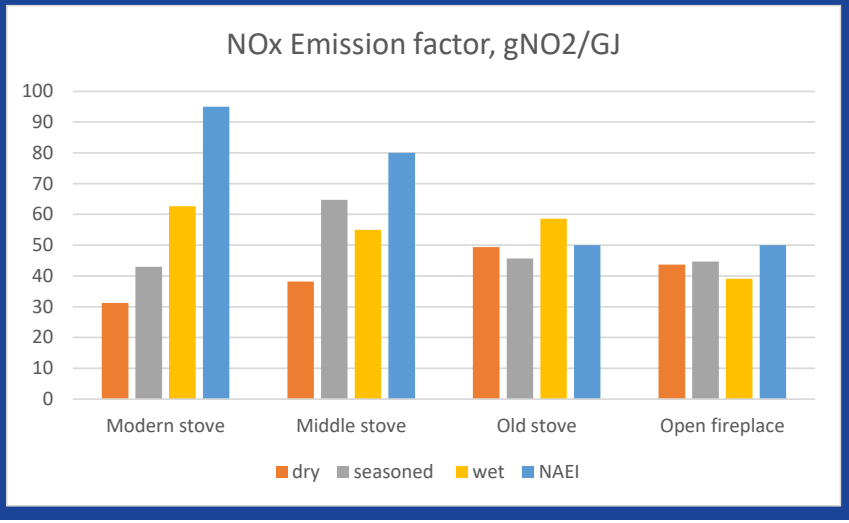
TOC

Emission factors increase with fuel moisture on the open fire and one of the older stoves. Emission factors used in NAEI for NMVOC frequently lower than TOC measurements but may reflect difference in measurement.

NOx

NOx EF appears to increase with moisture on modern stove but less variation on other appliances. NAEI EFs appear higher than measurements for modern and middle stove.

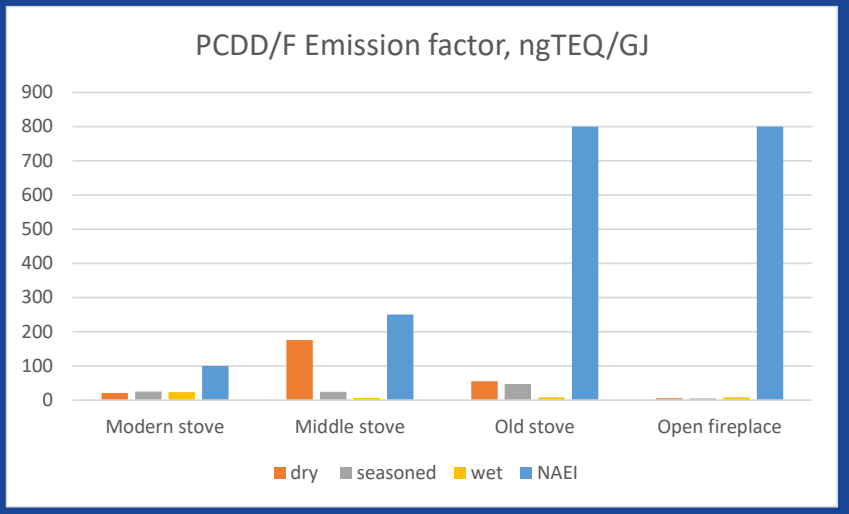


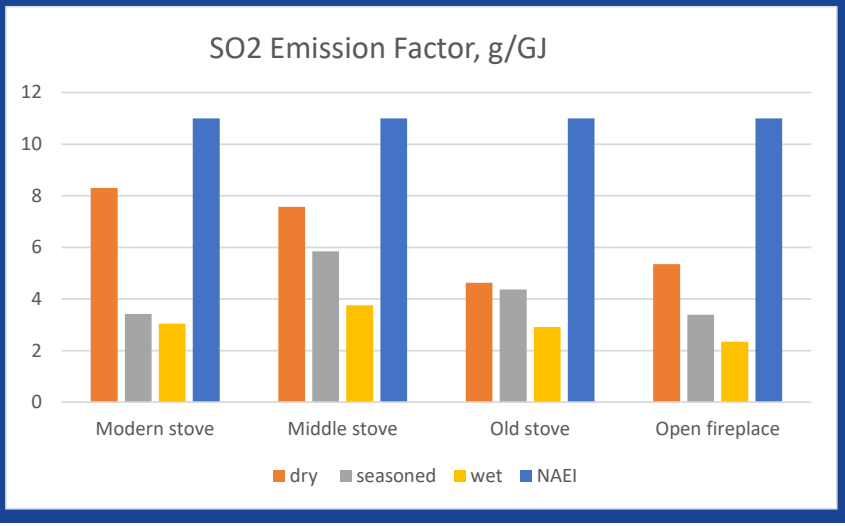


OUTPUTS

PCDD/F
Emission factors appear to show little impact of fuel moisture. Lowest emission factors determined on the open fire and for wet fuels. Emission factors used in NAEI for PCDD/F all higher than measured.

SOx
SOx EF appears to decrease with moisture on all appliances. NAEI EF appears higher than measurements for all stoves and fuels but wood-burning not a large SOx source in inventory.



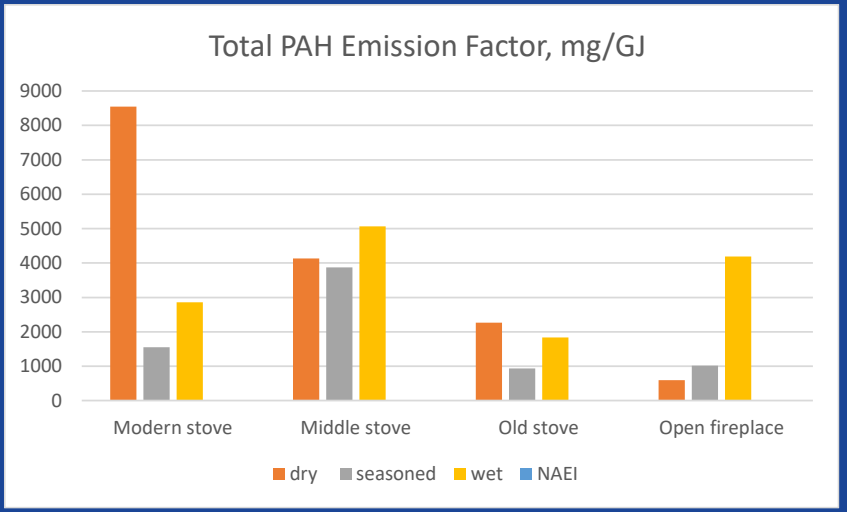


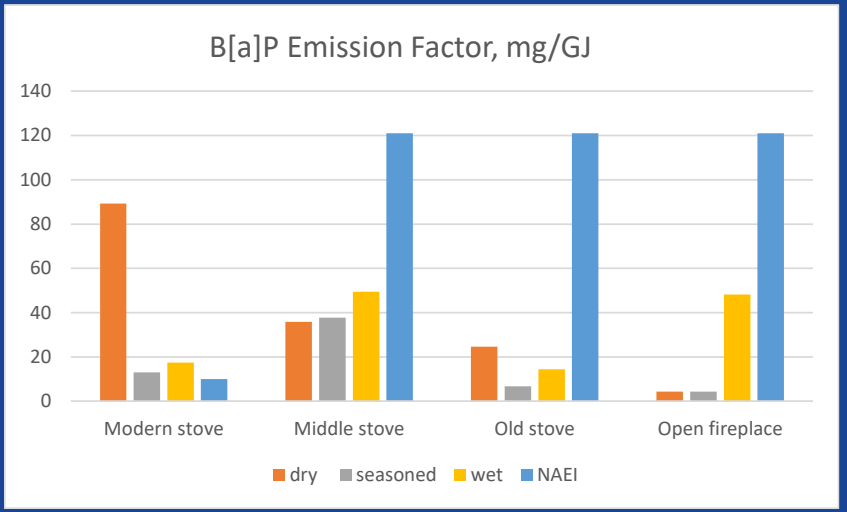
OUTPUTS

PAH

Highest total (16 PAH) emission factors determined on the modern stove and for dry fuel.

For B(a)P (and other CLRTAP PAH), NAEI emission factors are higher than measured on older stoves and the open fireplace. The EFs determined at the modern stove are higher than the NAEI.





OUTPUTS

Next steps

Work package 3 (WP3) test programme :
Underway – looks at further examples of stoves including a pellet stove and Blue Angel ecolabel log stove example and further examples of middle to old stoves.

Next inventory compilation (submission 2024) :
Implement remaining WP1 emission factors ($PM_{10/2.5/1}$) into UK emission inventory.

Implement mineral fuel emission factors into UK emission inventory.

The following inventory compilation (submission 2025) :

Adjust emission factors as needed for WP3 outputs.

Adjust inventory model assumptions for appliance/technology mix and fuel mix following 2nd Domestic Burning Survey (and legislation in England to ban residential use of bituminous coal and restrict use of wet wood).


RICARDO