New evidence on Non-Road Mobile Machinery Emissions supporting UK policy development

TFEIP Thurs 12th May 2022 – Dr Paul Quinn, Ricardo EE, UK

AGENDA

Introduction

Current Model in the National Atmospheric Emissions Inventory

Urban and Construction NRMM

Agricultural NRMM

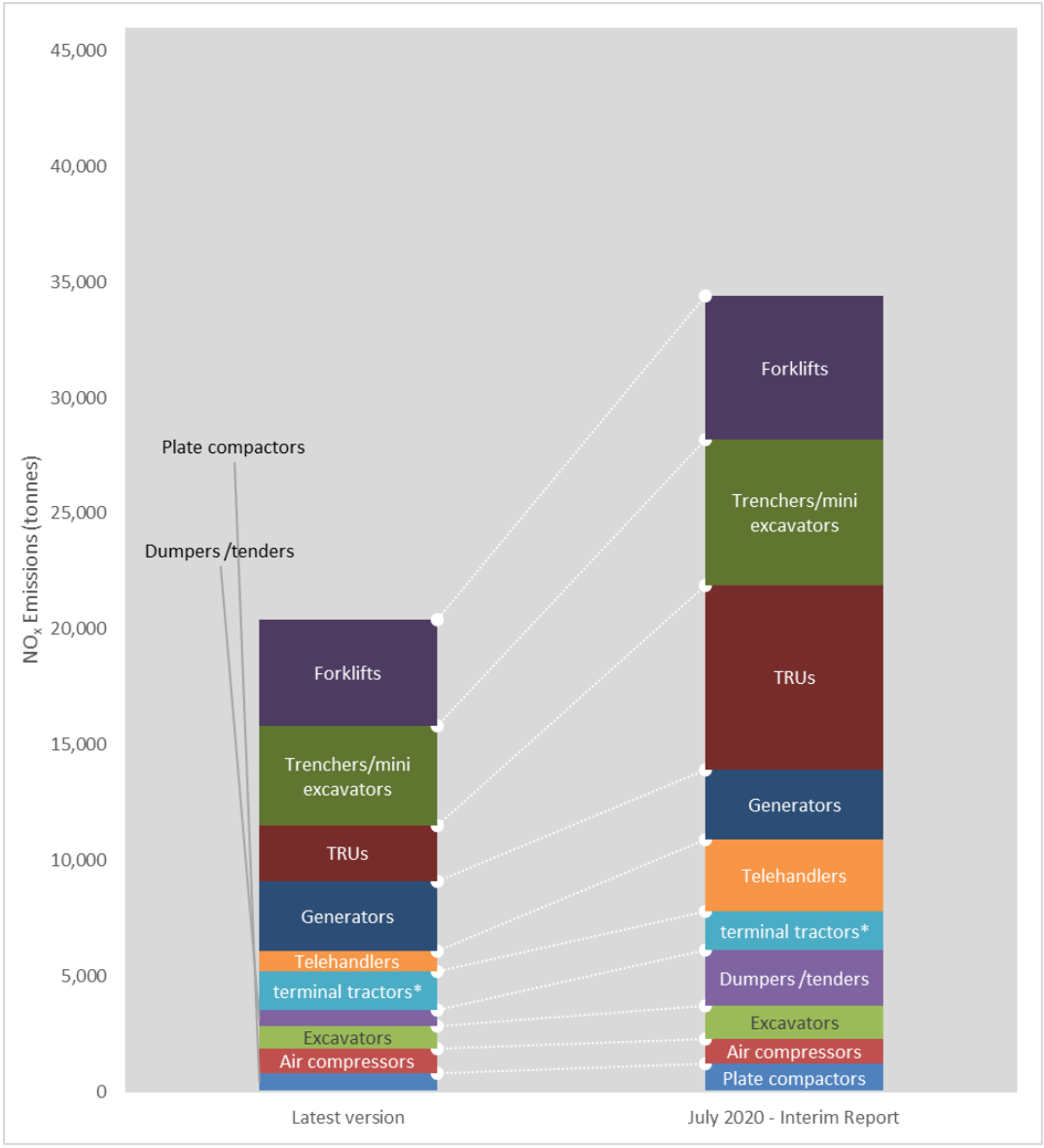
Summary

Key assumptions in the current NAEI NRMM Model

- Non-Road Mobile Machinery (NRMM) model is underpinned by a 2004 study which provided a snapshot of population and usage of machinery types.
- 77 NRMM Source types (populated into agricultural, airports, forestry, house & garden, construction, quarrying, industry)
- Assumed power, hours per year, weighting factor
- Fraction of sales of each technology stage per year (Stages I – IV)
- Amount of fuel sold each year to agriculture from DUKES database (Digest of UK Energy Statistics)
- Population Drivers (historic and proxy projected population data for equipment and UK households)
- Sales Drivers (sales of equipment and explicit forecasts of equipment by year)
- Total population of equipment by year (not split by class)
- Total sales of equipment by year, including lifetime of equipment
- Annual fuel consumption for each year (power, activity, weighting factor, fuel consumption factor, degradation factor).
- Fuel categorised into Petrol, DERV (diesel) and gas oil (red diesel).
- Makes assumptions about fuel used in each machinery class (eg: zero DERV used in agriculture & forestry)

NAEI and NRMM

- Ricardo maintains the UK's National Atmospheric Emissions Inventory (NAEI) which contains calculations of all emissions sources in the UK
- Time-series is developed using proxy data to back-cast and forecast population and activity data and is updated annually.
- Last year, Defra requested update for NRMM for construction, quarries, airports and TRUs as part of an Improvement Programme
- Databases and information provided by industry trade associations and stakeholder groups, though these weren't designed for use in inventories they provided valuable information.
- Machinery were categorised by fuel type, power rating band, annual hours of use and lifetime.
- Ongoing stakeholder consultation showed an overall drop in air quality emissions from initial calculations



Non-Road Mobile Machinery (NRMM) – Construction/Urban

Challenge

To formulate particulates PM2.5 and NOx emissions for Non-road mobile machinery in UK such as excavators, forklifts, loaders, generators and transport refrigeration units (TRUs)

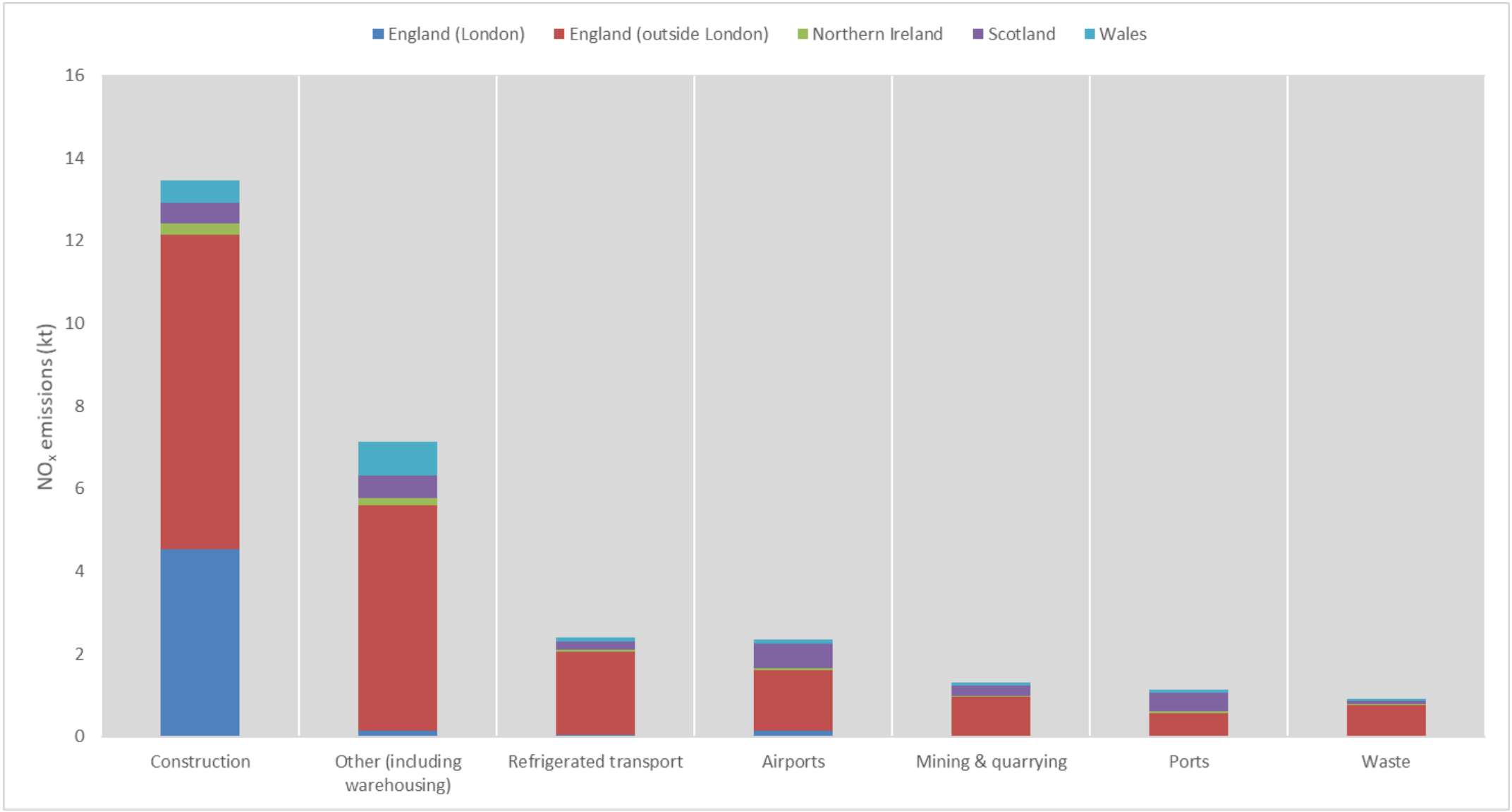
Solution

Employed Non-road mobile machinery CESAR database for number, age and power of machines, and conducted user and trade surveys to calculate emissions

Benefits

Produced PM2.5 and NOx emissions for Non-road mobile machinery in UK by urban/rural regions for 2018 and 2030. Next step was to extent to other species and agricultural machinery

NOx emissions by sector and region



Agricultural and Forestry NRMM

- Defra requested Agricultural and Forestry NRMM be updated and included in the NAEI model
- To include agricultural vehicles such as tractors, harvesters, sprayers, telehandlers, agricultural mowers, and any other agricultural equipment
- Model update also included forklift LPG and portable generators
- As with previous study, CESAR agricultural database was made available (134,000 records), but covered approx 50% of fleet.
- Similar information was requested from Agricultural Engineers Association (AEA) for engine size/power, etc.
- Average hours worked per year based on telemetry data (tractors by power band)
- Typical load factor and typical idle time for each vehicle type
- Fuel consumption (2020 registration)

Data Provided by Agricultural Engineers Association (AEA)

- Number of agricultural machines licensed for road use by year of first registration in UK (2000-2020 and Pre-2000)
- First registrations of agricultural tractors by year, compared with the number of licensed machines at end of 2020 & 2019 (2000-2020)
- First registrations of agricultural tractors by power band and average power of registrations (2000-2020)
- First registrations of agricultural combines by year, compared with the number of licensed machines at end of 2020 & 2019 (2010-2020)
- Estimated market size for other agricultural vehicles 2011-2020 (agricultural telehandlers, forage harvesters, sprayers)

Emission Factors

- Methodology followed European EMEP/EEA Tier 3 Method:

- $E = N * hrs * P * LF* (1+DFA) * LFA * EF_{base}$

  E = mass of pollutant emission during inventory period (g)

  N = no. of engines/units

  hrs = annual hours of use

  P = engine size (kW)

  LF = load factor

  DFA = deterioration factor adjustment

  LFA = load factor adjustment

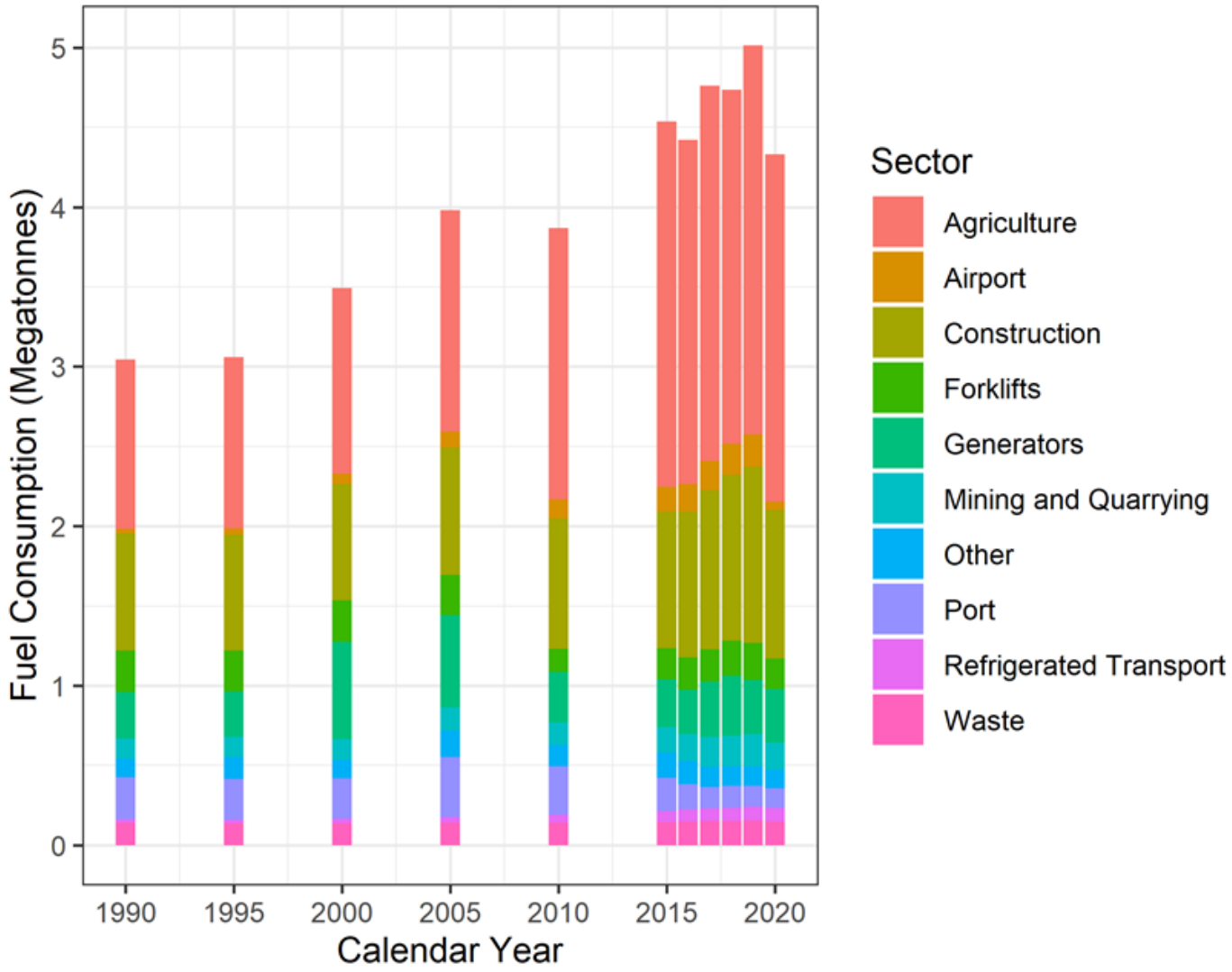
  EF_{base} = Base emission factor (g/kWh)

- https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-non-road-1/view

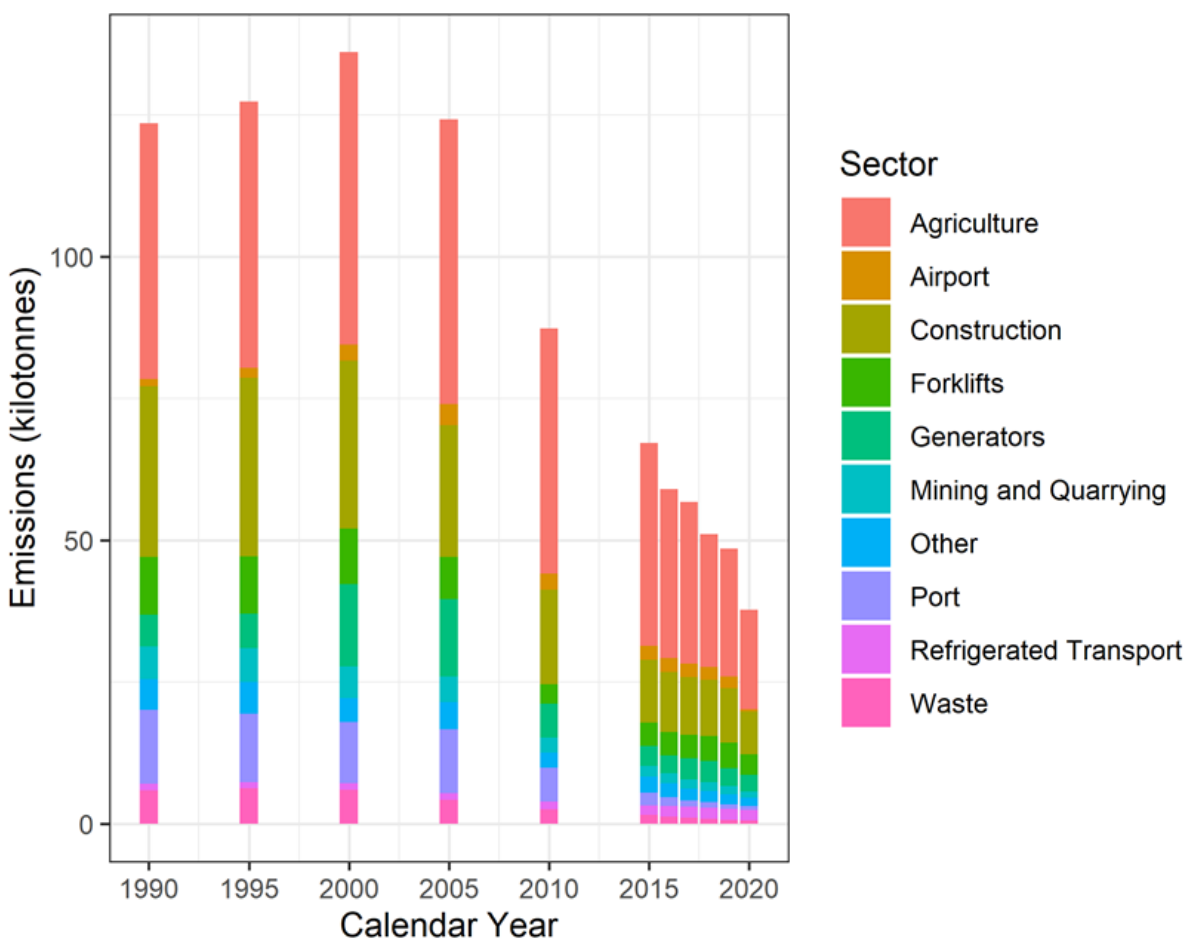
Key assumptions in the updated NAEI NRMM Model

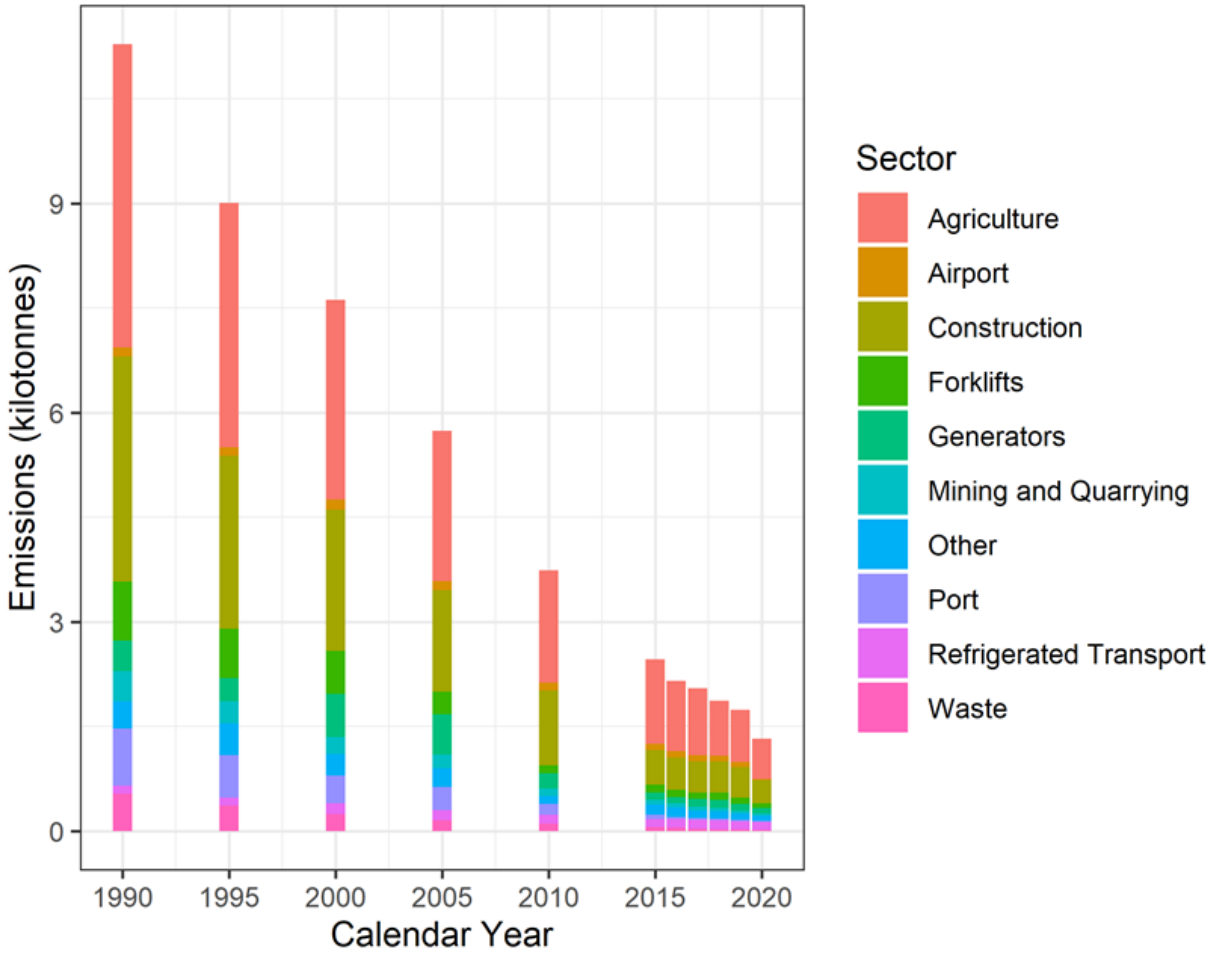
- Extend number and type of NRMM sources
- Engine data from updated surveys (power, type, hours per year and weighting factor)
- Activity data (hours per year) from telemetry where available/representative – otherwise calculated
- Fuel consumption data
- Adopt updated sales data per year for equipment types
- Adopt updated power data in power bands (use weight to power function where not available)
- Adopt updated lifetime data
- Adopt updated equipment population data per year
- Include any additional fuels used by machinery eg: LPG,
- Categorise machinery class by fuel used

Fuel Consumption from agricultural machinery and other NRMM (Mtonnes fuel)



NOx and PM Emissions from agricultural machinery and other NRMM (ktonnes)





Summary

- Machinery population data from CESAR dataset used to refine the current NAEI population estimates.
- London NRMM register used to inform machinery types and power rating band in construction sector
- Ongoing stakeholder consultation showed an overall drop in construction air quality emissions from initial calculations
- Telematic data for agricultural vehicles from Agricultural Engineers Association comes from more modern machinery
- Assumptions were made for older agricultural machinery which were expected to be used less frequently.
- Agricultural tractors dominate NOx and PM emissions
- Higher estimate for gas oil consumption by agricultural vehicles is somewhat offset by lower estimate for other NRMM.
- Thanks to Harry Smith, Yvonne Pang, Tim Murrells, Dan Wakeling, Jason Wong