Non-Road mobile machinery in construction - current practice and way forward

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FAIRMODE Technical Meeting

6-8 October 2021

Background

- The need to provide guidance for other sectors than traffic and residential heating has been brought by local and national agencies, and modelers.
- Provide relevant feedback to e.g., EMEP, CAMS-REG

NEW SECTORS

NRMM in Construction

GUIDANCE NEED

- **Guidance**:
  Existing data sources for activity data at local level
- Advanced methods for processing emissions (Activity data and emission factors)
- Advanced methods for **spatial mapping** and **temporal distribution**

PURPOSE

Best practice determine by the **purpose** of emissions (AQ, forecasting, planning)

Starting point

EMEP/EEA guideline as starting point

Scoping

Quality for **urban** areas should be priority

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Non-Road Mobile Machinery (NRMM) Timeline

2020

2021

- Mapping current practice (Plenary meeting)
- Current practice within FAIRMODE (Questionnaire)

2021-2022

- Way forward towards “Best Practice”

KEY CHALLENGES

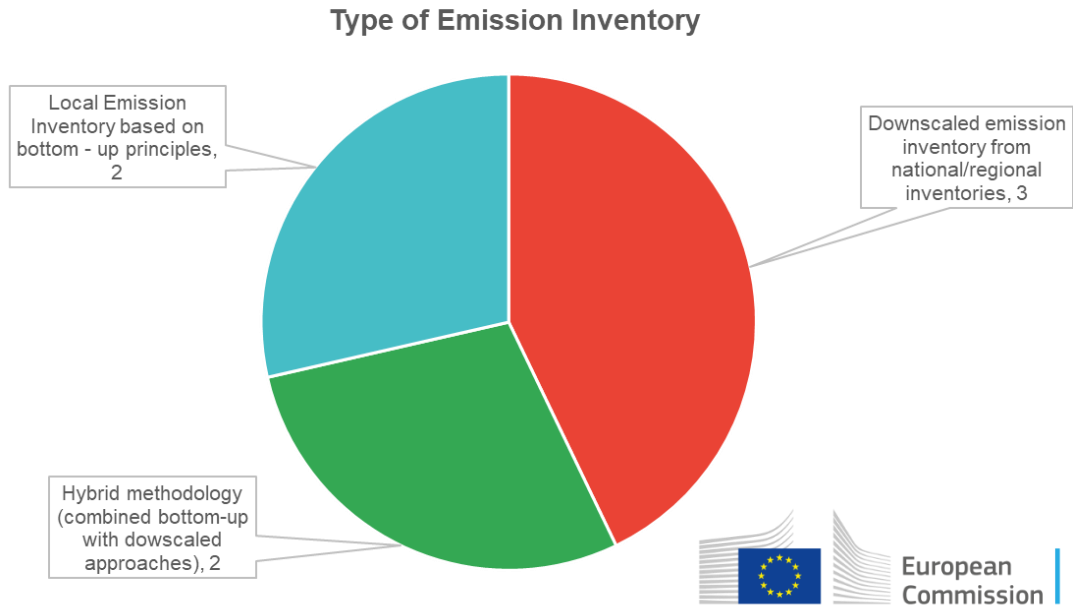
- **Data compilation**; Multiple sources of activity data need to be collected and processed.
- **Emission factors**; knowledge on fleet composition and EF for new machinery
- **Spatial distribution**; additional challenge with future scenarios
- **Temporal distribution**; additional challenge when addressing meteorology driven emissions (non-exhaust)

Questionnaire

- 7 answers [Macau, Greece, Belgium (Flanders), UK (England and urban areas), Germany, Norway, Finland]

- How large (e.g., %) is the contribution from NRMM in construction in comparison to other emissions in your area? (e.g., for NOx and PM)
  - PM_{10}: 41% of total emissions
  - NO_x: 8% of total emissions
  - NO_x: 0.5% of total emissions
  - 11% NO_x, <1% $PM_{2.5}$, 0.004% PM_{10}
  - 1-3% of total emissions

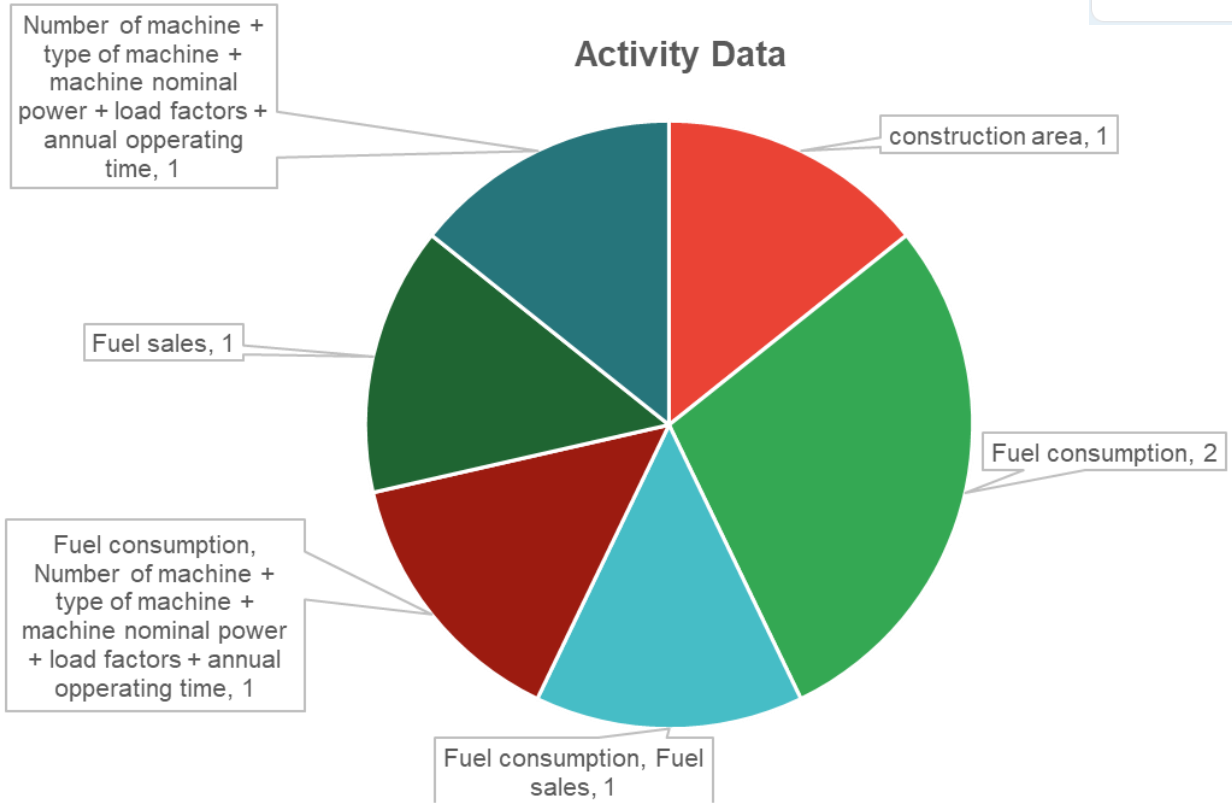
- Type of Emission Inventory

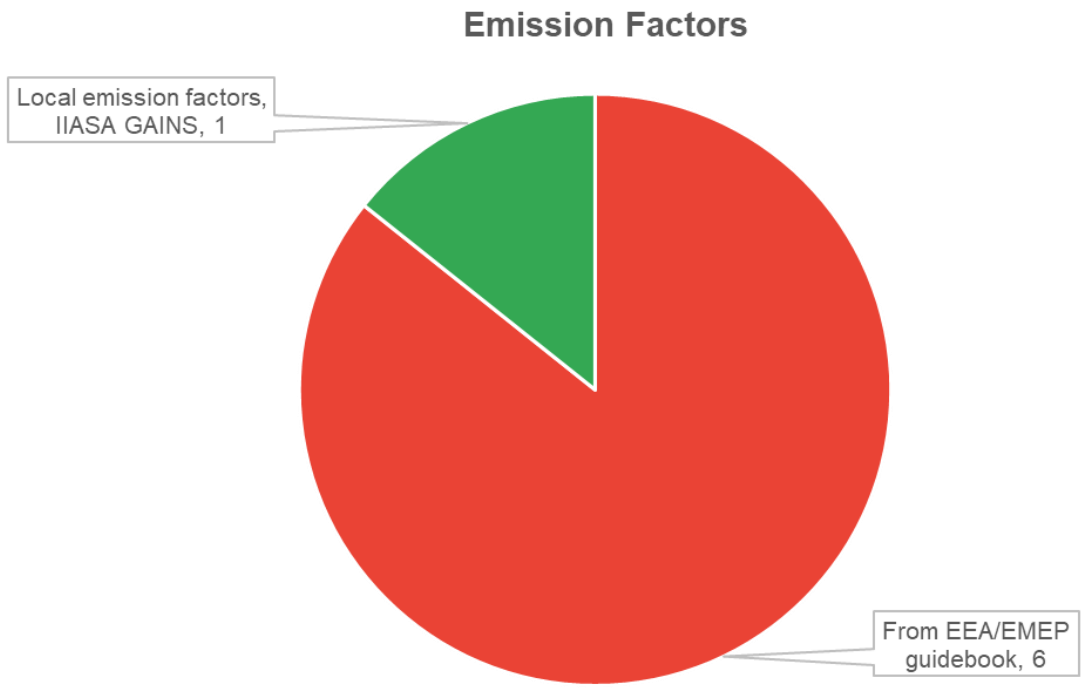


Questionnaire Activity Data & EF

Main activity data *

- [ ] Fuel consumption
- [ ] Fuel sales
- [ ] Number of machine + type of machine + machine nominal power + load factors + annual opperating time
- [ ] Non-applicable as we used regional available emissions
- [ ] Other...





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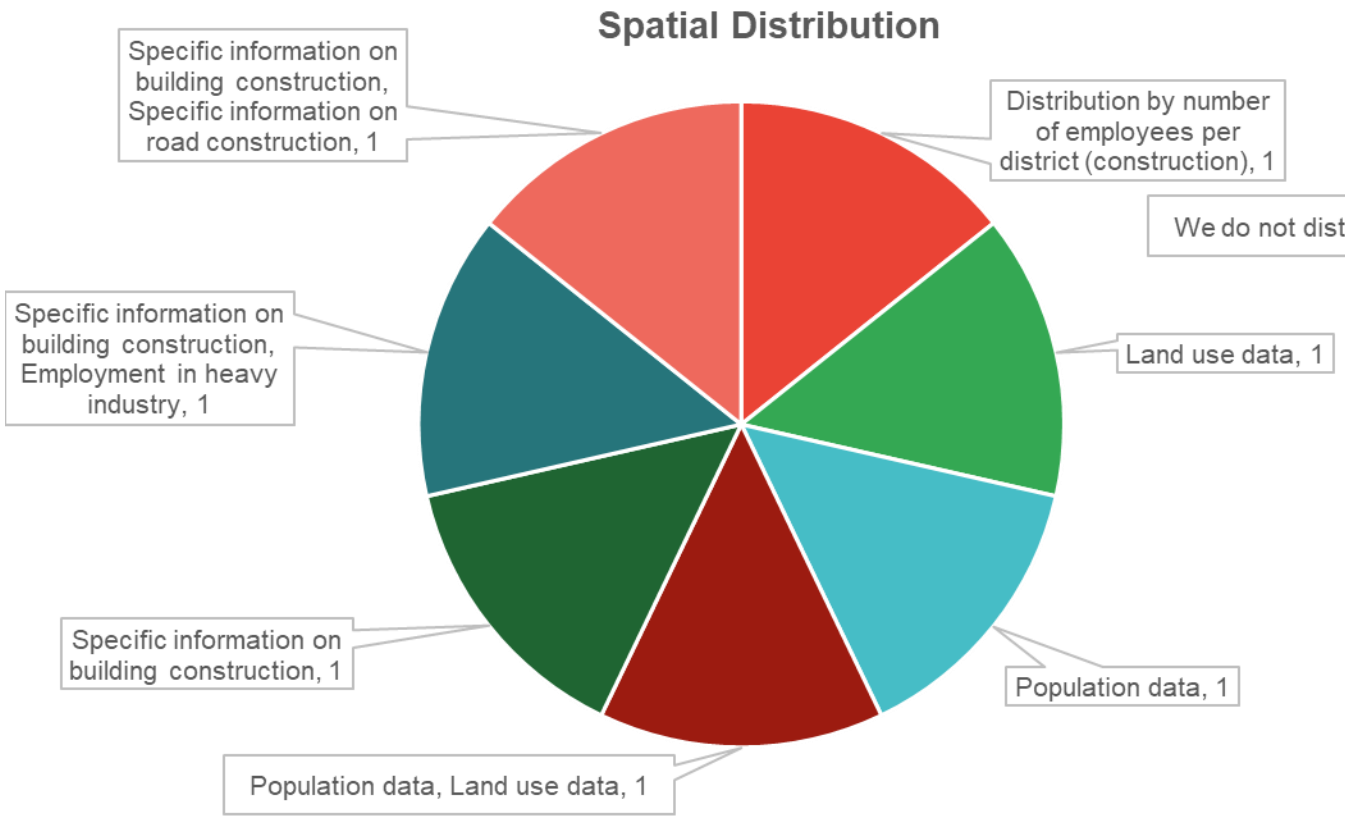
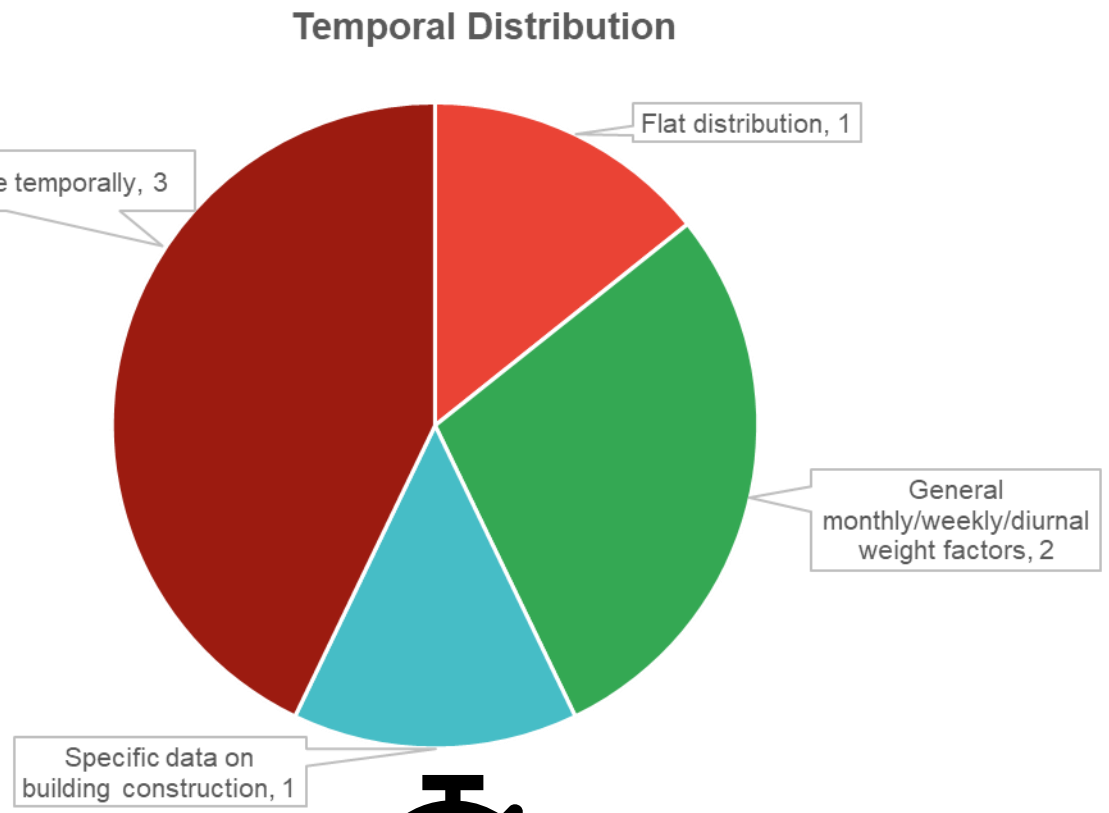
Questionnaire – Distribution of Emissions





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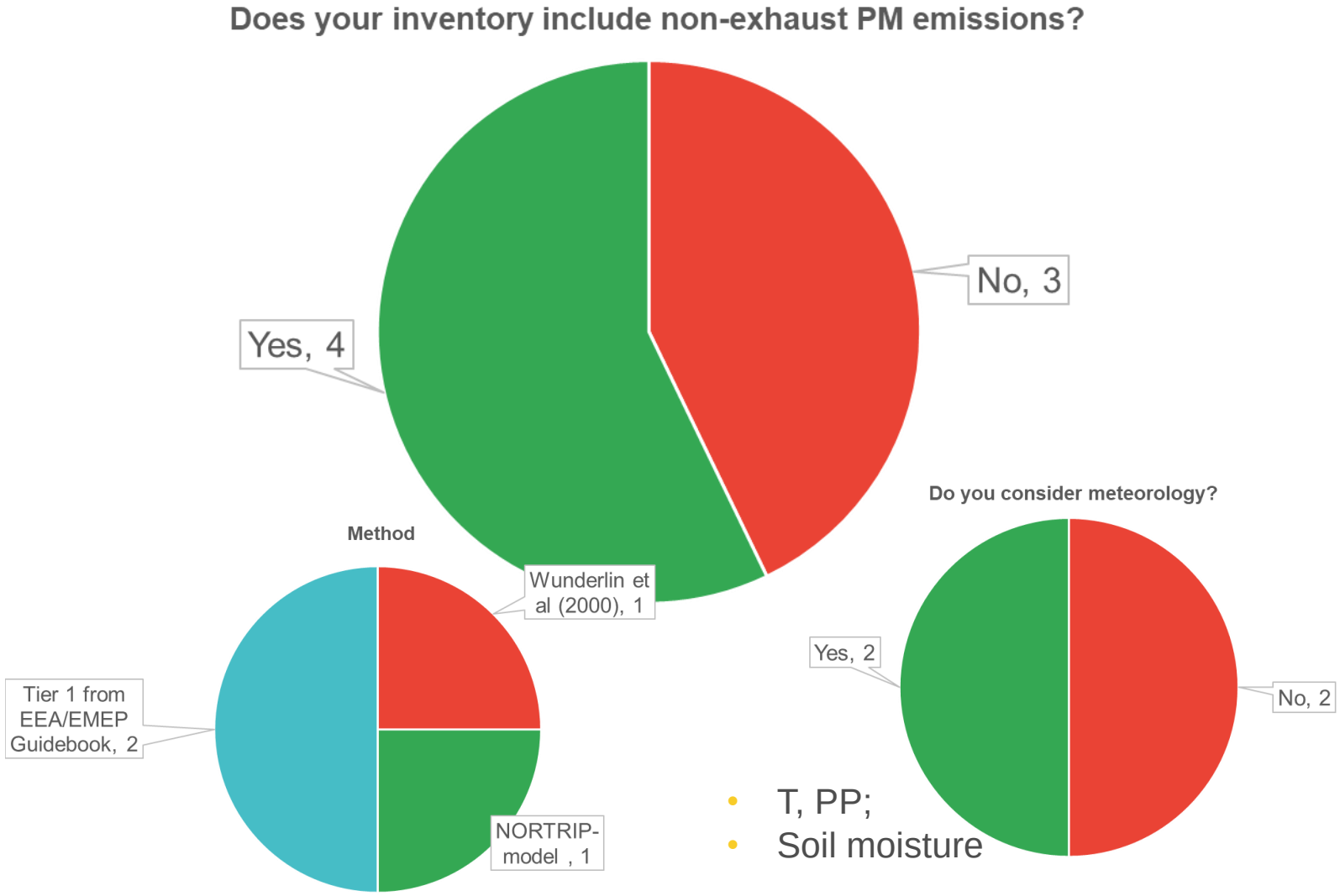
Questionnaire – Non-exhaust Emissions



- T, PP;
- Soil moisture

Summary – Questionnaire – Lessons learn

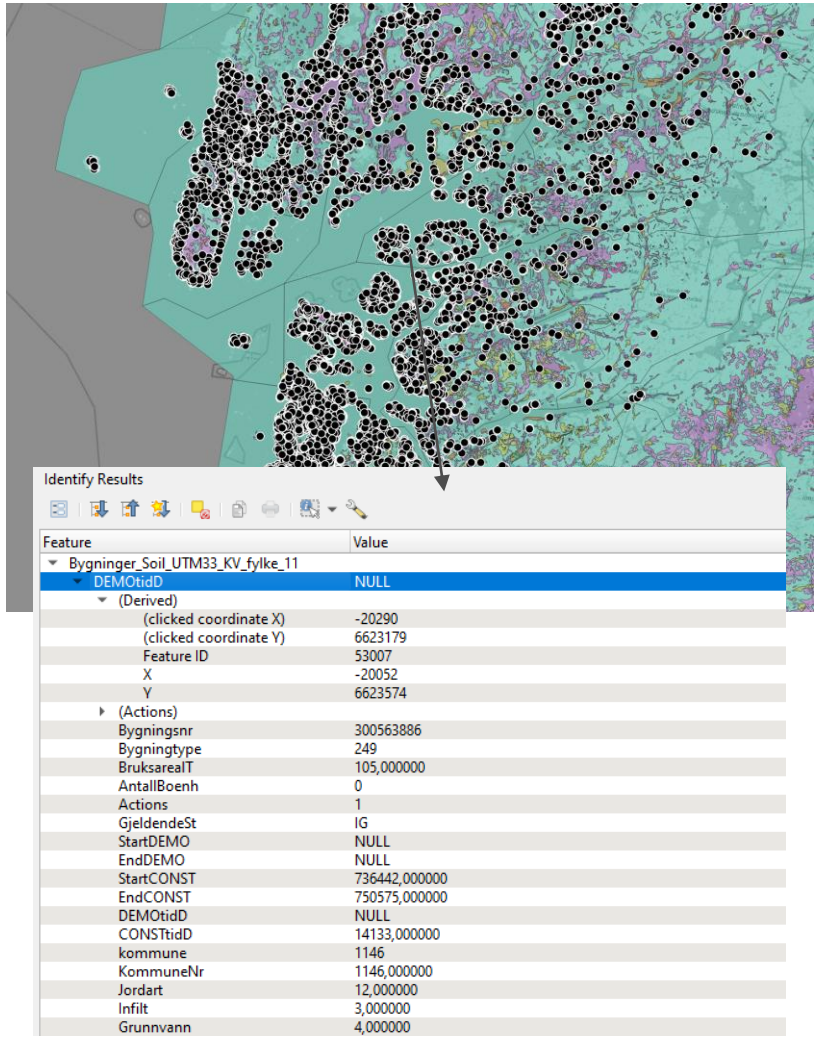
- NRMM in construction has received less attention than other sectors at urban scale;
- The contribution from this sector to total emissions shows a wide range of results (national vs urban level; different methods);
- Spatial distribution; use of traditional proxies (population, land use data) in combination with more sector specific (employment data, building construction).
- Temporal distribution; not addressed or simple approaches
- Important gaps concerning non-exhaust emissions

Way forward to best practice and recommendations

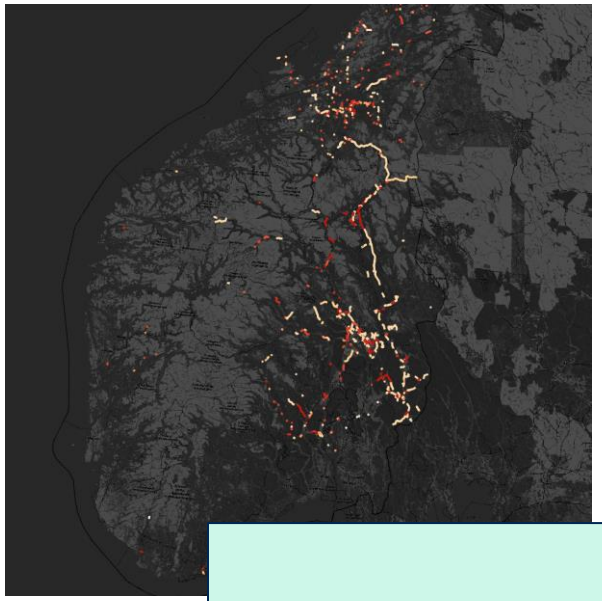
- **Starting point**: NRMM in construction has not been a priority sector, however it is becoming more important in urban areas.
- There is a lot of interest on understanding the contribution to urban emissions / pollution levels
- We have best practise / recommendation for national emission inventories (EEA/EMEP Guidebook) that is not applicable at high resolution for urban level.
- How do we identify successful approaches for high – resolution emission inventories?
- How can FAIRMODE contribute to develop best practice / recommendation for high resolution emissions? (e.g., state of the knowledge, existing methods, guidelines for input data (activity, EF, spatial and temporal distribution)

Example of a new approach

Building construction



Road construction



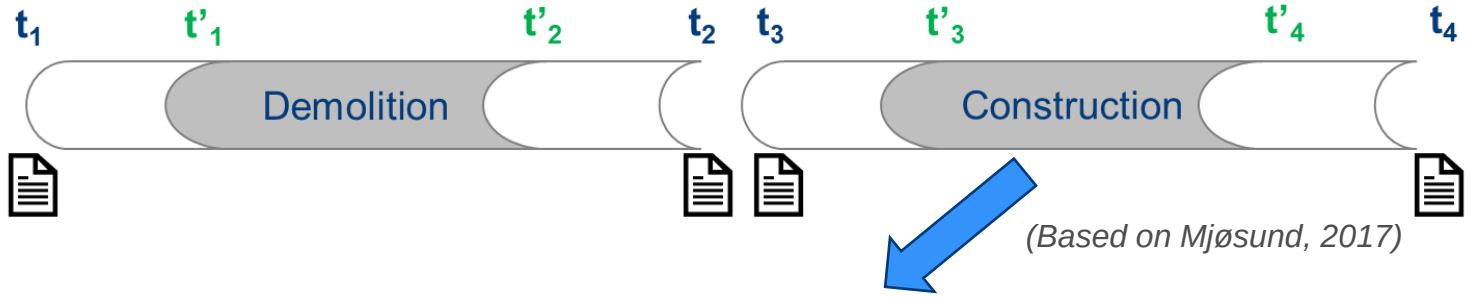
Building a «bottom-up» emission inventory for NRMM in construction

Data prosessering

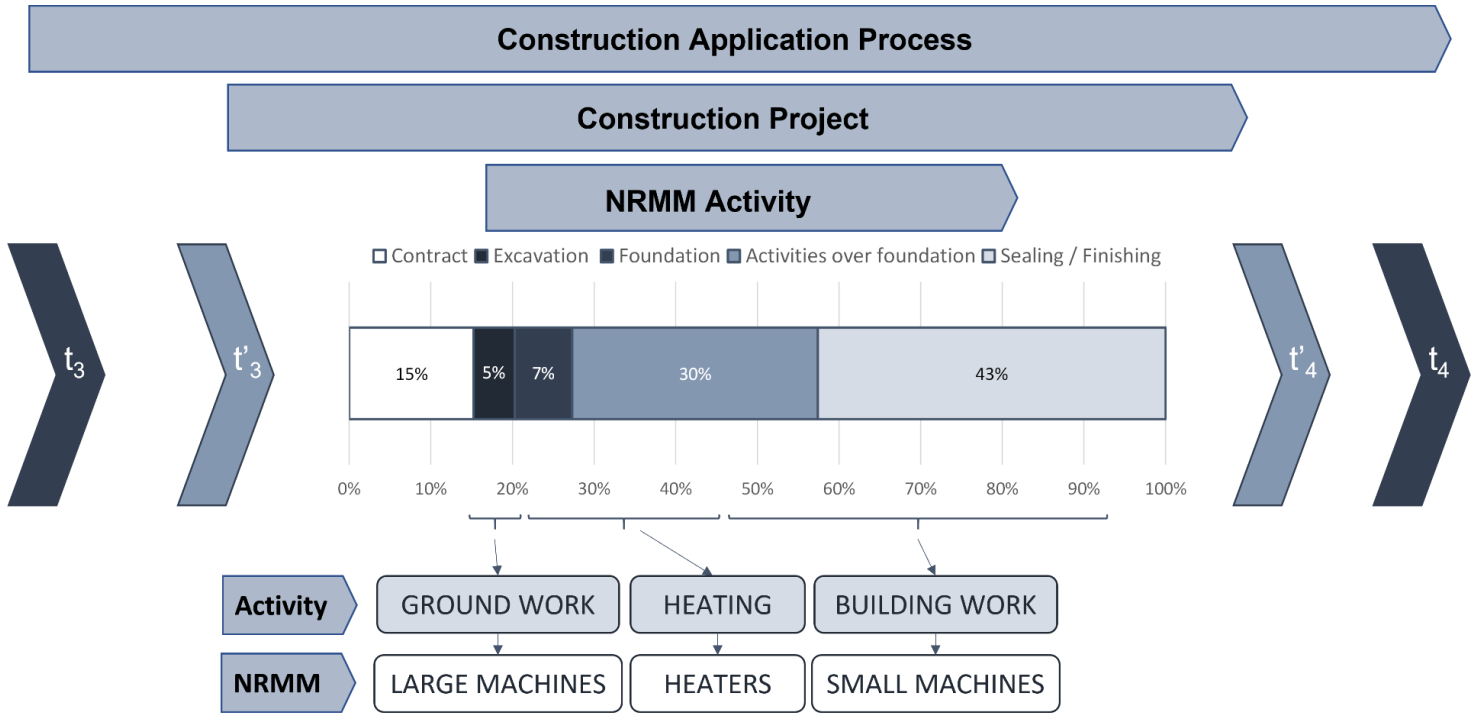
- Construction permits 2010 – 2020
- Geo-localization – points / lines
- Information on the building/road type
- Utility area
- Met-data (daily T and PP)
- Soil data
  - Ground conditions (energy needs for excavation)
  - Silt content (Non-exhaust emissions)

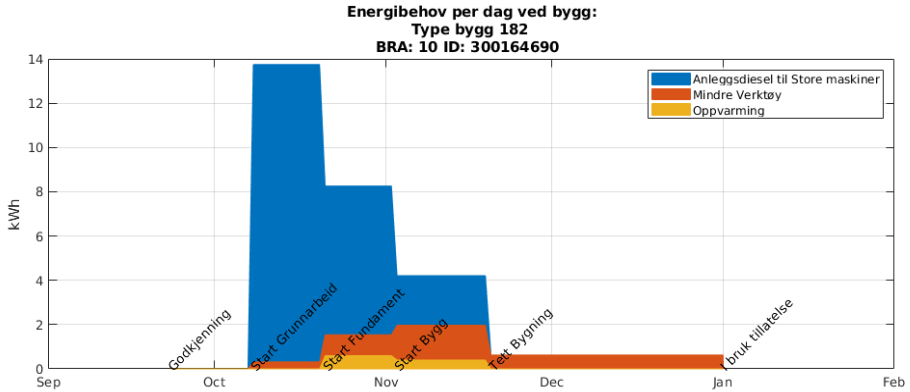
Example of a new approach

Duration of the construction process based on Construction permit



(Based on Mjøsund, 2017)





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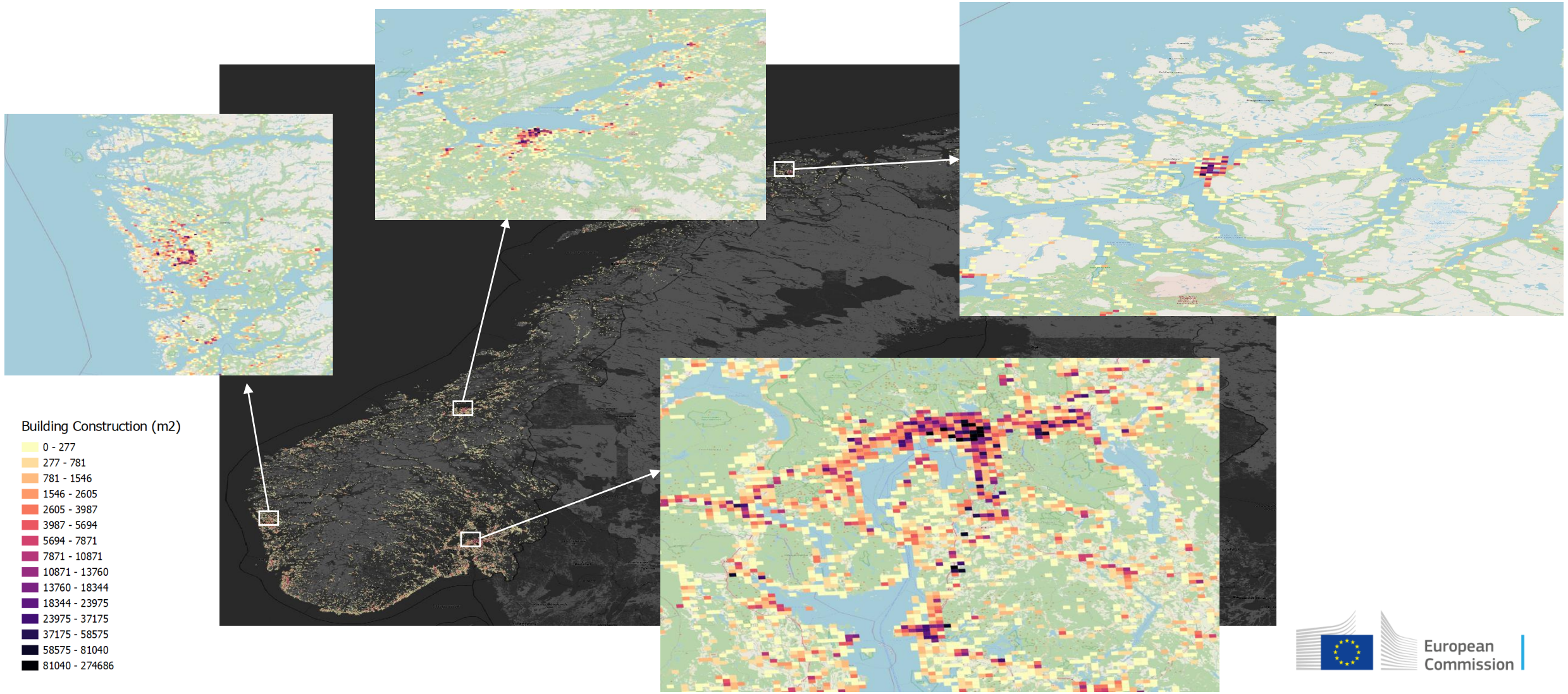
Example of a new approach

Activity per year * grid

Building Construction Activity (2018)



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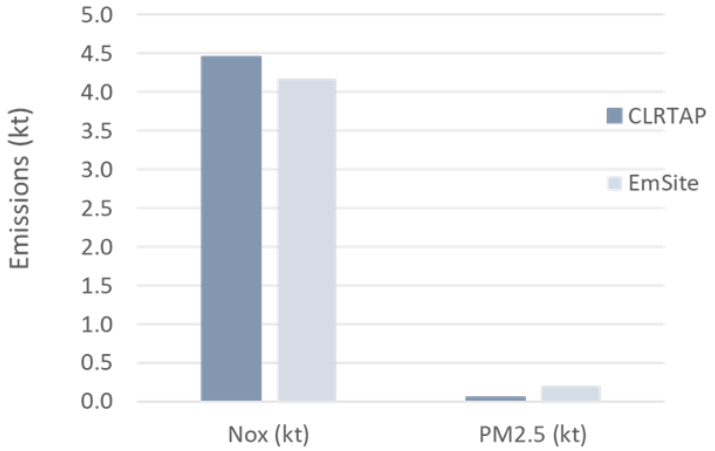
Example of a new approach

m^2 construction → Energy Demand (kWh)

Activity	GROUND WORK	HEATING	BUILDING WORK
NRMM	LARGE MACHINES	HEATERS	SMALL MACHINES

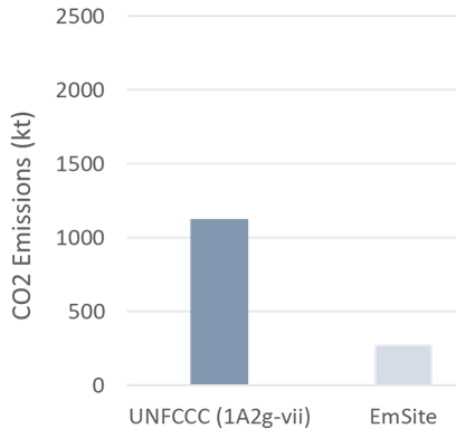


Simple ground condition (DNV, 2018)

Activity	Energy demand [kWh/m2]
Heating	47 kWh
Interior heating	34 kWh
Concrete setting	8 kWh
Concrete setting – grout casting	4 kWh
Façade heating	1 kWh
Construction machinery	30 kWh
IN TOTAL	77 kWh

Difficult ground condition (DNV, 2018)

Activity	Energy demand [kWh/m2]
Heating	47 kWh
Interior heating	34 kWh
Concrete setting	8 kWh
Concrete setting – grout casting	4 kWh
Façade heating	1 kWh
Construction machinery	45 kWh
IN TOTAL	92 kWh



Large NRMM (DNV, 2018)

Type of building site	Ground conditions	Area [m2]	Energy demand [kWh]
Apartment building	Simple	10 000	246 131
Multi-use-hall	Simple (tennis courts)	3600	122 407
Kindergarten	Simple (berg)	1650	33 520

Small NRMM (DNV, 2018)

Type of building site	Ground conditions	Area [m2]	Energy demand [kWh]
Apartment building	Simple	10 000	28 323
Multi-use-hall	Simple (tennis courts)	3600	-
Kindergarten	Simple (berg)	1650	882

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Example of ongoing development

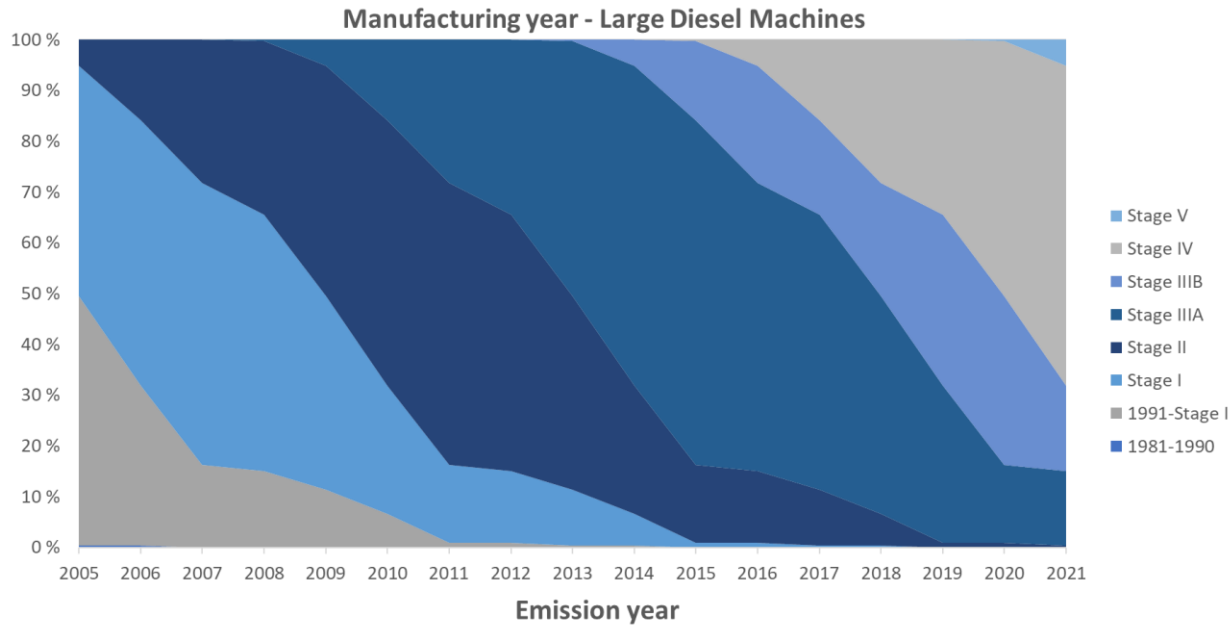
m^2 construction → Energy Demand (kWh) → Emissions

EF (g/kWh)

Engine Power (kW)	Technology Level	year	NOx	VOC	CH4	CO	N2O	NH3	PM	PM10	PM2.5	BC	FC
P<8	<1981	1980	12.00	5.00	0.12	7.00	0.04	0.00	2.80	2.80	2.80	1.54	300
P<8	1981-1990	1990	11.50	3.80	0.09	6.00	0.04	0.00	2.30	2.30	2.30	1.27	285
P<8	1991-Stage I	1991	11.20	2.50	0.06	5.00	0.04	0.00	1.60	1.60	1.60	0.88	270
P<8	Stage V	2019	6.08	0.68	0.02	4.80	0.04	0.00	0.40	0.40	0.40	0.32	270
8<=P<19	<1981	1980	12.00	5.00	0.12	7.00	0.04	0.00	2.80	2.80	2.80	1.54	300
8<=P<19	1981-1990	1990	11.50	3.80	0.09	6.00	0.04	0.00	2.30	2.30	2.30	1.27	285
8<=P<19	1991-Stage I	1991	11.20	2.50	0.06	5.00	0.04	0.00	1.60	1.60	1.60	0.88	270
8<=P<19	Stage V	2019	6.08	0.68	0.02	3.96	0.04	0.00	0.40	0.40	0.40	0.32	270
19<=P<37	<1981	1980	18.00	2.50	0.06	6.50	0.04	0.00	2.00	2.00	2.00	1.10	300
19<=P<37	1981-1990	1990	18.00	2.20	0.05	5.50	0.04	0.00	1.40	1.40	1.40	0.77	281
19<=P<37	1991-Stage I	1999	9.80	1.80	0.04	4.50	0.04	0.00	1.40	1.40	1.40	0.77	262
19<=P<37	Stage II	2001	6.50	0.60	0.01	2.20	0.04	0.00	0.40	0.40	0.40	0.32	262
19<=P<37	Stage IIIA	2007	6.08	0.60	0.01	2.20	0.04	0.00	0.40	0.40	0.40	0.32	262
19<=P<37	Stage V	2019	3.81	0.42	0.01	2.20	0.04	0.00	0.02	0.02	0.02	0.00	262
37<=P<56	<1981	1980	7.70	2.40	0.06	6.00	0.04	0.00	1.80	1.80	1.80	0.99	290
37<=P<56	1981-1990	1990	8.60	2.00	0.05	5.30	0.04	0.00	1.20	1.20	1.20	0.66	275
37<=P<56	1991-Stage I	1991	11.50	1.50	0.04	4.50	0.04	0.00	0.80	0.80	0.80	0.44	260
37<=P<56	Stage I	1999	7.70	0.60	0.01	2.20	0.04	0.00	0.40	0.40	0.40	0.32	260
37<=P<56	Stage II	2004	5.50	0.40	0.01	2.20	0.04	0.00	0.20	0.20	0.20	0.16	260
37<=P<56	Stage IIIA	2008	3.81	0.40	0.01	2.20	0.04	0.00	0.20	0.20	0.20	0.16	260
37<=P<56	Stage IIIB	2013	3.81	0.28	0.01	2.20	0.04	0.00	0.03	0.03	0.03	0.02	260
37<=P<56	Stage V	2019	3.81	0.28	0.01	2.20	0.04	0.00	0.02	0.02	0.02	0.00	260
56<=P<75	<1981	1980	7.70	2.40	0.06	6.00	0.04	0.00	1.80	1.80	1.80	0.99	290
56<=P<75	1981-1990	1990	8.60	2.00	0.05	5.30	0.04	0.00	1.20	1.20	1.20	0.66	275
56<=P<75	1991-Stage I	1991	11.50	1.50	0.04	4.50	0.04	0.00	0.80	0.80	0.80	0.44	260
56<=P<75	Stage I	1999	7.70	0.60	0.01	2.20	0.04	0.00	0.40	0.40	0.40	0.32	260
56<=P<75	Stage II	2004	5.50	0.40	0.01	2.20	0.04	0.00	0.20	0.20	0.20	0.16	260
56<=P<75	Stage IIIA	2008	3.81	0.40	0.01	2.20	0.04	0.00	0.20	0.20	0.20	0.16	260
56<=P<75	Stage IIIB	2012	2.97	0.28	0.01	2.20	0.04	0.00	0.03	0.03	0.03	0.02	260
56<=P<75	Stage IV	2014	0.40	0.28	0.01	2.20	0.04	0.00	0.03	0.03	0.03	0.02	260
56<=P<75	Stage V	2020	0.40	0.13	0.00	2.20	0.04	0.00	0.02	0.02	0.02	0.00	260
75<=P<130	<1981	1980	10.50	2.00	0.05	5.00	0.04	0.00	1.40	1.40	1.40	0.77	280
75<=P<130	1981-1990	1990	11.80	1.60	0.04	4.30	0.04	0.00	1.00	1.00	1.00	0.55	268
75<=P<130	1991-Stage I	1991	13.30	1.20	0.03	3.50	0.04	0.00	0.40	0.40	0.40	0.22	255
75<=P<130	Stage I	1999	8.10	0.40	0.01	1.50	0.04	0.00	0.20	0.20	0.20	0.16	255
75<=P<130	Stage II	2003	5.20	0.30	0.01	1.50	0.04	0.00	0.20	0.20	0.20	0.16	255
75<=P<130	Stage IIIA	2007	3.24	0.30	0.01	1.50	0.04	0.00	0.20	0.20	0.20	0.16	255
75<=P<130	Stage IIIB	2012	2.97	0.13	0.00	1.50	0.04	0.00	0.03	0.03	0.03	0.02	255
75<=P<130	Stage IV	2014	0.40	0.13	0.00	1.50	0.04	0.00	0.03	0.03	0.03	0.02	255
75<=P<130	Stage V	2020	0.40	0.13	0.00	1.50	0.04	0.00	0.02	0.02	0.02	0.00	255
130<=P<560	<1981	1980	17.80	1.50	0.04	2.50	0.04	0.00	0.90	0.90	0.90	0.45	270
130<=P<560	1981-1990	1990	12.40	1.00	0.02	2.50	0.04	0.00	0.80	0.80	0.80	0.40	260
130<=P<560	1991-Stage I	1991	11.20	0.50	0.01	2.50	0.04	0.00	0.40	0.40	0.40	0.20	250
130<=P<560	Stage I	1999	7.60	0.30	0.01	1.50	0.04	0.00	0.20	0.20	0.20	0.14	250
130<=P<560	Stage II	2002	5.20	0.30	0.01	1.50	0.04	0.00	0.10	0.10	0.10	0.07	250
130<=P<560	Stage IIIA	2006	3.24	0.30	0.01	1.50	0.04	0.00	0.10	0.10	0.10	0.07	250
130<=P<560	Stage IIIB	2011	1.80	0.13	0.00	1.50	0.04	0.00	0.03	0.03	0.03	0.02	250
130<=P<560	Stage IV	2014	0.40	0.13	0.00	1.50	0.04	0.00	0.03	0.03	0.03	0.02	250
130<=P<560	Stage V	2019	0.40	0.13	0.00	1.50	0.04	0.00	0.02	0.02	0.02	0.00	250
P>560	Stage V	2019	3.50	0.13	0.00	1.50	0.04	0.00	0.05	0.05	0.05	0.00	250

EF (g/kWh) / year

- Air pollutants – technological changes
- GHGs – fuel consumption



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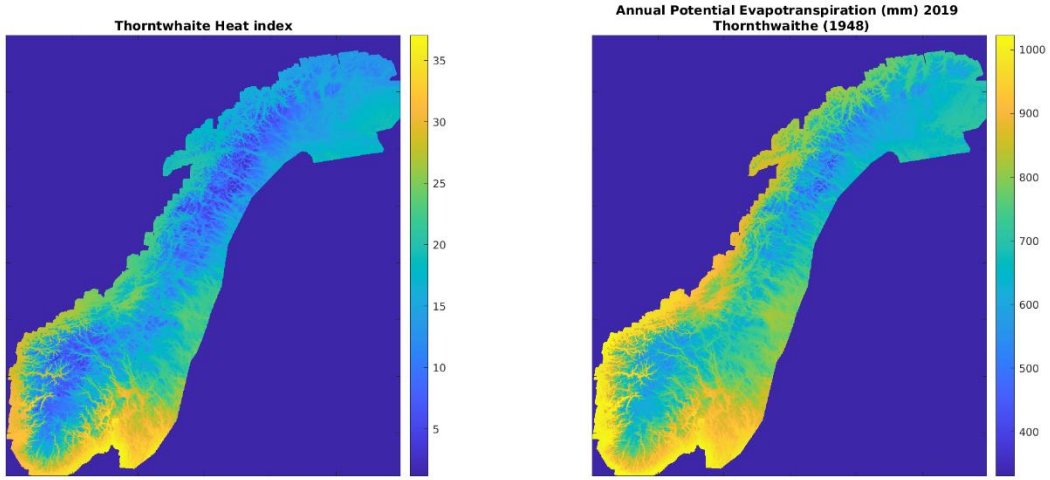
Example of ongoing development

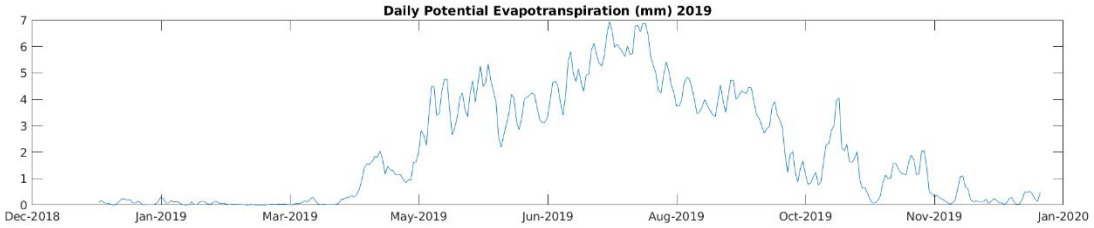
Non-exhaust Emissions (PM)

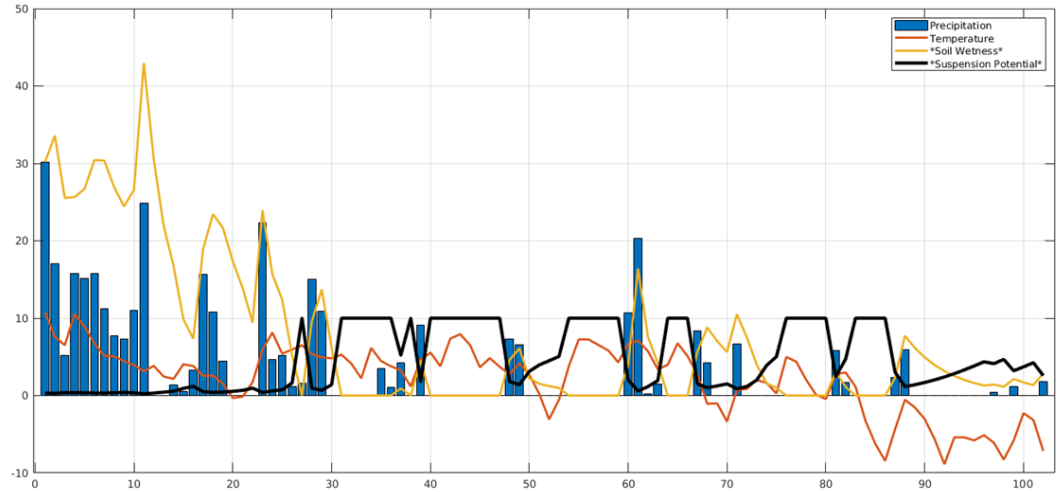
$$EM_{PM_{10}} = EF_{PM_{10}} \times A \times D \times (1 - CE) \times \frac{24}{PE} \times \frac{S}{9\%}$$

$$PE_{index} = 3.16 \sum_{i=0}^{12} \left(\frac{P_i}{1.8T_i + 22} \right)^{\frac{10}{9}}$$

Innitial starting point







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Way forward to best practice and recommendations

- **Starting point**: NRMM in construction has not been a priority sector, however it is becoming more important in urban areas.
- There is a lot of interest on understanding the contribution to urban emissions / pollution levels
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- How do we identify successful approaches for high – resolution emission inventories?
- How can FAIRMODE contribute to develop best practice / recommendation for high resolution emissions? (e.g., state of the knowledge, existing methods, guidelines for input data (activity, EF, spatial and temporal distribution)
- Is our new development in line with best practise? Is applicable to other areas?

Thanks!

FAIRMODE Technical Meeting

6-8 October 2021

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