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SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

# *Current and future emissions from inland navigation*


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# Outline

- *Emission factors from onboard measurements*
- *Emissions modeling*
- *Current emissions*
- *Future scenarios*

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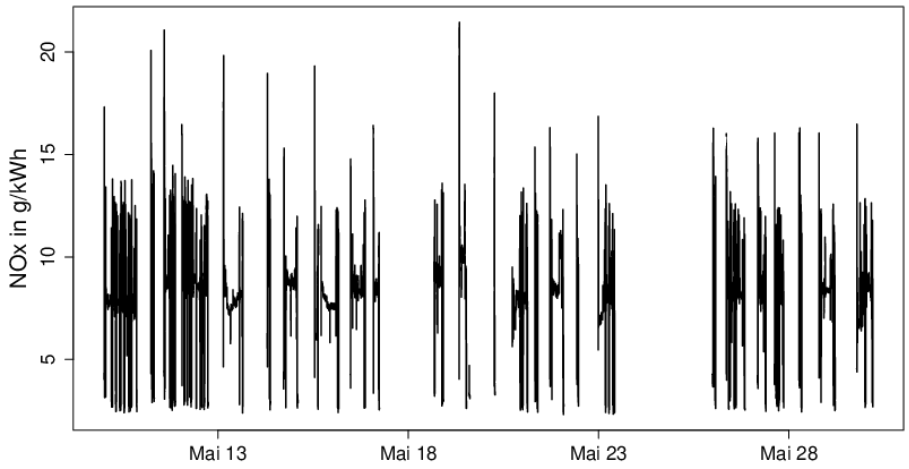
# Measurement episode from CCNR2 (SCR-DPF)



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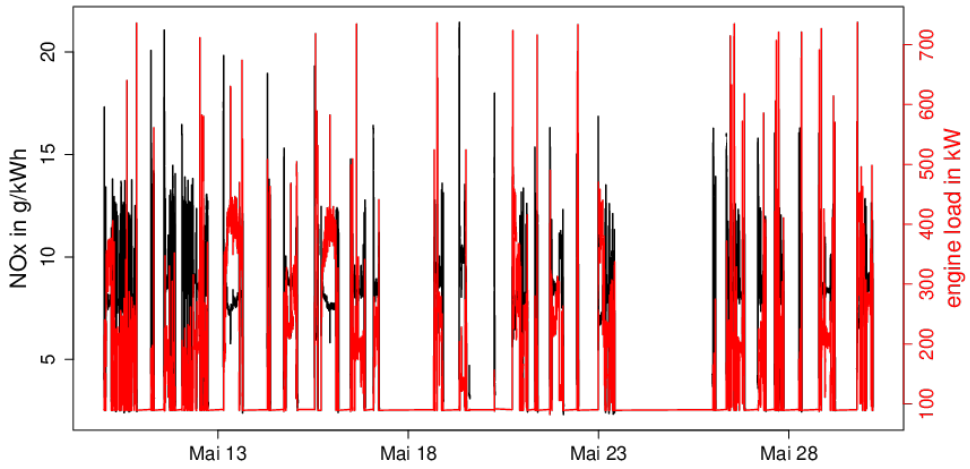
# Measurement episode from CCNR2 (SCR-DPF)



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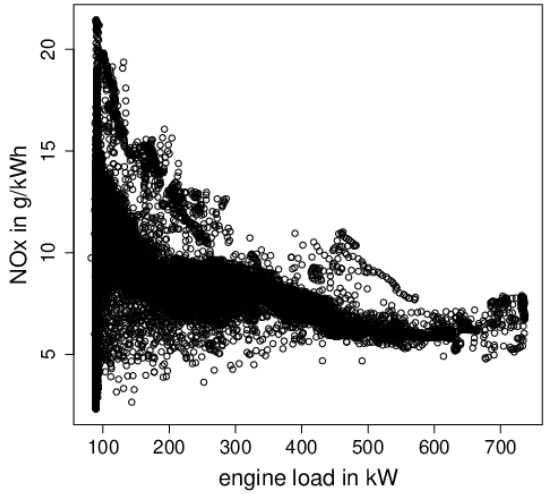

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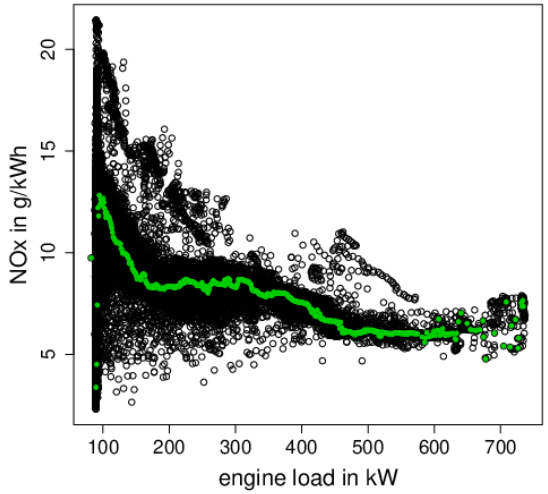
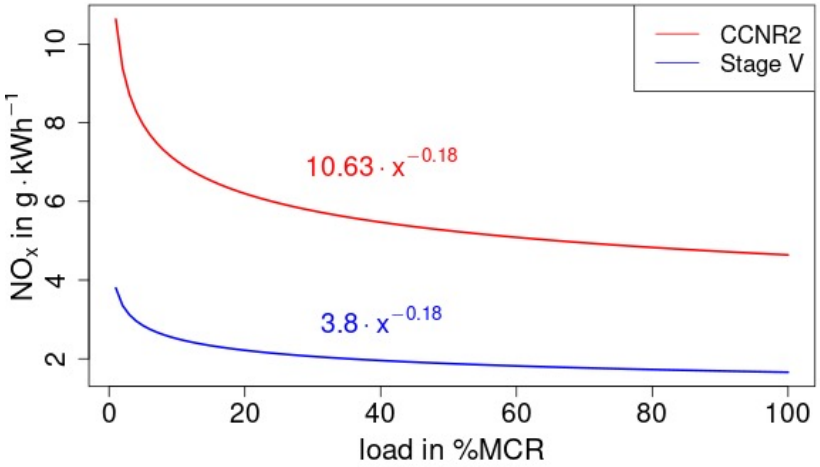


# Emission factor functions per technology



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# Averaged emission factor functions for NOx

| Engine type | m | n | E3 average | Error |
|---|---|---|---|---|
| CCNR0 | 26.8 | -0.23 | 10.59 | 3.66 |
| CCNR1 | 25.28 | -0.27 | 8.31 | 3.66 |
| CCNR2 | 10.63 | -0.18 | 5.16 | 1.65 |
| SCR | 10.28 | -0.39 | 2.07 | 1.65 |
| LNG | 3.8 | -0.18 | 1.8 | 1.25 |
| GTL | 9.55 | -0.18 | 4.55 | 1.70 |
| FWE | 21.45 | -0.40 | 4.14 | 2.58 |
| Euro VI | 0.85 | -0.18 | 0.4 | 0.29 |
| Stage V | 3.8 | -018 | 1.8 | - |

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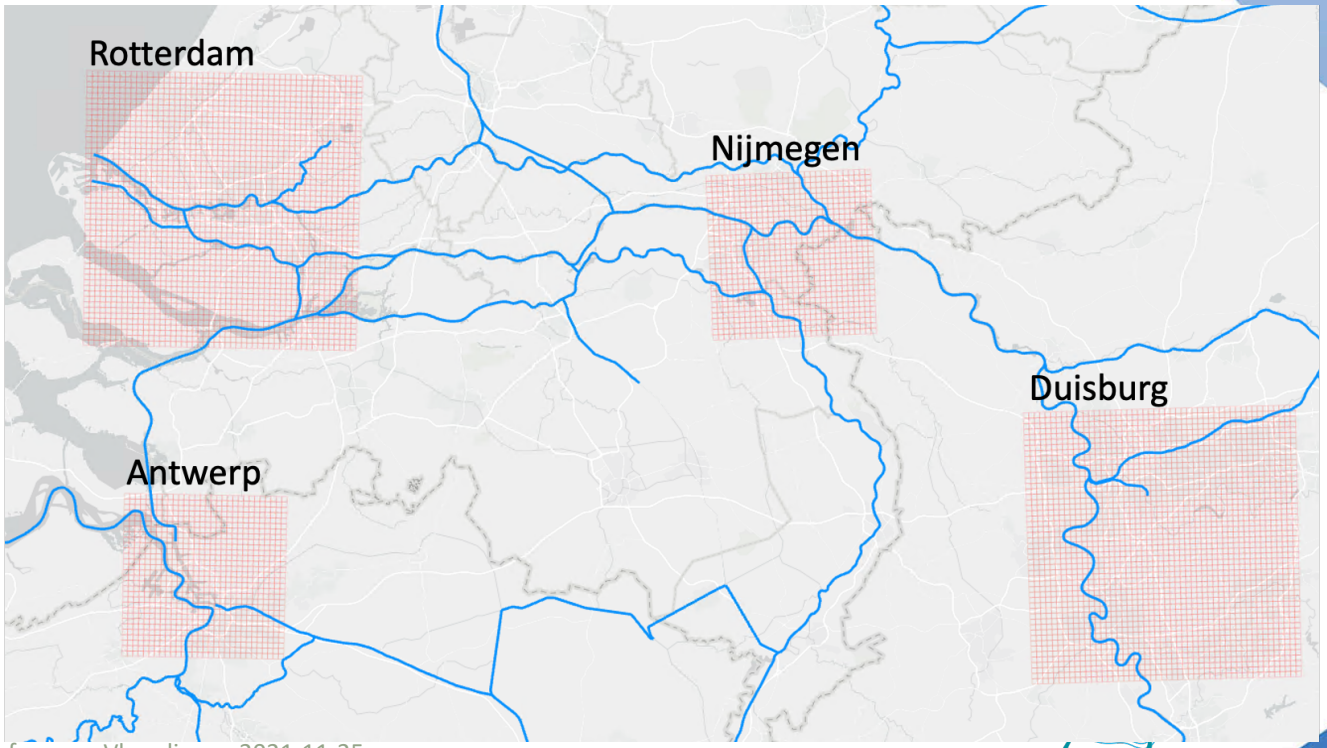
# Study domains



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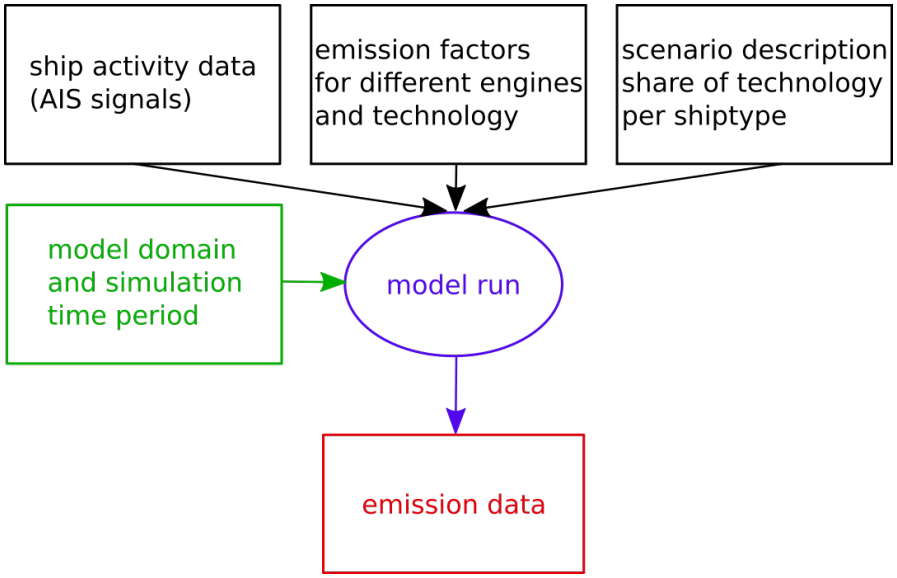
# Emission model for inland navigation

- *Coded in R*
- *Configured with scripts*
- *Highly flexible and extendable*
- *Open source*

# Emission model for inland navigation



# Applying emission factors

- *Getting ship type and size (length) from AIS data.*
- *Getting speed over ground from AIS data and deriving engine load.*
- *Calculate weighted average of emission factors according to the distribution of engines in the ship type and size.*

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# Applying emission factors

| Vessel type | Revision CCR0/1 | Revision CCR2 | Stage V | LNG mono fuel | LNG Dual fuel refit | SCR + DPF | Diesel electric | FWE | GTL |
|---|---|---|---|---|---|---|---|---|---|
| Passenger vessel <250 kW | 92% | 8% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Passenger vessel 250 - 500 kW | 89% | 11% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Passenger vessel 500 - 1000 kW | 78% | 22% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Passenger vessel >1000 kW | 46% | 54% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Push boats <500 kW | 79% | 21% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Push boats 500-2000 kW | 50% | 47% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Push boats ≥2000 kW | 3% | 94% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels <80 m. length | 77% | 23% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Motor vessels dry cargo typical 80 and 86 m ship | 76% | 21% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels dry cargo typical 105 m ship | 59% | 38% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels dry cargo 110 m ship | 52% | 45% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels dry cargo >130 (135 m ship) | 40% | 56% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels liquid cargo 80-109m length (typical 86 m ship) | 43% | 54% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels liquid cargo 110 m ship | 29% | 65% | 0% | 2% | 0% | 3% | 0% | 0% | 0% |
| Motor vessels liquid cargo >130 (135 m ship) | 21% | 75% | 0% | 0% | 0% | 3% | 0% | 0% | 0% |
| Coupled convoys | 33% | 62% | 0% | 1% | 0% | 3% | 0% | 0% | 0% |
| Ferry | 67% | 32% | 0% | 1% | 0% | 0% | 0% | 0% | 0% |
| tugboat and workboat | 87% | 13% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

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# Scenario assumptions

| Scenario | Unregu-lated | CCNR1 | CCNR2 | Stage V | LNG mono fuel | SCR + DPF | SCR | GTL |
|---|---|---|---|---|---|---|---|---|
| 2020 baseline | 41.9 | 23.7 | 32.6 | 0.0 | 0.3 | 1.5 | 0.0 | 0.0 |
| 2035 baseline | 18.4 | 19.8 | 35.5 | 24.3 | 0.3 | 1.6 | 0.0 | 0.0 |
| 2035 clinsh | 0.0 | 0.0 | 0.0 | 88.6 | 0.0 | 0.0 | 1.7 | 9.7 |

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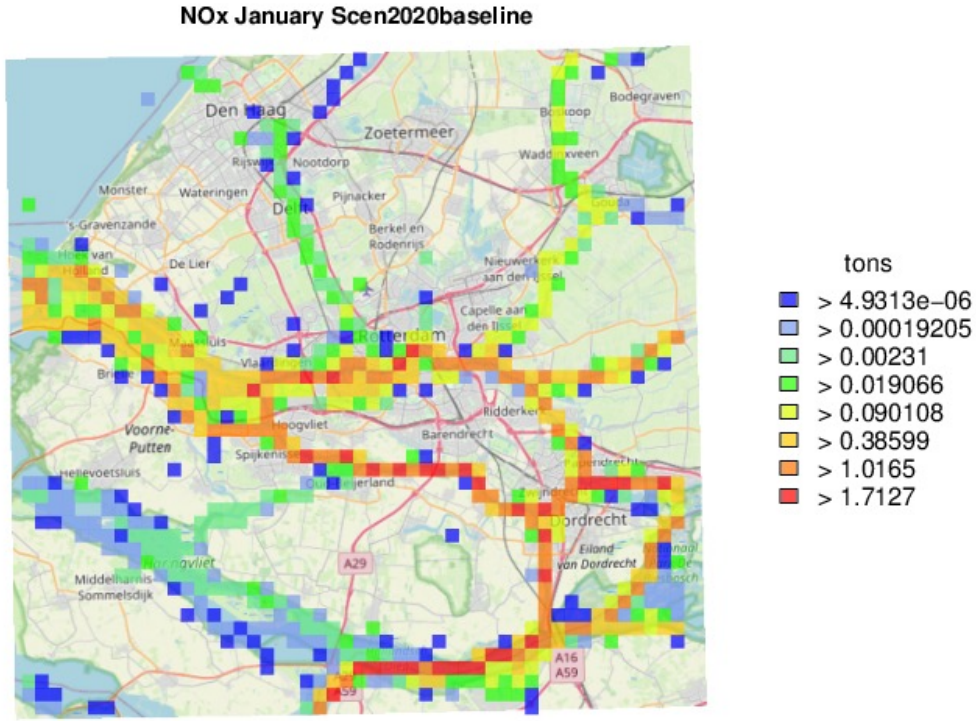
# Map of NOx emissions for Rotterdam 2020



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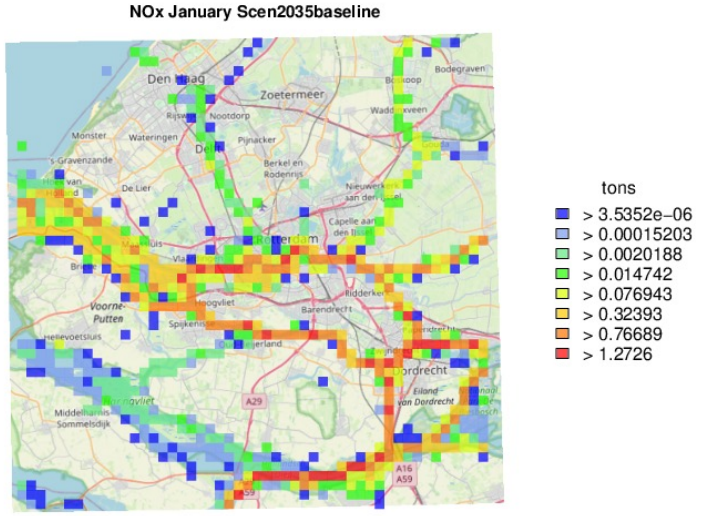
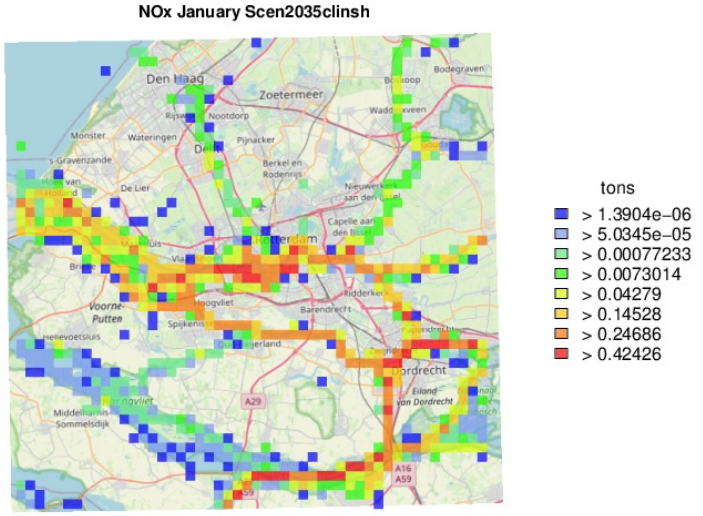
# Scenario comparisons for NOx in Rotterdam

## *2035 baseline*




## *2035 clinsh*



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# Share of inland navigation emissions

| | Rotterdam | | Nijmegen | | Antwerp | | Duisburg | |
|---|---|---|---|---|---|---|---|---|
| | NOx | PM10 | NOx | PM10 | NOx | PM10 | NOx | PM10 |
| other [kt/a] | 41.3 | 3.64 | 4.39 | 0.78 | 32.50 | 2.69 | 57.22 | 10.29 |
| ships [kt/a] | 2.68 | 0.09 | 1.32 | 0.04 | 0.97 | 0.03 | 2.05 | 0.06 |
| share [%] | 6.49 | 2.48 | 30.11 | 5.13 | 2.97 | 1.12 | 3.58 | 0.58 |

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# Comparison of scenario emissions in Duisburg

| pollutant | scenario | July | January | annual | decrease % |
|---|---|---|---|---|---|
| NOx | 2020 baseline | 138.97 | 202.28 | 2047.53 | |
| PM | 2020 baseline | 4.27 | 6.31 | 63.47 | |
| NOx | 2035 baseline | 106.01 | 158.59 | 1587.59 | 22.5 |
| PM | 2035 baseline | 3.04 | 4.67 | 46.25 | 27.1 |
| NOx | 2035 clinsh | 30.46 | 44.36 | 448.95 | 78.0 |
| PM | 2035 clinsh | 0.57 | 1.12 | 10.17 | 84.0 |

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# Comparison of scenario emissions in Antwerp

| pollutant | scenario | July | January | annual | decrease % |
|---|---|---|---|---|---|
| NOx | 2020 baseline | 74.09 | 87.12 | 967.31 | |
| PM | 2020 baseline | 2.64 | 3.06 | 34.21 | |
| NOx | 2035 baseline | 57.07 | 67.59 | 747.97 | 22.7 |
| PM | 2035 baseline | 2.06 | 2.38 | 26.64 | 22.1 |
| NOx | 2035 clinsh | 20.57 | 24.39 | 269.77 | 72.1 |
| PM | 2035 clinsh | 1.08 | 1.17 | 13.48 | 60.6 |

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# THANK YOU FOR YOUR ATTENTION!

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