Supplement of

The impact of ship emissions on air quality and human health in the Gothenburg area – Part II: Scenarios for 2040

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### Supplement 1 – emission factors for 2040

Table S1: Emission factors to derive 2040 emissions (CLE2040) from 2012 emissions from the Greenhouse Gas - Air Pollution Interactions and Synergies (GAINS) model using the emission scenario ECLIPSE_V5a_CLE_base.

| Emission sectors                              | SO₂       | NOₓ       | PM₁₀      | NMVOC     |
|-----------------------------------------------|-----------|-----------|-----------|-----------|
| Energy Industries                             | 0.662978  | 0.854049997 | \         | 0.889792231 |
| Fuel combustion within industry for energy use | 1.196401  | 0.846780766 | 1.657303371 | 1.448372093 |
| Diffuse emissions from fuel management        | 0.843987  | 0.808     | 11.10621762 | 0.736323394 |
| Refineries                                    | 0.558219  | 0.917042889 | 11.51612903 | 0.958333333 |
| Boilers                                       | \         | \         | 0.075342466 | 3.432692308 |
| Residential heating                           | 0.575404  | 0.731368781 | 0.216500766 | 0.410687481 |
| Mineral industry                              | \         | \         | 1.857886905 | \         |
| Chemical industry                             | 1.183701  | 1.18066561 | 3.930084746 | 0.988788041 |
| Metal industry                                | 1.179078  | \         | 0.133764833 | \         |
| Pulp and paper industry                       | 1.138498  | 1.138363893 | 2.289488477 | \         |
| Other industry                                | \         | \         | 0.520822622 | 1.007579302 |
| Non-road mobile machinery                     | 0.454545  | 0.118023075 | 3.801980198 | 0.435876623 |
| Solvents (use of chemical products in households and operations) | \         | \         | 0.075296108 | 0.984338488 |
| Agriculture                                   | 1         | 1         | 24.1754386  | 1         |
Figure S1: The total modeled present day winter (December, January, February) concentration for NO\textsubscript{2}, O\textsubscript{3}, PM\textsubscript{2.5} and SO\textsubscript{2} (column 1) as well as the concentration in BAU2040 (column 2) and the difference between the present day and BAU2040 in absolute (column 3) and relative (column 4) values. © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
Figure S2: The total modeled present day summer (June, July, August) concentration for NO$_2$, O$_3$, PM$_{2.5}$ and SO$_2$ (column 1) as well as the concentration in BAU2040 (column 2) and the difference between the present day and BAU2040 in absolute (column 3) and relative (column 4) values. © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
Supplement 3 – EEDI2040 results

Figure S3: The total modeled present day concentration for NO$_2$, O$_3$, PM$_{2.5}$ and SO$_2$ (column 1), as well as the concentration in EEDI2040 (column 2) and the difference between the present day and EEDI2040 in absolute (column 3) and relative (column 4) values. © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
Figure S4: The total modeled present day summer (June, July, August) concentration for NO$_2$, O$_3$, PM$_{2.5}$ and SO$_2$ (column 1) as well as the concentration in EEDI2040 (column 2) and the difference between the present day and EEDI2040 in absolute (column 3) and relative (column 4) values. © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
| Base 2012 | EEDI 2040 | Absolute Changes | Relative Changes |
|-----------|-----------|------------------|------------------|
| **NO₂** [ppb] | **NO₂** [ppb] | **Abs. diff DJF 2040-2012 NO₂ [ppb]** | **Rel. diff DJF 2040-2012 NO₂ [%]** |
| 0 | 0 | -10 | 80 |
| 2 | 0.75 | -7.5 | 70 |
| 5 | 1.5 | -5 | 60 |
| 8 | 2.25 | -2.5 | 50 |
| 10 | 3 | 0 | 40 |

| **O₃** [ppb] | **O₃** [ppb] | **Abs. diff DJF 2040-2012 O₃ [ppb]** | **Rel. diff DJF 2040-2012 O₃ [%]** |
| 23 | 26 | 2 | 10 |
| 25 | 27 | 3 | 15 |
| 27 | 28 | 4 | 20 |
| 29 | 29 | 5 | 25 |
| 31 | 30 | 6 | 30 |

| **PM₂.₅ [µg/m³]** | **PM₂.₅ [µg/m³]** | **Abs. diff DJF 2040-2012 PM₂.₅ [µg/m³]** | **Rel. diff DJF 2040-2012 PM₂.₅ [%]** |
| 0 | 3 | -1.6 | -35 |
| 2 | 3.75 | -1.45 | -28.75 |
| 3 | 4.5 | -1.3 | -22.5 |
| 5 | 5.25 | -1.15 | -16.25 |
| 8 | 6 | -1 | -10 |

| **SO₂ [µg/m³]** | **SO₂ [µg/m³]** | **Abs. diff DJF 2040-2012 SO₂ [µg/m³]** | **Rel. diff DJF 2040-2012 SO₂ [%]** |
| 0 | 0 | -1.2 | -80 |
| 0.3 | 0.1 | -0.95 | -62.5 |
| 0.5 | 0.18 | -0.7 | -45 |
| 1 | 0.3 | -0.45 | -27.5 |
| 1.5 | 1.5 | -0.2 | -10 |

Figure S5: The total modeled present day winter (December, January, February) concentration for NO₂, O₃, PM₂.₅ and SO₂ (column 1) as well as the concentration in EEDI2040 (column 2) and the difference between the present day and EEDI2040 in absolute (column 3) and relative (column 4) values. © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
Figure S6: Absolute contributions of local ship emissions to annual mean concentration levels in Gothenburg in 2012 (column 1) and EEDI2040 (column 2), as well as the relative contributions (columns 3 and 4). © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
Figure S7: Relative changes in annual mean NO₂, PM₂.₅ and O₃ concentrations for EEDI2040LP compare to EEDI2040 scenario. © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.
Table S4-1: City-scale model setup.

|                          | Domain       | Spatial resolutions | Model / Database                      |
|--------------------------|--------------|---------------------|---------------------------------------|
| Meteorology 2012         | 30 km × 30 km| 500 m               | ECMWF ERA5 0.3° × 0.3°, 21 layers     |
| Background concentrations| 160 km × 96 km| 4 km × 4 km         | CMAQ                                  |
| Local shipping emissions 2012 | 30 km × 30 km| 250 m × 250 m       | STEAM2                                |
| Local traffic emissions 2012 | 30 km × 30 km| meters (line sources)| Miljöförvaltningen and HBEFA v. 3.2 |
| Local industrial, machines, wood burning and aviation etc. 2012 | 30 km × 30 km| 1 km × 1 km         | SMED                                  |

The period of the simulation is the year 2012 (introduced in the manuscript) and due to the rather fast chemistry on urban-scales, there is no model spin-up necessary. Tests with and without a model spin-up time of one week have shown differences in results below 0.1% for the first hours of simulated concentrations in the simulation period.”
Maps of shipping emissions as given in part 1:

**Figure 2.** Annual local shipping emissions of (a) NO$_x$ and (b) PM$_{10}$ (equal to PM$_{2.5}$) from small vessels with a stack height below 36 m (assumed 15 m) and (c) NO$_x$ and (d) PM$_{10}$ from large vessels with high stack height above 36 m (assumed 36 m) in the Gothenburg area. Base map credits: © OpenStreetMap contributors 2020. Distributed under a Creative Commons BY-SA License.

Map of spatial distribution of local emissions from road traffic and industrial point sources. In addition, other emissions such as domestic heating, working and off-road machinery etc. expressed as grid sources in the model.
Figure x. The spatial distribution of local emissions from road traffic (red lines), industrial point sources (green circles), and other sources (yellow lines).