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Norwegian national non-exhaust emission trends using gridded NORTRIP (G-NORTRIP)

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Abstract

Every year Statistics Norway (SSB) reports emissions of air pollutants and climate gases. One of these emissions is related to non-exhaust road transport emissions, particularly road, tyre and brake wear. In Norway road wear from studded tyres is the largest emission source for particulate matter (PM_{10}). Up until recently, SSB has been using a formula to calculate these emissions based on the road traffic volumes, studded tyre share and a wear factor per vehicle with studded tyres. Over the last decade more advanced methods for calculating road transport non-exhaust emissions have been developed. In particular, the NORTRIP non-exhaust emission model has been developed and has for many years been implemented as part of the Norwegian national air quality forecasting system. Recently a comparison of NORTRIP and SSB emissions was undertaken and large differences were found, with NORTRIP emissions being a factor of 5 higher. This report outlines new calculations of the non-exhaust emissions using the gridded version of NORTRIP (G-NORTRIP). This version of the model provides emissions on a 0.1° x 0.1° grid and is significantly faster than the normal NORTRIP model that calculates emissions for each road segment. Due to the efficiency of G-NORTRIP long term trends can be calculated over many years. In this report the methodology is presented and the results of the trend calculations, 1990 - 2024, are provided. The calculated emissions are delivered to SSB and these in turn are provided to the Norwegian Environment Agency for reporting under the Convention on Long Range Transboundary Air Pollution (LRTAP).

Keywords

NORTRIP, non-exhaust emissions, PM10, PM2.5, trends, air quality

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Abstract

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1. Introduction

Every year Statistics Norway (SSB) reports emissions of air pollutants and climate gases. One of these emissions is related to non-exhaust road transport emissions, particularly road, tyre and brake wear. In Norway road wear from studded tyres is the largest emission source for particulate matter > 10 μm (PM_{10}). Up until recently, SSB has been using a formula to calculate these emissions based on the road traffic volumes, studded tyre share and a wear factor per vehicle with studded tyres (SFT, 1999). Reported emissions are provided every year for the past 30 years.

Over the last decade more advanced methods for calculating road transport non-exhaust emissions have been developed. In particular, the NORTRIP model (NOn-exhaust TRansport Induced Particle emissions) has been developed (Denby et al, 2013a; 2013b) and has for many years been implemented as part of the Norwegian national air quality forecasting system (NEA, 2025a). In 2023, a comparison of NORTRIP and SSB emissions was undertaken (Denby, 2023) and large differences were found. As a result of that study, parameters in the SSB model were updated to correspond to NORTRIP parameters, resulting in a significant change, around a factor of 5 larger, in national reported emissions in 2022 and 2023. A comparison was made at the time between NORTRIP calculations and the updated SSB emissions for some recent years.

Since that study, NORTRIP has now been extended as a gridded model, allowing much faster calculations of non-exhaust emissions, when compared to modelling individual road links. This allows for the full calculation of the long term trend (35 years) of these emissions. This document outlines the gridded NORTRIP (G-NORTRIP) methodology and the results of these trend calculations. SSB will report these emissions for 2024 as part of the national reporting in 2026. Thereafter, emissions will be updated every year.

2. Gridded road data

Gridded road data is created on a 0.1° x 0.1° grid by aggregating the existing Norwegian road data, from NVDB (Nasjonal vegdatabank) (NVDB, 2025) and used in the air quality forecasting and assessment, into 4 categories in each grid: Europaveier, Riksveier, Fylkesveier and Kommuneveier. In addition to NVDB, the municipal roads are added based on SSB's road network calculations used for noise modelling (Nordbeck and Langsrud, 2015).

Traffic trend calculations are carried out by SSB using HBEFA4.2 data (UNCC, 2025). This is provided as passenger cars (PC), light duty vehicles (LDV) and heavy duty vehicles (HDV). This is then translated to the long and short vehicle NVDB classification by assuming 0.25 of LDV belong to the long category. After this conversion the number of long and short vehicles from SSB are compared to NVDB for the reference year 2024. There is a slight overestimate of traffic in NORTRIP from NVDB and this is compensated for by scaling the entire period with a scaling factor for short and long vehicles derived for 2024. This scaling factor is 0.966 and 0.880 for short and long vehicles respectively and included in the retrogressive traffic scaling.

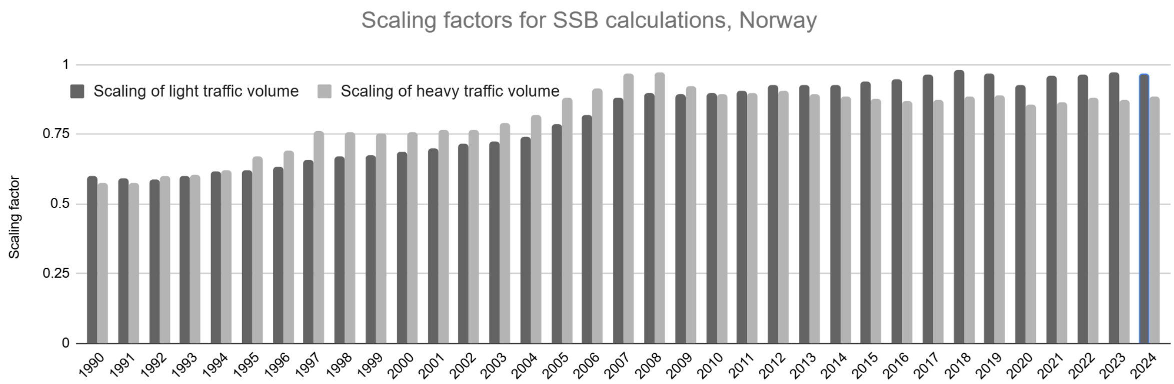


Figure 1. Scaling factors for light and heavy vehicles 1990-2024. The reference year for traffic is 2024.

Studded tyre data is also provided by SSB (NEA, 2025b). This is shown in Figure 2, along with the traffic scaling, see Figure 1, and the effective scaling for road wear. This effective scaling is simply the traffic volume trends multiplied by the studded tyre share trends. If most of the road wear comes from studded tyre wear then the effective scaling will be a good indicator for trends in road wear emissions. This is indeed how the parameterised road wear algorithm from SSB works.

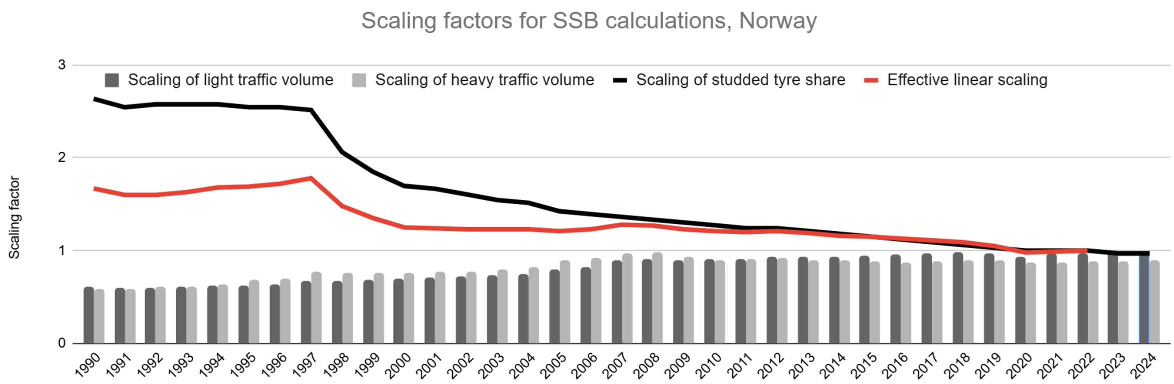


Figure 2. Scaling factors for traffic, studded tyre usage and effective road wear scaling.

In Figure 3 the spatial distribution of the gridded road data is shown for the 4 different road types.

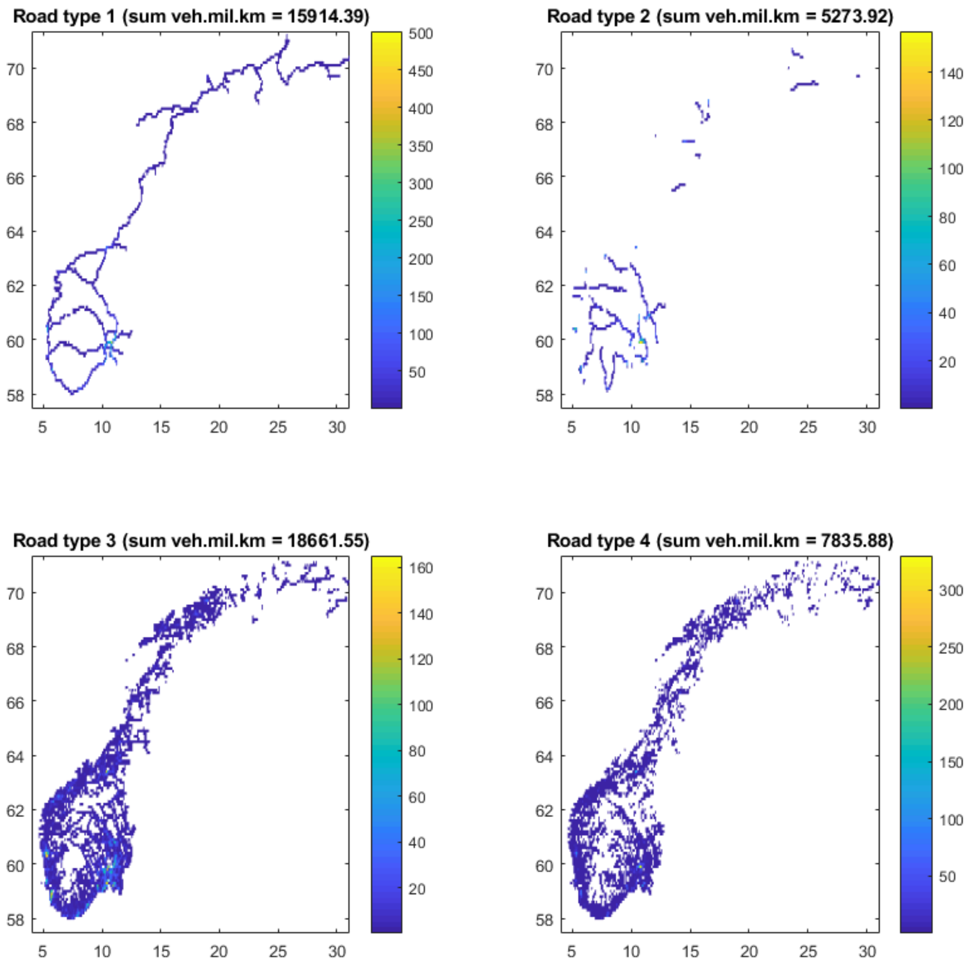


Figure 3. Vehicle million kilometers assigned to the 0.1° grid for the 4 different road categories. Europaveier (Road type 1), Riksveier (Road type 2), Fylkesveier (Road type 3) and Kommuneveier (Road type 4).

In addition to road wear, brake and tyre wear are also calculated. For this study we adapted the NORTRIP wear rates and size distributions to be more aligned with those reported in the EMEP/EEA handbook (EMEP/EEA, 2023). This is the most common source of wear rates used in European air quality modelling.

Though not part of the reporting, exhaust emissions for NO_X and $PM_{2.5}$ are also included in the calculations. These are based on municipality level emission factors from the NERVE model (Weydahl and Grythe, 2024). Exhaust emission trends from SSB have been applied to these 2024 emissions.

3. Meteorological data

Meteorological data back to 1990 is provided from NORA3 (Solbrekke, et al., 2021), which is at 3 km resolution. The meteorological grid used is the one closest to the centre of the 0.1° G-NORTRIP grid. The mismatch in resolution between the meteorological data and the aggregated road network gridded data can lead to some discrepancies, when comparing to non-gridded NORTRIP calculations.

4. Calculations

Each year is calculated separately and in parallel starting on 1st of August of the previous year and ending on the 31st of December of the calculation year. This first round calculation is the normal procedure for NORTRIP calculations, where the mass loading of the road surface must be built up prior to the start of a calendar year. To be more consistent across years, each calendar year is rerun again starting with the initialisation from the 31st December from the first round of calculations. A single year calculation takes around 3-4 hours. These are carried out in parallel. Standard input data such as parameters, as used in normal NORTRIP calculations, are applied. Sanding emissions have been removed from the calculations as these are too uncertain.

Table 1. Outputs are in the form of daily netcdf files of 24 hours with the following variables

Source	PM_{co}	$PM_{2.5}$	PM_{10}	NO_x
Road wear	X	X		
Tyre wear	X	X		
Brake wear	X	X		

Sand (not included)	0	0		
Salt	X	X		
Exhaust		X		X
Total non-exhaust	X	X	X	

5. Results

5.1 Reported emission trends

The results of the trend calculations are summarized in Figure 4 where the coarse and fine emissions are shown separately for road, tyre and brake wear, as well as exhaust and road salt emissions. There is a general downward trend in emissions over the 35 year period. This reflects the expected result as shown in Figure 2. Meteorological variability accounts for around 10% of the interannual variability. Though exhaust is not part of the non-exhaust reporting, the significance of these emissions has been significantly reduced over the past 35 years.

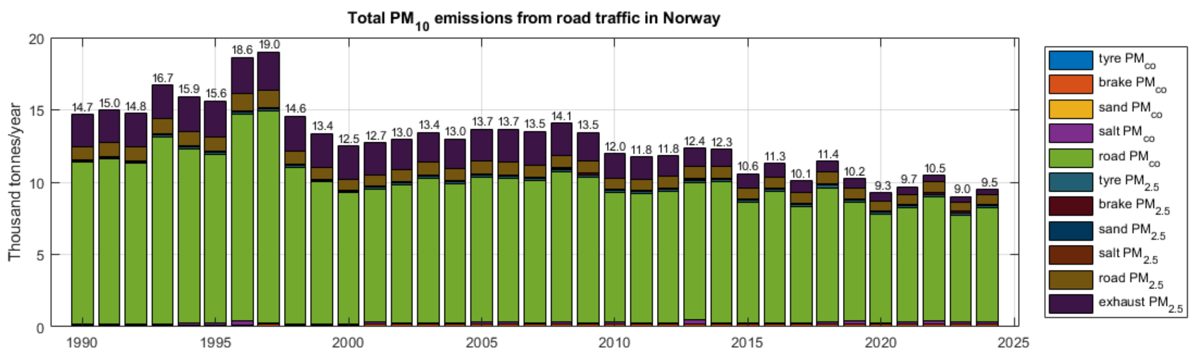


Figure 4. Calculated non-exhaust emissions of road, tyre and brake wear, as well as emitted road salt and exhaust. The emissions are split into the coarse fraction (co) and the fine fraction (2.5). All exhaust is in the fine fraction.

In Table 2 the submitted emissions for reporting are presented. Emissions of tyre and brake wear are aggregated for this reporting.

Table 2. PM_{10}, $PM_{2.5}$ and TSP emissions of road wear and tyre/brake wear as calculated by G-NORTRIP for the years 1990 - 2024.

Year	PM_{10} road wear emissions (tonnes/year)	PM_{10} brake and tyre wear emissions (tonnes/year)	$PM_{2.5}$ road wear emissions (tonnes/year)	$PM_{2.5}$ brake and tyre wear emissions (tonnes/year)	TSP road wear emissions (tonnes/year)	TSP brake and tyre wear emissions (tonnes/year)
1990	12195	264	958	143	43553	349

1991	12384	271	973	146	44227	358
1992	12145	273	954	148	43375	362
1993	14095	288	1107	156	50339	382
1994	13097	292	1029	157	46776	386
1995	12721	294	1000	158	45433	389
1996	15531	325	1220	176	55467	432
1997	15979	351	1256	192	57069	469
1998	11701	319	919	172	41790	422
1999	10618	326	834	177	37923	433
2000	9825	326	772	177	35089	434
2001	10003	344	786	186	35726	455
2002	10366	365	814	198	37023	485
2003	10849	373	852	202	38745	496
2004	10426	370	819	201	37236	492
2005	10846	412	852	225	38736	550
2006	10758	417	845	226	38423	554
2007	10655	448	837	243	38052	596
2008	11248	460	884	250	40173	613
2009	10924	445	858	240	39013	589
2010	9652	448	758	240	34473	589
2011	9663	433	759	234	34509	573
2012	9834	442	773	238	35121	584
2013	10271	464	807	252	36682	617
2014	10568	452	830	246	37741	602
2015	9005	440	708	238	32160	583
2016	9802	464	770	251	35009	616
2017	8712	442	684	238	31114	584
2018	10040	484	789	262	35856	641
2019	8906	453	700	245	31805	600
2020	8129	440	639	239	29032	586
2021	8548	466	672	251	30529	617
2022	9357	480	735	261	33417	639
2023	7997	452	628	243	28562	596
2024	8556	452	672	244	30558	598

5.2 Spatial distribution of emissions

In Figure 4 and Table 2 the total national annual emissions are reported. Gridded results are also available. The annual average total gridded emissions are shown in Figure 5. These data are also available for reporting purposes if required.

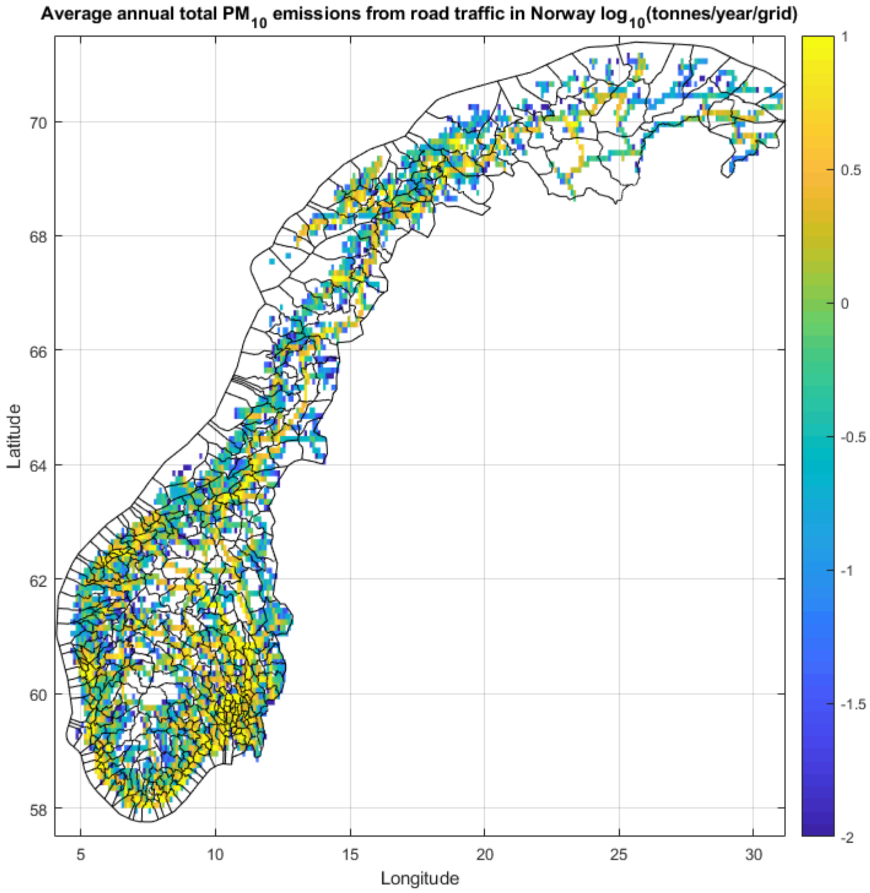


Figure 5. Spatial distribution of the 0.1° x 0.1° gridded emission data. Here the average annual emissions over the 35 year period (1990-2024) are shown.

5.3 Intercomparison of gridded emissions

In Figure 6 a comparison is made of the gridded emissions. Road wear, and exhaust emissions are presented in scatter plots. As expected, $PM_{2.5}$ exhaust and NO_X exhaust emissions are almost perfectly correlated. The slight variation is due to emission factors being specified on a municipal basis. Brake and tyre wear are also highly correlated with NO_X emissions but with slightly more variability since the brake and tyre wear are also influenced by meteorological conditions. Road wear shows more variability when compared to NO_X emissions. Since studded tyre use is specified on a municipality basis then the relative emissions of road wear and NO_X can vary significantly.

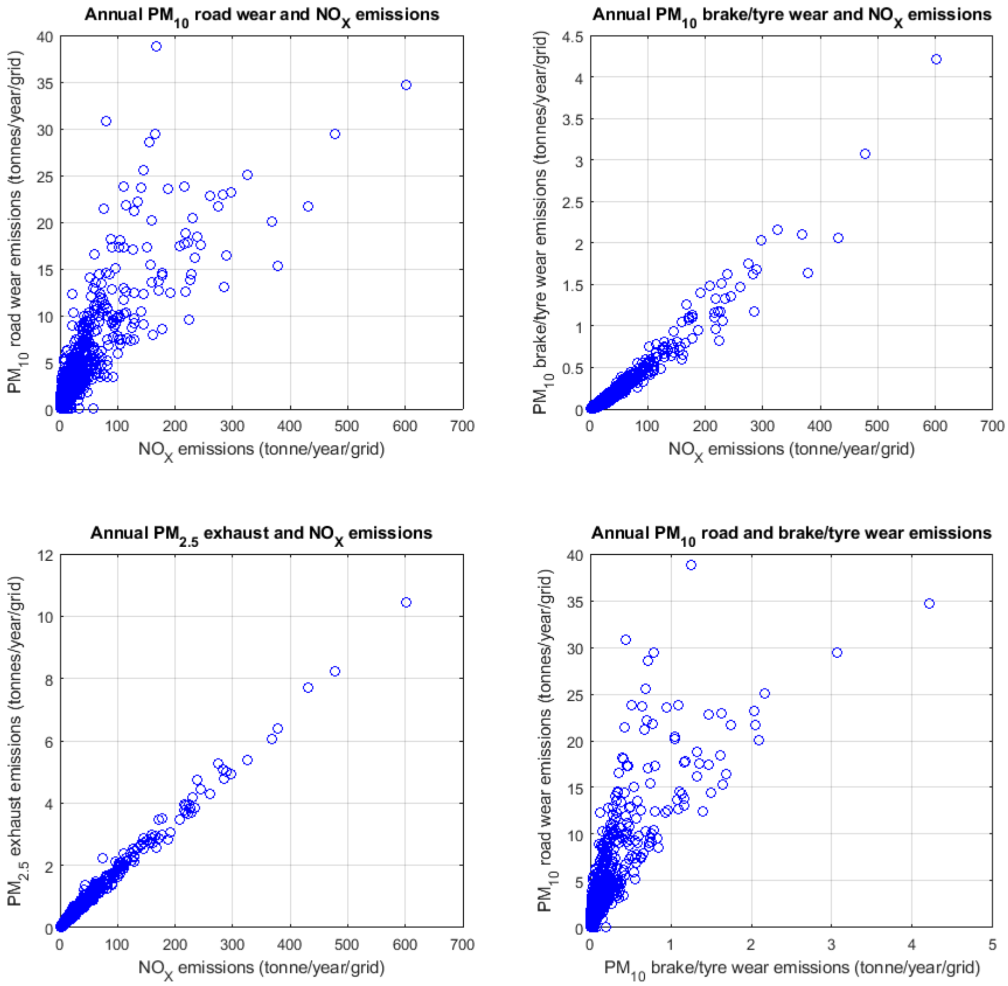


Figure 6. Intercomparison of the different emissions shown as a scatter plot of the gridded values. Average annual emissions over the 35 year period (1990-2024) are shown.

5.4 Temporal variation

There is a distinct seasonal cycle in non-exhaust emissions due to the build up of road dust during the wet/frozen winter period and the suspension in the spring dry period. In Figure 7 the daily mean emissions, wear rates and mass loading for all of Norway are shown for the year 2024. Similar seasonal cycles can be found for the other years. Peak emissions occur in April, in the spring dry period, whilst there is generally little emission in the winter months due to the wet/frozen road conditions.

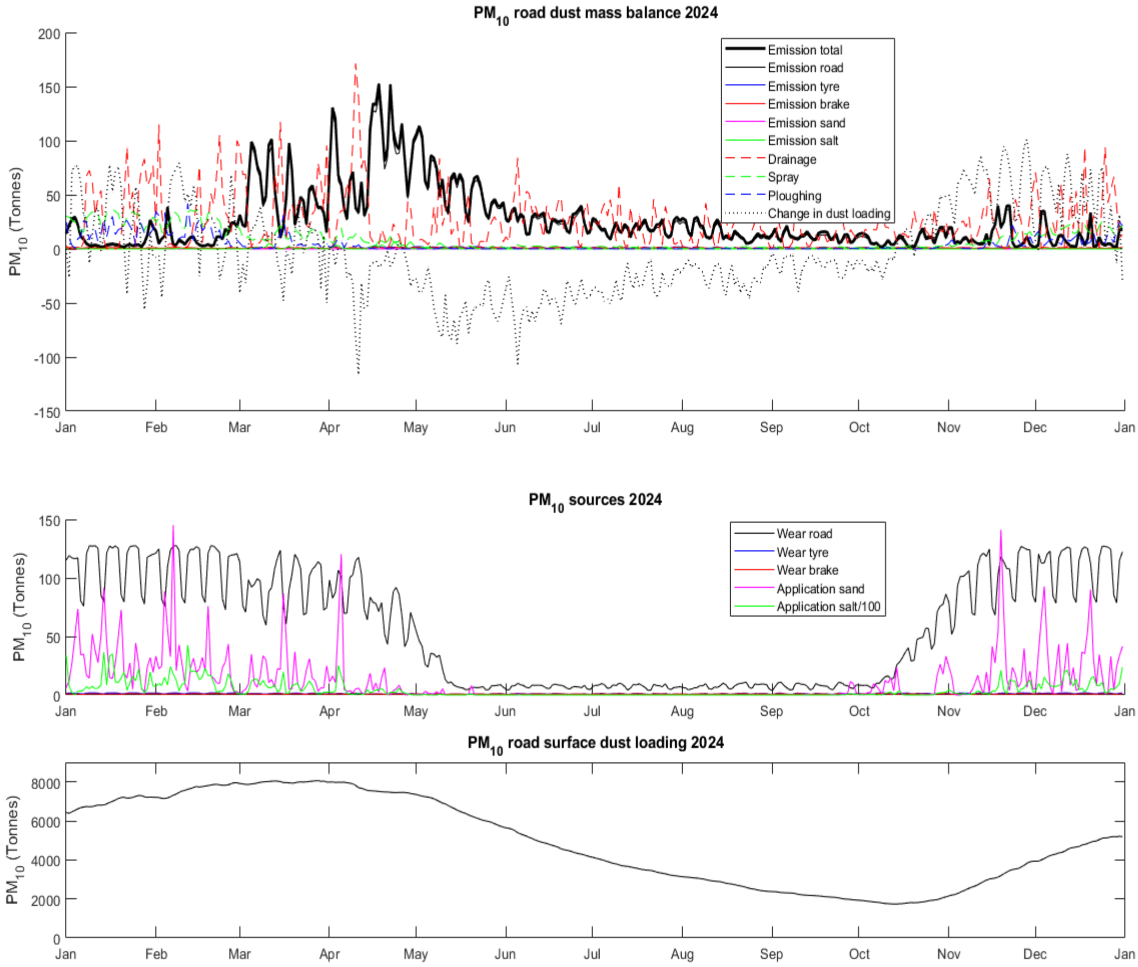


Figure 7. Daily mean mass balance, source production rates and mass loading for all roads in Norway for 2024. Sand application is included but this is not included in the final non-exhaust emission calculations. Included in the mass balance sinks are the emissions, both direct and suspended, as well as the wet removal processes of drainage, vehicle spray and snow ploughing. These wet removal processes are significant and account for around half of the total removal of non-exhaust particles from the road surface.

5.5 Comparison of gridded and non-gridded road network calculations

To check the consistency of the gridded calculations, a standard calculation with all road links individually calculated was carried out. The individual road link emissions were then gridded to the same 0.1° x 0.1° grid as used in G-NORTRIP. These calculations were limited to the years 2021-2024.

In Figure 8 the results of this comparison for the year 2024 are shown. NO_X emissions should be almost the same in both calculations, with only a slight variability because of the municipality based emission factors that can differ between the gridded and non-gridded calculations. Therefore, NOx emissions were included as a control.

For PM_{10} non-exhaust we see very similar results for almost all grids. However there are around 10 - 15 grids, out of 4582 grids in total, where there are larger deviations from the 1:1 line in Figure 8. This appears to be mainly due to the meteorological part of the modelling.

Since NORA3 is on a 3 km resolution and the G-NORTRIP gridding is carried out at roughly 6 x 11 km^2, only the meteorological grid that is closest to the grid centre is used. In other words, 5 meteorological grids are ignored in the calculation. In earlier calculations when gridding was carried out at the same resolution as the meteorological model, these deviations were not observed. In future calculations this problem should be addressed.

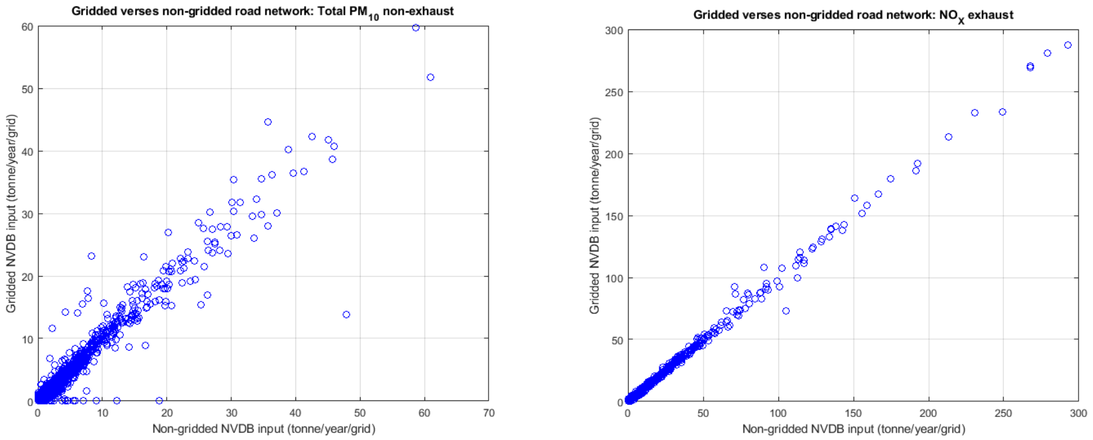


Figure 8. Comparison of gridded road network calculations with non-gridded road network calculations for the year 2024. Left is for PM_{10} and right for NO_X.

5.6 Comparison of trend results with reported SSB emissions

In this section we compare SSB reported emissions, from 2023, with the newly calculated emissions from G-NORTRIP. In Figure 9 the national total road wear emissions are compared for 4 different calculation types. 'NORTRIP calculated' are the results presented in this report. 'SSB published' are the emissions reported in 2024 by SSB based on the updated SSB model with NORTRIP parameters. 'SSB pre-calculated' was the calculation made during the initial assessment in 2023 (Denby, 2023) and follows closely the actual reported emissions. Updates in traffic trends (UNCC, 2025) account for the small differences from 2009 to 2018. The final plotted series, 'SSB linear + quadratic' is also a parameterised form of the SSB equation but includes a quadratic dependence on traffic volume in addition to the linear dependence in 'SSB pre-calculated', also as shown in Figure 2 as 'effective linear scaling'. The reason for this partial quadratic dependence is that suspended dust is dependent on both the wear rate and the suspension rate, both of which depend on traffic volume. This parameterised form fits much better to the calculated NORTRIP emission results.

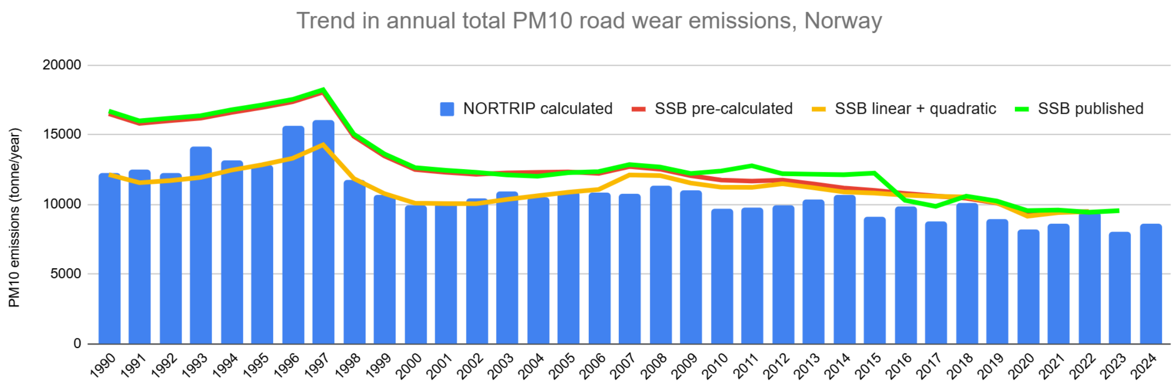


Figure 9. Comparison of road wear emissions with 4 different types of calculation methods. See text for details.

In addition to PM_{10}, $PM_{2.5}$ emissions are also reported by SSB. The comparison with NORTRIP is shown in Figure 10. There is a significant difference in these results. SSB assumes a constant 17% fraction of PM_{10} to be $PM_{2.5}$ for road wear. In NORTRIP this fraction is set at 8%. A discussion around the $PM_{2.5}$ is given in this document in Section 6.

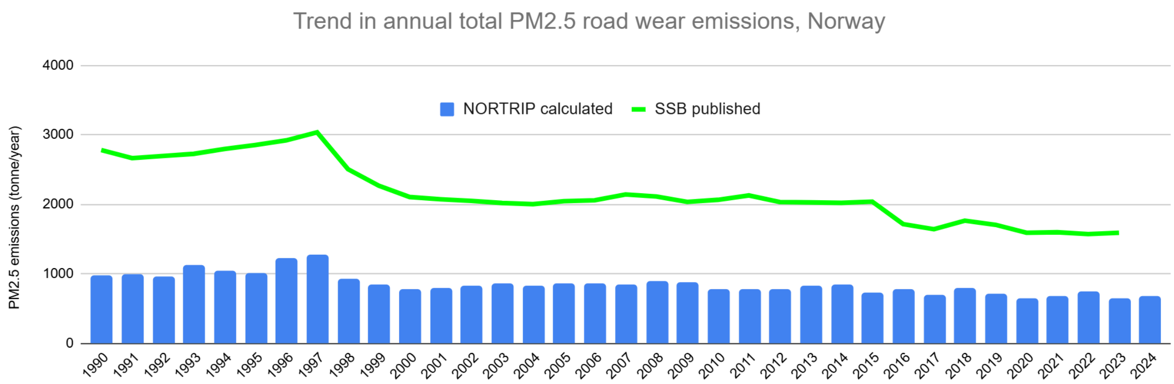
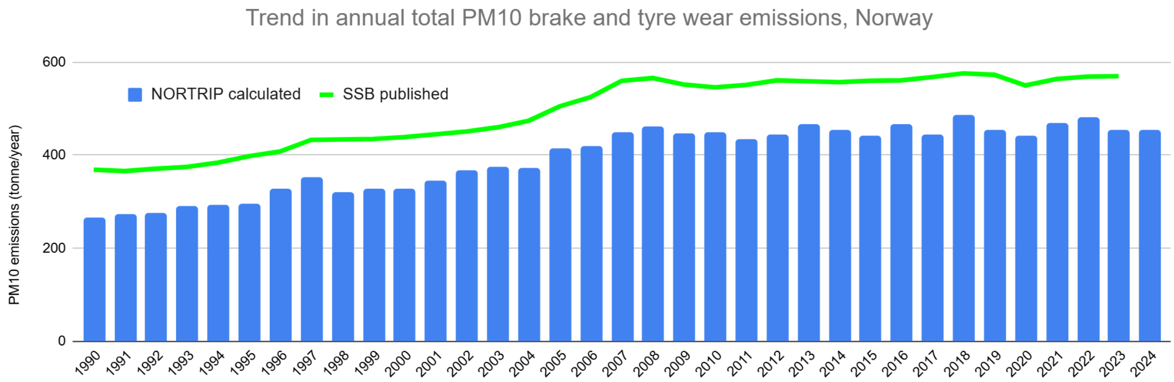


Figure 10. Comparison of NORTRIP calculated and SSB reported emissions for $PM_{2.5}$ road wear.

In Figure 11 the same comparison is carried out as in Figures 9 and 10, but for tyre and brake wear combined. We see that NORTRIP gives lower emissions than SSB reporting for both PM size ranges. The emission factors used by SSB for tyre and brake wear are documented in the 'Informative Inventory Report (IIR) 2025. Norway – Air Pollutant Emissions 1990-2023' (NEA, 2025b). Emission factors used in NORTRIP for brake and tyre wear are similar to SSB's for $PM_{2.5}$ but larger for PM_{10}. Even so, NORTRIP gives lower emissions than SSB. This is because the wet removal processes that apply to road wear also apply to brake and tyre wear. These will reduce the total wear that is emitted to air.



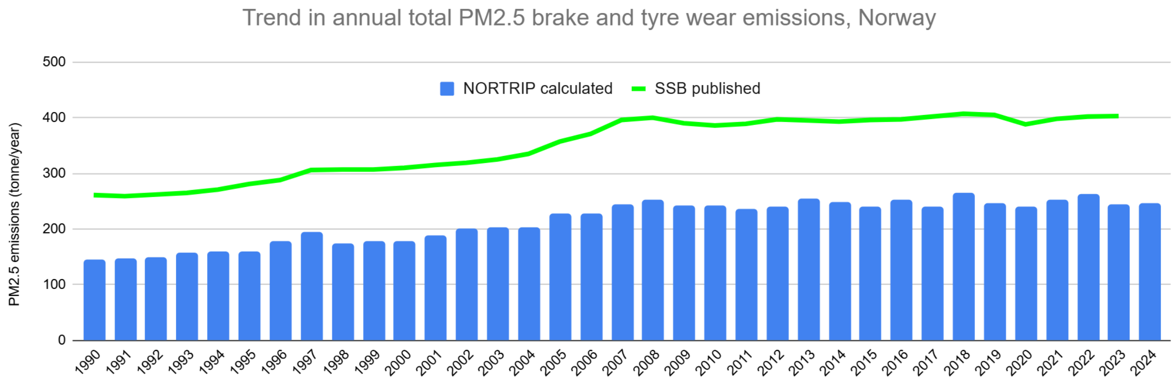
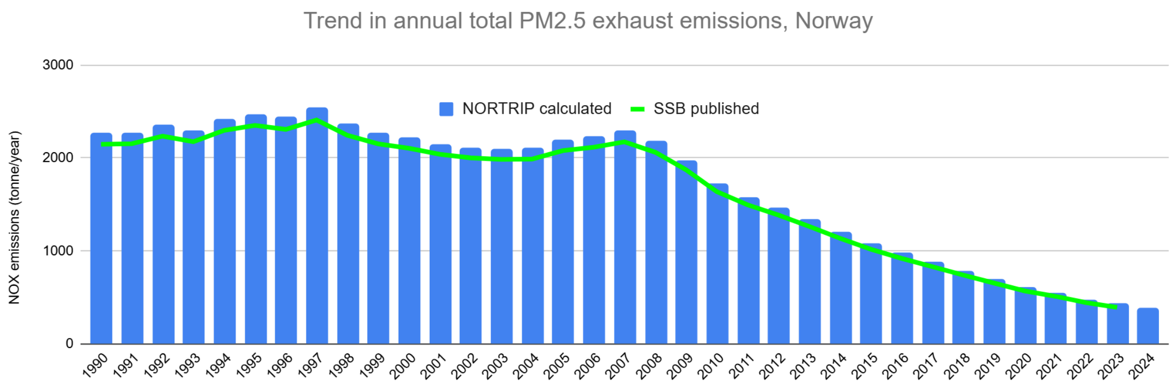


Figure 11. Comparison of NORTRIP calculated and SSB reported emissions for PM_{10} (top) and $PM_{2.5}$ (bottom) tyre+brake wear.

For comparative purposes we also show the exhaust emissions of $PM_{2.5}$ and NO_X as calculated with NORTRIP and reported by SSB in Figure 12. These emissions are very similar and confirm the gridded methodology is consistent.



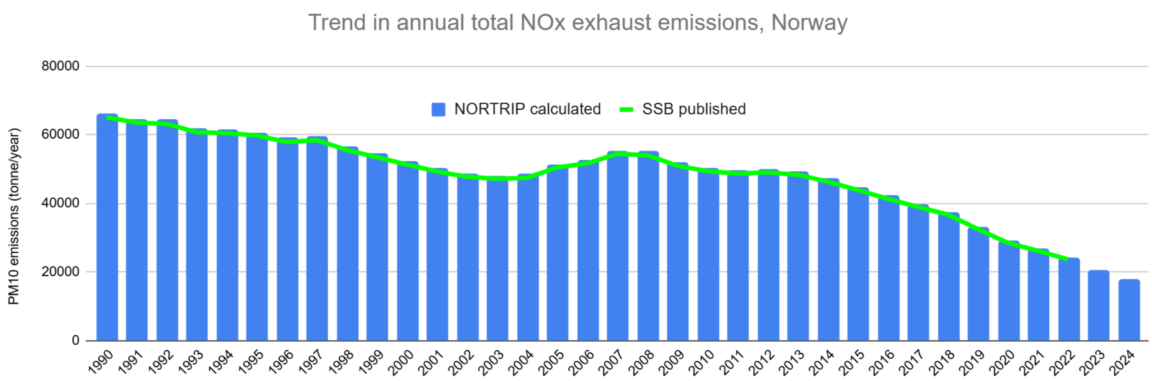


Figure 12. Comparison of NORTRIP calculated and SSB reported exhaust emissions for $PM_{2.5}$ (top) and NO_X (bottom).

6. $PM_{2.5}$ fraction of PM_{10} for road wear

In NORTRIP the $PM_{2.5}/PM_{10}$ ratio for road wear is 8%. This has not been well documented but is based on analysed measurement data during the NORDUST projects. To assess if this is a suitable ratio, observations at traffic stations, during the road dust emission season, are compared to NORTRIP calculations. Such a comparison is complicated by the existence of other sources contributing to the observed PM.

Using all available traffic stations in Norway, hours with PM_{10} > 100 µg/m^3 and with a ratio of $PM_{2.5}/PM_{10}$ < 0.5, were selected which focus on stronger road dust events. Under this selection there are only 26 stations with at least 50 hours of data. The results are shown in Figure 13. The observed $PM_{2.5}/PM_{10}$ ratio is 15% for this selection, which is similar to the model (not shown). To account for the other sources we subtract modelled source contributions, for example exhaust, wood burning and long range transport, from the observations. This will provide an estimate of the contribution from the other sources, which is removed, leaving in principle just the non-exhaust emissions in the observations (including road, brake and tyre wear). After this subtraction the observed non-exhaust $PM_{2.5}/PM_{10}$ ratio is 10%. Finally, the expected ratio (as used in the model) of $PM_{2.5}$ tyre/brake wear to total PM_{10} non-exhaust emissions is around 2%. Subtracting this gives a $PM_{2.5}/PM_{10}$ ratio for road wear emissions to be 8%, as used in the model.

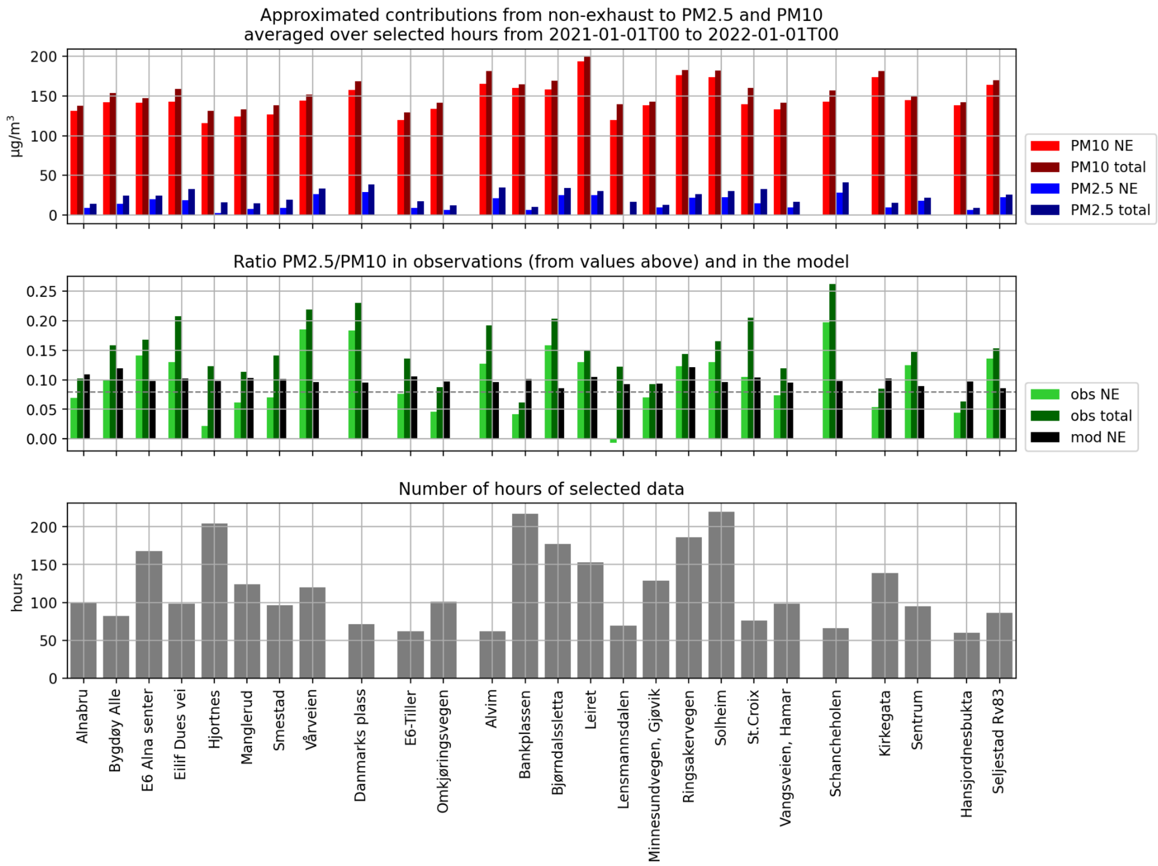


Figure 13. Analysis of PM_{10} and $PM_{2.5}$ concentrations for selected hours and stations in Norway, see text. The top plot shows the observed average values (total) and with the subtraction of other modelled sources to estimate just the non-exhaust (NE). The middle plot shows the derived $PM_{2.5}/PM_{10}$ ratios for these total and non-exhaust concentrations, as well as the modelled non-exhaust $PM_{2.5}/PM_{10}$ (mod NE). The lowest plot gives the number of hours used in the analysis. Only stations with > 50 hours are included.

7. Conclusions

Annual 0.1° x 0.1° gridded emissions have been calculated using the gridded NORTRIP (G-NORTRIP) model for Norway, from 1990 - 2024. From these, total national emissions have been derived for road, tyre and brake wear. These emissions are intended for national reporting purposes under the Convention on Long Range Transboundary Air Pollution (LRTAP) and for use in regional scale air quality modelling applications. They replace the current emission trends reported by SSB, based on a parameterised model. Despite the simplified parameterisation used by SSB, the reported emissions, after updates with NORTRIP parameters, were quite similar to the full G-NORTRIP calculations. The same parameterisation could be adjusted to account for the additional traffic volume scaling related to suspended emissions, and this parameterisation was very close to the NORTRIP calculated values, but without the meteorological variability.

The G-NORTRIP calculations differ slightly from the full road network calculations. For example, shading is not included and the meteorology is not as well represented in the gridded version. Some effort should be made to better match the meteorological and NORTRIP grids in future calculations. Though historical information is available on traffic volume, there is little data available, or difficult to access, concerning structural changes in the road network.

Due to the variation in studded tyre usage in Norway, it is recommended to use the gridded non-exhaust emission data when applying emissions in regional air quality models. It has been shown that gridded non-exhaust emission data is different in its spatial distribution to exhaust emissions and these two emission sources should be treated spatially individually.

The seasonal variation of non-exhaust emissions is also significant and should be included in any regional scale air quality modelling. Meteorological variability from year to year accounts for just ±10% of the variability of the national total emissions.

It is intended to update these reported emissions every year. Due to the continuous development of the NORTRIP model this will likely entail recalculations of the full 30 year period. Due to the efficiency of using G-NORTRIP, as opposed to modelling each road link individually, this reduces the calculation time significantly and a full 30 year period can be made within a single day.

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Appendix

Traffic statistics and adjustments

Statistics from the NVDB traffic data file are:
total_short_(veh.mil.km)= 42400.837
total_long_(veh.mil.km)= 5284.899
total_traffic_veh_km_(veh.mil.km)= 47685.736
Itotal_traffic_ADT_km_(veh/day.mil.km)= 130.646
total_km_(1000.km)= 85.225

The original NVDB data consists of 735380 separate road links. The gridded road data consists of 8711 separate aggregated road links on a 271 x 139 grid

According to SSB in 2024, reference year for traffic, the total traffic volume in Norway was
total_short_(veh.mil.km)= 35442.9 + 0.75 * 7521.5 = 41084.0
total_long_(veh.mil.km)= 2058.0 + 577.0 + 0.25 * 7521.5 = 4515.4
total_traffic_veh_km_(veh.mil.km)= 45599.4
NB: Assumed 75% of light good vehicles are 'short'

Scaling factors to match the national totals are then
scaling_total_light_(veh.mil.km)= 0.966
scaling_total_heavy_(veh.mil.km)= 0.880
scaling_total_traffic_veh_km_(veh.mil.km)= 0.956

Technical information on configuration and input files

The NORTRIP traffic data file used to create the traffic grids is:
/lustre/storeB/project/fou/kl/uemep/uEMEP_demo/NORTRIP/Norway/NORTRIP_multiroad_in/traffic/SSB_Road_data_Norway_SVV_ADT100_2024_corrected.txt'

The equivalent G-NORTRIP file aggregated to 0.1° x 0.1° is:
/lustre/storeB/project/fou/kl/NORTRIP_gridded/Input_data/Static_gridded_data/NOR_road_data_GNORTRIP_NVDB_0101grid.txt'.

Path to script for running G-NORTRIP:
/lustre/storeB/project/fou/kl/uemep/uEMEP_demo/NORTRIP/Norway/scripts/NORTRIP_script_Norway_trends-r8.sh

Path to configuration file used in G-NORTRIP:
/lustre/storeB/project/fou/kl/NORTRIP_gridded/config/GNORTRIP_multiroad_config_Norway_rerun_PPI_update_17_normal_gridded_trend.txt

Path to parameter files used in G-NORTRIP *:
/lustre/storeB/project/fou/kl/NORTRIP_gridded/Input_data/NORTRIP_parameters/Road_dust_parameter_table_v15_gridded_Norway

[*]Adjustments from the normal NORTRIP parameters were made to the brake and tyre wear to make them compatible with the EMEP/EEA emission handbook. v14 parameter file of the same name uses the default NORTRIP tyre and brake wear parameters.

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