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Baseline dispersion and exposure calculations of PM_{10} and NO_2 for 2010, 2015, and 2020 for Oslo

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Summary

Commissioned by the Norwegian Pollution Control Authority (SFT), NILU has performed dispersion and exposure calculations for 2010, 2015 and 2020 to evaluate the concentration and exposure levels with respect to the National Air Quality Target and EU guidelines for PM_{10} and NO_2.

By applying the model system AirQUIS (AirQUIS, 2007) ambient concentrations of PM_{10} and NO_2 have been computed for Oslo. Based on projections of both emissions and regional background concentrations from a reference year (2005), baseline calculations for 2010, 2015, and 2020 have been performed. These simulations include exposure calculations in order to indicate the expected exceedance levels for the various years.

Ambient air concentrations and population exposure have been calculated both in the positions of buildings located close to the main road network, and within a two-dimensional grid with a quadratic 1 km^2 grid size.

The total number of inhabitants exposed beyond the National Target and EU guideline for PM_{10} and NO_2 for the baseline simulations for 2010, 2015 and 2020 are summarized below in Table A (PM_{10}) and Table B (NO_2).

Table A: Exposure results with respect to the National target and the EU guidelines for PM_{10}. Values in brackets indicates the portion of the population exposed in building points.

	No. of people exposed 8th highest daily value beyond 50 µg/m³	**No. of people exposed 36th beyond highest daily value 50 µg/m³**	**No. of people exposed to Yearly average beyond 40 µg/m³**	**No. of people exposed to Yearly average beyond 20 µg/m³**
Reference 2005	235849 (75623)	11536 (11536)	1731 (1731)	102768 (50006)
Baseline 2010	54056 (27670)	1882 (1882)	282 (282)	5527 (5527)
Baseline 2015	41349 (27473)	2323 (2323)	291 (291)	5469 (5469)
Baseline 2020	26286 (24992)	2855 (2855)	323 (323)	5513 (5513)

Table B: Exposure results with respect to the National target and the EU guidelines for NO_2. Values in brackets indicates the portion of the population exposed in building points.

	No. of people exposed, 9^{th} highest hourly value beyond 150 µg/m^3	**No. of people exposed, 19^{th} highest hourly value beyond 200 µg/m^3**	**No. of people exposed to Yearly average beyond 40µg/m^3**
Reference 2005	652 (652)	26 (26)	2825 (2825)
Baseline 2010	4321 (4321)	43 (43)	15422 (15422)
Baseline 2015	522 (522)	0	4373 (4373)
Baseline 2020	179 (179)	0	2055 (2055)

For PM_{10} a reduction of the concentrations are calculated from 2010 to 2020. Only for the national target value, e.g. 8^{th} highest daily value, concentrations are beyond the limit value in grids for 2020. However, a strong reduction of exceedances are calculated for the National target. For the EU guidelines exceedances are calculated only in building points, e.g. close to the main road network. The number of exceedances from 2010 to 2020 either slightly increase or are unaltered with respect to these guidelines.

In general, for NO_2, a reduction in concentrations and hence the population weighted average are calculated from 2010 to 2020. Only a few people are exposed beyond the hourly limit values of the national target and the EU guidelines for 2020, whereas a slightly higher percentage of the population live in areas where exceedances of the yearly average limit value are expected.

Baseline dispersion and exposure calculations of PM_{10} and NO_2 for 2010, 2015 and 2020 for Oslo

1 Introduction

Commissioned by the Norwegian Pollution Control Authority (SFT), NILU has performed dispersion and exposure calculations for PM_{10} and NO_2 for Oslo for the years 2010, 2015, and 2020. The computed concentration levels have been compared with the limit values defined in the National Air Quality Target and EU guidelines. Calculations have been performed by applying the model system AirQUIS (AirQUIS, 2007).

Both the local emissions and the regional background concentrations have been projected towards 2010, 2015 and 2020 from a reference year (2005). The calculations for 2010, 2015 and 2020 apply meteorological input data from the reference year (2005). Dispersion calculations for the reference year have also been carried out in order to evaluate the model calculations against measurements (Slørdal et al., 2006a).

The concentration levels of PM_{10} and NO_2 are calculated only for the winter season. The yearly average has been estimated using a scaling factor from the winter mean to the annual mean, based on measured concentrations for the reference year.

Ambient air concentrations and population exposure have been calculated both in the positions of buildings, located close to the main road network, and within a two-dimensional grid with a quadratic 1 km^2 grid size.

This report describes how the modelling work has been accomplished, and gives an overview of the modelling results.

2 Description of the model calculations

The AirQUIS modelling system developed by NILU is applied in this study to calculate concentrations of PM_{10} and NO_2 (AirQUIS, 2007). AirQUIS is a GIS based integrated management system that includes a user interface, comprehensive measurement and emission inventory databases, and a suite of models for use in simulating ambient air concentrations and exposure.

The models used in the calculations are the MATHEW diagnostic wind field model (Sherman, 1978; Foster et al., 1995) and the EPISODE dispersion model (Slørdal et al., 2003). The dispersion model contains a Eulerian model with embedded sub-grid line source and point source models for calculating ambient concentrations. The line source model HIWAY-2 (Petersen, 1980) is used to calculate traffic related contributions at receptor points close to roads.

The meteorological field is calculated with MATHEW using measurement inputs from a meteorological station located at Valle Hovin.

Boundary concentrations for the model area are measurements from regional background stations. Measured daily background values of PM_{10} and NO_2 from Birkenes have been applied. The regional background concentrations of O_3 are from Hurdal, Birkenes and Prestebakke. (Appendix B).

The model domain applied for the Oslo region is a 22 x 18 km grid with a horizontal grid size of 1 km and with 10 vertical levels distributed with increasing separation from ground level up to a height of 2400 m above sea level.

Ambient concentration values and exposure estimates are calculated both in building points along the main road network (i.e., buildings within a distance of 100 – 500 m from each road depending on traffic volume) and in the domain covering grid system. The inhabitants of the considered buildings are assigned to building point concentrations, while the rest of the population are assigned to concentration values computed in the grid squares containing the location of their home address. As a part of the evaluation the population weighted average concentration has been calculated for the model domain. This number is defined as,

$$C_{PWA} = \frac{1}{N}\sum_{m=1}^{M}\overline{C}_m n_m \quad ; \qquad (1)$$

where M is the sum of all grid cells and building points (here M = 22 x 18 + total number of building points), n_m is the number of people in each of the m grid cells or building points, N is the total population within the modelling area, i.e., $N = \sum_{m=1}^{M} n_m$, and $\overline{C}_m$ is the mean concentration in each grid cell or building point m. Note that for the grid cells, the applied n_m is the rest population after having subtracted the people living in the building points within the grid cell.

As an additional exposure quantity the population weighted average exceedance has also been calculated. This quantity is defined as

$$C_{PWAE} \equiv \frac{1}{N}\sum_{m=1}^{M}\left(\overline{C}_m - C_T\right)n_m \qquad (2)$$

where C_T is the threshold (limit) value considered and the other variables are as defined in (1). In the expression (2) only positive contributions from the terms $\overline{C}_m - C_T$ are considered.

C_{PWA} is thus a measure of the average concentration level experienced by the population, whereas C_{PWAE} is a related measure of the average exceedance level for the total population within the modelling domain.

Calculations are carried out for a winter period, i.e., from the beginning of January to the end of April, and from the beginning of October to the end of December.

2.1 Reference calculation for the year 2005

In a previous project NILU has carried out PM_{10} and NO_2 calculations for Oslo for the year 2005 (Slørdal et al., 2006a). The results from these calculations have been applied as the reference basis for making the 2010, 2015 and 2020 projections. A detailed description of the calculations for the year 2005 has been given in the report ”Dispersion and exposure calculations of PM_{10}, NO_2, and Benzene for Oslo and Trondheim for the year 2005” (Slørdal et al., 2006a), and the reader is referred to this report for further information.

2.2 Baseline projection for 2010, 2015 and 2020.

With the reference 2005 model setup as starting point, the emissions and the regional background concentrations have been projected towards 2010, 2015 and 2020. All other model settings are identical to those applied in the reference 2005 simulations, e.g. meteorology, the adjustment factor of the source strength of the coarse fraction particles, and population.

Based on this updated emission inventory and background concentrations, baseline concentrations and exposure simulations for 2010, 2015 and 2020 have been performed.

2.2.1 Emission projections

2.2.1.1 Traffic data

In the project ”Tiltaksutredning i Osloregionen etter forskrift om lokal luftkvalitet med forslag til handlingspakker”, projected traffic data were constructed for Oslo for the year 2015 (Oslo kommune/Statens vegvesen Region øst, 2004). These data were applied in the 2010, 2015 and 2020 baseline calculations. The road network, vehicle composition, road classifications, speed limits, road slope, etc. were the same for all the three calculation years. The only differences were in traffic emission factors and annual daily traffic (ADT).

For 2010 the ADT prognosis was taken as 90% of the 2015 ADT. The same scaling was applied for all roads. According to the most updated prognosis from the Norwegian Public Roads Administration, the ADT in 2020 was increased by 9% relative to 2015 (personal communication, Kjell Johansen). (Appendix B)

A growth in vehicles with un-studded tyres from 76 % in 2005 to 85 % in 2010 has been implemented. However, no change has been expected in the use of un-studded tyres between 2010 and 2020)(Appendix B).

The traffic emission factors have been updated according to a prognosis from the Institute of Transport Economics (Johansen, K.W., 2003), Statistics Norway (Kjetil Flugsrud, personal communication), the European Environmental Agency (EEA, 2006) and a draft report from the Air Quality Expert group results (2006). (Appendix B).

2.2.1.2 Wood burning

Updated emissions from domestic wood combustion have been estimated based on expected changes in wood consumption and expected renewal of old ovens with new clean burning ones. The fraction of open fireplaces have been assumed constant. The emission data have been scaled as described in Appendix A, and the resulting total annual emissions for the different years are given in Appendix B.

2.2.2 Projections of the regional background (boundary conditions).

Measured hourly and/or daily data of ozone, NO_2 and PM_{10} for 2005 have been scaled (in percentage) according to EMEP predictions for the Oslo area for 2010, 2015 and 2020 (Appendix B).

3 Discussion of uncertainties

When interpreting the modelling results the uncertainties linked to the various elements of the computational procedure should be kept in mind. A detailed discussion of this issue is given in the report ”Dispersion and exposure calculations of PM_{10}, NO_2, and Benzene for Oslo and Trondheim for the year 2005” (Slørdal et al., 2006a).

It should be noted that the projections of the emissions and the background concentrations adds further to the overall uncertainty in the dispersion and exposure calculations.

In the baseline simulations, the road link network and the traffic data (e.g. speed, gradient etc.) are different from the data applied in the reference 2005 simulations. This of course complicates the interpretation of the changes in the model results from 2005 to the baseline calculations in 2010, 2015 and 2020. This is particularly the case for the PM_{10} levels along the roads, since these concentrations are highly dependent on traffic speed.

4 Exposure results for 2010, 2015 and 2020.

The calculated dispersion and exposure results have been evaluated against the National Air quality targets and the European Guidelines for PM_{10} and NO_2 (Table 1). A summary of the emission projections for the various simulations are given in (Table 2).

The total number of inhabitants exposed beyond the "National Target" and EU guidelines for PM_{10} and NO_2 for the baseline simulations for 2010, 2015 and 2020 are summarized in Table 3(PM_{10}) and Table 5(NO_2). In addition the population weighted average (C_{PWA}) and population weighted average exceedances (C_{PWAE}) are calculated for national target values and EU guidelines for PM10 (Table 4)and NO_2 (Table 6).

Table 1: The National air quality targets and the European guidelines for PM_{10} and NO_2.

National target PM_{10}	National target NO_2	EU guidelines PM_{10}	EU guidelines NO_2
Daily values of 50 µg/m³ PM_{10}, not to be exceeded more than 7 times a calendar year	Hourly values of 150 µg/m³ NO2,not to be exceeded more than 8 times a calendar year	Daily values of 50 µg/m³ PM_{10}, not to be exceeded more than 35 times a calendar year	Hourly values of 200 µg/m³ NO2, not to be exceeded more than 18 times a calendar year
		Year:40 µg/m³ and 20 µg/m³ PM_{10}	Year:40 µg/m³ NO_2

Table 2: Summary of the emission projections 2010, 2015 and 2020 baseline simulations and the reference 2005 simulation.

	Description
Reference 2005	76 % non-studded vehicles Emissions from wood burning scaled as shown in Appendix A Traffic emission factor estimated for 2005
Baseline 2010	85 % non-studded vehicles. Emissions from wood burning scaled as shown in Appendix A Regional background scaled as shown in Appendix B Updated estimates for traffic emission factor for 2010 Estimated ADT for 2010 Updated road link network compared to 2005 including, speed, gradient etc.
Baseline 2015	85 % non-studded vehicles. Emissions from wood burning scaled as shown in Appendix A, Regional background scaled as shown in Appendix B, Traffic emission factor estimated for 2015 Same road link network as for 2010 only changes are estimates for ADT for 2015
Baseline 2020	85 % non-studded vehicles. Emissions from wood burning scaled as shown in Appendix A, Regional background scaled as shown in Appendix B, Traffic emission factor estimated for 2020 Estimated ADT for 2020 Same road link network as for 2010 only changes are estimates for ADT for 2020

Table 3: Exposure results with respect to the National target and the EU guidelines for PM_{10}. Values in brackets indicates the portion of the population exposed in building points.

	No. of people exposed 8th highest daily value beyond 50 µg/m³	**No. of people exposed 36th beyond highest daily value 50 µg/m³**	**No. of people exposed toYearly average beyond 40 µg/m³**	**No. of people exposed to Yearly average beyond 20 µg/m³**
Reference 2005	235849 (75623)	11536 (11536)	1731 (1731)	102768 (50006)
Baseline 2010	54056 (27670)	1882 (1882)	282 (282)	5527 (5527)
Baseline 2015	41349 (27473)	2323 (2323)	291 (291)	5469 (5469)
Baseline 2020	26286 (24992)	2855 (2855)	323 (323)	5513 (5513)

Table 4: The population weighted average (C_{PWA}) and the population weighted average exceedances (C_{PWAE}) with respect to the National target and the EU guidelines for PM_{10}.

	8th highest daily value 50µg/m³	**36th highest daily value 50µg/m³**	**Yearly average 40µg/m³**	**Yearly average 20µg/m³**
Reference 2005	48/69.6	25.8/65.9	14.6/47.7	14.6/23.2
Oslo Baseline 2010	32.7/56.0	18.3/66.7	10.5/51.3	10.5/25.7
Oslo Baseline 2015	30.2/57.9	16.2/67.3	9.2/54.0	9.2/26.3
Oslo Baseline 2020	28.0/62.9	14.2/67.0	7.9/54.9	7.9/26.7

Table 5: Exposure results with respect to the National target and the EU guidelines for NO_2. Values in brackets indicates the portion of the population exposed in building points.

	No. of people exposed, 9th highest hourly value beyond 150 µg/m³	**No. of people exposed, 19th highest hourly value beyond 200 µg/m³**	**No. of people exposed to Yearly average beyond 40µg/m³**
Reference 2005	652 (652)	26 (26)	2 825 (2825)
Baseline 2010	4321 (4321)	43 (43)	15 422 (15 422)
Baseline 2015	522 (522)	0	4 373 (4373)
Baseline 2020	179 (179)	0	2 055 (2055)

Table 6: The population weighted average (C_{PWA}) and the population weighted average exceedances (C_{PWAE}) with respect to the National target and the EU guidelines for NO_2.

Oslo	**9th highest daily value 150µg/m³**	**19th highest daily value 200µg/m³**	**Yearly average 40µg/m³**
Reference 2005	95.3/171.3	89.2/242.7	16.6/43.4
Oslo Baseline 2010	105.1/159.6	98.1/214.9	19.1/44.2
Oslo Baseline 2015	99.0/161.4	92.6/-	16.5/44.1
Oslo Baseline 2020	94.3/158.5	88.4/-	14.8/43.2

5 Concentration maps related to the National Target and EU guidelines for PM_{10} and NO_2.

Concentration maps of PM_{10} and NO_2 for 2010, 2015 and 2020 showing various percentile concentration levels are presented in this section. In addition to the concentration fields, the figures also indicate (by black dots) the building points, where exceedances are calculated according to the National Target values and the EU guidelines . The results are discussed further in section 6 "Discussion of the modelling results".

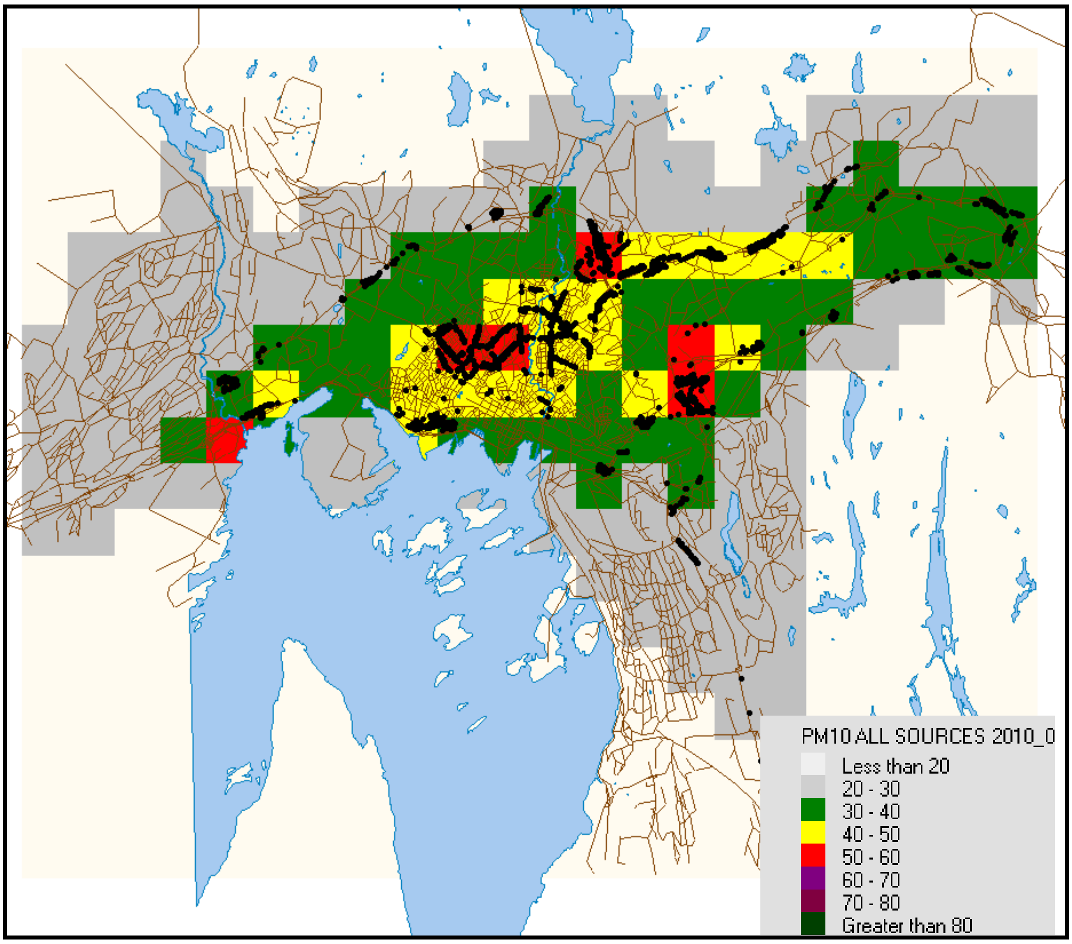

Figure 1: Projection of the 8th highest daily grid value (National Target) of PM_{10} ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the 8th highest daily PM_{10} value is above limit value of 50 $\mu g/m^3$.

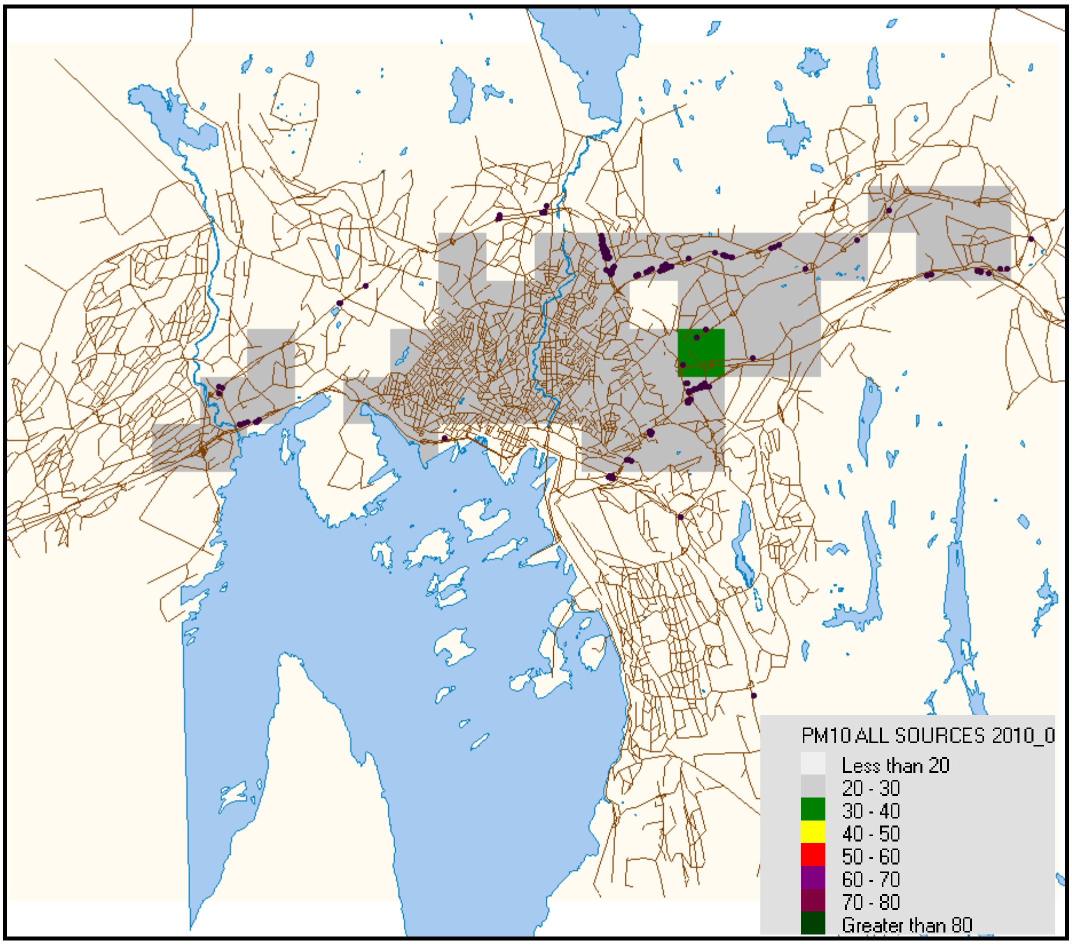

Figure 2: Projection of the 36th highest daily grid value (EU) of PM_{10} ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the 36th highest daily PM_{10} value is above limit value of 50 ($\mu g/m^3$).

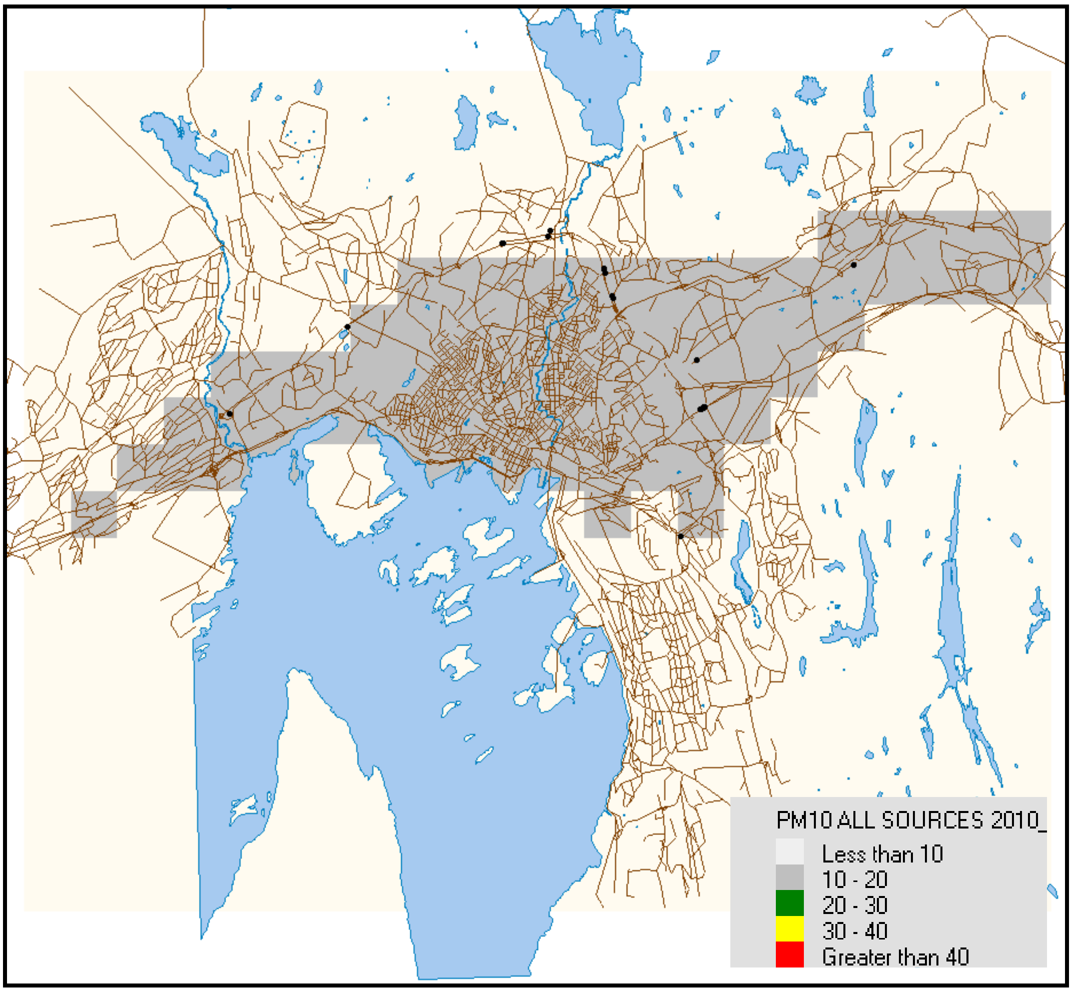

Figure 3: *Projection of the yearly grid value (EU) of PM_{10} ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the yearly value of PM_{10} is above the limit value of $40 \mu g/m^3$.*

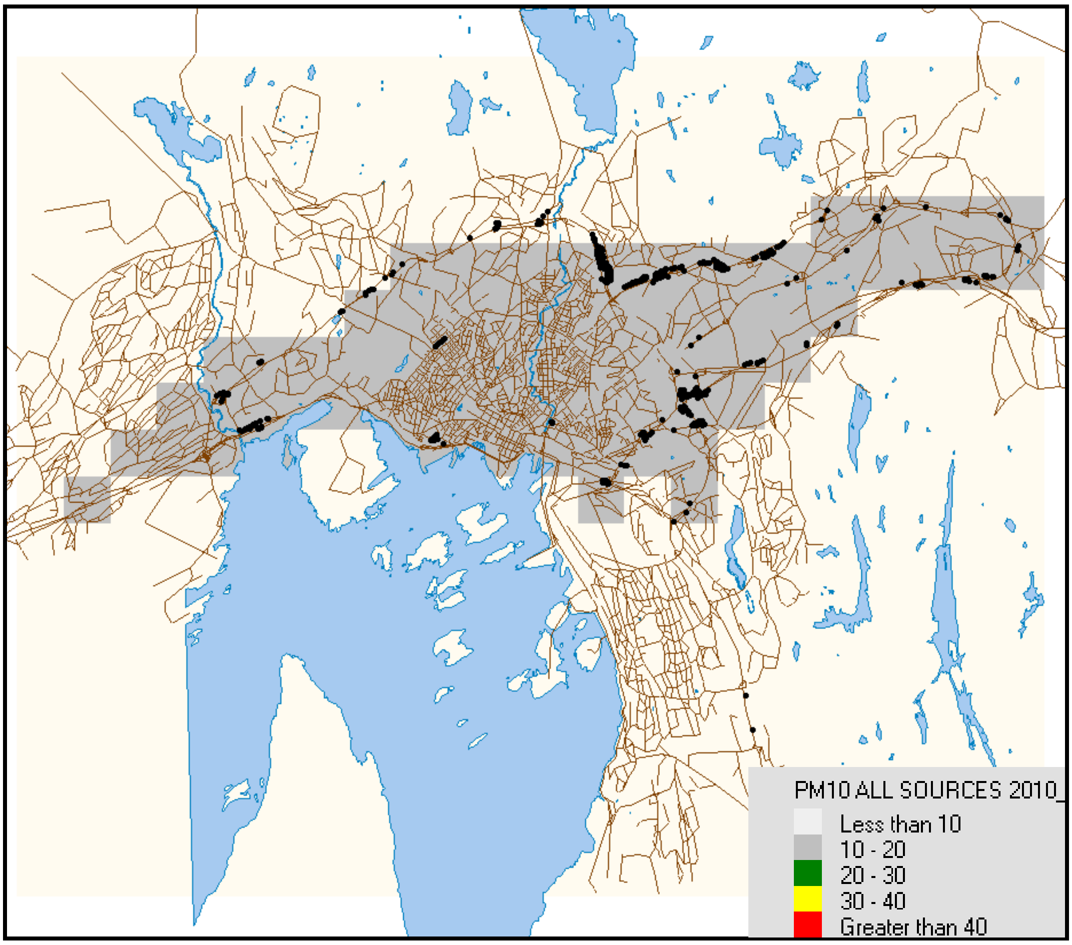

Figure 4: Projection of the yearly grid value (EU) of PM_{10} ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the yearly value of PM_{10} is above the limit value of 20 ($\mu g/m^3$).

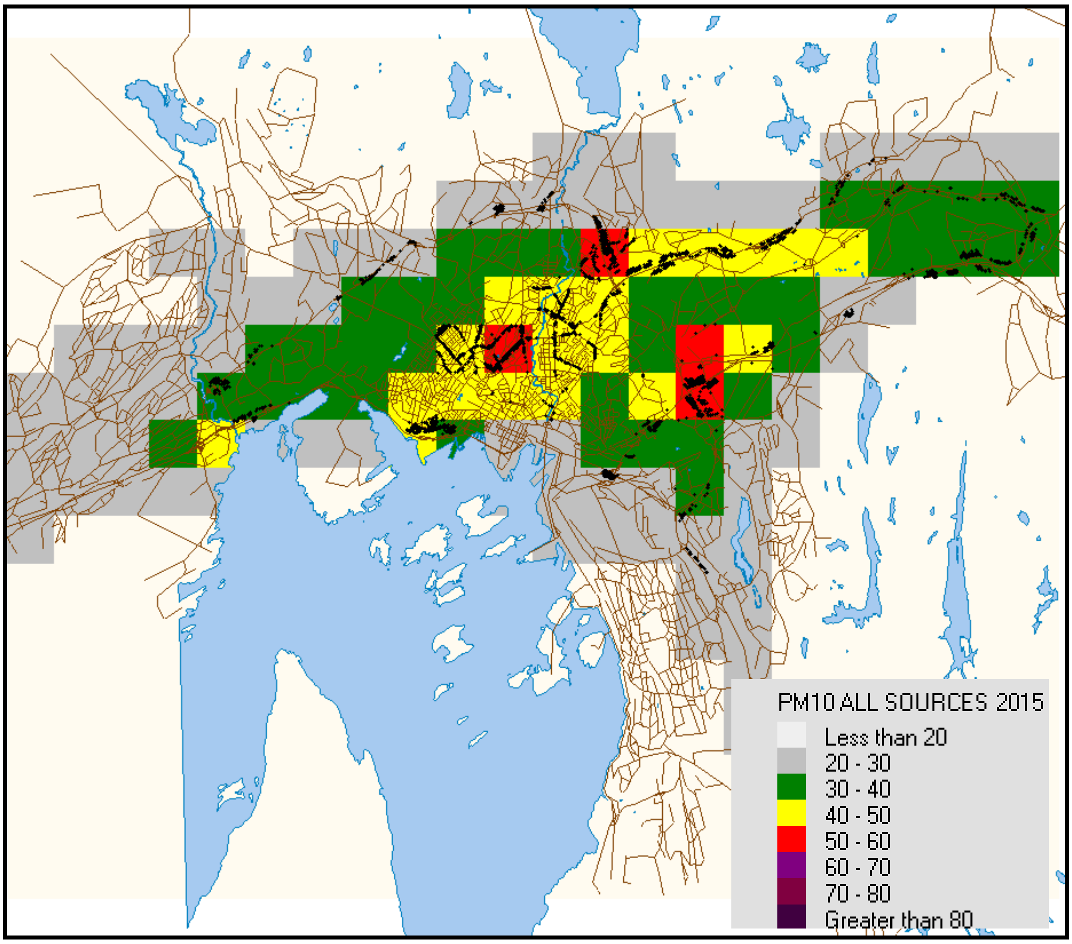

Figure 5: Projection of the 8th highest daily grid value (National Target) of PM_{10} ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the 8^{th} highest daily PM_{10} value is above limit value of $50 \mu g/m^3$.

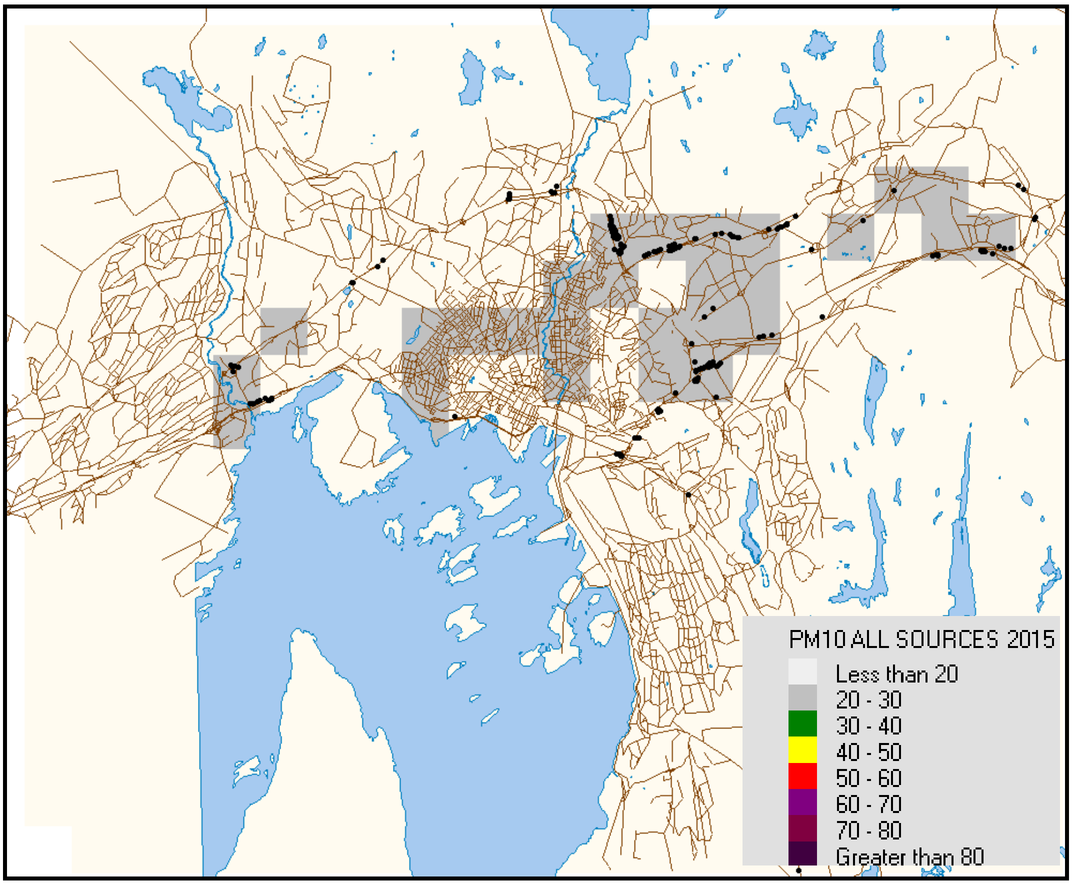

Figure 6: Projection of the 36th highest daily grid value (EU) of PM_{10} ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the 36th highest daily PM_{10} value is above limit value of 50 $\mu g/m^3$.

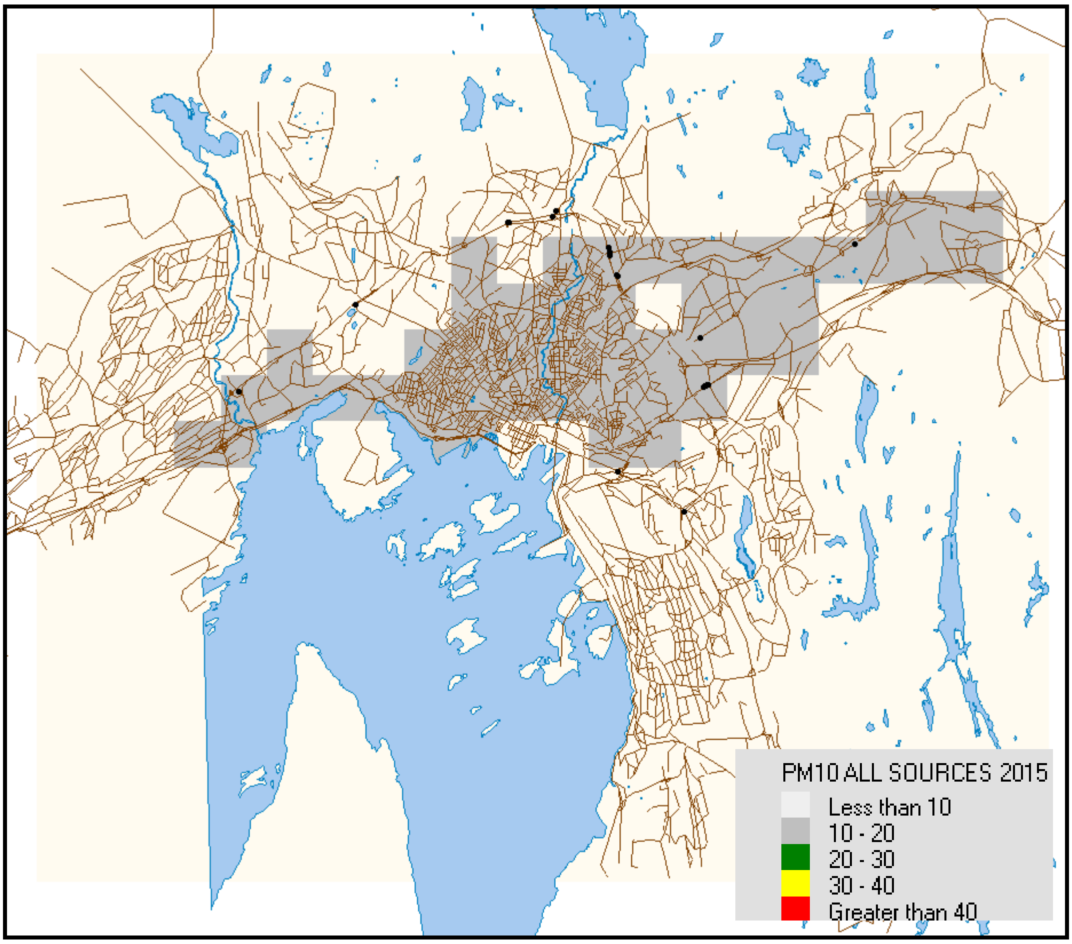

Figure 7: Projection of the yearly grid value (EU) of PM_{10} ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the yearly value of PM_{10} is above the limit value of 40 $\mu g/m^3$.

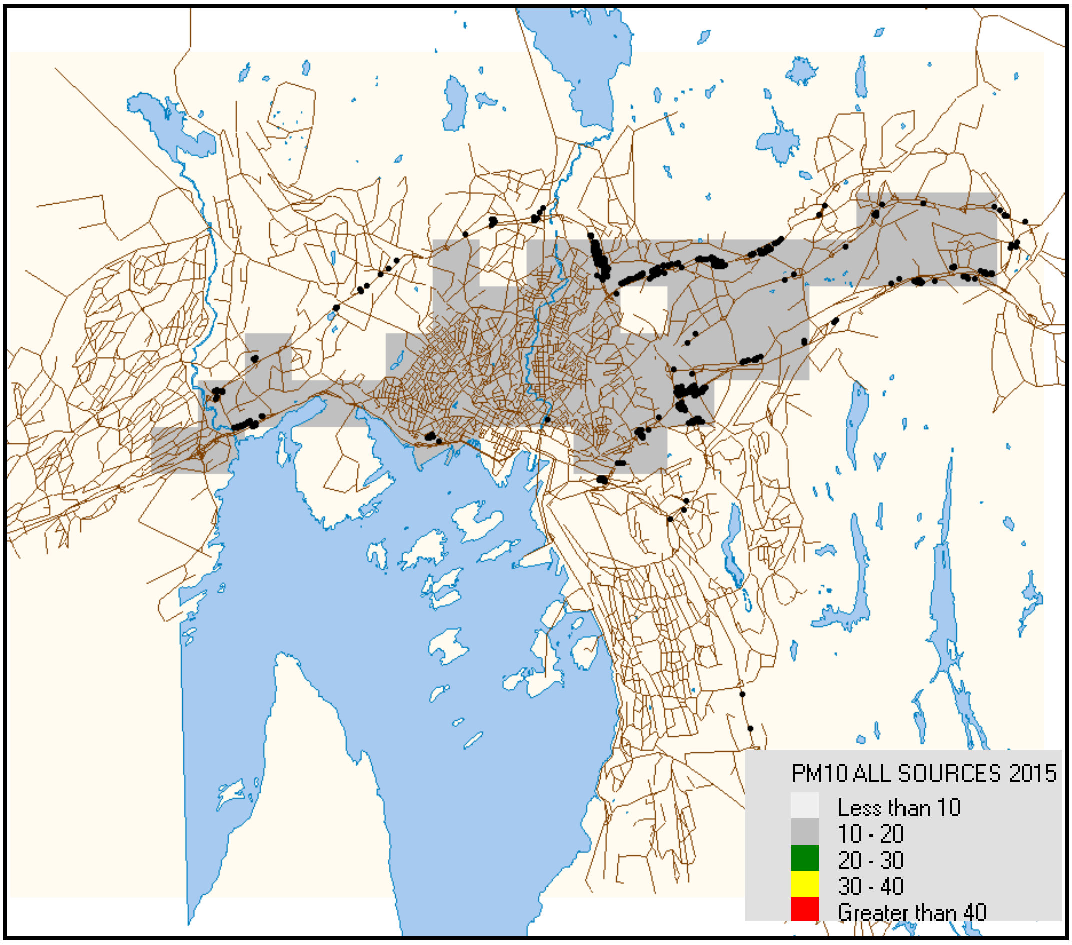

Figure 8: Projection of the yearly grid value (EU) of PM_{10} ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the yearly value of PM_{10} is above the limit value of 20 $\mu g/m^3$.

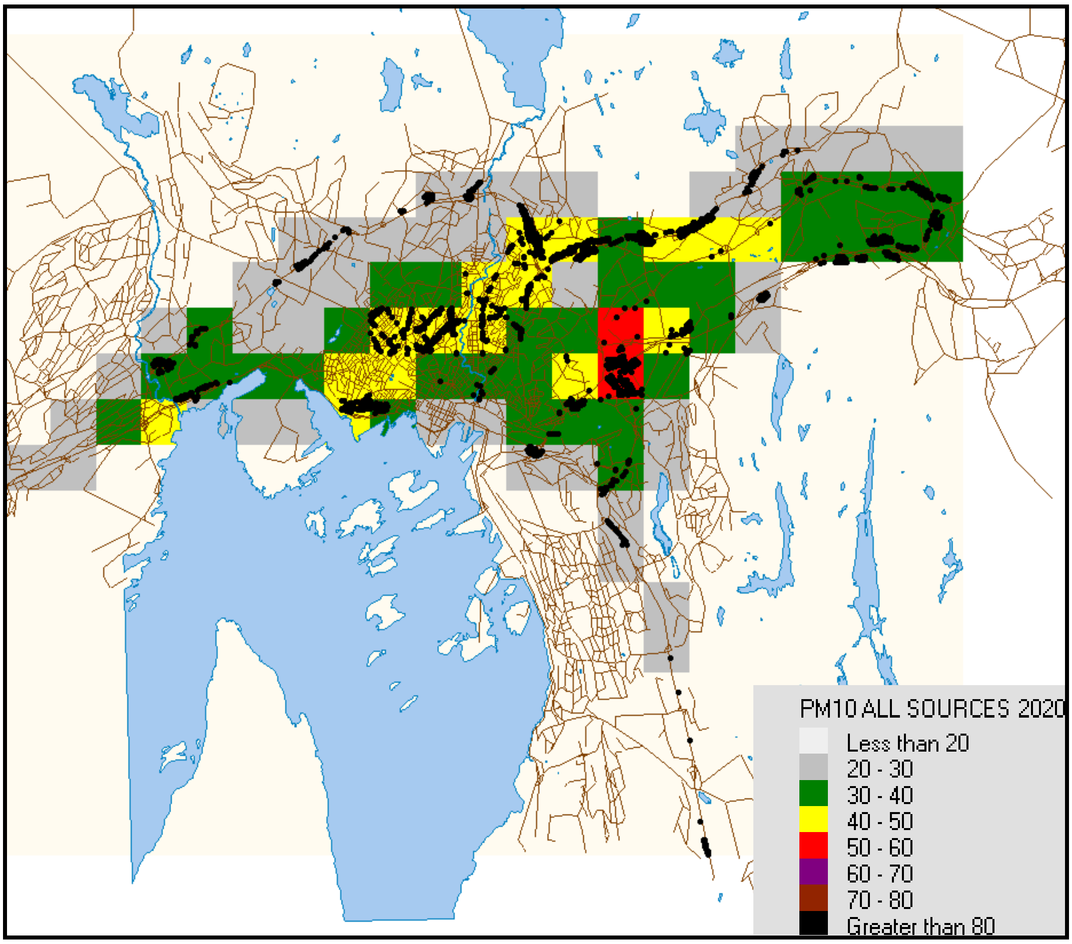

Figure 9: Projection of the 8th highest daily grid value (NM) of PM_{10} ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the 8^{th} highest daily PM_{10} value is above limit value of 50 $\mu g/m^3$.

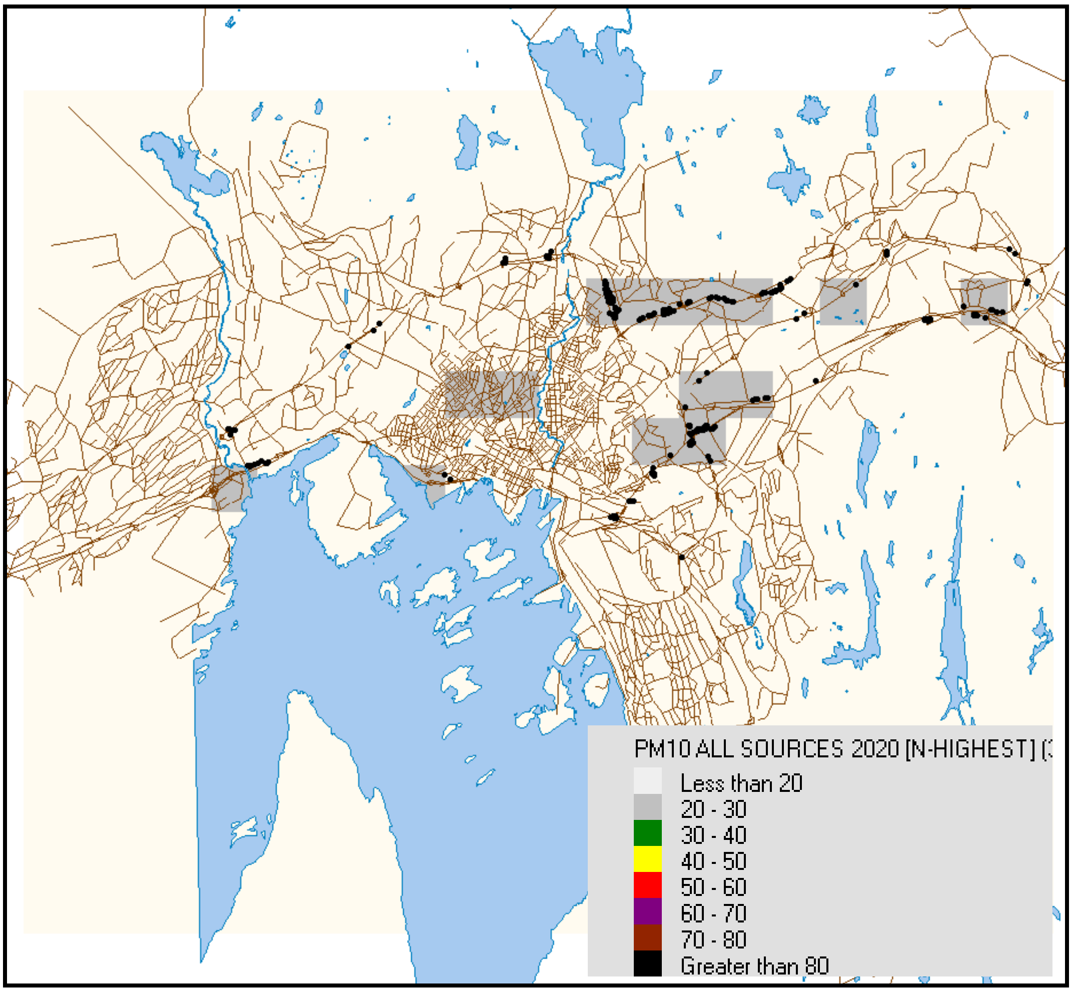

Figure 10: Projection of the 36th highest daily grid value (EU) of PM_{10} ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the 36th highest daily PM_{10} value is above limit value of 50 $\mu g/m^3$.

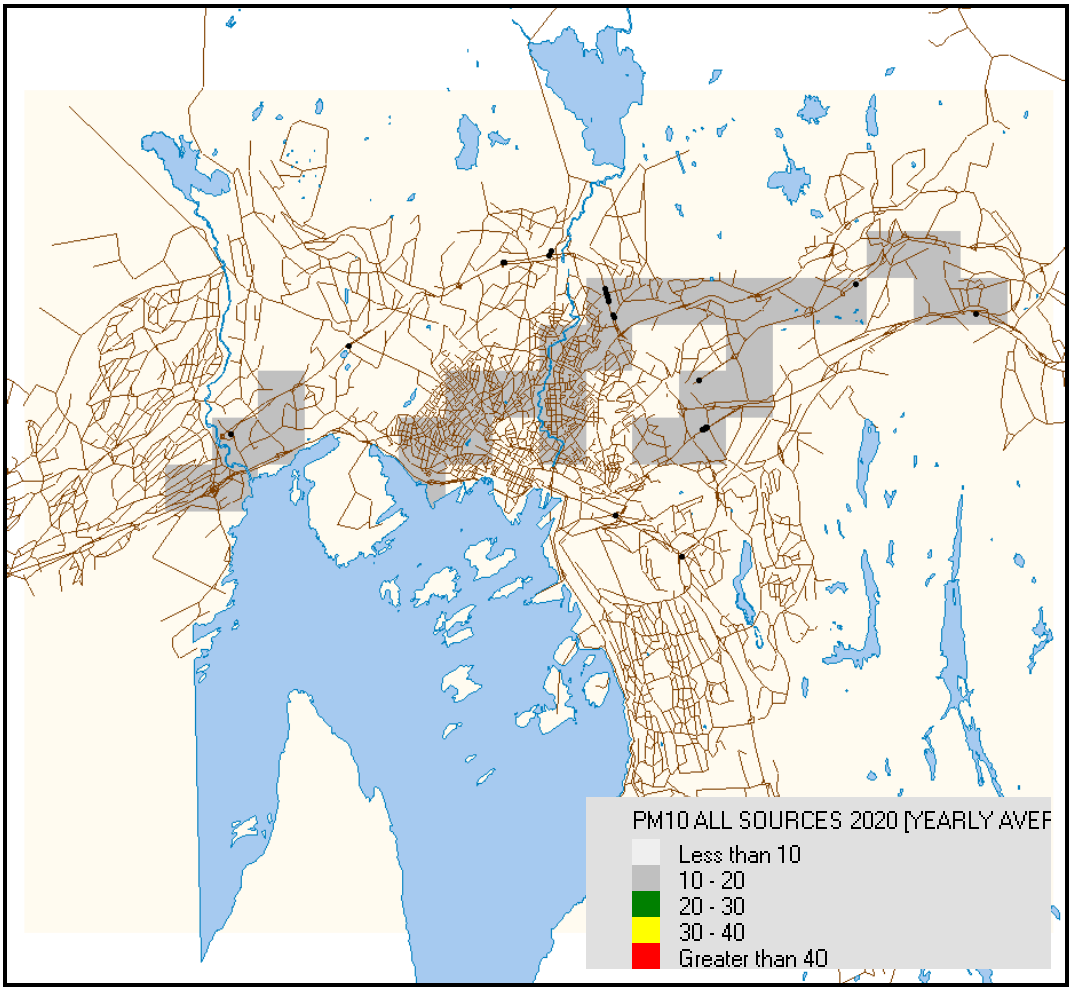

Figure 11: Projection of the yearly grid value (EU) of PM_{10} ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the yearly value of PM_{10} is above the limit value of 40 $\mu g/m^3$.

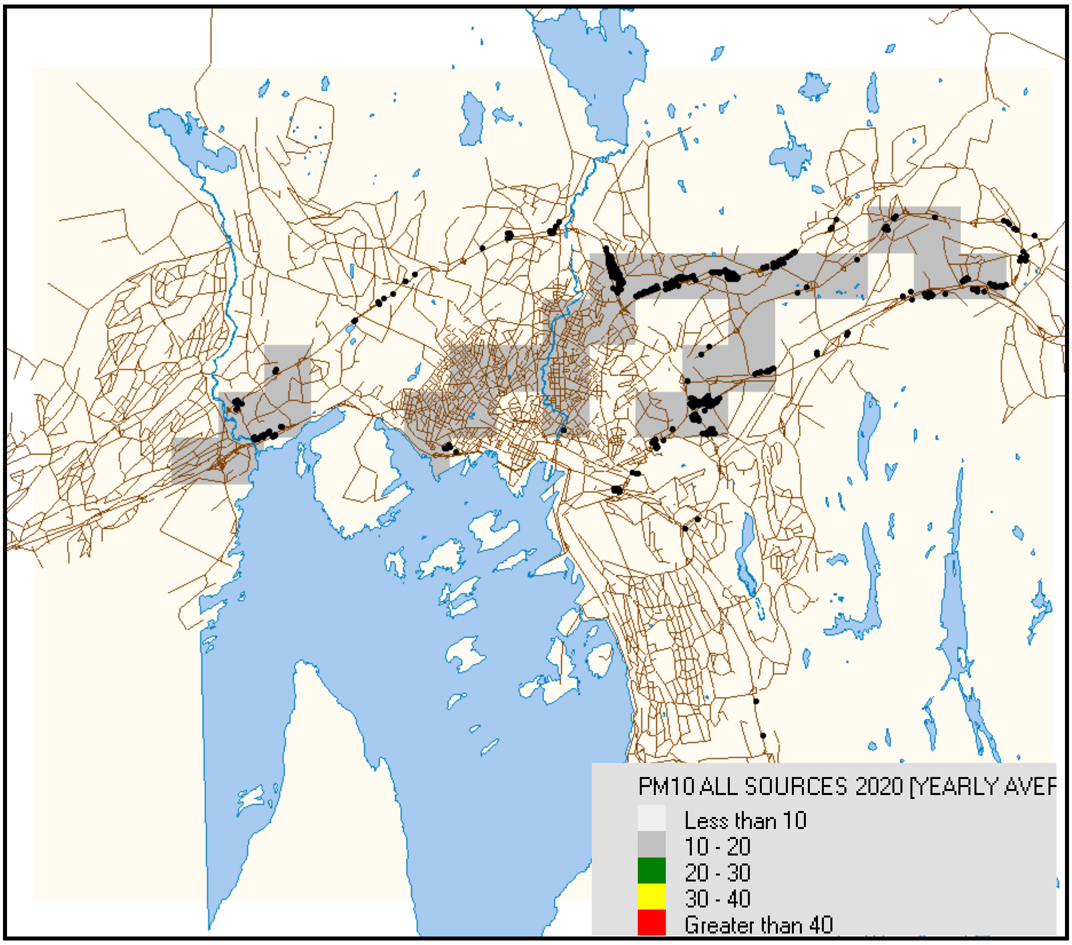

Figure 12: Projection of the yearly grid value (EU) of PM_{10} ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the yearly value of PM_{10} is above the limit value of 20 $\mu g/m^3$.

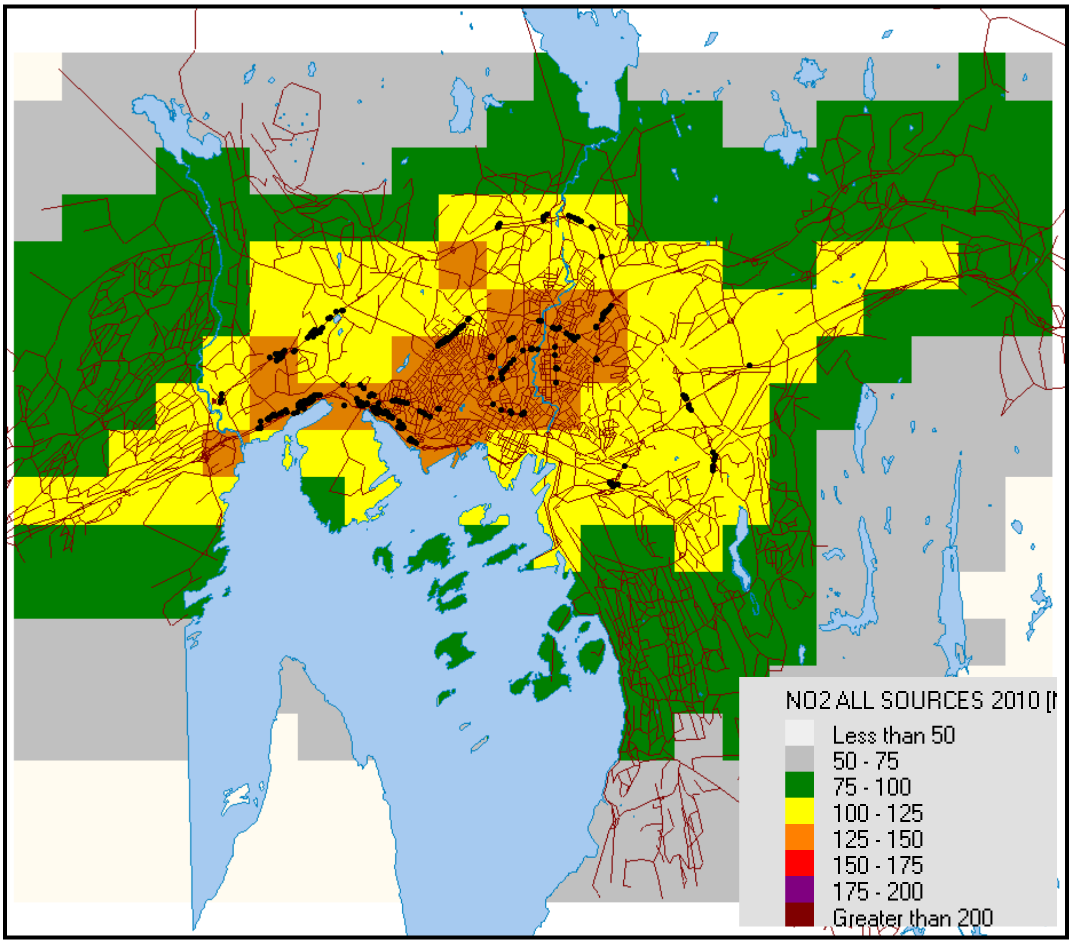

Figure 13: Projection of the 9th highest hourly grid value (National Target) of NO_2 ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the 9th highest daily NO_2 value is above limit value of 150 $\mu g/m^3$.

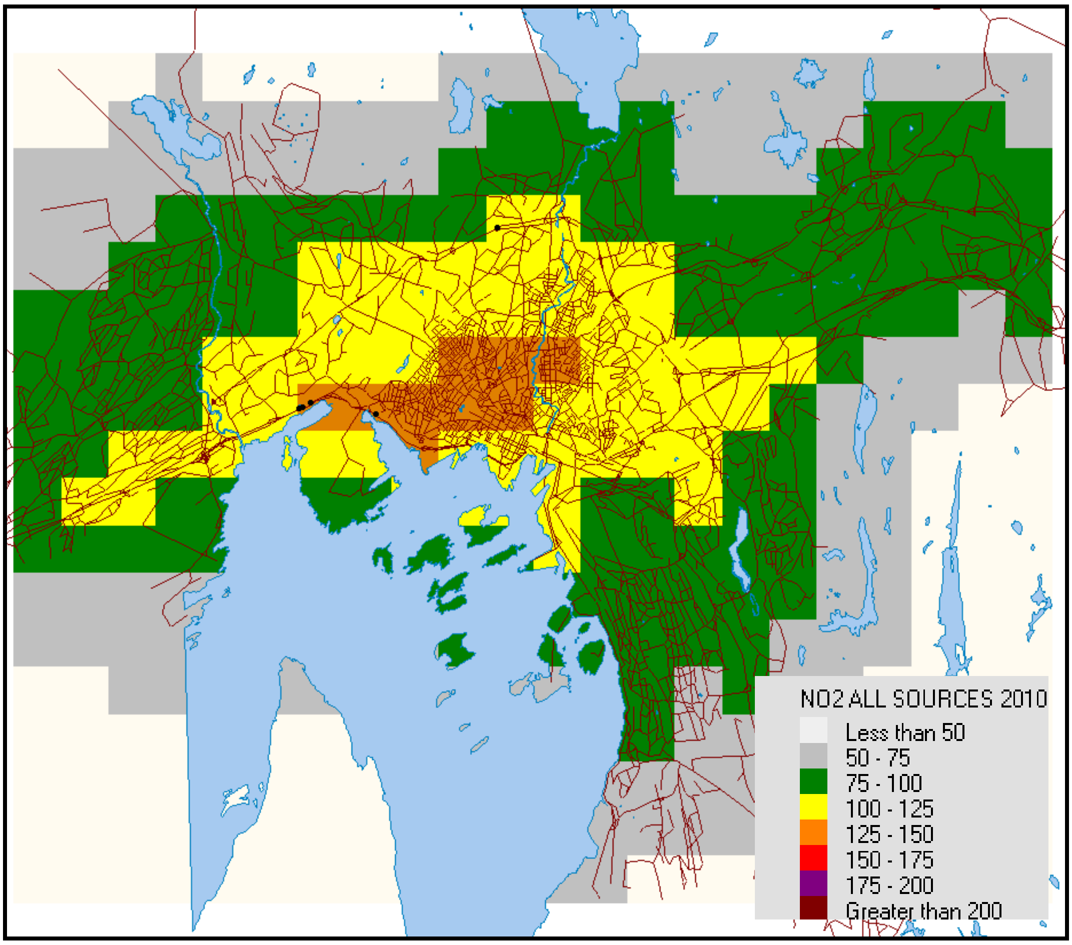

Figure 14: Projection of the 19^th highest hourly grid value (National Target) of NO_2 ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the 19^th highest daily NO_2 value is above limit value of 200 $\mu g/m^3$.

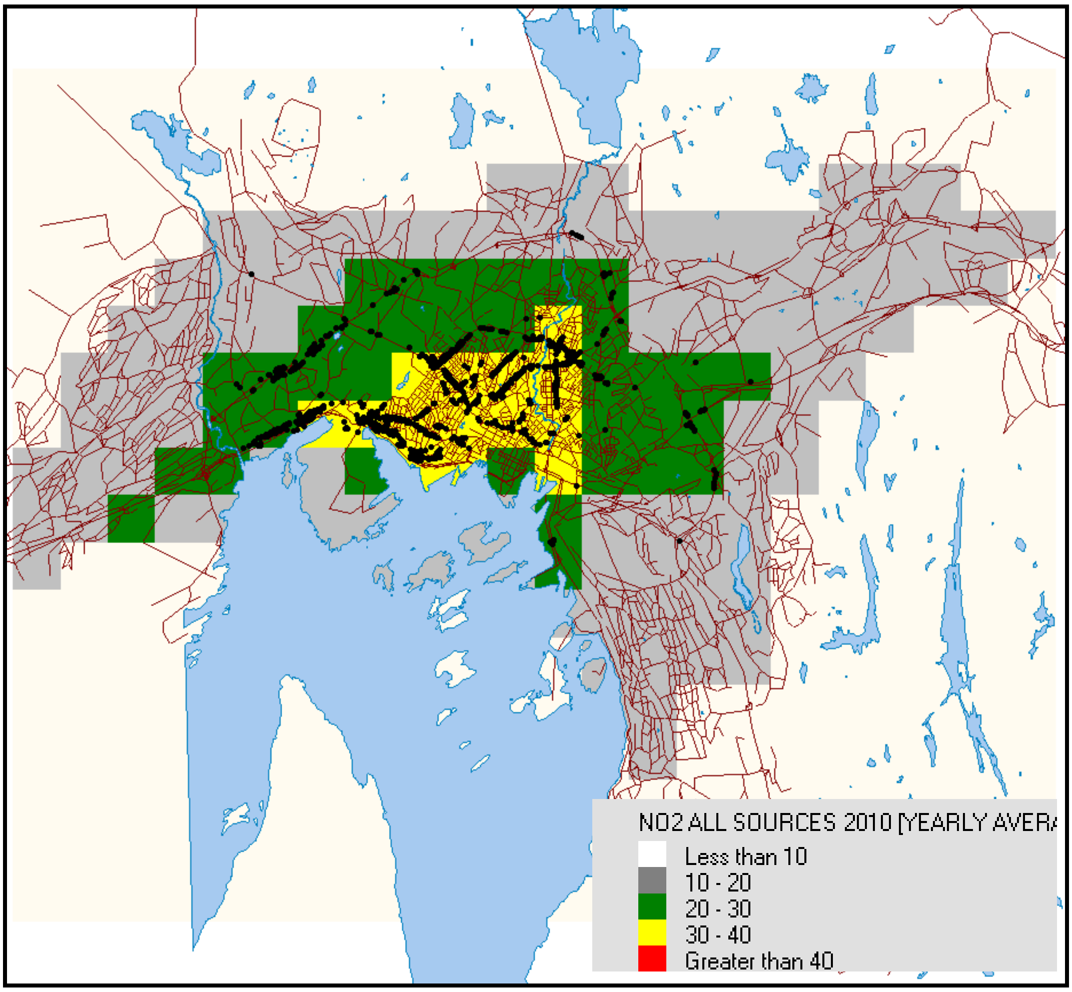

Figure 15: Projection of the yearly grid value (EU) of NO_2 ($\mu g/m^3$) for 2010. The black dots are illustrating the building points where the yearly value of NO_2 is above limit value of 40 $\mu g/m^3$.

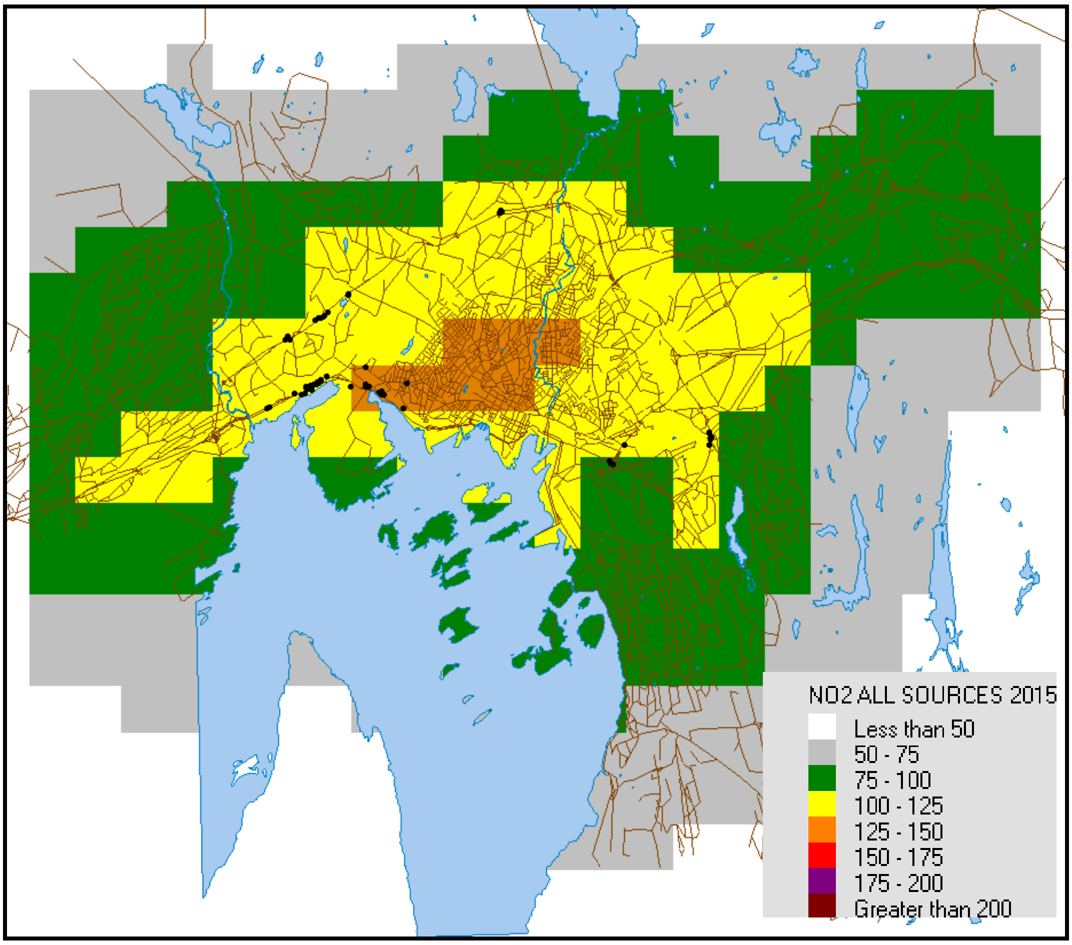

Figure 16: Projection of the 9th highest hourly grid value (National Target) of NO_2 ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the 9th highest daily NO_2 value is above limit value of 150 $\mu g/m^3$.

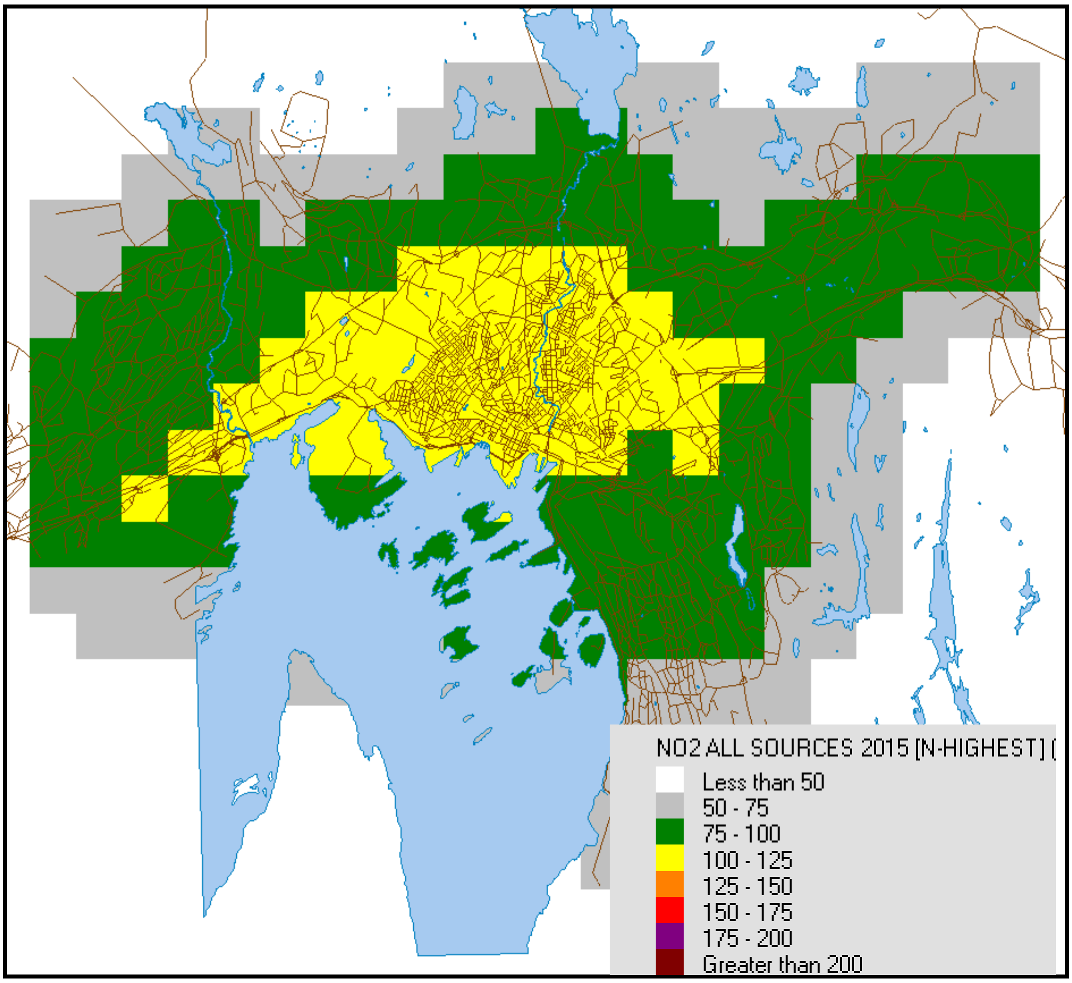

Figure 17: Projection of the 19th highest hourly grid value (National Target) of NO_2 ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the 19th highest daily NO_2 value is above limit value of 200 $\mu g/m^3$.

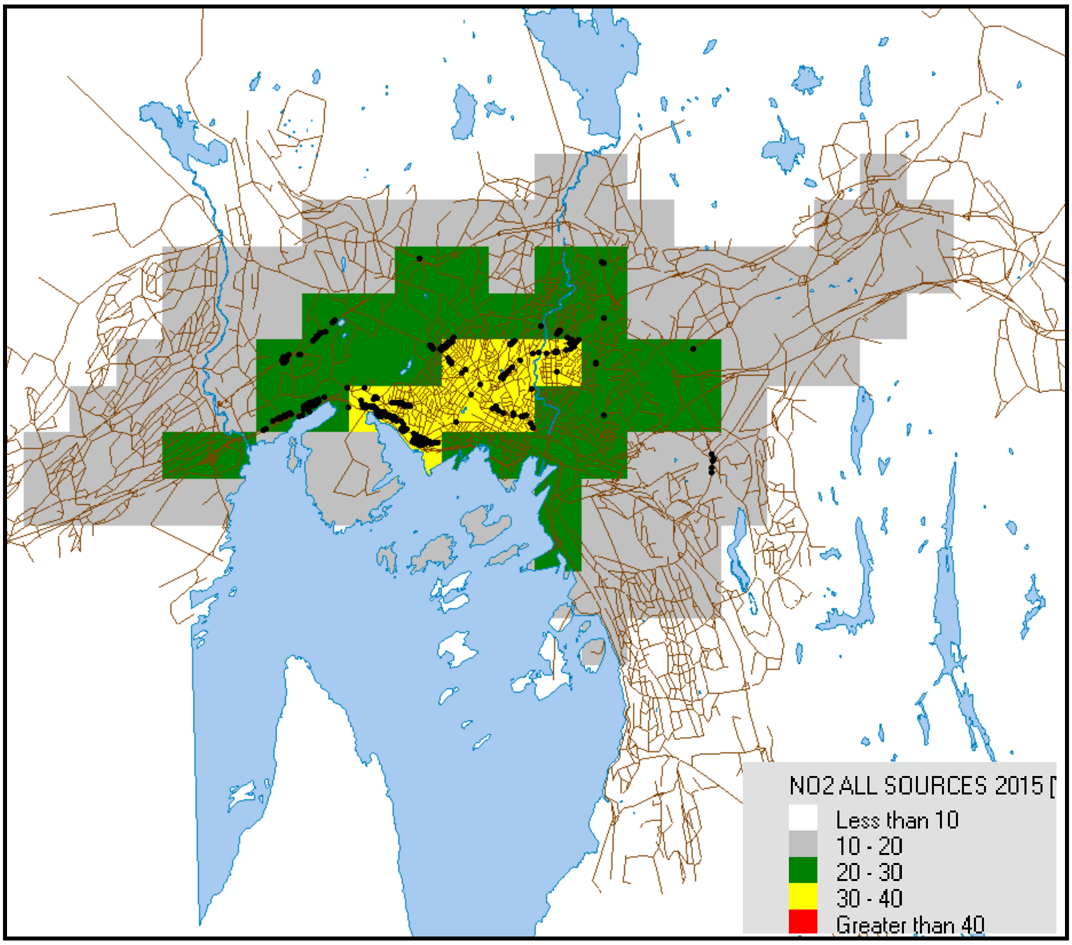

Figure 18: Projection of the yearly grid value (EU) of NO_2 ($\mu g/m^3$) for 2015. The black dots are illustrating the building points where the yearly value of NO_2 is above the limit value of 40 $\mu g/m^3$.

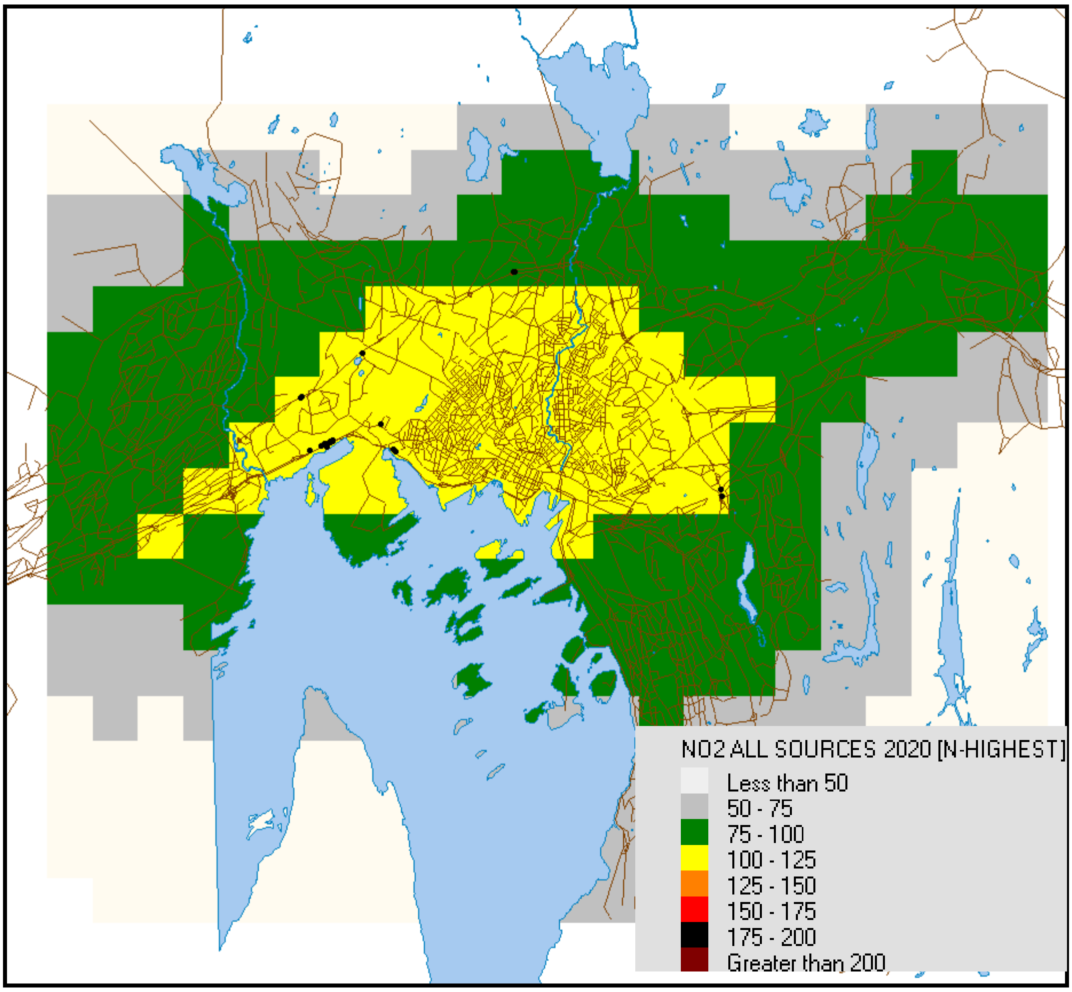

Figure 19: Projection of the 9th highest hourly grid value (National Target) of NO_2 ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the 9th highest daily NO_2 value is above limit value of 150 $\mu g/m^3$.

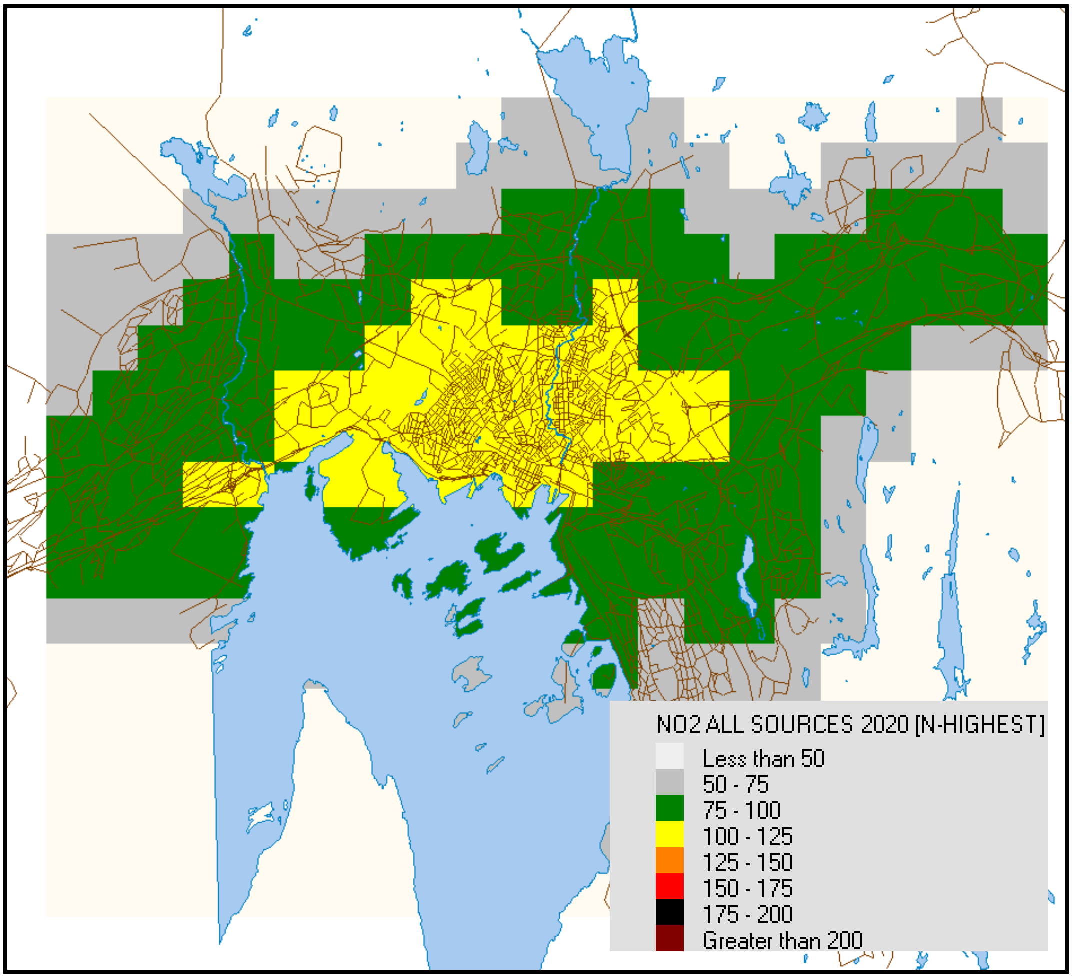

Figure 20: Projection of the 19th highest hourly grid value (National Target) of NO_2 ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the 19th highest daily NO_2 value is above limit value of 200 $\mu g/m^3$.

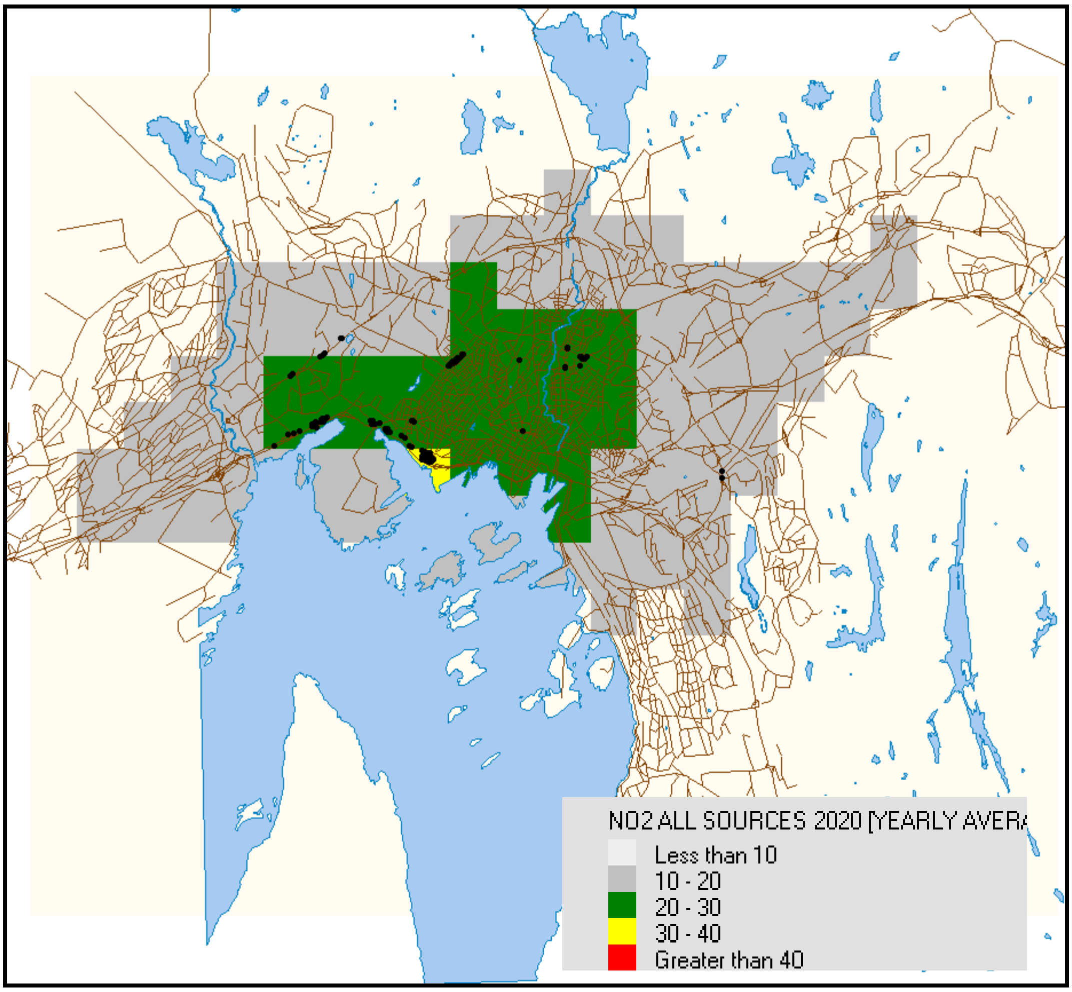

Figure 21: Projection of the yearly grid value (EU) of NO_2 ($\mu g/m^3$) for 2020. The black dots are illustrating the building points where the yearly value of NO_2 is above the limit value of 40 $\mu g/m^3$.

6 Discussion of the modelling results

Since meteorological conditions are the same for all the calculations, changes in dispersion and exposure results reflect changes in local emissions and regional background concentrations.

6.1 PM_{10}

Reference 2005 and Baseline 2010 PM_{10} calculations

A relative large change in total number of exceedances is found between reference 2005 (Slørdal et al. 2006a) and baseline 2010 (Table 3). With respect to the National target value, for instance, the number of people experiencing exceedances are 235849 and 54056 in the 2005 and 2010 calculations, respectively. A relative large reduction in exceedances are also found with respect to the EU guidelines (Table 3). This is due to the expected reduction of emissions from 2005 to 2010.

The reduction in emissions from domestic wood burning is estimated to be 22% from 2005 to 2010 and the use of non-studded tyres is expected to increase from 76% to 85% during this period. Moreover, the traffic emission factors are lower for the 2010 calculations due to a newer vehicle fleet.

It should be noted that there is a general increase in ADT from 2005 to 2010. Furthermore, the road link network for 2010 is more detailed compared to the network applied for the 2005 simulations. The effect of these changes will possibly counteract the general reduction in exhaust emissions from the vehicles, especially close to the roads with the strongest increase in ADT.

In addition to the general reductions in emissions the regional background levels of PM_{10} is assumed to drop by about 22 %. (-22.4%, e.g. -1.4 $\mu g/m^3$ on the average) (Jan Eiof Johnson, met.no, personal communication, 2007).

The population weighted average, C_{PWA}, is reduced from 2005 to 2010 showing that the general concentration levels decreases (Table 4). However, a slight increase is found in the population weighted average exceedance, C_{PWAE}, (Table 4), indicating that the increase in ADT actually leads to an increase of the highest concentrations close to the main road network.

Previous calculations for 2010 (Slørdal et al. 2006b) estimate slightly higher number of exceedances with respect to the National target (66071) compared to the baseline 2010 calculations (54056). This is to be expected since the differences in the two model simulations are: a) the reduction of the regional background concentrations, and b) the updated traffic emission factors for the 2010 baseline calculations. The ADT is the same in these two projections and the change in the traffic emission factors for exhaust particles are relative small. Therefore the main reason for the reduction in exceedances is the reduction of the regional background.

PM_{10} 2010, 2015 and 2020 baseline calculations

Exposure estimates related to the National Target

In the calculations for 2010, 2015 and 2020 there is a gradual decrease in the regional background concentrations, the emissions from domestic wood burning. and exhaust traffic emissions. However, the expected increase in traffic amount (ADT) during this period will act in the opposite direction and may even lead to increased PM_{10} concentration close to the main road network

The baseline calculations for 2010, 2015 and 2020 show a gradual decrease in number of exceedances with respect to the National Target Value, i.e. 54056, 41248 and 26286, respectively.(Table 3). Due to the increase in ADT the number of exceedances in building points close to the main road network are fairly constant.

The model results show a clear reduction in grid concentrations (Figure 1,Figure 5,Figure 9) and hence in the number of people exposed in grids. However, the number of people exposed in building points are more or less unaltered since the increased ADT more or less neutralize the reductions in emissions and background concentrations. This is also demonstrated in the values of C_{PWA} and C_{PWAE} (Table 4). C_{PWA} decreases from 32.7 to 28.0 from 2010 to 2020 while C_{PWAE} increases from 56.0 to 62.9..

Exposure estimates related to the EU guidelines

The grid distributed concentrations for the 36th highest daily value: (Figure 2,Figure 6, Figure 10; and the yearly average: Figure 3,Figure 7,Figure 11) also decreases and hence the population weighted average decreases from 2010 to 2020 (Table 4).

Exceedances with respect to the EU guidelines is only calculated in building points for the all three years. The calculations show that number of exposed people increase slightly (36th highest daily vales)or are unaltered (yearly values) from 2010 to 2020 (Table 3). Even though the concentration in general decreases for 2010 to 2020 the concentrations along the roads are more or less unaltered due to the increase ADT during this period. This is also supported by the values of C_{PWAE} in Table 4.

6.2 NO_2

Reference 2005 and Baseline 2010 NO_2 calculations

From 2005 to 2010 the calculations show an increase in number of exceedances with respect to the National target value (from 652 people to 4321 people) and EU guidelines (from 26 to 43 for 19th highest hourly value and from 2825 to 15422 for annual average) (Table 5). Exceedances are only calculated in building points.

The main reason for this is the increase in traffic (ADT) and increased emission factors for NO_2 for light duty diesel vehicles. Additionally, as mentioned in section 6.1, the road link network for the baseline calculations for 2010, 2015 and 2020 is more detailed compared to the network applied for the reference 2005 simulations. Since traffic is by far the most dominant local source of NO_2, it is

expected that changes in these emissions will be directly reflected in the calculated NO2 levels.
In addition the regional ozone background is increased in the 2010 simulations, which increases the oxidation of NO_x to NO_2 and hence the NO_2 concentration.

NO_2 2010, 2015 and 2020 baseline calculations

Exposure estimates related to the National target and EU guidelines

Exceedances related to National Target value and EU guidelines for NO_2 for 2010, 2015 and 2020 are only calculated in building points, e.g. close to the main road network. The number of people exposed beyond the target value and EU guidelines decreases considerably from 2010 to 2015 and 2020.

The highest number of exceedances are estimated for annual average (EU guideline). The number of exceedances of yearly limit value decreases from 15422 in 2010 to 2055 people in 2020. Also for the short term averages the number of exposed people decrease from 2010 to 2020 (Table 5). No people are exposed to hourly concentration beyond 200µg/m^3 of the 19th highest hourly value in 2015 and 2020.

As for PM_{10} the grid distributed concentrations for the 9th highest hourly values (Figure 13, Figure 16, Figure 19), the 19th highest hourly values(Figure 14, Figure 17, Figure 20) and the yearly averages Figure 15, Figure 18, Figure 21) decreases between 2010 and 2020. This is also illustrate by the clear reduction in values of the population weighted averages (C_{PWA}) (Table 6) In contrast to the PM_{10} results, however, the total number of people exposed beyond the limit values is reduced along the main road network as well. The main reason for this is the decrease in exhaust traffic emissions for NO_X has a stronger impact than the increase in ADT and regional ozone level from 2010 to 2020.

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Appendix A

Description of the applied method for scaling the emissions from domestic wood burning in Oslo to 2010, 2015 and 2020

Scaling factors for emissions from domestic wood-burning

The basic parameters used in the estimation of the PM_{10} emissions from domestic wood burning are listed below. These parameters are also used when constructing scaling factors for these emissions for the year 2005, 2010, 2015 and 2020.

F^{02} [ton wood/year]	: Consumption of wood per unit time, valid for the year 2002.
Q^{02} [kg PM_{10}/year]	: Emissions of PM_{10} per unit time, valid for the year 2002.
a^{new} = 6.2 kg/ton	: Emission factor for new clean-burning ovens.
a^{old} = 33.0 kg/ton	: Emission factor for old ovens.
a^{fp} = 17.3 kg/ton	: Emission factor for open fireplaces.
$\Delta F^{02\text{-}05}$; $\Delta F^{05\text{-}10}$	: Change (in percentage) of the wood consumption between the given years indicated by the superscript.

The above parameters are the one used for Oslo since the wood consumption data for this city are valid for 2002. Knowing the values of the above parameters we now seek a scaling factor, $k^{02\text{ - selected year}}$, such that the emission for the selected year can be expressed simply as:

$$Q^{\text{selected year}} = k^{02-\text{selected year}} \cdot Q^{02}.$$

Oslo:

In ***2002*** 18 % of the consumed wood was burnt in new clean-burning ovens, 60 % in old ovens and 22 % in open fireplaces. In ***2005*** this was changed to 30 % clean-burning, 48 % old and 22 % open, in ***2010*** we apply 50 % clean-burning, 28 % old and 22 % open, in 2015 60 %, clean burning, 18 % old and 22 % open, and finally in 2020 70 % old 8 % old and 22 % open.

Estimations for Oslo indicate an increase in yearly wood consumption from 15700 tons in 2002 to 16500 tons in 2005. This means an increase of 5.1 %, which further imply that $\Delta F^{02-05} = 5.1$. Moreover, a yearly increase of 1 % has been estimated for the years after 2005 until 2010, which gives $\Delta F^{05-10} = 100 \cdot (1.01^5 - 1) = 5.1$. Between 2010 and 2020 we assume no change in wood consumption.

The total PM_{10}-emissions from domestic wood consumption for 2005, 2010, 2015 and 2020 can therefore be computed from the following scaling expressions

$$Q^{05} = \frac{0.3 \cdot a^{new} + 0.48 \cdot a^{old} + 0.22 \cdot a^{fp}}{0.18 \cdot a^{new} + 0.6 \cdot a^{old} + 0.22 \cdot a^{fp}} \cdot \left(1 + \frac{\Delta F^{02-05}}{100}\right) \cdot Q^{02} = 0.914 \cdot Q^{02},$$

$$Q^{10} = \frac{0.5 \cdot a^{new} + 0.28 \cdot a^{old} + 0.22 \cdot a^{fp}}{0.18 \cdot a^{new} + 0.6 \cdot a^{old} + 0.22 \cdot a^{fp}} \cdot \left(1 + \frac{\Delta F^{02-05}}{100}\right) \cdot \left(1 + \frac{\Delta F^{05-10}}{100}\right) \cdot Q^{02} = 0.721 \cdot Q^{02}$$

$$Q^{15} = \frac{0.6 \cdot a^{new} + 0.18 \cdot a^{old} + 0.22 \cdot a^{fp}}{0.18 \cdot a^{new} + 0.6 \cdot a^{old} + 0.22 \cdot a^{fp}} \cdot \left(1 + \frac{\Delta F^{02-05}}{100}\right) \cdot \left(1 + \frac{\Delta F^{05-10}}{100}\right) \cdot Q^{02} = 0.602 \cdot Q^{02}$$

$$\mathrm{Q}^{20} = \frac{0.7 \cdot \mathrm{a}^{\mathrm{new}} + 0.08 \cdot \mathrm{a}^{\mathrm{old}} + 0.22 \cdot \mathrm{a}^{\mathrm{fp}}}{0.18 \cdot \mathrm{a}^{\mathrm{new}} + 0.6 \cdot \mathrm{a}^{\mathrm{old}} + 0.22 \cdot \mathrm{a}^{\mathrm{fp}}} \cdot \left(1 + \frac{\Delta \mathrm{F}^{02-05}}{100}\right) \cdot \left(1 + \frac{\Delta \mathrm{F}^{05-10}}{100}\right) \cdot \mathrm{Q}^{02} = 0.482 \cdot \mathrm{Q}^{02}$$

and the scaling factors for the four years are therefore 0.914 (emission reduction of 8.6 % from 2002 to 2005), 0.721 (emission reduction of 27.9 % from 2002 to 2010), 0.602 (emission reduction of 39.8 % from 2002 to 2015), and 0.482 (emission reduction of 51.8 % from 2002 to 2020), respectively.

NO2/NOX

The basis for the database in the Oslo BASELINE project is the 2010 database from Oslo abatement study for 2010. The wood burning emissions for PM is scale according to the procedure above, but the NOx and No2 emissions are not updated according to changes in consumptions. We have only changes in consumption data from 2002 to 2020. From the description above we have following changes in consumption:

$\Delta F^{02-05} = 5.1$ and $\Delta F^{05-10} = 100 \cdot (1.01^5 - 1) = 5.1$.

The NO2 and NOx emissions for all the years, 2010, 2015, 2020 will be updated according to the changes in consumption from 2002 to 2010 e.g.:

$$\cdot \left(1 + \frac{\Delta F^{02-05}}{100}\right) \cdot \left(1 + \frac{\Delta F^{05-10}}{100}\right) \cdot Q^{02} = 1.105 \cdot Q^{02}$$

PM10/PM2.5

For 2010 the data is already updated in the project Oslo abatement study for 2010. Since 2015 and 2020 is a copy of 2010, the scaling of 2015 and 2020 must be according to the 2010 data.

$$Q^{10} = 0.721 \cdot Q^{02}$$

$$Q^{15} = 0.602 \cdot Q^{02} = \frac{0.602}{0.721} Q^{10} = 0.835 Q^{10}$$

$$Q^{20} = 0.482 \cdot Q^{02} = \frac{0.482}{0.721} Q^{10} = 0.669 Q^{10}$$

Table 7:Scaling of wood burning emissions for 2010, 2015 and 2020 for Oslo.

Database	PM10	PM2.5	NOX	NO2
OSLO_BASELINE_2010_BASIS	$0.721 \cdot Q^{02}$	$0.721 \cdot Q^{02}$	$1.105 \cdot Q^{02}$	$1.105 \cdot Q^{02}$
OSLO_BASELINE_2015_BASIS	$0.835Q^{10}$	$0.835Q^{10}$	$1.105 \cdot Q^{02}$	$1.105 \cdot Q^{02}$
OSLO_BASELINE_2020_BASIS	$0.669Q^{10}$	$0.669Q^{10}$	$1.105 \cdot Q^{02}$	$1.105 \cdot Q^{02}$

Appendix B

Technical description of model calculations

1. Software versions

Table 8: AirQUIS specifications

	AirQUIS	EPISODE	MATHEW
Software versions	496	02.11.2005	21.12.2004

2. Meteorological data applied in the model calculations

Table 9: Meteorological data used for model calculations

	Period	Parameters
Valle Hovin	1.1.2005-.5.2005 and 1.10-31.12 2005	FF; DD; RH; precipitation, Temperature, Delta T

3 Regional background data applied in the model calculations

Observations for 2005 of daily averaged values of NO_2 and Pm10 and hourly values of ozone measured at the closest regional background stations have been applied as boundary conditions on the open boundaries of the model domain. To estimate of the regional contribution for 2010, 2015 and 2020 the measured hourly/daily data have been scaled (in percentage) according to EMEP predictions to 2010. 2015 and 2020.

Table 10: Boundary conditions for the model calculations . The measured regional background data for 2005 are scaled according to changes computed in the EMEP.

	PM10	Ozon	NO2
Stations	Birkenes	Maximum hourly values either from Birkenes, Hurdal or Prestebakke.	Birkenes
Period	1.1.2005-.5.2005 and 1.10-31.12 2005	1.1.2005-.5.2005 and 1.10-31.12 2005	1.1.2005-.5.2005 and 1.10-31.12 2005
Time resoultion	Daily	Hourly	Daily
Start time and end time for daily values	07:00-07:00		07:00-07:00

Table 11: Scaling of hourly/daily regional background values applied in the model calculations for 2010, 2015 and 2020.

	O3 (µg/m^3)	**NO2** (µg/m^3)	**PM10** (µg/m^3)
Measured data from 1.1.2005-.5.2005 and 1.10-31.12 2005	Average: 67 µg/m^3	Average: 1.7 µg/m^3	Average: 6.4 µg/m^3
Scaling factors from 2005 to 2010 applied on measured data	Average: 68.5 µg/m^3 Different scaling are used on hourly values for the different months. Scaling relative to 2005	Average: 1.5 µg/m^3 The daily/hourly values are changed with -10,6% relative to 2005 data.	Average: 5.0 µg/m^3 The daily/hourly values are changed with -22.4% relative to 2005

	Month O3 1 +7.0% 2 +3.1% 3 +0.9% 4 -0.8% 10 +4.1% 11 +1.7% 12 +3.8%		
Scaling factors from 2005 to 2015 applied on measured data	Average: 71.1 $\mu g/m^3$ Different scaling are used on hourly values for the different months. Scaling relative to 2005: Mnd O3 1 +13.9% 2 +6.2% 3 +1.7% 4 -1.5% 10 +8.3% 11 +3.4% 12 +7.7%	Average: 1.4 $\mu g/m^3$ The daily/hourly values are changed with -21.1% relative to 2005.	Average: 3.56 $\mu g/m^3$ (The daily/hourly values are changed with -44.2% relative to 2005)
Scaling factors from 2005 to 2020 applied on measured data	Average: 72.0$\mu g/m^3$ Different scaling are used on hourly values for the different months. Scaling relative to 2005: Mnd O3 1 +20.9 2 +9.3 3 +2.6 4 -2.3 10 +12.4 11 +5.1 12 +11.5	Average: 1.18$\mu g/m^3$ The daily/hourly values are changed with -36.2% relative to 2005.	Average: 2.12$\mu g/m^3$ The daily/hourly values are changed with -67.2% relative to 2005.

Average background values for the simulation period are applied when a background value is missing.

Note: Since the values in the NILUdb are given as NO2_N, the values are converted from N to NO2 by use of the following relation: NO_2=NO_2-N*(46/14).

Negative background values means that the concentration is below the detection limit. In these situations we apply a background value which is equal to the absolute value multiplied by 2.

Background values of NO are set equal to zero.

4. Population data

Table 12: Population data. For all the calculations population data for 2005 are used, but number of people calculated in building points are updated according to changes in buffer zones due to increase of annual daily traffic.

	Total number of people (2005)	People calculated in building points (within buffer zones)
2005 reference	526258	90885
2010	526258	95950
2015	526258	120687
2010	526258	134162

5. Emission from wood burning

Table 13: Emissions from wood burning

		State of the environment 2005 (tons/year)	Oslo baseline calculations 2010 (tons/year)	Oslo baseline calculations 2015 (tons/year)	Oslo baseline calculations 2020 (tons/year)
PM10	Bærum	256.8	202.5	169.1	135.5
PM10	Oslo	330.4	260.6	217.6	174.3
PM10	SUM	587.1	463.1	386.7	309.8
NO2	Bærum	1.1	1.2	1.2	1.2
NO2	Oslo	1.6	1.7	1.7	1.7
NO2	SUM	2.7	2.9	2.9	2.9

6. Traffic data

Table 14: Use of un-studded tyres.

2005	**2010**	**2015**	**2020**
76%	85%	85%	85%

Traffic emission factors:
2010/2015 and 2020
The vehicle distribution and average driving distance for light duty vehicles are according to prognoses from Institute of Transport Economics (Vehicle Generation Model BIG2) (Johansen, K.W. (2003))

The vehicle distribution for heavy duty vehicles are according to ongoing work from Statistics Norway (Kjetil Flugsrud, personal communication).

EURO 5 light duty vehicles are included. Emission factors from EEA (EEA,2006)

The NO2 fraction of NOx for light duty vehicles using diesel are updated (Air Quality Expert Group (2006)). The emissions are doubled for EURO 4 and EURO 5 compared to previous emission factor set.

2015
In previous calculations for 2015 also the vehicle class "hybrid cars" were included. This class is not included in the emission factor set anymore.

2015/2020
EURO 6 light duty vehicles are included. Emission factors from EEA (EEA,2006)

EURO 6 heavy duty vehicles are included. Emission factors estimated based on expected emissions inventory regulations from EEA (EEA,2006)

7. Conversion factor between winter mean and annual average

Table 15: Conversion factors between average winter mean (1 October to 1 May) and annual average for 2005.

Measurement stations: **Kirkeveien, Manglerud og Alnabru**	**PM10**	**NO2**
	0.815	0.888

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