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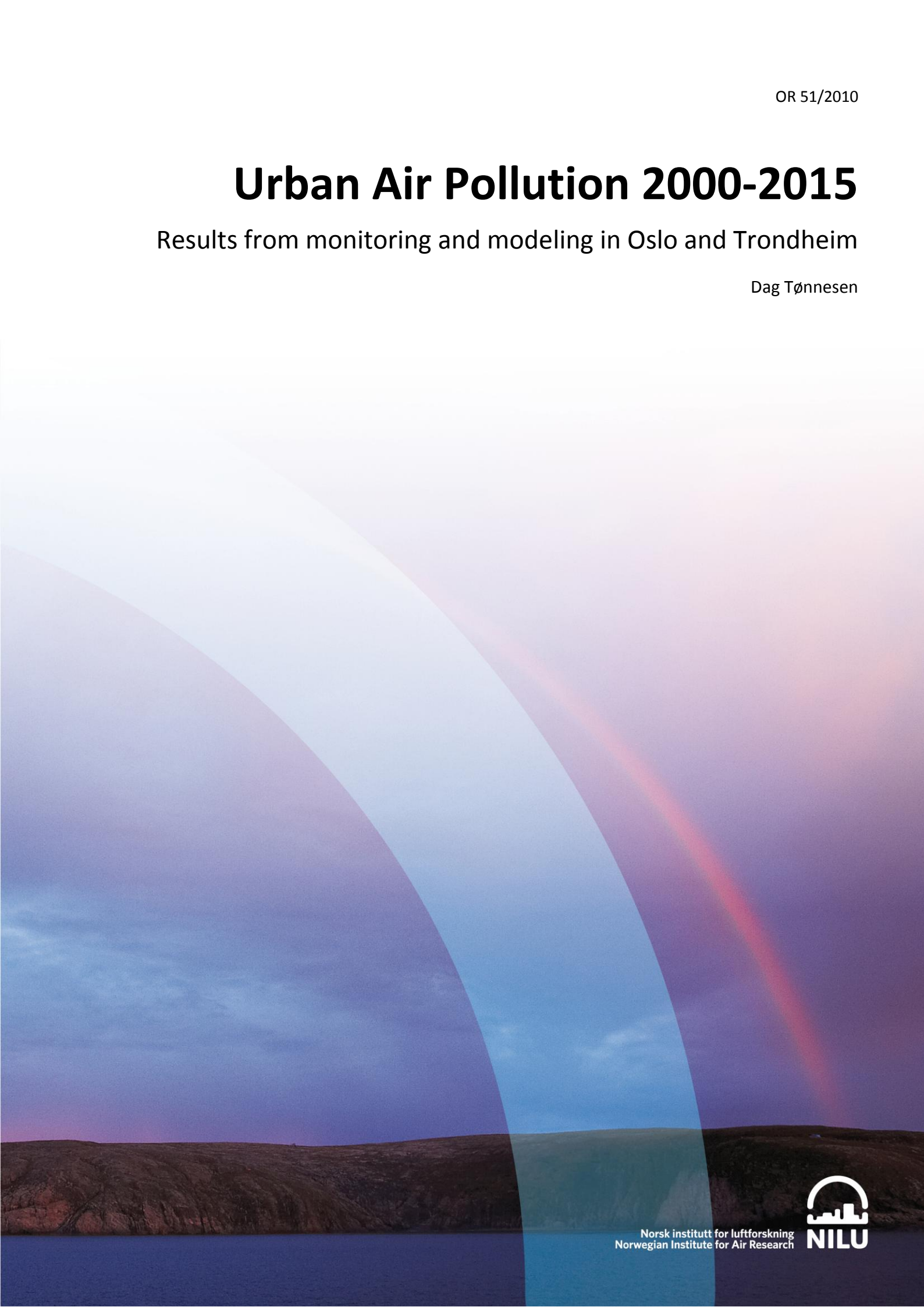
Urban Air Pollution 2000-2015

Results from monitoring and modeling in Oslo and Trondheim

Dag Tønnesen



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NILU

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Summary

During the past years the exhaust emissions from new gasoline and diesel vehicles have been reduced to very low levels due to improved engine technology, exhaust after treatment devices, and improved fuel quality.

The addition of bio components in the fuel have generally shown further decrease in most emissions. We have evaluated the impacts on NO_X, PM and VOC concentrations in air. The effect of bio fuels is larger in NO_X and VOC than in PM.

There are three major sources to air pollution of particulate matter in Norwegian cities: 1) stationary combustion, primarily from domestic wood burning, 2) road dust due to the use of studded tires and vehicle resuspension, and 3) long-range transport.

Diesel vehicles are still the most important contributor to NO_X. Biodiesel may cause a small increase in NO_X due to increased fuel oxygen, and ethanol in gasoline may lead to increased emissions of aldehydes and possibly other VOC components.

Bio fuels only contribute to a few per cent of today's fuel consumption and air quality modelling and measurements have not yet been able to track changes in air pollution that can be attributed to the use of bio fuels. The reduced contribution from vehicle exhaust to air pollution makes changes due to small amounts of bio fuels even more difficult to detect. Extended mapping of VOC in roadside environments is needed before a more widespread use of bio fuels in order to quantify their impact on VOC concentrations in air.

The recent gains in NO_X emission reduction from vehicles have been accompanied by an increased fraction of NO_2 in the NO_X emission, and the trend towards increased use of diesel passenger cars contribute to a higher fraction of NO_2 in NO_X emissions. This effect, coupled with increased traffic volume, has led to a stagnation in the decrease of urban NO_2 levels in air.

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1 Introduction

On behalf of Statoil, the Norwegian institute for air research (NILU) has made a trend analysis of urban air pollution in Norway. The work is an initial contribution to analyse the impact on local air pollution derived from the introduction of bio fuels. The trend analysis includes data from air quality monitoring for the period 2000 to 2009, and vehicle emission modelling and air quality modelling for the period of 2000 to 2015. For the last part of the trend period, assessment of the effects of bio fuels have been made. The basis for this assessment is a report made by Ecotraffic for Statoil, Particle and NO_X emissions from automotive diesel and petrol engines (Erikson and Yagci, 2009).

2 Air pollution components

The air pollution components considered in this report are nitrogen oxides, particulate matter, sulphur oxides and volatile organic compounds.

Nitrogen oxides (NO_X) are a group of gases consisting of nitrogen dioxide (NO_2) and nitrogen oxide (NO). Regulations for vehicle exhaust emissions refer to NO_X, while air quality regulations refer to NO_2. Considering the effect of different emission reduction techniques, this difference is not trivial.

Particulate matter is regulated (and monitored) for two size fractions, PM_{10} and $PM_{2.5}$. These abbreviations mean **P**articulate **M**atter with (aero dynamical) diameter less than 10 µm and 2.5 µm, respectively. By definition, the $PM_{2.5}$ is also included in the size fraction of PM_{10}. For these particles, the gravitational settling velocity (the speed with which they fall and attach themselves to surfaces) is very small compared to the turbulent mixing in the atmosphere.

Sulphur oxides (SO_X) are a group of gases consisting of sulphur and oxygen. The most important oxide regarding air pollution, and the only one considered here, is sulphur dioxide (SO_2).

Volatile organic compounds (VOCs) are a very large group of compounds, mainly consisting of hydrogen and carbon. Monitoring of VOCs in urban air in Norway on a regular basis have been done for the subgroup of BTEX (benzene, toluene, xylene), and regularly reported only for benzene (C_6H_6).

3 Data sources

Four different categories of data have been used in this work. The primary input sources for the various categories are shown in Table 1 below.

Table 1: Categories of data and main data sources used in this work.

Data Category	Main data source
Air Quality data	Municipalities of Oslo and Trondheim, Norwegian road authorities
Air Quality modelling and Source contribution	NILU modelling projects using the AirQUIS system
Vehicle fleet composition and size, emission trends	Statistics Norway, results from BIG4 (car generation model version 4)
Vehicular emission modelling	AirQUIS emission module, National emission model for vehicular emissions, Ecotraffic report

For Air Quality data, the annual reports by the municipal agencies in Oslo and Trondheim have been used. These include monitoring stations owned both by the municipalities and the road authorities. A common feature for both these cities is that, within the trend period, they have employed abatements for reducing resuspension of road dust in order to achieve better air quality for PM_{10}. The abatement measures consist of increased road surface cleaning, fees on the use of studded tires, and spreading of salt solution to increase road surface wetness.

The Air Quality modeling data consists of both diagnostic modeling results and scenario projection modeling results. The extracted trends for modeling are based on summary tables for population exposure and common features for the concentration description for the selected years. Source apportionment estimates from the different model runs vary within the time span for this analysis, emphasis have been made to present an average apportionment for the exceeding of air quality regulation limit values.

Historical data for the vehicle fleet size and distribution have been compiled by Statistics Norway. In addition Statistics Norway has compiled national emissions divided by source sectors for various components. The State pollution control agency of Norway (KLIF) has provided NILU with model results from the car generation model (BIG4) in connection with work on projections for future air quality situations. These data have been combined with the latest trends in car sales, expected new emission regulations and statistics on changes in accumulated driving distance in order to compose a relative emission curve for urban traffic for different emission components.

The potential changes in emissions of VOC, NOX and particles with introduction of bio fuels have then been discussed.

4 Trends from Air Quality monitoring 2000-2009

4.1 Particulate matter

The figures below show trends from the monitoring networks in Oslo and Trondheim regarding PM_{10} and $PM_{2.5}$. Source analysis for these two size fractions show that the difference between PM_{10} and $PM_{2.5}$ (representing particles greater than 2.5 µm but smaller than 10 µm) is completely dominated by resuspended road dust, while the $PM_{2.5}$ fraction contain contributions from all sources of PM

emissions. The abatements done at municipality level should have strongest influence on the PM($_{10-2.5}$) fraction. This size fraction will also be the one that has the strongest dependence on meteorological variation from one year to the next.

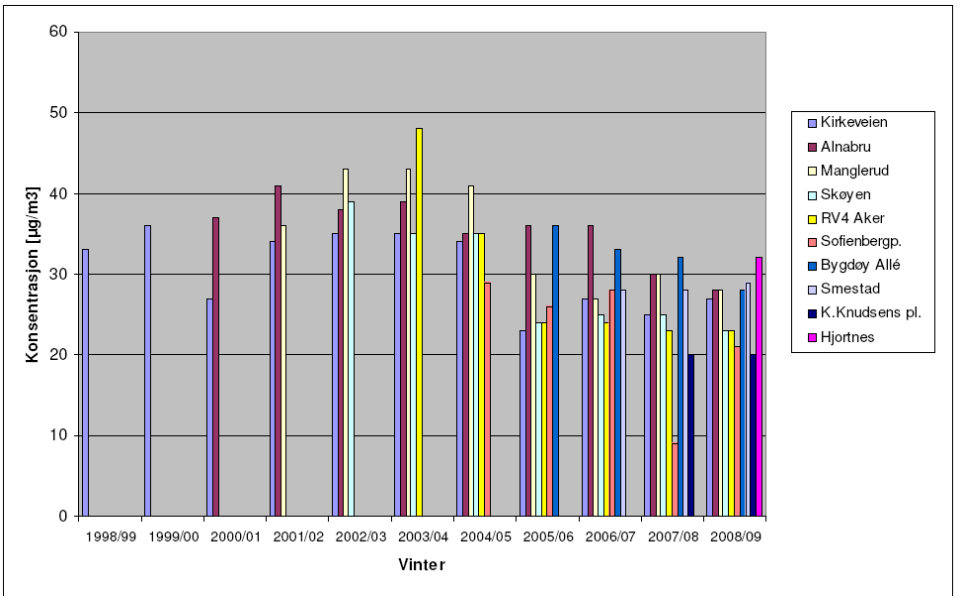

Figure 1: Average winter concentrations of PM_{10} in Oslo (Department of Health and welfare, Oslo).

Although the number and location of operative stations have changed somewhat during the 11 year period shown, a reduction of concentrations can be seen from 2003/04 to 2008/09, despite increased traffic density in the same period.

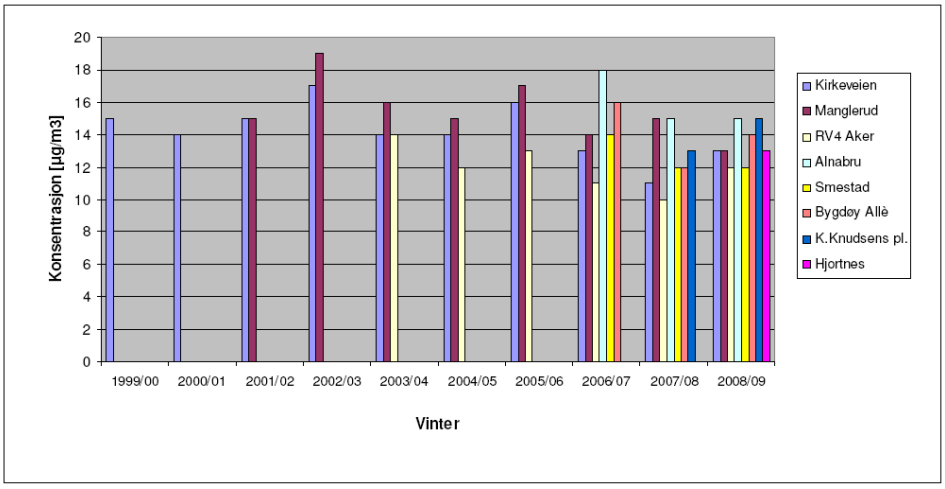

Figure 2: Average winter concentrations of $PM_{2.5}$ in Oslo (Department of Health and welfare, Oslo).

Compared to PM_{10}, the reduction of $PM_{2.5}$ level is less evident (although present at least at some stations). This size fraction also contains a substantial contribution from sources outside of the urban areas, and this contribution influence the yearly average values of $PM_{2.5}$ significantly.

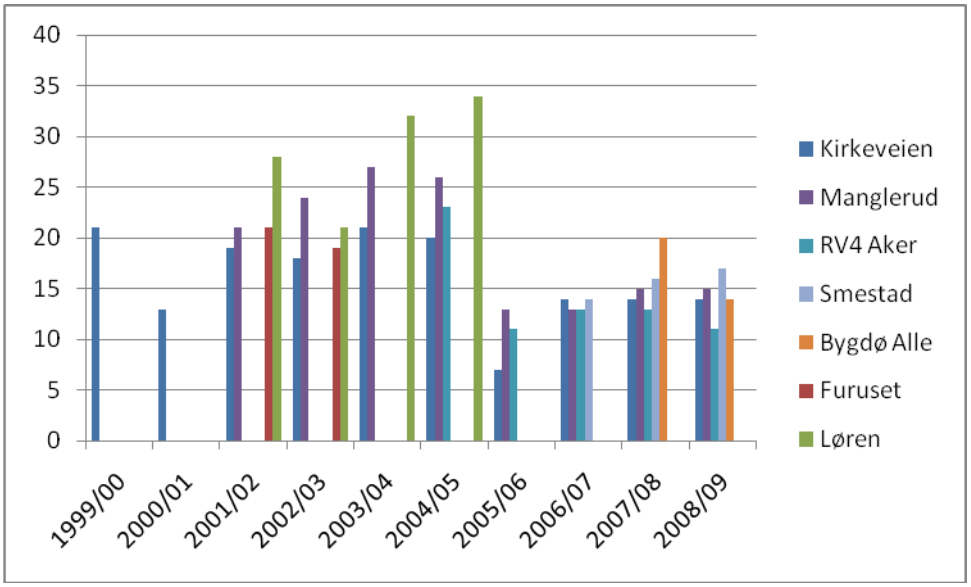

Figure 3: Difference between average winter concentrations of PM_{10} and $PM_{2.5}$, in Oslo for all stations measuring both components.(Unit µg/m^3)

The coarse fraction (PM_{10}-$PM_{2.5}$) shows a sharp drop from 2004/05 to 2005/06, and after that a station dependent level, either slightly increasing or slightly decreasing. From 2003/04 to 2005/06, the use of studded tires dropped from 30 % to 20 %, and winter season reduced speed limits were introduced. The main emission source for the coarse fraction is resuspended road dust, and this makes the coarse fraction to be the best monitoring indicator value for the impact of this source. The abatement measures introduced from 2003 an onwards have clearly worked towards lower concentrations of PM in air.

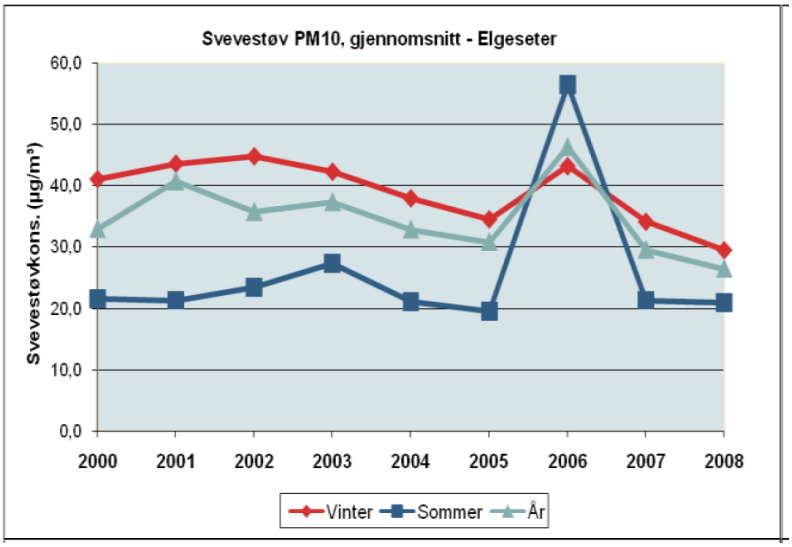

Figure 4: Seasonal averages, and yearly averages of PM_{10} at Elgeseter, Trondheim (Environmental unit, Trondheim).

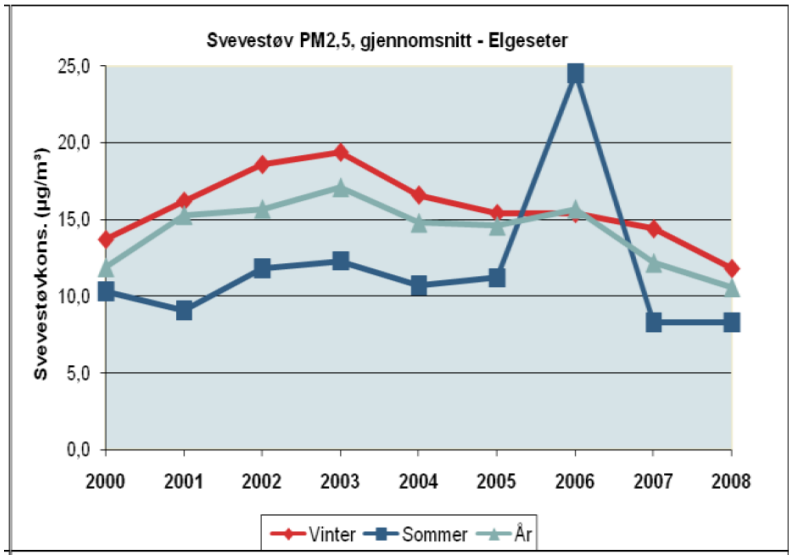

Figure 5: Seasonal averages, and yearly averages of $PM_{2.5}$ at Elgeseter, Trondheim (Environmental unit, Trondheim).

When interpreting the trends in PM for Trondheim in Figure 4 and Figure 5, it must be taken into account that in 2006, the monitoring station was strongly influenced by local construction work in the immediate vicinity of the station. Abatements against dust pollution started in 2001 in Trondheim. From 2001 to 2003 the use of studded tires dropped from nearly 70 % to below 40 %. From 2003 both size fractions show a marked decrease.

4.2 Nitrogen dioxide

In Figure 6 - Figure 10 trends in NO_2 concentration and NO_X concentration as well as the measured ratio between NO_X and NO_2 (Oslo) or ratio between NO_2 and NO (Trondheim) are shown. Combustion is the main source of urban NO_2 pollution, and the main emission source is vehicular traffic in general, with diesel engine vehicles being a stronger source than gasoline engine vehicles. Emission from ships in the harbor area is also an important source. Over the periods shown, there have been significant reductions of both emissions and concentrations of NO_X (Figure 8). However, there is no corresponding reduction in the levels of NO_2 (Figure 6); the values show either a stable or an increasing level. Ozone is a primary agent for conversion of NO to NO_2 in the atmosphere. However, the background level of ozone is either stable or decreasing, as shown in Figure 7. The lack of the expected reduction in the NO_2 level is probably caused by a combination of an increase in the NO_2 fraction of the NO_X emissions in combination with the overall increase in traffic volume.

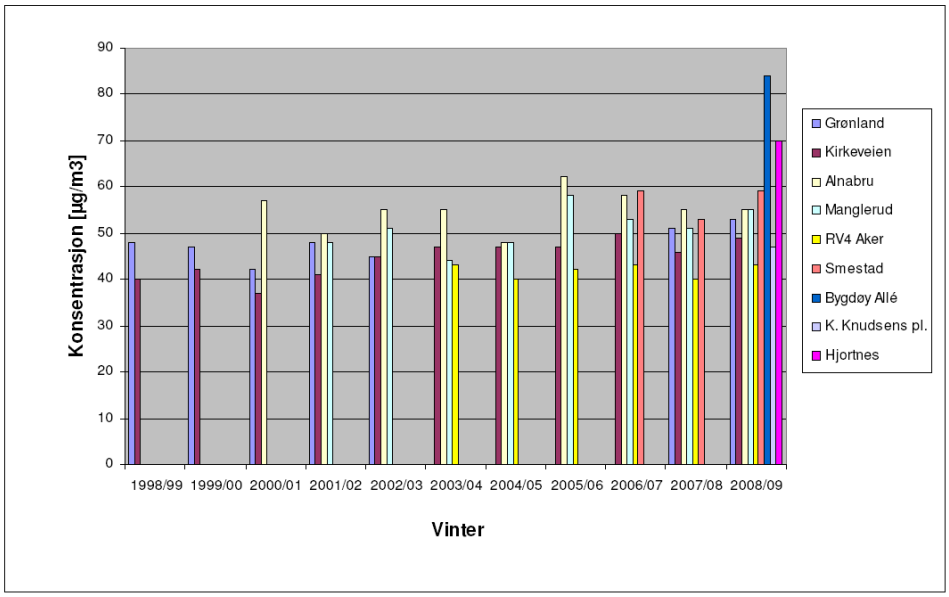

Figure 6: Winter averages of NO_2 concentrations in Oslo (Department of Health and welfare, Oslo).

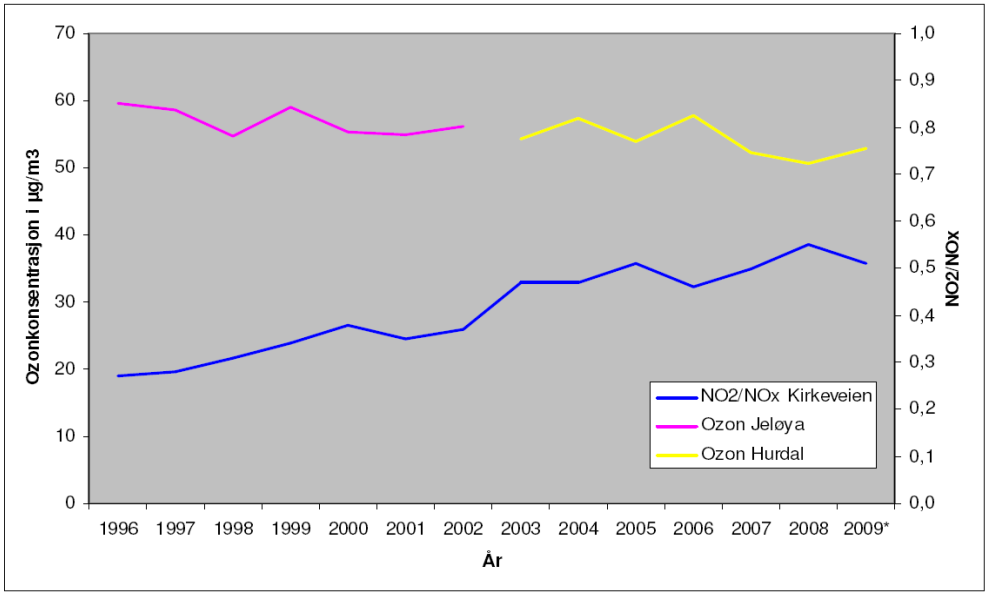

Figure 7: Yearly average NO_2/NO_X ratio and yearly average O_3 concentrations outside Oslo (Department of Health and welfare, Oslo).

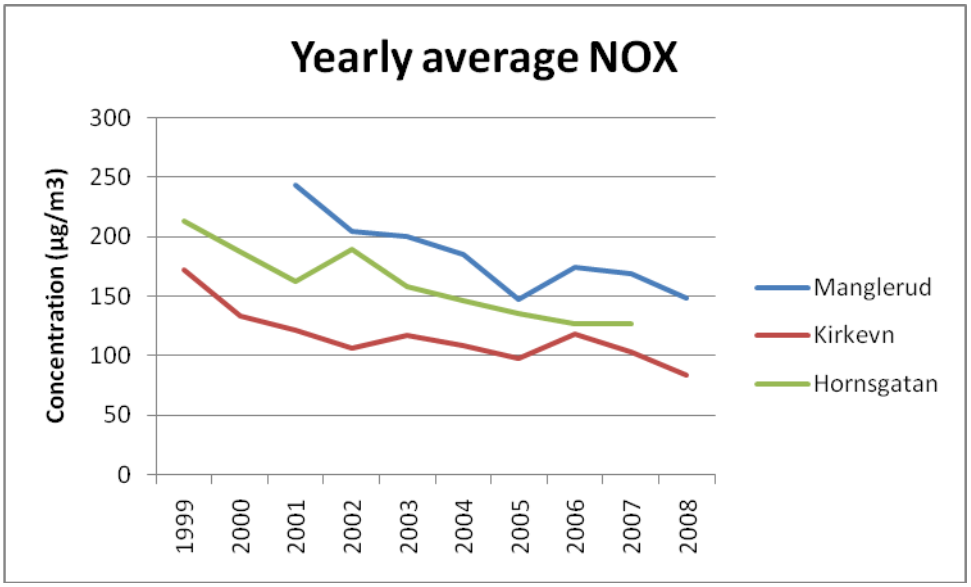

Figure 8: Yearly average NO_X concentrations from two stations in Oslo (Kirkeveien, Manglerud) and one in Stockholm (Hornsgatan).

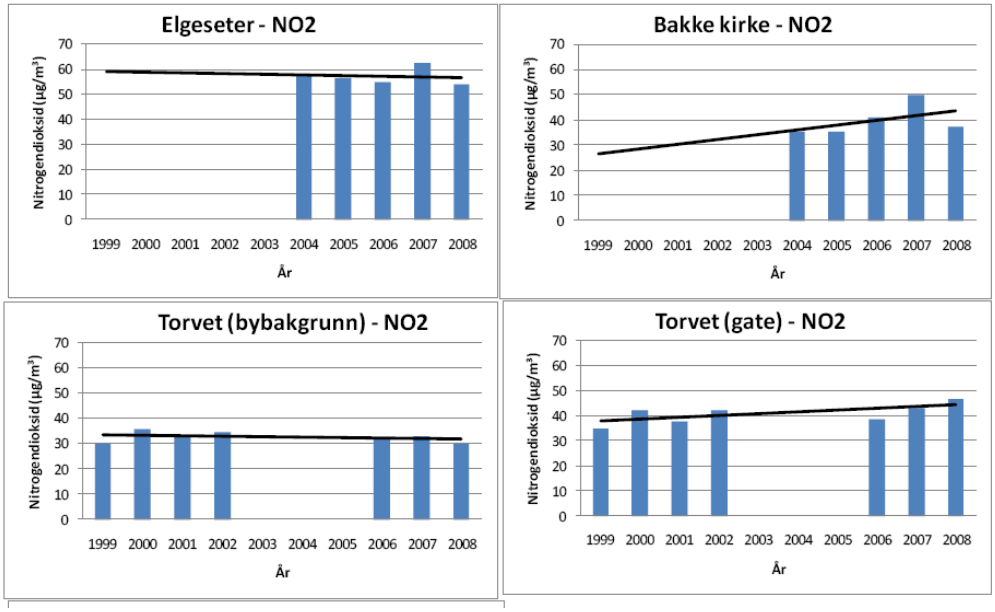

Figure 9: Yearly averages of NO_2 in Trondheim (Environmental unit, Trondheim).

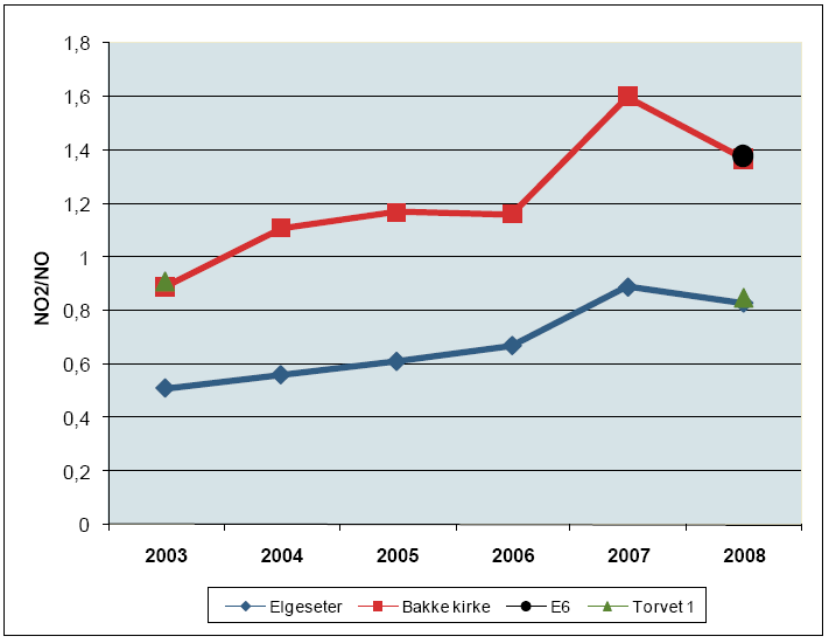

Figure 10: Ratios between NO_2 and NO in Trondheim (Environmental unit, Trondheim).

4.3 Benzene

The only VOC components that are routinely monitored in Oslo and Trondheim are benzene, toluene and xylene. Results are shown in Figure 11 for benzene. The trends in the two cities are quite different. The variations in Trondheim are on the order to be expected with a near constant emission, reflecting variations in dispersion conditions. In Oslo there seems to be a trend of reduction up to 2008, and a sharp increase from 2008 to 2009. With only one data point, it is too early to tell if it is emission changes or other effects that cause this increase. The operator of the network did change from 2008 to 2009. All the monitored concentration values are below the Air Quality limit though. VOC contain several components where air concentrations could be affected by introduction of bio fuels. To be able to detect any change in air concentration levels, the VOC monitoring program should be extended by more components.

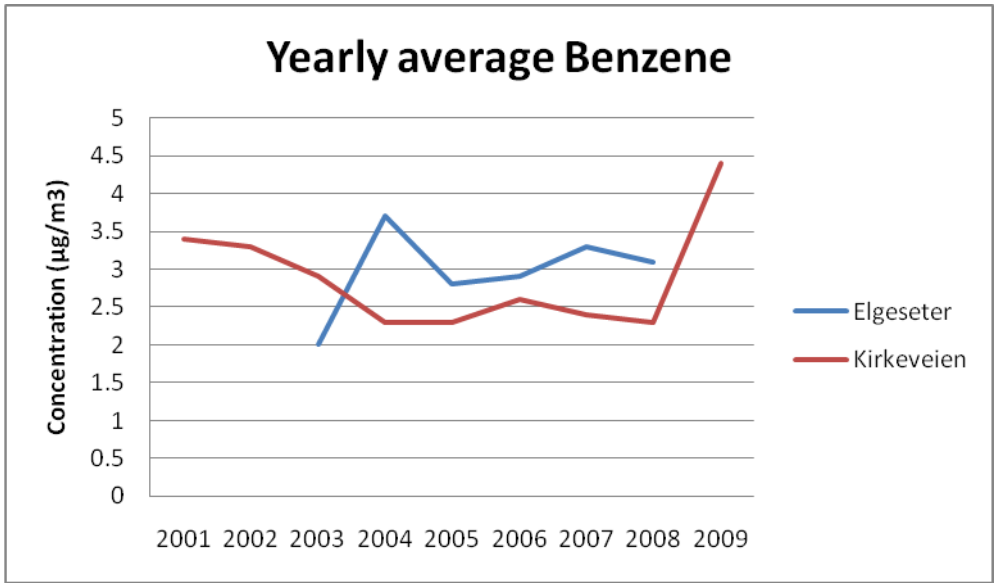

Figure 11: Yearly average concentrations of benzene in Oslo and Trondheim.

4.4 Sulphur doixide

The pollution level of sulphur dioxide during the period considered here has been low and nearly constant. The measured average winter concentration in the center of Oslo has been 4 µg/m^3 every year, except 2003/04 when the value was 5 µg/m^3.

5 Trends from Air Quality modeling

Air Quality modeling can be (and have been) used for many purposes.

In **diagnostic modeling**, the model is used together with monitoring data to fill in gaps in time and primarily in space from the monitoring network. The resulting model concentration fields are then often used to calculate population exposure within the model domain, and to quantify the impact of different sources to the total concentration load.

In **scenario modeling**, the model is used to estimate the effect of changes in emissions on concentration and often also population exposure. This type of modeling is also used in studies of future **projections** of ambient air quality and population exposure.

The primary goal of **source apportionment modeling** is to determine the specific contribution of various pollution sources to a particular measurement site.

Another application of modeling is **short term pollution forecasting**. Results from this type of modeling will not be used here.

In Table 2 below the different model results that has been considered in this analysis is listed.

Table 2: Model exercises assessed for use in this analysis.

Report No (OR:)	Title	Area(s)	Year used	Type of results *
06/2003	Historical dispersion calculations for Oslo 1995/96, 1998 and 2001	Oslo	2001	C,E,S
46/2004	Calculation of 3-year average concentrations in administrative regions in Oslo for the period 1992-2002	Oslo	1998-2001	C
06/2005	Calculations of PM_{10} and $PM_{2.5}$ for Oslo in 2010 and 2015	Oslo	2003, 2010,2015	C,E
10/2005	Dispersion and exposure calculation of PM_{10}, NO_2 and benzene for Oslo, Trondheim and Bergen for 2003	Oslo and Trondheim	2003	C,E,S
41/2005	Environmental speed limit in Oslo. Effects on air quality of reduced speed limit on rv4	Oslo	2004	S
28/2006	Concentrations of $PM_{2.5}$ from wood burning	Oslo	2003-04	C,S
82/2006	Evaluation of abatement measures for PM10 in Oslo and Trondheim for the year 2010	Oslo and Trondheim	2010	C,E
90/2006	Dispersion and exposure calculation of PM_{10}, NO_2 and Benzene for Oslo and Trondheim for the year 2005	Oslo and Trondheim	2005	C,E,S
35/2007	Dispersion calculations - Alnabru	Part Oslo	2006-07	C,S
56/2007	Baseline dispersion and exposure calculations of PM_{10} and NO_2 for 2010,2015 and 2020 for Oslo	Oslo	2010,2015	C,E
59/2008	Scenario dispersion and exposure calculations of NO_2 for 2010,2015 and 2020 for Oslo	Oslo	2010,2015	C,E
09/2009	Dispersion and exposure calculation of PM_{10}, NO_2 and Benzene for Oslo and Trondheim for 2007	Oslo and Trondheim	2007	C,E,S

*: C: Concentration values, E: Exposure values, S: Source group impact

Generally, the concentration values in the reports are presented as maps, showing concentration intervals in the model area by color coding. For the diagnostic model applications, some key concentration values are listed in connection with model validation. The population exposure (to air pollution) is described by number of people exposed to pollution levels above limit values (or in some cases target values), and as the population weighted concentration level for persons exposed to concentration values above the limits. The source group impact is, in most cases, only calculated for the selected time periods (hours for NO_2, days for PM_{10}) where the total concentration is above the limit values. In order to show the model results in a compressed form for several years at once, the following key figures have been extracted:

- The number of square kilometers with exceedance of the limit values
- Mean concentration model values from the validation against measurements
- The total number of people exposed to values above the limit values

- The population weighted concentration for exceedance
- The average source group contribution for exceedance on square kilometer scale
- The maximum contribution from any of the main source groups to exceedance anywhere in the model domain (along with the other groups contribution in that place)
- Source contributions reported from the model runs are given for the source groups of road traffic, domestic heating by wood, regional pollution (the level of the considered pollutant imported into the model grid with the inflowing air), and a lump category of "other" sources.

The data extracted from the different model runs are shown in Table 3 to Table 6 below. All population exposure calculations have been done with respect to the National Target values for hourly NO_2 concentrations (not more than 8 hours above 150 µg/m^3 pr year) and daily PM_{10} concentrations (not more than 7 days above 50 µg/m^3 pr year).

Table 3: Model results for NO_2 in Oslo.

Year:		2001	2003	2005	2007	2010	2015
Squares		4	2	0	0	23	24
Model average	µg/m^3	44.5	37.2	32.5	35.4		
Ppl. Exp.		13566	6893	652	4193	146257	150032
Weighted concentr.		166		171.3		167.7	169.2
average source	road	86.9	84.9	96.59	93.52		
(%)	wood	0.2	0.1	0.05	0.06		
	regional	0.1	0.11	0.15	0.18		
extreme source	road	98.64	98.76	99.27	98.76		
(%)	wood	0.36	0.1	0.09	0.21		
	regional	0.21	0.34	0.23	0.35		

Table 4: Model results for PM_{10} in Oslo.

Year:		2001	2003	2005	2007	2010	2015
Squares		42	61	46	33	6	4
Model average	µg/m^3	21.94	26.9	25.9	18.4		
Ppl. Exp.		220783	239595	235849	187744	54056	41349
Weighted concentr.		63		69.6		56	57.9
average source	road	21.3	62.1	66.7	62.29		
(%)	wood	69.9	23.4	21.8	29.71		
	regional	5.2	11.5	8.5	3.9		
extreme source	road	63.63	84.52	85.16	91.68		
(%)	wood	85.96	49.63	44.13	52.93		
	regional	9.02	23.68	15.39	8.04		

Table 5: Model results for NO_2 in Trondheim.

Year:		2001	2003	2005	2007	2010	2015
Squares			0	0	0		
Model average	µg/m^3		44.6	37.6			
Ppl. Exp.			708	40	85		
Weighted concentr.							
average source	road		96.4	97.13	98.88		
(%)	wood		0.04	0.36	0.02		
	regional		0.23	0.08	0.32		
extreme source	road		98.65	97.13	98.88		
(%)	wood		0.12	0.36	0.02		
	regional		0.35	0.08	0.32		

Table 6: Model results for PM_{10} in Trondheim.

Year:		2001	2003	2005	2007	2010	2015
Squares			3	8	0	4	
Model average	µg/m^3		34.1	41.4	27.3		
Ppl. Exp.			8065	20914	4994	8555	
Weighted concentr.							
average source	road		70.02	59.2	83.5		
(%)	wood		18.03	27	10.1		
	regional		11.71	13.2	5.95		
extreme source	road		84.02	93.06	94.43		
(%)	wood		49.74	56.11	33.24		
	regional		20.98	16.97	9.86		

For these "time series" , or rather, the values extracted for any year that data is found, a comparison of all of them has been made by relating the values to the earliest data point and normalize them against that value. The model source contributions to exceedance are relative values (percentages) and are shown separately. The trend results are shown in figures Figure 12 to Figure 15. The source contributions are shown in Figure 16 and Figure 17.

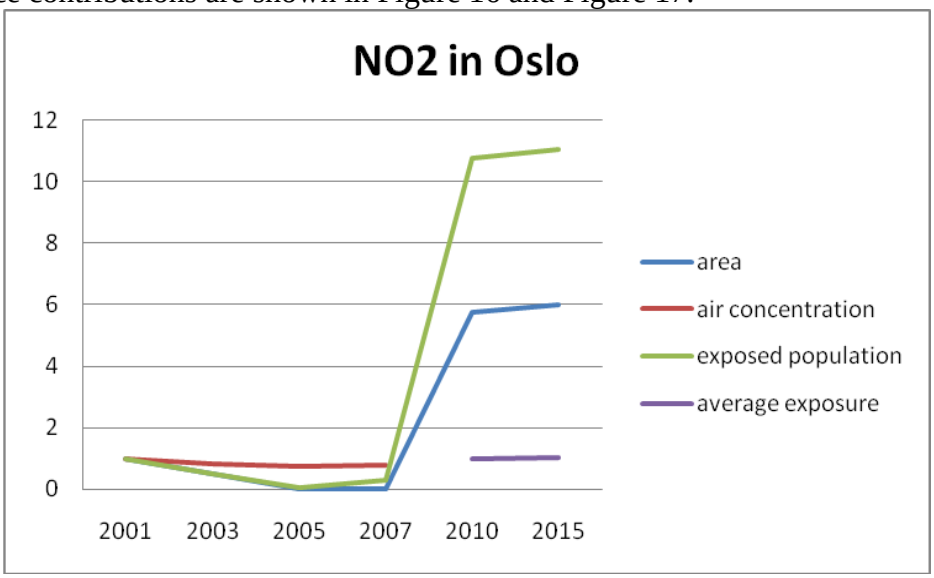

Figure 12: Parameters for NO2 in Oslo normalized to 2001.

The rather drastic change in exposure to NO_2 in this figure is based on results from a scenario projection taking into account increased oxidation of the NO_X emissions observed in air quality monitoring. The applied vehicle fleet composition in this modelling exercise also maintained a larger fraction of older types of heavy duty diesel vehicles than in previous model work. These assumptions led to a very modest increase of the NO_X emissions but a doubling of the NO_2 emissions. It should be noted that there is increasing evidence that the model results from 2003 to 2007 underestimated the NO_2 concentrations.

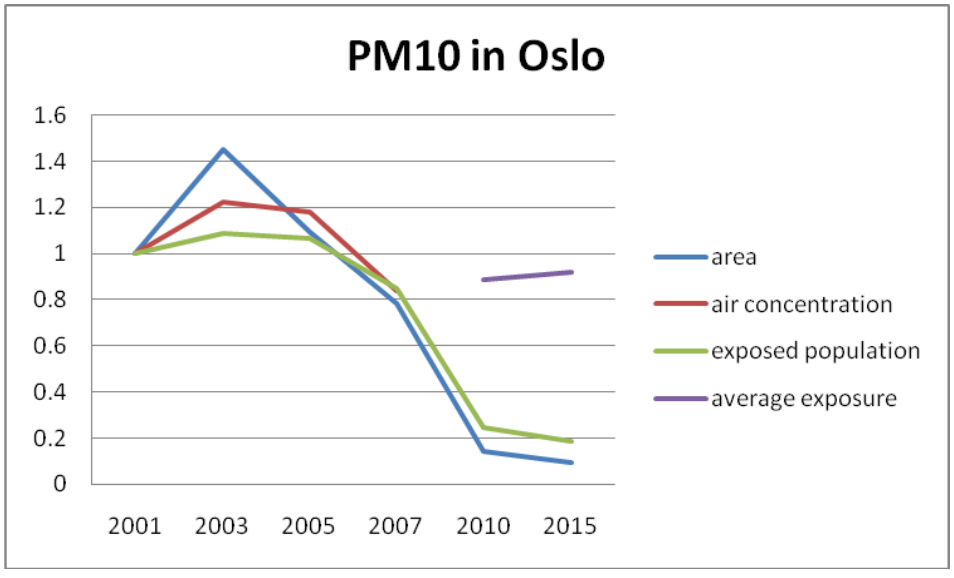

Figure 13: Parameters for PM_{10} in Oslo normalized to 2001.

The trends for PM_{10} modelling reflect the effects of the abatements made, and the expectation that further abatement will continue to reduce the problem with PM_{10} concentrations.

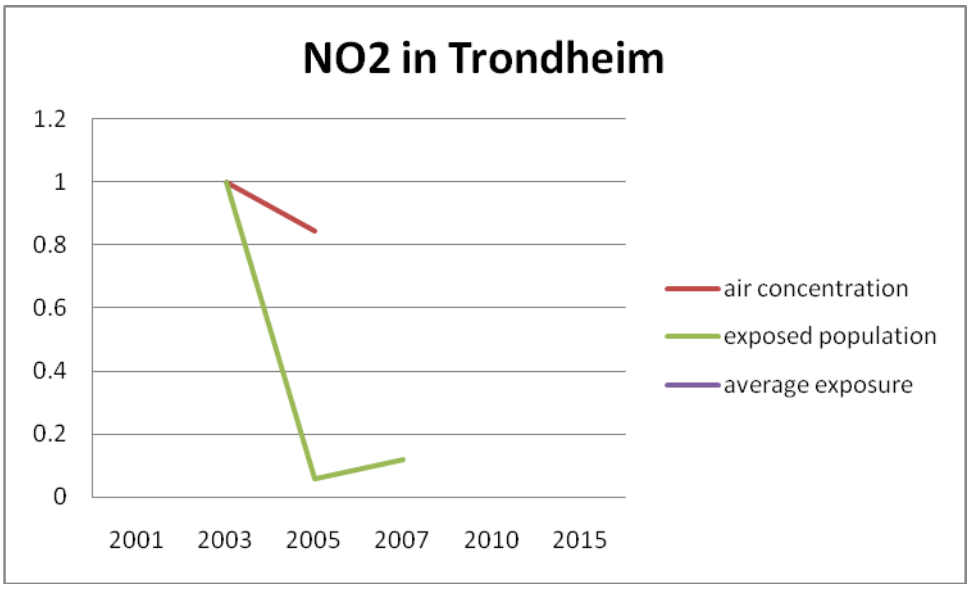

Figure 14: Parameters for NO_2 in Trondheim normalized to 2003.

For Trondheim, no corresponding scenario modelling as in Oslo has been made, and the difference between 2005 and 2007 is small.

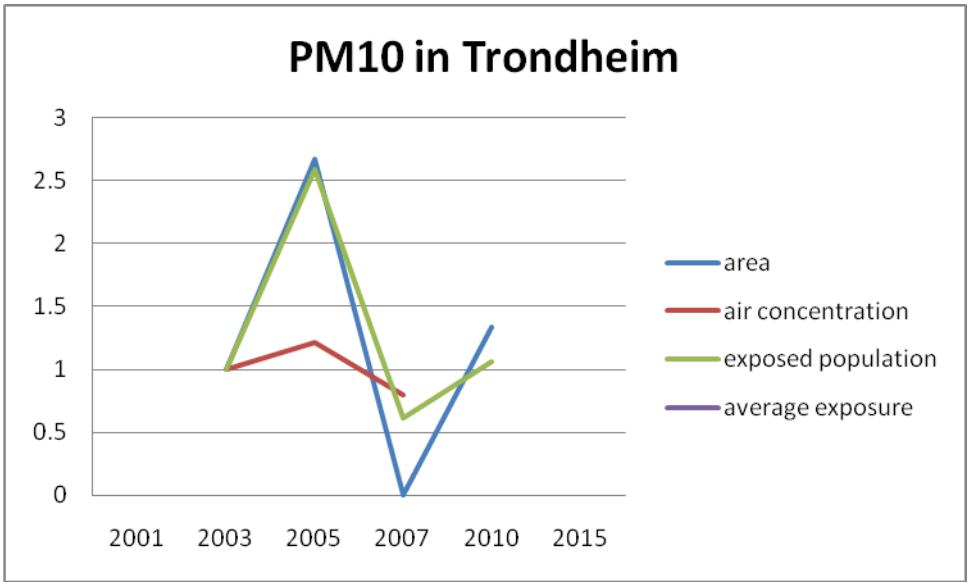

Figure 15: Parameters for PM_{10} in Trondheim normalized to 2003.

Variations in the model output for Trondheim reflect that small changes in modelled concentrations (red curve) can have large impact towards exposure (green and blue curves). The projection for 2010 were based on the model runs for 2005, and actually showed improvement in the exposure situation.

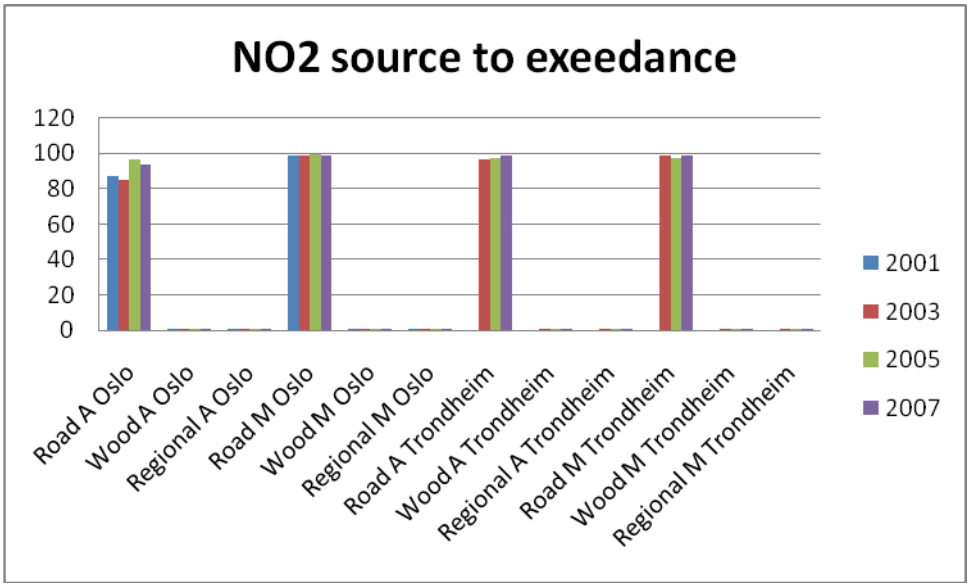

Figure 16: Source group contribution to exceedance of National targets for NO_2. A: Average source contribution, M: Maximum source contribution.

The model results point to roadside emissions as the totally dominating source group causing exceedances.

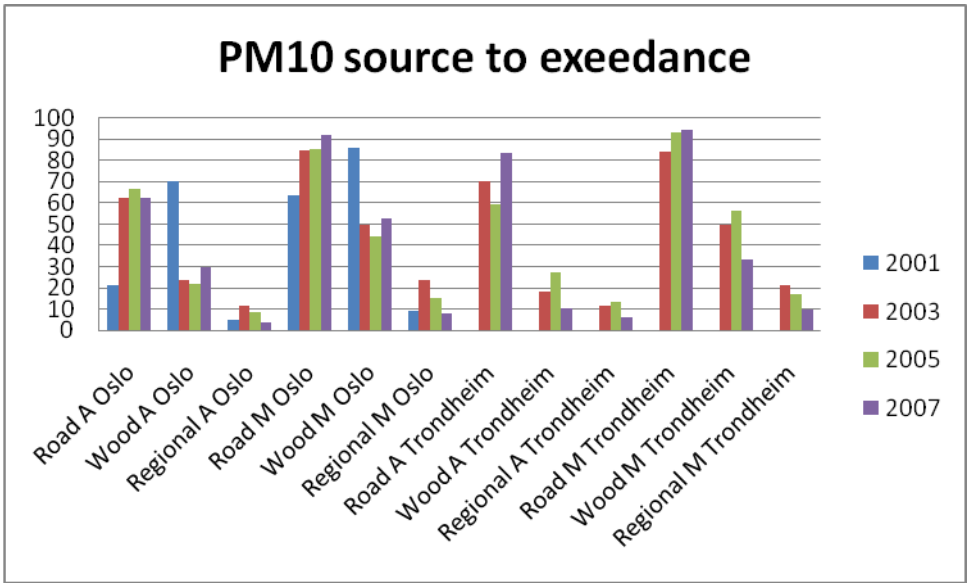

Figure 17: Source group contribution to exceedance of National targets for PM_{10}. A: Average source contribution, M: Maximum source contribution.

For pollution of PM_{10}, all the 3 listed source groups have some significance. The change in model source apportionment from 2001 to 2003 (and later) from wood combustion towards road traffic, as can be seen in Figure 17, reflects improvements in the emission model for resuspension of road dust.

The air quality limit value for $PM_{2.5}$ is given as a yearly average. Monitoring, supported by model calculations, show that there are no exceedances of the limit value. Due to this fact, no source group contributions for population exposure have been made. An indication for the size order and variety of source origin can be found from investigations made at Aker (National road 4) and Alna (NILU OR 41/2005, NILU OR 35/2007), results are shown in Table 7 and Table 8.

Table 7: Source apportionment by chemical characterisation and statistical modelling, $PM_{2.5}$ at a roadside location near National road 4.

Source description	Contribution to concentration (%)
Resuspended road dust	26.5
Exhaust particles, diesel	10.9
Exhaust particles, gasoline	23.4
Wood combustion	18.8
Regional background	20.4

Table 8: Area average winter season contribution to $PM_{2.5}$ at Alnabru, Oslo.

Source group	Contribution to concentration (%)
Road traffic	11.0
Point sources (stacks)	0.5
Area sources (including wood combustion and small stationary combustion sources)	47.5
Regional background	41.0

The differences in the tables reflect differences both in the space resolution and methodology, as well as real differences between pollution exposure at a roadside location and an area averaged pollution exposure. An interesting additional work would be to compare the observed and modelled trends, but this is beyond the scope of the present report.

6 Trend from emission modeling

The focus in this chapter is modelling of vehicular emissions. This type of modelling attempts to describe the vehicle fleet composition as it operates on the road net, the actual quantity of vehicles driving on a specific road, and the emission attributes of the different type of vehicles, as a function of the driving condition. As model input to a dispersion model, the required time resolution of the modelled emissions must correspond to the time resolution of the dispersion model. This implies the need for hourly emission data. There are very few in situ measurements to control or support this type of modelling effort.

The emission trends shown in this report focus on NO_X (and NO_2) and VOCs. Although particle emission from road traffic is not an insignificant source to air pollution, the sources of resuspended road dust and domestic heating are both more important. Emission trends of VOCs have been listed as a basis for evaluating bio fuel impact.

National trends in emissions have been compiled by National Bureau of Statistics The national emissions of NO_X are shown in Figure 18. The emission axis in this figure has a logarithmic scale.

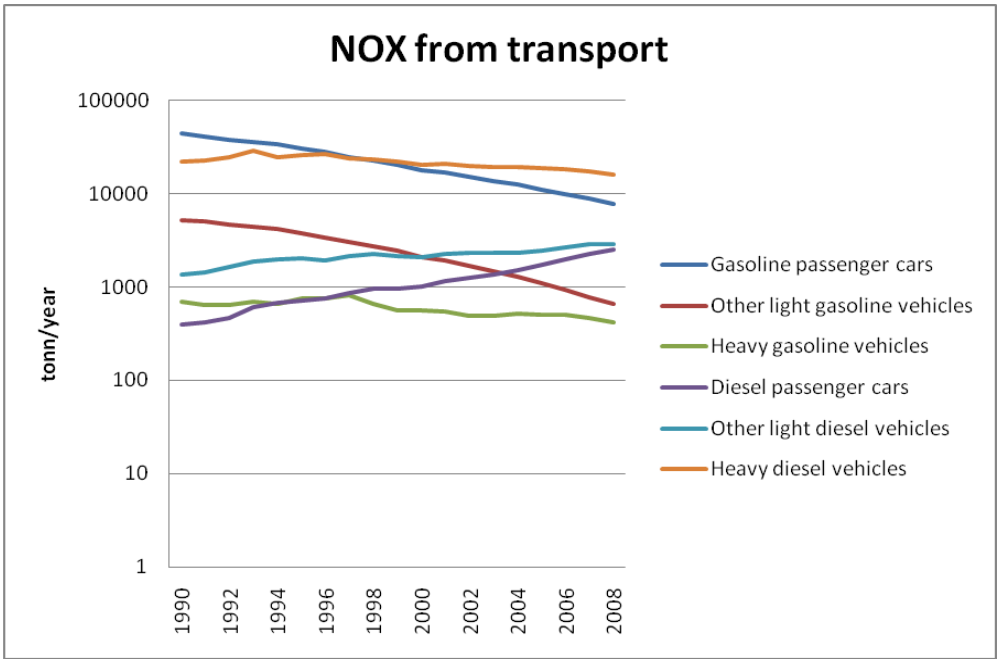

Figure 18: National emissions of NO_X from road transport by type of motor vehicle (SSB).

The two main emission groups (gasoline passenger cars and heavy diesel vehicles) show a reduction of emissions. Diesel passenger cars and other light diesel vehicles show an increase of emissions. The shift in sales of new cars from gasoline towards diesel is an embedded effect in the curves shown. In the Ecotraffic report (Erikson and Yagci, 2009), measurement results for NO_2 oxidation in emissions have been collected. These results are shown in Figure 19.

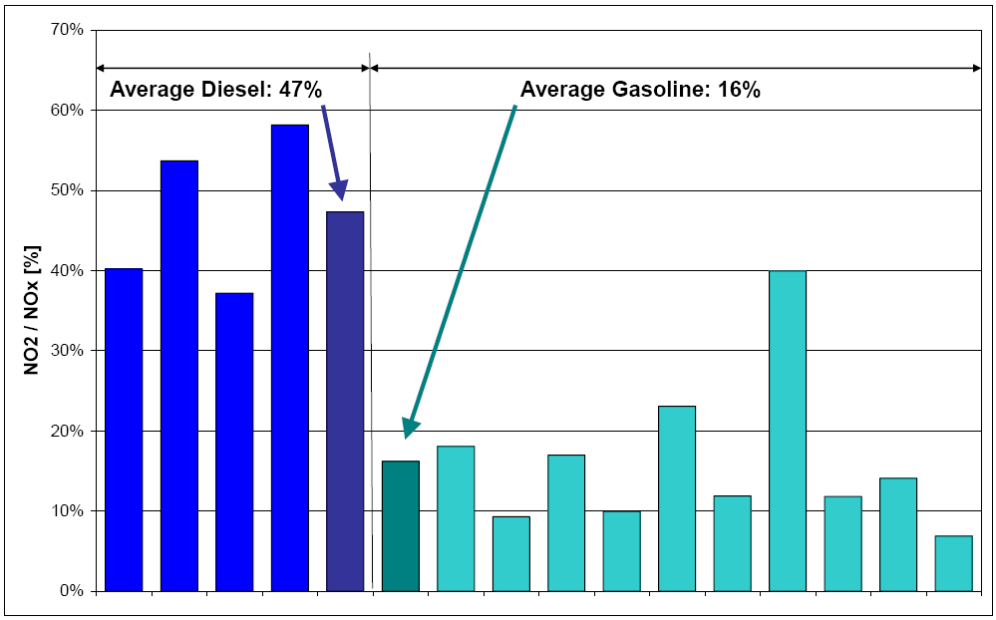

Figure 19: NO_2/NO_X ratio, results from Swedish IUC tests in 2007. The graph represents tests of 79 individual cars. Each bar in the graph represents the average of all tested cars of the same car model.

These oxidation rates have been transferred to the NO_X trend curves from Figure 18 for the years 2000 to 2008 to compute an emission trend for NO_2 for three important groups of vehicles. The result is shown in Figure 20.

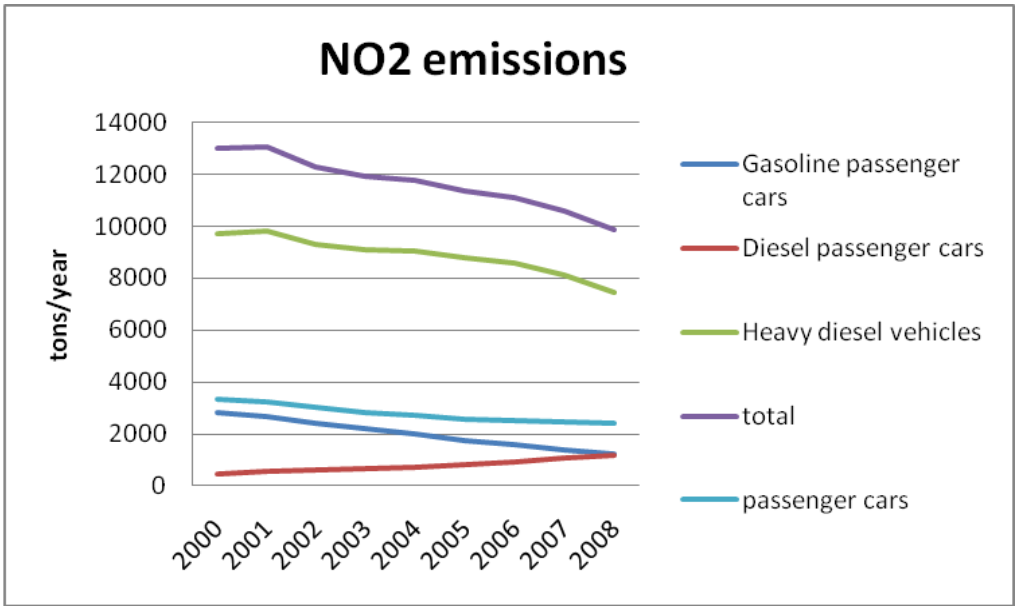

Figure 20: Trends in national NO_2 emission from 3 groups of vehicles, computed from NO_X trends.

The figure show that the total emissions of NO_2 from the passenger car fleet are levelling off. The figure indicates a reduction in total emissions. However, the few available measurements of oxidation rate for heavy vehicles indicate that the oxidation rate is increasing. The effect of this increase has not been built into the trend curves in Figure 20.

In Figure 21, national trends for VOC emissions (including road traffic) are shown. Emissions from road traffic are reduced by 50 % from 2000 to 2009.

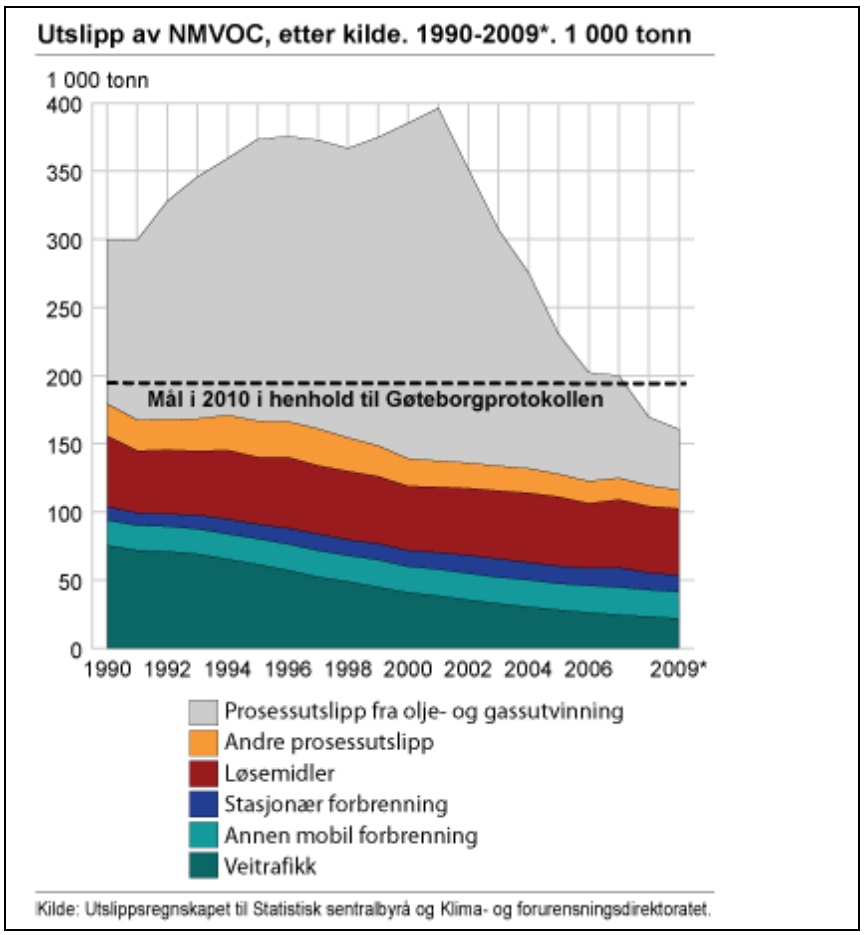

Figure 21: National emissions of VOCs from different source groups. The bottom (olive green) curve show emissions from road traffic.

The air pollution of sulphur dioxide has been significantly reduced in Norway over the later years. Trends in National emissions and emissions in Oslo are shown in Figure 22 and Figure 23. The emissions of SO_2 from road traffic have decreased drastically since the early 1990s.

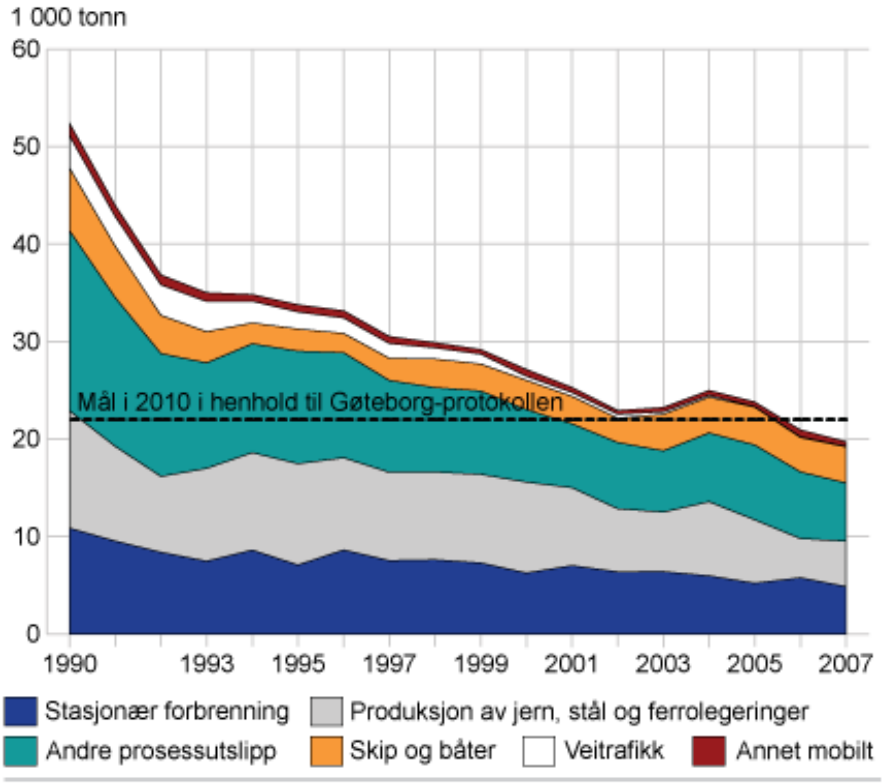

Figure 22: National trends in emissions of SO_2 from different source groups (Statistics Norway). The dotted line shows the 2010 target from the Gothenburg protocol. The source groups (in the same order as the key text) are: Stationary combustion, production of iron, steel and alloys, other process industry emissions, ships and boats, road traffic, and other mobile sources.

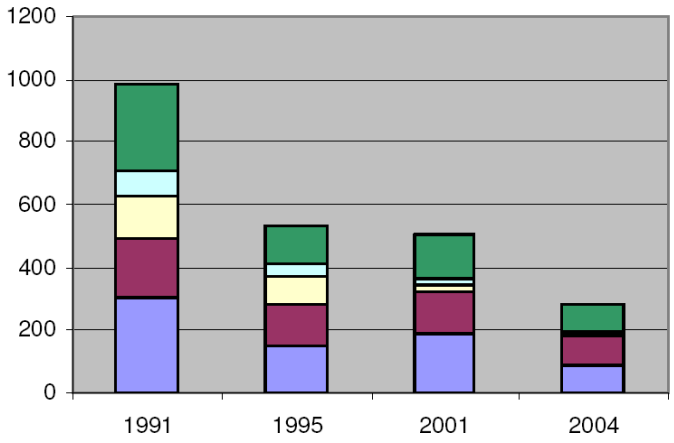

Figure 23: Yearly emissions of SO2 in Oslo (tons/year). Source groups (top to bottom): Other sources, gasoline vehicles, diesel vehicles, naval transport, heating.

7 Bio fuel impact

According to Ericson and Yagci, the addition of bio components have generally lead to a decrease in most emissions. However, biodiesel may cause a small increase in NO_X due to increased fuel oxygen, and ethanol in gasoline may lead to increased emissions of aldehydes. In Figure 24 (Erikson and Yagci, 2009), the effect on regulated emissions from bio fuel blending into diesel fuel is shown. All of the components except NO_X show decrease in emissions with increased blending of bio fuel. The increase in NO_X emissions is at most 10 % (with 100 % blending). As can be seen from the trends from monitoring and modelling, however, the concentrations of NO_2 in air could be a revived problem, due to changes in the composition of the NO_X emissions. Regarding the VOC emissions, the Ecotraffic report indicate the possibility of an increase in oxygenated compounds such as aldehydes and ketones when blending ethanol into gasoline. These components would be precursors for ozone formation. It must be added that for the urban atmosphere in Norway, ozone is hardly any problem, and the contribution to total ozone from domestic emissions in Norway is lower than the transboundary transport.

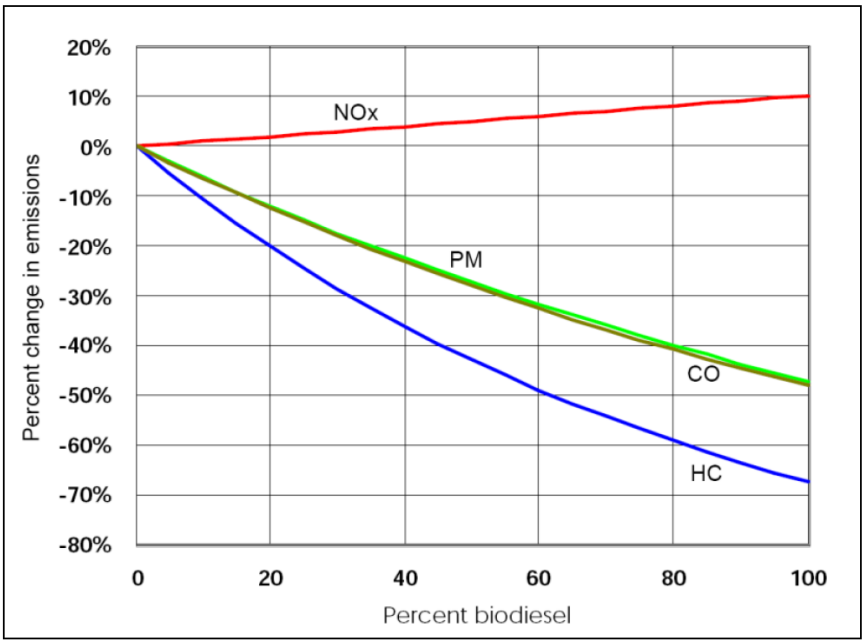

Figure 24: Regulated emissions as a function of biodiesel content in the fuel. (Erikson and Yagci, 2009).

8 Conclusions

During the past years the exhaust emissions from new gasoline and diesel vehicles have been reduced to very low levels due to improved engine technology, exhaust after treatment devices, and improved fuel quality.

The addition of bio components in the fuel have generally shown further decrease in most emissions. However, biodiesel may cause a small increase in NO_X due to increased fuel oxygen, and ethanol in gasoline may lead to increased emissions of

aldehydes. As the use of bio fuels is expanded, there is a need to expand the number of components in the monitoring programs to get sufficient data for modelling of atmospheric chemistry both for gases and aerosols.

There are three major sources to air pollution of particulate matter in Norwegian cities: 1) stationary combustion, primarily from domestic wood burning, 2) road dust due to the use of studded tires and vehicle resuspension, and 3) long-range transport. There are differences in source contribution of particle pollution when considering yearly average values and high level short term concentrations. This is caused by both seasonal emission variations and the strong variation within season of the two important source groups of wood combustion and road traffic.

Diesel vehicles are still the most important contributor to NO_X. Biodiesel may cause a small increase in NO_X due to increased fuel oxygen, and ethanol in gasoline may lead to increased emissions of aldehydes and possibly other VOC components.

Bio fuels only contribute to a few per cent of today's fuel consumption and air quality modelling and measurements have not yet been able to track changes in air pollution that can be attributed to bio fuels. The reduced contribution from vehicle exhaust to air pollution makes changes due to small amounts of bio fuels even more difficult to detect. Extended mapping of VOC in roadside environments is needed before a more widespread use of bio fuels in order to quantify their impact on VOC concentrations in air.

The recent gains in NO_X emission reduction from vehicles have been accompanied by an increased fraction of NO_2 in the NO_X emission, and the trend towards increased use of diesel passenger cars contribute to a higher fraction of NO_2 in NO_X emissions. This effect, coupled with increased traffic volume, has led to a stagnation in the decrease of urban NO_2 levels.

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REPORT PREPARED FOR
Statoil
0246 OSLO

ABSTRACT
The expected changes in emission profiles for vehicular traffic has been investigated by Ecotraffic on behalf of Statoil. This report gives a trend analysis of monitoring and model results for air quality in Oslo and Trondheim. The period covered is 2000 to 2015, the last third of the period is covered only by modelling. The impact of introduction of bio fuel have been reflected upon, based on the changes in emission profiles given by Ecotraffic. For particulate matter, the introduction of bio fuels will likely contribute to a continuous reduction of ambient air concentrations. For NO_X and NO_2, introduction of bio fuel will have an adverse effect, and the urban air pollution level of NO_2 is no longer decreasing.

NORWEGIAN TITLE
Luftkvalitetstrend i byer 2000-2015. Resultater fra målinger og modellering i Oslo og Trondheim

KEYWORDS		
Monitoring	Modelling	Emissions

ABSTRACT (in Norwegian) Ecotraffic har på oppdrag fra Statoil undersøkt forventede endringer i utslipp fra vegtrafikk ved overgang til biodrivstoff. Denne rapporten oppsummerer trender fra måle- og modellresultater for luftkvalitet i Trondheim og Oslo fra 2000 til 2015, den siste tredjedelen av perioden bare med modellresultater. Noen mulige effekter ved introduksjon av biodrivstoff er undersøkt. For konsentrasjon av partikler vil introduksjon av biodrivstoff bidra til en reduksjon av nivået. For NOX og NO2 vil imidlertid biodrivstoff kunne ha en ugunstig effekt og føre til økt konsentrasjonsnivå.

** Classification*
A Unclassified (can be ordered from NILU)
B Restricted distribution
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