SLB·analys

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The effects of the congestion tax on emissions and air quality

EVALUATION UNTIL, AND INCLUDING, THE YEAR 2008

STOCKHOLMS STAD
MILJÖFÖRVALTNINGEN

STOCKHOLMS OCH UPPSALA LÄNS LUFTVÅRDSFÖRBUND

Foreword

This report has been carried out by SLB-analys at the Stockholm Environment and Health Administration. SLB-analys operates the systems of the Stockholm-Uppsala Air Quality Management Association regarding the monitoring and evaluation of air quality in the region. The office of Traffic Administration of the City of Stockholm commissioned the report.

The permanent congestion tax was implemented in August, 2007. The follow-up work regarding the evaluation of its effects was led by the Traffic Administration office of Stockholm City. This report covers effects on the environment concerning air pollution. The report presents results of measurements during the years 2005-2008, and emissions from 2006 to 2008.

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1 Summary

The introduction of the congestion tax has affected road traffic emissions of air pollutants in the Stockholm region. This report documents how emissions and concentrations of air pollutants have changed since the trial implementation of the congestion tax. The evaluation is based on data from the congestion tax control points, the national road traffic registry and fuel sales, as well as on calculations of vehicle mileage (vehicle kilometres travelled). The control points, the national road traffic registry and fuel sales provide complementary data regarding the vehicle mix and the emissions from different kinds of vehicles, including so-called alternative fuel vehicles. With the help of vehicle mileage figures for the different types of vehicles, the total amount of emissions can be calculated. Their effects on air quality are analysed based on continuous monitoring of nitrogen oxides, carbon monoxide and particulate matter (PM10) concentrations from a range of locations in Stockholm. Concentrations of air pollutants are compared from periods with and without congestion tax during 2005 to 2008.

1.1 Changes in traffic volume – more alternative fuel vehicles

The effect of the congestion tax on vehicle mileage in the inner city of Stockholm was considerably lower when the tax was made permanent, compared to during the trial. This is explained by the residual effects of the Stockholm Trial, in that traffic did not return to the levels observed in 2005, i.e. before the trial. Inner city traffic, however, has continued to decline, while figures for the city as a whole show a weakening of the trial's effects, with traffic increasing since autumn 2006. One of the reasons for this is that the number of exempt vehicles is higher. According to traffic flow figures from the congestion tax control points, the proportion of alternative fuel vehicles was 3% in 2006 (trial) and 12% in 2008. The proportion of private alternative fuel cars registered in the city of Stockholm increased from about 5% at the end of 2006 to around 14% at the end of 2008. For buses, the proportion increased from 6% to 38%.

For total vehicle mileage in the city of Stockholm, the percentage made up by alternative fuel vehicles increased from around 4% in 2006 to around 10% in 2008 (most are ethanol-fuelled cars). During the same period, petrol-fuelled vehicles have decreased from 77% to 63%. Diesel-fuelled vehicles, however, have increased in numbers (both private cars and goods vehicles). In 2006, these made up roughly 16% of the city's vehicle mileage, and increased to 23% by 2008. The proportion of heavy duty vehicles (buses and heavy goods vehicles) remained unchanged 2006-2008. Among heavy goods vehicles, alternative fuel vehicles only make up a few percent.

The changes in the vehicle fleet are supported by statistics for fuel deliveries to the county of Stockholm. Between the years 2006 and 2008, petrol deliveries decreased by around 7%. The volume of diesel and ethanol increased by roughly 18% and 48%, respectively.

1.2 Changes in emissions

For the inner city of Stockholm, emissions of hydrocarbons and carbon monoxide decreased by about one third between 2006 and 2008. This is due to ethanol- and diesel-fuelled vehicles emitting less of these substances compared to petrol-fuelled vehicles. For particulate matter (PM10) released via exhaust fumes and road wear, the reduction is around 6% and around 2%, respectively. As for emissions of exhaust particles, the increase in diesel-fuelled vehicles has counter-balanced the larger decrease that would otherwise have been achieved. For road wear particles, these emissions are mainly a result of the use of studded tyres and not an effect of changes in the vehicle fleet (usage of studded tyres has been virtually unchanged during the period 2005-2008). In total, the concentration of particulate matter (PM10) has been reduced by roughly 3% in the inner city between 2006 and 2008. Emissions of nitrogen oxides are calculated to have decreased by around 13% for the same period (here again, the increase in diesel-fuelled vehicles has held back the decrease in emissions). Emissions of carbon dioxide from fossil fuel (petrol, diesel and natural gas) in the inner city are calculated to have decreased by around 8% since 2006.

For the whole of Stockholm city, the reduction in road traffic emissions of air pollutants is smaller, since traffic has increased by a few percent since 2006. Also for the city as a whole, changes in the car fleet have led to the largest emissions reduction for hydrocarbons and carbon monoxide, while emissions of nitrogen oxides are calculated to have decreased by around 8% between 2006 and 2008. Emissions of carbon dioxide from fossil fuel in the city have decreased by about 4% since 2006.

1.3 Effects on air quality

Analysis of the monitoring data regarding air pollutants for weekdays, daytime during congestion tax hours, shows that concentrations in the inner city of Stockholm were lower during periods with tax compared to periods without tax. The analysis encompasses nitrogen oxides (NO_x), particulate matter (PM10) and carbon monoxide (CO) during 2005-2008, i.e. two years with congestion tax (including the Stockholm Trial) and two years without tax. For NO_x, concentrations were almost 10% lower, while CO concentrations were around 15% lower during periods with tax along the inner city streets of Hornsgatan, Sveavägen and Norrlandsgatan. Regarding PM10, concentrations are 15 to 20% lower with tax. Along the tax-exempt Essingeleden, NO_x concentrations are higher during times with congestion tax than without, during the same period (daytime, weekdays), but the difference is slight; around 3% higher. Increased emissions due to increased traffic volumes have thereby been compensated for, by the fact that each vehicle, on average, releases a smaller amount of NO_x.

In the case of particulate matter, PM10, concentrations are the same both with and without tax. PM10 concentrations have not been affected by the cleaner vehicle fleet in the way that NO_x concentrations have, since particulate matter primarily results from road surface wear due to studded tyres. Even if the proportion of studded tyres does not seem to have changed during the period 2005-2008, PM10 concentrations appear to have decreased somewhat. This decrease results in the concentrations ending up slightly lower during periods with tax, since they fall towards the end of the observed period. PM10 concentrations also depend to a high degree on meteorological conditions, which affect the moistness of the road surface and decides how fast it dries up during spring in different years. During the trial of spring 2006, for example, PM10 concentrations were significantly lower than normal, due to unusually heavy snowfall during the late winter and spring, rather than decreased traffic caused by the congestion tax.

1.4 The importance of the congestion tax

The altered vehicle fleet and emissions situation in Stockholm with, among other things, more alternative fuel vehicles, is of course not exclusively an effect of the introduction of the congestion tax. However, surveys show that exemption from congestion tax has been the single most important incentive to getting Stockholmers to buy more alternative fuel vehicles (BEST, 2009). The environmental gains, which during the trial of 2006 consisted primarily of less traffic volume, have thereby been replaced by gains due to the altered and cleaner vehicle fleet.

The composition of the vehicle fleet has changed faster in Stockholm than in the country as a whole. Emissions in the city and the inner city are considerably lower with the current vehicle mix compared to the one nationwide in Sweden. The largest differences are to be found regarding emissions of carbon dioxide from fossil fuel, carbon monoxide and hydrocarbons.

Even though it is not possible to calculate exactly to what extent the environmental improvements are a result of the congestion tax, two important contributing factors are that i) emissions have declined faster than what they would have otherwise, due to more alternative fuel vehicles, and ii) traffic volumes have been somewhat lower during periods with congestion tax.

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3 Introduction

The trial phase of the congestion tax was carried out during the first seven months of 2006. Its effects on the environment and on air pollution were evaluated by SLB-analys and showed relatively large reductions in emissions (SLB-rapport 2:2006). In the inner city of Stockholm, emissions of air pollutants from road traffic decreased by 8-14%. The corresponding figure for the entire city of Stockholm was 3-5%.

The reductions in emissions are estimated to have contributed to a reduced exposure to air pollutants, and substantial improvements in the health of Stockholmers, in the shape of fewer premature deaths and reduced infirmity caused by traffic emissions (SLB-rapport, 2006; Johansson, et al, 2009). There has only been one earlier study where health effects of a traffic adjustment have been quantified. This earlier study quantifies the effects of the congestion taxes in London, and shows very similar results.

The permanent congestion tax was implemented in August 2007. The system has the same geographical limitations and tax levels as during the trial. Congestion tax is charged for travelling into and out of the inner city of Stockholm between 6.30 am and 6.30 pm. The fee varies with different time intervals between 10 kronor and 20 kronor, with a maximum charge of 60 kronor per day per vehicle. Evenings, nights, Saturdays, public holidays and days before public holidays are free of charge, and certain types of vehicles are exempt. The congestion tax does not apply to traffic on Essingeleden, nor for journeys to and from Lidingö island which pass through the inner city within a window of 30 minutes. Parts of the expansion of public transport that was a part of the Stockholm Trial have also been made permanent. The main remaining differences are:

- The congestion tax is deductible for business and work-related journeys
- The congestion tax is invoiced monthly
- The exemption for alternative fuel vehicles is discontinued on 1 January 2012
- Alternative fuel vehicles registered after 1 January 2009 are not exempt
- The exemption for taxis and transport for the disabled is discontinued
- The month of July is free of congestion tax

This report describes developments before, during and after the congestion tax trial implementation of 2006. The goal of this report is to present how emissions and concentrations of air pollutants in the air of Stockholm have changed and what effect the congestion tax has had.

4 The development of the vehicle fleet

This chapter presents a summary of how traffic in Stockholm has developed during 2006-2008 regarding the composition of the vehicle fleet. The data have been collected from the congestion tax control points, fuel sales and the national road traffic registry. Data from the control points span periods when the congestion tax has been levied, i.e. during the trial (first seven months of 2006) and after the permanent implementation in August 2007. The data encompasses traffic on weekdays between 6 am and 7 pm.

4.1 Vehicle passages at control points

Table 1 shows the number of vehicle passages from the control stations (18 in total), which are placed at the approach roads to Stockholm's inner city. The data includes private cars, goods vehicles (both light and heavy) and buses. The group "Miscellaneous vehicles" includes motorcycles, utility vehicles, tractors, etc. They make up a very small part of vehicle passages and total traffic in Stockholm. Data are available for alternative fuel vehicles ("fuel exemptions"), but since this group consists of vehicles using different types of fuel, and thus have different emissions, these data points have not been used for estimations of emissions. Data for the year 2006 cover the period of the congestion tax trial. Statistics for 2007 and 2008 cover the permanent congestion tax.

Data from the control stations show minor differences between the years regarding the proportion of individual cars, goods vehicles and buses. Private cars make up about 78% of all vehicle passages, and buses make up roughly 2%. Among goods vehicles, around 80% are light (total weight of less than 3.5 tons). These account for the increase in goods vehicle numbers of around two percent from 2006 to 2008. The heavy duty vehicles, which apart from heavy goods vehicles also includes buses, has remained unchanged, at around 5%, between 2006 and 2008. The changes are relatively minor except when it comes to the proportion of alternative fuel vehicles, which was 3% during the 2006 trial and around 12% in 2008. It is also uncertain how representative it is to compare different periods for different years.

Table 1: Number of vehicle passages per weekday (6 am-7 pm) at control stations approaching the inner city of Stockholm, for the years 2006-2008.

Vehicle category	**2006** (Jan-July)		**2007** (Aug-Dec)		**2008** (Jan-Dec)	
Private cars	259,333	77%	278,186	78%	283,155	78%
Goods vehicles	53,526	16%	61,469	17%	64,135	18%
Buses	7,179	2.1%	7,108	2.0%	6,850	1.9%
Miscellaneous vehicles [1)]	516	0.2%	590	0.2%	528	0.1%
Not allocated	14,085	4.2%	9,108	2.6%	8,364	2.3%
Sum of passages	334,639	100%	356,461	100%	363,033	100%
... of which are alternative fuel vehicles [2)]	11,374	3.4%	30,244	8.5%	42,203	12%

1) *Motorcycles, utility vehicles, trailers, snowmobiles, cross-country vehicles, tractors*

2) *Vehicles which according to the national road traffic registry are equipped with technology for propulsion in full or in part by biogas, E85, ethanol, electricity, producer gas, methane, methanol, natural gas or hydrogen gas. (The exemption is valid until July, 2012)*

Figure 1 shows the development of the number of vehicle passages at entry and exit points to the inner city of Stockholm during weekdays between 6 am and 7 pm. Data for 2005 (before the congestion tax trial implementation) encompasses measurements during April and October, as well as estimates for the remaining months. The comparison shows that the total number of vehicle passages decreased during the trial by roughly 100,000 vehicles/day (about 23%). The number of passages per 24-hour period has thereafter increased and was, during 2008, about 28,000 more. The number of alternative fuel vehicles ("fuel exemptions") simultaneously increased by roughly 31,000 vehicles.

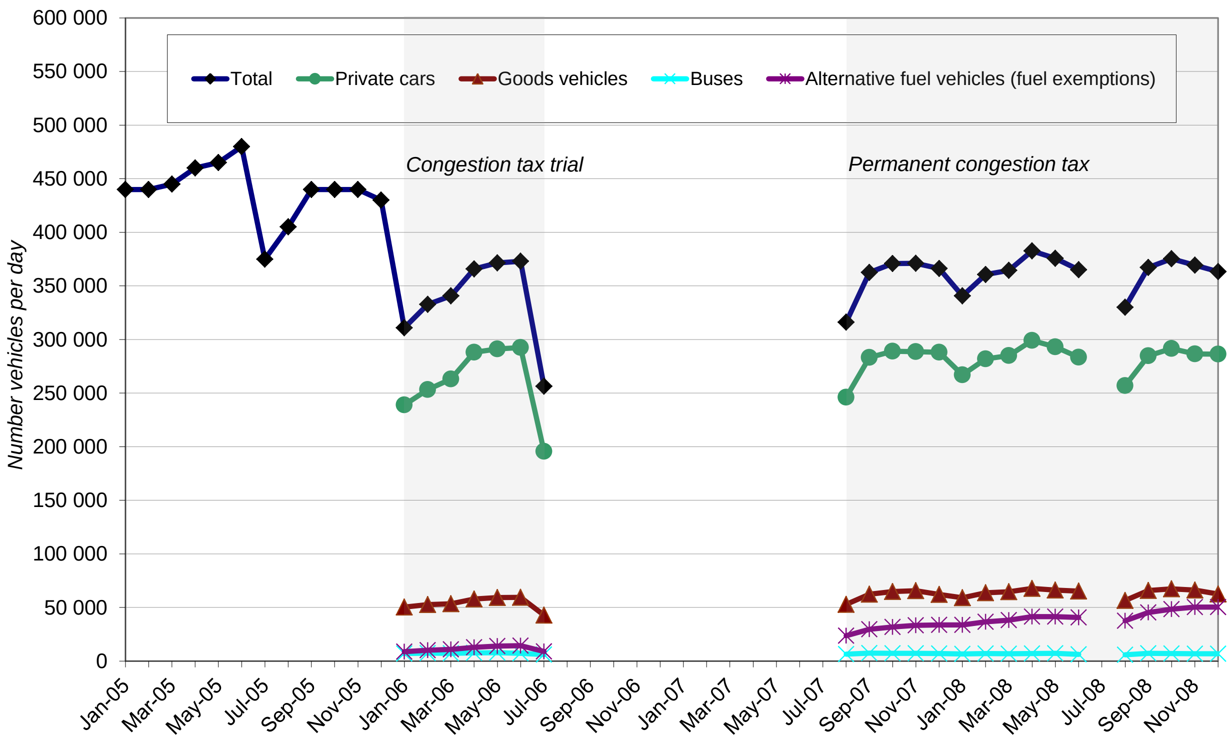


Figure 1: Development of the number of vehicle passages at congestion tax control stations. Data for the year 2005 are from measurements during April and October (Traffic Administration Office, Stockholm). Passages per weekday between 6 am and 7 pm. Shaded areas mark periods with congestion tax.

4.2 Vehicles according to the national road traffic registry

This section presents the number of vehicles of different types according to the national road traffic registry. Data encompasses vehicles, in traffic (not off-road notified), in the city and county of Stockholm at the end of 2006 (turn of the year 2006/2007), 2007 (turn of the year 2007/2008) and 2008 (turn of the year 2008/2009). The information has been gathered from reports that WSP Analys & Strategi has compiled for the Stockholm Environment and Health

Administration (Clean Vehicles in Stockholm, 2009). The national road traffic registry provides more detailed information regarding the vehicle fleet composition compared to data from the congestion tax control points.

4.2.1 Private cars

Table 2 and Table 3 show the development of the number of private cars, separated by fuel type according to the national road traffic registry. Since 2006, the number and proportion of private cars using petrol has decreased in the city and county. The decrease has been balanced by increases in mainly diesel and ethanol fuels. The city of Stockholm has, since 2006, seen a doubling of the proportion of diesel-fuelled private vehicles to 14%, and ethanol has tripled to 11%. Alternative fuel vehicles have increased their share from 5% at the end of 2006 to 14% two years later.

The same developmental trend can be observed for Stockholm County (Table 3), albeit to a lesser degree; the proportion of alternative fuel vehicles has increased from 3% to 9%. The total number of registered private cars has increased, both in the city and the county.

It is also noteworthy that the number of alternative fuel taxis in the county amounted to almost 1,700 at the turn of the year 2008/2009, which represents 30% of all (not off-road notified) taxis (Appendix 1). The corresponding number for the city is 870 cars (32%). Compared to the whole country, the proportion of taxis in the county and city is high. The greater part of the alternative fuel fleet consists of ethanol-fuelled cars, which make up 30% in the city and county, compared to 15% in Sweden as a whole. Even though the number of taxis make up a small part of the total number of private cars, they are responsible for a greater part of the vehicle mileage, particularly in the inner city.

Table 2: The number of private cars in Stockholm city at the end of the years 2006-2008, separated by fuel type.

Fuel	**2006**		**2007**		**2008**	
Petrol	250,536	88%	238,466	81%	217,303	73%
Diesel	20,453	7.2%	34,126	12%	43,039	14%
Ethanol	10,438	3.7%	18,379	6.2%	33,097	11%
Vehicle gas	2,425	0.8%	2,709	0.9%	2,355	0.8%
Electric hybrid/Electric	1,314	0.5%	2,521	0.9%	3,753	1.3%
Miscellaneous	641 [1)]	0.2%	6 [2)]	0.0%	0	0%
Private cars, total	285,807	100%	296,207	100%	299,547	100%
... of which are alternative fuel vehicles [3)]	14,703	5.1%	25,105	8.5%	41,555	14%

1) *Vehicles that could not be allocated*
2) *LPG vehicles (liquefied petroleum gas)*
3) *Stockholm City's definition*

Table 3: The number of private cars in the county of Stockholm at the end of the years 2006-2008, separated by fuel type.

Fuel	**2006**		**2007**		**2008**	
Petrol	700,457	91%	674,235	86%	635,873	80%
Diesel	43,451	5.7%	68,443	8.7%	88,182	11%
Ethanol	17,958	2.3%	31,332	4.1%	56,236	7.1%
Vehicle gas	3,249	0.4%	3,639	0.5%	3,671	0.5%
Electric hybrid/Electric	2,582	0.3%	3,954	0.6%	7,101	0.9%
Miscellaneous	1,260 [1)]	0.2%	24 [2)]	<0.1%	0	0%
Private cars, total	768,957	100%	783,417	100%	791,063	100%
... of which are alternative fuel vehicles [3)]	25,222	3.3%	44,027	5.6%	73,032	9.2%

1) *Vehicles that could not be allocated*
2) *23 LPG vehicles (liquefied petroleum gas) and one methanol*
3) *Stockholm City's definition*

4.2.2 Buses

Table 4 and Table 5 show the number of buses in the city and county, separated by fuel type. The proportion of diesel-fuelled buses has been substantially reduced between 2006 and 2008; from 94% to 62% in the city. Vehicles using alternative fuels have increased from 6% in 2006 to 38% at the turn of the year 2008/2009 in Stockholm city. In the county, the proportion of alternative fuel buses was 19%. Most of the alternative fuel buses are ethanol-fuelled.

Table 4: The number of buses in the city of Stockholm at the end of the years 2006-2008, separated by fuel type.

Fuel	**2006**		**2007**		**2008**	
Diesel (petrol)	848	94%	599 (2)	63%	608 (2)	62%
Vehicle gas	10	1.1%	50	5.2%	72	7.3%
Ethanol	47	5.2%	309	32%	305	31%
Buses, total	905	100%	960	100%	987	100%
... of which are alternative fuel vehicles [1)]	57	6.3%	359	37%	377	38%

1) *Stockholm City's definition*

Table 5: The number of buses in Stockholm County at the end of the years 2006-2008, separated by fuel type.

Fuel	2006		2007		2008	
Diesel (petrol)	2,560	95%	2,147 (9)	83%	2,156 (8)	81%
Vehicle gas	10	0.4%	54	2.1%	75	2.8%
Ethanol	119	4.4%	398	15%	430	16%
Buses, total	2,690	100%	2,609	100%	2,669	100%
... of which are alternative fuel vehicles 1)	130	4.8%	453	17%	505	19%

1) *Stockholm City's definition*

4.2.3 Light goods vehicles

Table 6 and Table 7 show the fleet of light goods vehicles (total weight ≤ 3,500 kilograms) in use 2006-2008 in the city and the county. All in all, there were roughly 43,000 and close to 95,000 light goods vehicles registered in the city and the county, respectively, at the turn of the year 2008/2009. About 1.4% of these were alternative fuel vehicles, of which, the majority were biogas (1.0%). There are a relatively large number of ethanol and biogas vehicles among light goods vehicles that do not fulfill Stockholm City's demands on alternative fuel vehicles. Diesel and petrol vehicles make up 98% of the light goods vehicle fleet (2008/2009).

Table 6: Light goods vehicles (≤3.5 tons) in Stockholm city at the end of the years 2006-2008, separated by fuel type.

Fuel	2006		2007		2008	
Diesel (petrol)	35,798	99.5%	26,248 (14,355)	99.0%	29,068 (12,918)	98.1%
Vehicle gas	120	0.3%	237	0.6%	575	1.3%
Ethanol	20	0.1%	130	0.3%	204	0.5%
Electricity	29	0.1%	29	<0.1%	29	<0.1%
Miscellaneous	0	0%	4 1)	<0.1%	0	0%
Light goods vehicles, total	35,967	100%	41,003	100%	42,794	100%
... of which are alternative fuel vehicles 2)	169	0.5%	219	0.5%	586	1.4%

1) *LPG vehicles (liquefied petroleum gas)*
2) *Stockholm City's definition*

Table 7: Light goods vehicles (≤3.5 tons) in Stockholm County at the end of the years 2006-2008, separated by fuel type.

Fuel	2006		2007		2008	
Diesel (petrol)	84,106	99.7%	62,043 (27,672)	99.2%	68,827 (24,661)	98.6%
Vehicle gas	194	0.2%	440	0.5%	921	1.0%
Ethanol	32	<0.1%	250	0.3%	394	0.4%
Electricity	52	<0.1%	49	<0.1%	49	<0.1%
Miscellaneous	0	0%	17 [1)]	<0.1%	0	0%
Light goods vehicles, total	84,384	100%	90,471	100%	94,852	100%
... of which are alternative fuel vehicles [2)]	278	0.5%	396	0.4%	927	1.0%

1) *16 LPG vehicles (liquefied petroleum gas) and one methanol vehicle*
2) *Stockholm City's definition*

4.2.4 Heavy goods vehicles

The number of alternative fuel vehicles is roughly the same among heavy goods vehicles as among light goods vehicles. Around 1.7% of the heavy goods vehicles registered in the city of Stockholm at the turn of the year 2008/2009 were classified as alternative fuel vehicles. All of these were fuelled by vehicle gas. In the county as a whole, the proportion was about half as big; 0.9%.

Table 8: Heavy goods vehicles (> 3.5 t) in the inner city of Stockholm at the end of the years 2006-2008, separated by fuel type.

Fuel	2006		2007		2008	
Diesel (petrol)	3,951	99.1%	4,108 (119)	98.4%	4,404 (111)	98.3%
Vehicle gas	36	0.9%	68	1.6%	77	1.7%
Ethanol	0	0%	0	0%	1	<0.1%
Heavy goods vehicles, total	3,987	100%	4,297	100%	4,593	100%
... of which are alternative fuel vehicles [1)]	36	0.9%	68	1.6%	78	1.7%

1) *Stockholm City's definition*

Table 9: Heavy goods vehicles (> 3.5 t) in Stockholm County at the end of the years 2006-2008, separated by fuel type.

Fuel	2006		2007		2008	
Diesel (petrol)	12,138	99.6%	12,168 (307)	99.1%	12,282 (276)	99.1%
Vehicle gas	45	0.4%	105	0.8%	107	0.8%
Ethanol	0	0%	1	<0.1%	2	0.1%
Heavy goods vehicles, total	12,183	100%	12,588	100%	12,668	100%
... of which are alternative fuel vehicles [1)]	45	0.4%	106	0.8%	110	0.9%

1) *Stockholm City's definition*

4.3 Fuel deliveries

Table 10 shows the sale of fuel to vehicles in Stockholm County for the years 2005 to 2008 (Clean Vehicles in Stockholm, 2009). The figures for petrol and diesel have been gathered from SPI (The Swedish Petroleum Institute). Sales figures have also been collected from fuel suppliers and others.

The volume of distributed petrol has decreased between 2005 and 2008, while the volume of diesel fuel has increased (Figure 2 and Table 10). The total volume of diesel and petrol were roughly the same in 2006 as in 2008. Deliveries of ethanol and biogas have increased substantially. The changes correspond to the development of vehicles in the city and county, according to the national road traffic registry.

The increased proportion of deliveries of renewable fuels to Stockholm County is largely due to increased sales of ethanol (mostly E85). The volume of low-blend ethanol has decreased somewhat due to lower petrol sales. The volume of biogas has also increased. The proportion of natural gas, which is a part of the vehicle gas group, increased during 2008 compared to the year before.

The proportion of renewable energy used in the vehicle fleet increased from 2.4% in 2005 to 6.8% in 2008. However, the total energy consumption for fuel used by vehicles has increased by about 4% during the same period (Figure 2).

Table 10: Delivered amount of vehicle fuel in Stockholm County, 2005-2008 (Clean Vehicles in Stockholm, 2009).

Fuel	**2005**	**2006**	**2007**	**2008**
Petrol (m^3)	917,500	941,400	928,800	870,916 [1)]
Diesel (m^3) (excluding construction machinery)	403,200	426,804	477,708	503,682 [1)]
Ethanol (m3)	48,011	72,601	90,867	107,559
Rapeseed methyl ester, RME (m^3)	299	264	198	172
Biogas (1000 Nm^3)	2,192	4,010	5,970	6,445
Natural gas (1000 Nm^3)	-	410	320	984
Hydrogen gas (1000 Nm^3)	142	0	0	0
Total energy consumption (GWh)	12,622	13,241	13,909	13,813
… of which is fossil fuel	97.6%	96.5%	94.6%	93.2%
… of which is renewable fuel	2.4%	3.5%	5.4%	6.8%

1) *Preliminary figure (Clean Vehicles in Stockholm, 2009)*

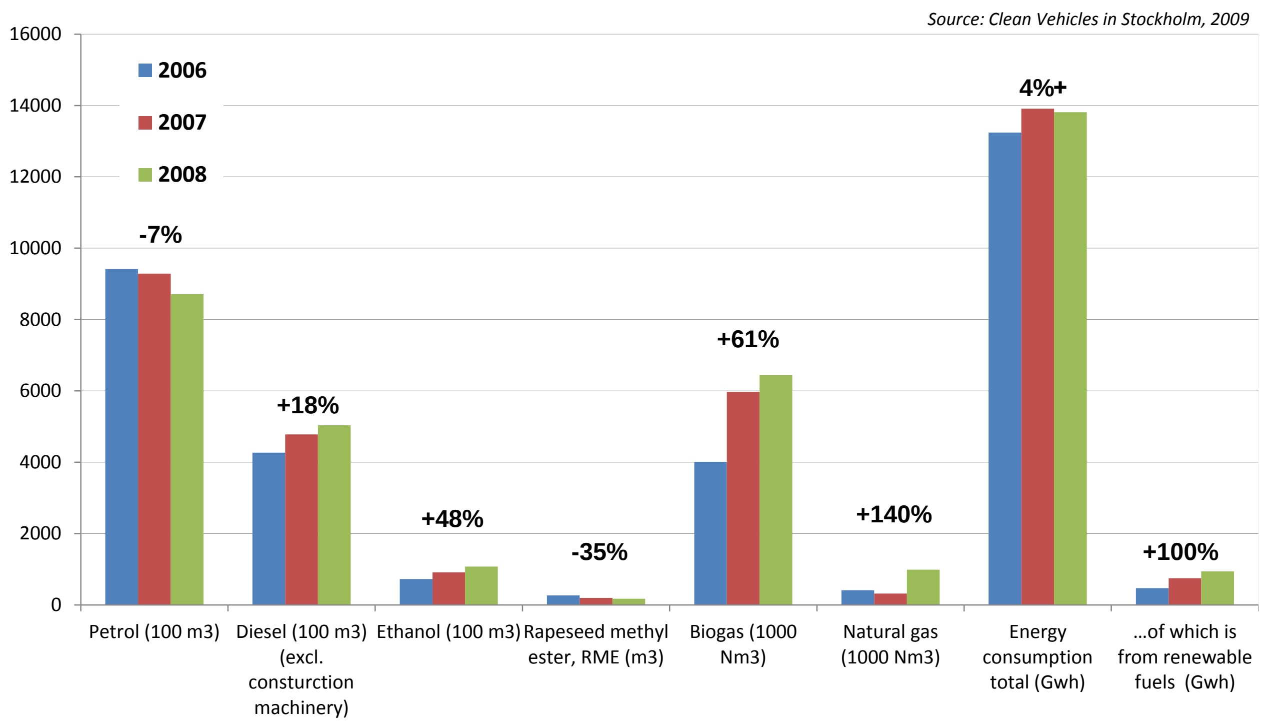


Figure 2: Deliveries of fuel to Stockholm County, energy content and proportion renewable fuel, 2006-2008. Percentages show the change between 2006 and 2008 (Clean Vehicles in Stockholm, 2009).

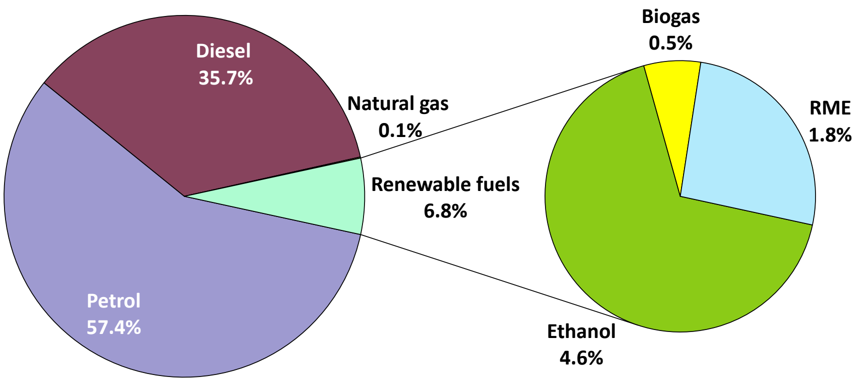


Figure 3: Proportions of energy content in fuel delivered to Stockholm County in 2008 (Clean Vehicles in Stockholm, 2009).

5 Emissions factors

Table 11 shows average emissions factors for nitrogen oxides, exhaust particles and carbon dioxide for the inner city of Stockholm according to the Artemis model (Infras, 2007). The data were retrieved from the emissions databases of the Stockholm-Uppsala Air Quality Management Association (LFV, 2009). The report also presents calculations for carbon monoxide, volatile organic compounds and particulate matter (PM10). These are also encompassed by the Artemis emissions factors, with the exception of the road wear portion of PM10, which were derived from measurements in Stockholm. The emissions factors in Table 11 are weighted for the years 2006-2008 respectively, depending on the technological development for each vehicle category.

Table 11: Emissions factors weighted together (g/km or mg/km) for different vehicle categories in the inner city of Stockholm, 2006-2008.

	Nitrogen oxides, NO_x g/km			Exhaust particles mg/km			Carbon dioxide, CO_2 [1)] g/km		
Vehicle:	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**
Private car petrol	0.44	0.40	0.36	1.0	1.0	1.0	260	255	252
Private car diesel	0.80	0.72	0.67	40	32	27	216	215	214
Private car ethanol	0.20	0.19	0.20	0.54	0.48	0.44	217	213	212
Private car vehicle gas	0.03	0.03	0.03	0.1	0.1	0.1	216	213	210
Light goods vehicle petrol	1.0	0.96	0.88	2.0	2.0	1.9	344	347	339
Light goods vehicle diesel	1.4	1.3	1.2	123	112	101	461	468	468
Heavy goods vehicle diesel	13.3	12.8	12.1	333	311	287	1,368	1,358	1,336
Bus diesel	11.3	11.0	10.3	267	242	210	1,096	1,115	1,105
Bus ethanol	7.3	6.9	6.0	69	63	48	1,176	1,173	1,164

1) Represents both carbon dioxide from fossil and renewable fuels

6 Changes in vehicle mileage

The traffic situation changes in different ways on different streets and roads in the Stockholm region. To obtain a combined weighted picture of traffic development, calculations of vehicle mileage are carried out. This is the total number of kilometres driven by all vehicles on roads within a certain geographical area. The combined weighting can be carried out in different ways. For example, the changes on all individual street sections (links) can be weighted equally, according to the length of the streets, or in relation to the number of residents. The calculation of vehicle mileage also gives added emphasis to those links that are long and have large traffic flows. Vehicle mileage is also an important parameter for achieving an overview of what happens with emissions of air pollutants in different areas.

Calculations of vehicle mileage for the Stockholm region have been performed by WSP Analys & Strategi (WSP, 2009). The starting point are the traffic measurements carried out by the Traffic Administration office of the City of Stockholm during April and October of the years 2005-2008 (Traffic Administration Office, 2009), i.e. before, during and after the congestion tax trial. Table 12 presents the changes in vehicle mileage for Stockholm's inner city, city and county during 24-hour weekday periods.

Table 12: Changes in vehicle mileage in Stockholm's inner city, city and county (WSP Analys & Strategi, 2009).

Period of comparison	Inner city of Stockholm [1)]	City of Stockholm	Stockholm County
Apr-05 to Apr-06 [2)]	-8.5%	-2.4%	-3.9%
Oct-06 to Oct-07	-1.3%	+2.2%	+2.7%
Oct-07 to Oct-08	-1.0%	+0.6%	-1.8%

1) *The inner city is defined here as the area inside the control stations*
2) *Figures are revised compared to earlier estimates concerning the congestion tax trial*

The effect of the congestion tax on vehicle mileage in the inner city was considerably less (-1.3%) at the start of the permanent tax (October 2007 compared to October 2006), than during the trial, when vehicle mileage decreased by 8.5% (April 2005 compared to April 2006). This is explained by the residual effects of the Stockholm Trial, in that traffic did not return to the levels before 2005, i.e. before the trial (Traffic Administration Office, 2009). Traffic in the inner city, however, has continued to decrease, albeit slightly, while the city as a whole has seen a decline of the trial effects. Traffic has increased in the city since October 2006. The county as a whole experienced a few percent increase in vehicle mileage between October 2006 and 2007, an effect that was largely reversed between then and October 2008.

Apart from the fact that vehicle mileage estimates are inherently uncertain, it is also important to point out that changes in vehicle mileage depend on a host of different factors, besides the congestion tax. The traffic increase, or the diminished traffic decrease, are believed to be an effect of taxable private cars having been replaced by tax-exempt alternative fuel vehicles which have longer driving distances, since they can drive in and out of the tax zone without incurring any cost (Traffic Administration Office, 2009).

6.1 Vehicle mileage in the city and inner city of Stockholm

Figure 4 shows the vehicle mileage for different vehicle categories in the city of Stockholm for 2006-2008, divided according to data from control stations and road traffic registries. The data are taken from the emissions databases of the Stockholm-Uppsala Air Quality Management Association (LVF, 2009).

Of the total vehicle mileage in the city of Stockholm (about 3,000 mvkm/year), petrol-fuelled vehicles (cars and light goods vehicles) comprise the largest part. Between the years 2006 and 2008, however, their proportion has decreased from 77% to 63%. Vehicles fuelled by diesel, on the other hand, have increased in numbers (both private cars and goods vehicles). In 2006, these made up around 16% of the city's vehicle mileage, a figure that increased to around 23% by 2008. The proportion of heavy duty vehicles (buses and heavy goods vehicles) remained unchanged 2006-2008. When it comes to alternative fuel vehicles (neither petrol, diesel nor natural gas), their proportion has increased from about 4% in 2006 to about 10% in 2008. Most of these are ethanol-fuelled cars. The proportions for the inner city correspond to a large degree with those for the city as a whole.

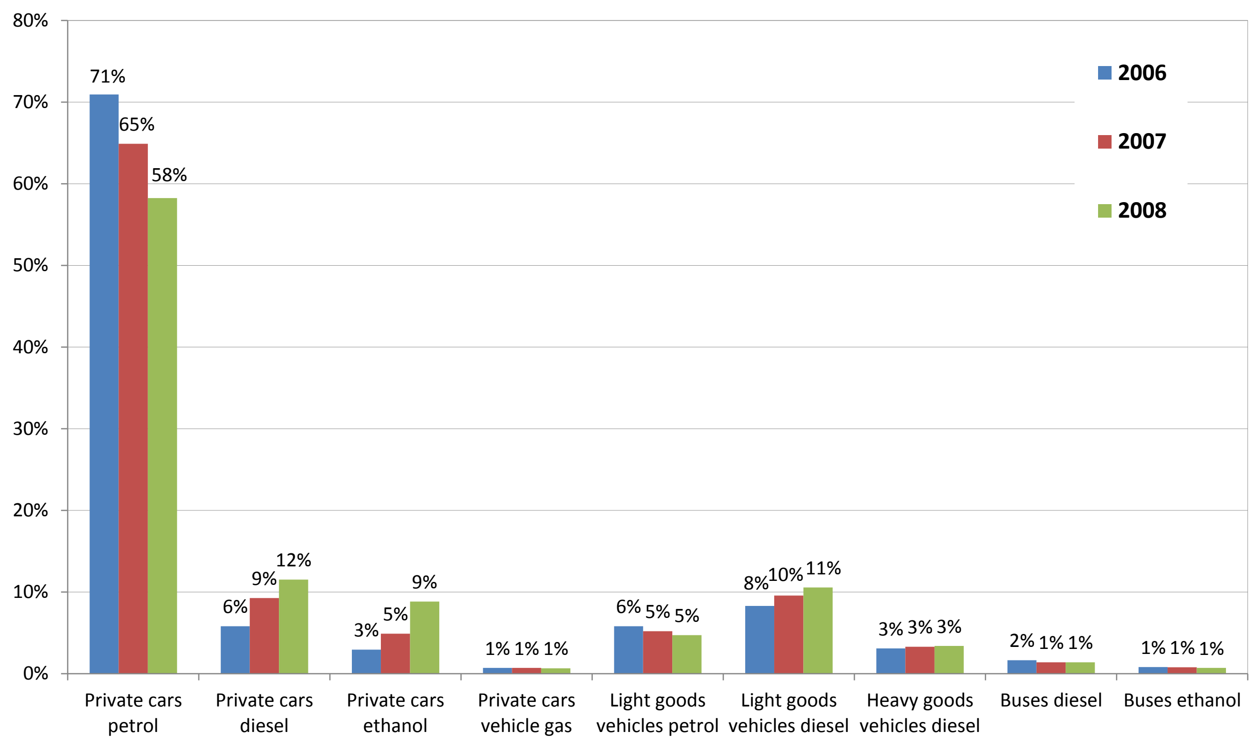


Figure 4: Proportions of vehicle mileage for different vehicle categories in the inner city of Stockholm, 2006-2008.

7 Emissions and air quality

This chapter accounts for how emissions and concentrations of pollutants in Stockholm's air have changed with the congestion tax.

7.1 Changes in road traffic emissions

The following calculations are based on data from the congestion tax control stations, the national road traffic registry and estimates of vehicle mileage. The emissions factors for specific vehicle categories are derived from the Swedish version of the Artemis model (Appendix 2). Data on road traffic have been integrated into the emissions databases of the Stockholm-Uppsala Air Quality Management Association (see Reports section at www.slb.nu/lvf). Carbon dioxide estimates comprise both total emissions and emissions from fossil fuel. The fossil fuel part of carbon dioxide emissions has been calculated using statistics for deliveries of fuel to the county.

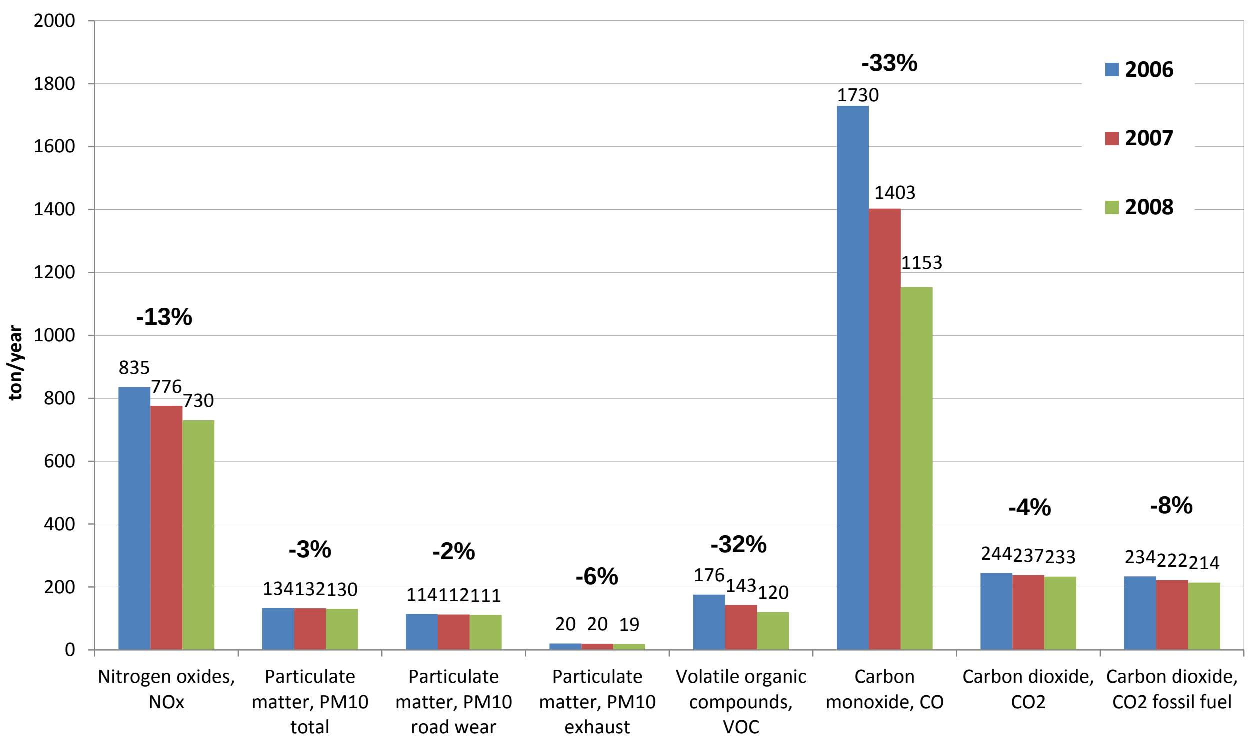


Figure 5: Compilation of road traffic emissions of pollutants in the inner city of Stockholm, 2006-2008. The percentages above the bars signify the change from 2006 to 2008.

For the inner city, the change in vehicle mix and a somewhat lower vehicle mileage (vehicle kilometres travelled) have resulted in a drop in road traffic emissions. The largest decrease can be seen for hydrocarbons and carbon monoxide (roughly one third reduction), which is related to ethanol and diesel vehicles having lower emissions of these substances in comparison to petrol-fuelled vehicles. For particulate matter (PM10) emitted through exhausts and road wear, the decrease is about 6% and 2%, respectively. For exhaust particle emissions, the increase in the number of diesel-fuelled vehicles has counteracted what would have otherwise been a larger decrease in emissions. For road wear particles, they are first and foremost a result of studded tyres and not of the altered vehicle mix. The proportions attributed to studded tyres have remained largely unchanged between 2005 and 2008. In total, emissions of particulate matter (PM10) have decreased by around 3% in the inner city between 2006 and 2008. Emissions of nitrogen oxides are estimated to have decreased by about 13% (even here, the increase in diesel vehicles has offset the decrease in emissions.)

Emissions of carbon monoxide in the inner city are estimated to have decreased by around 11,000 tons since 2006, which represents roughly 4%. Carbon dioxide emissions from fossil fuel (petrol, diesel and natural gas) are estimated to have decreased by about 20,000 tons, or roughly 8% since 2006.

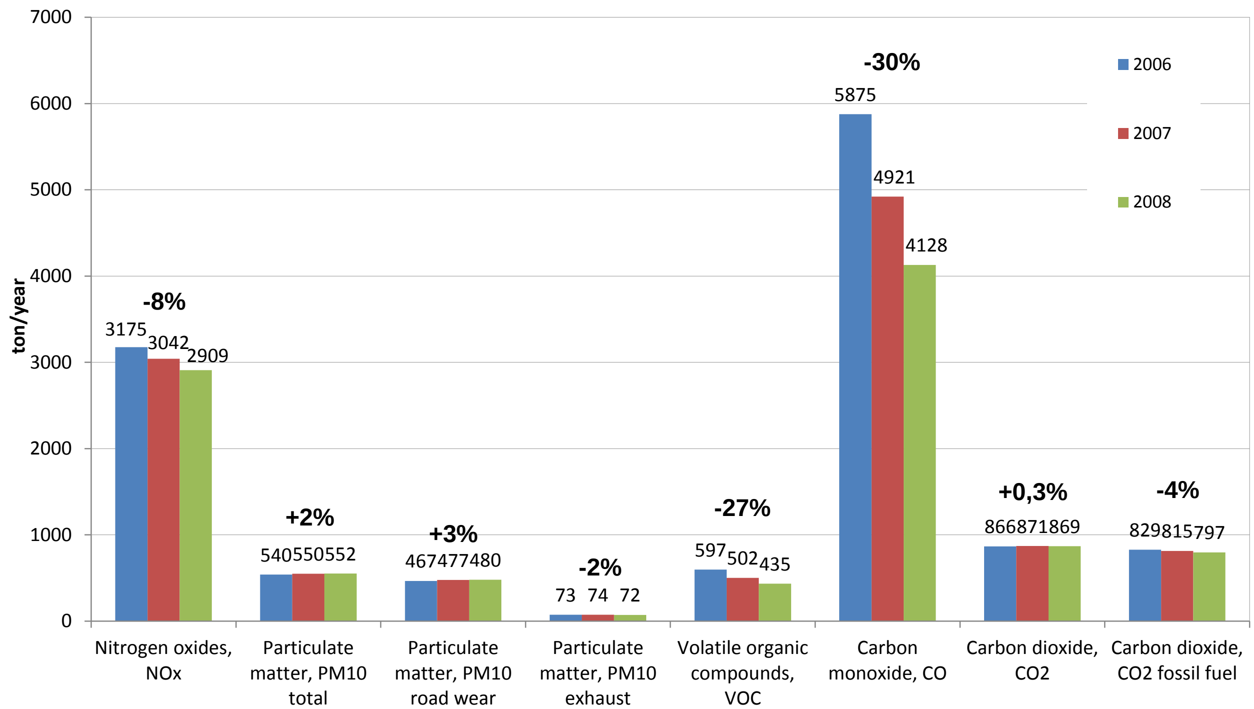


Figure 6: Compilation of road traffic emissions of pollutants in the city of Stockholm, 2006-2008. The percentages above the bars signify the change from 2006 to 2008.

For Stockholm city as a whole, the decrease in road traffic emissions is smaller due to the traffic increasing by a few percent since 2006. For particulate matter (PM10) released through road wear, increased vehicle mileage leads to increased emissions since the changes in the vehicle fleet have not affected the proportions of studded tyre use (which account for most of the wear). Particulate matter released by way of exhaust fumes, however, has decreased by a few percent. Also for the city as a whole, the changes to the vehicle fleet accounts for the largest reductions in emissions of hydrocarbons and carbon monoxide, while emissions of nitrogen oxide are estimated to have decreased by 8% between 2006 and 2008.

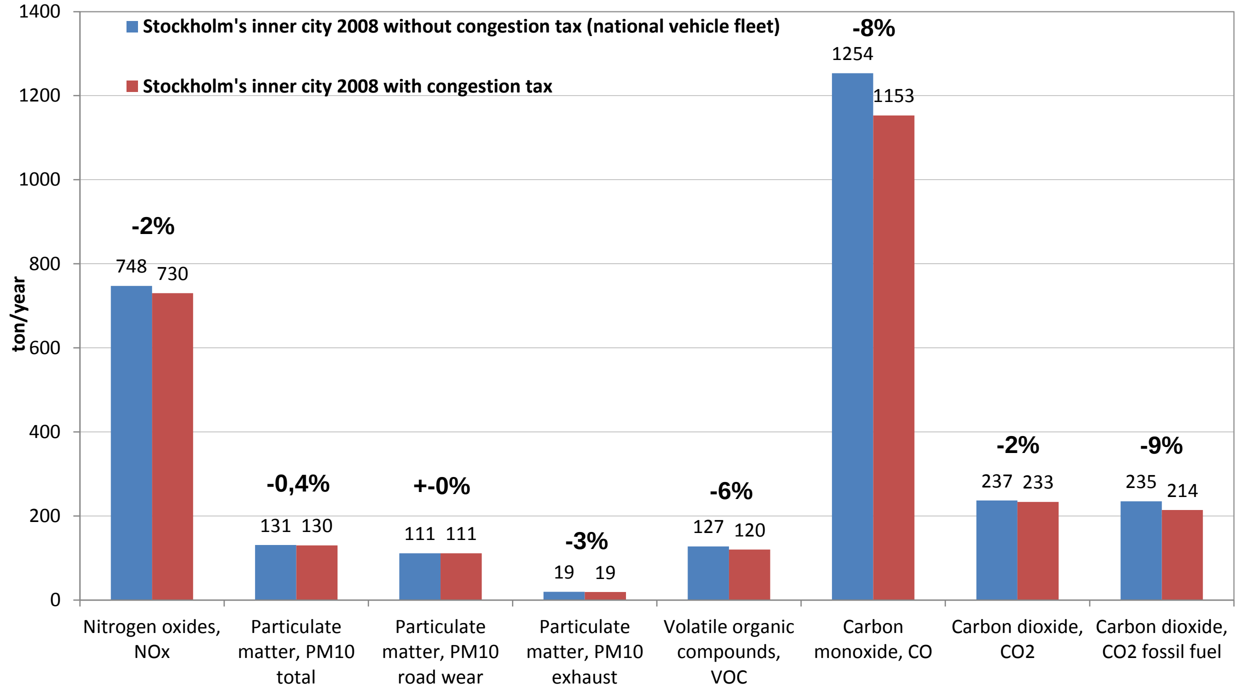
Total emissions of carbon dioxide in the city of Stockholm have essentially remained unchanged since 2006, while emissions from fossil fuel have decreased by roughly 31,000 tons (about 4%).

7.2 Comparison with the national vehicle fleet

The altered vehicle fleet and the outlook for emissions in Stockholm with, among other things, more alternative fuel vehicles, are not, of course, merely a result of the implementation of the congestion tax. However, studies show that exemptions from congestion tax have been very influential in convincing Stockholm's inhabitants to purchase more alternative fuel vehicles (BEST, 2009). In comparison to the development in the rest of Sweden, there are today relatively more alternative fuel vehicles in both the city and county of Stockholm.

Figure 7 shows calculations in which the emissions with congestion tax in Stockholm in 2008 are compared to what the emissions would have been, had the composition of the vehicle fleet been the same as that of Sweden as a whole. The comparison is made for the inner city and the city of Stockholm.

The figure shows that when it comes to the inner city and the city, emissions are considerably lower with the current vehicle mix compared to the one for the whole country. The largest differences can be seen for carbon dioxide from fossil fuel, carbon monoxide and hydrocarbons.



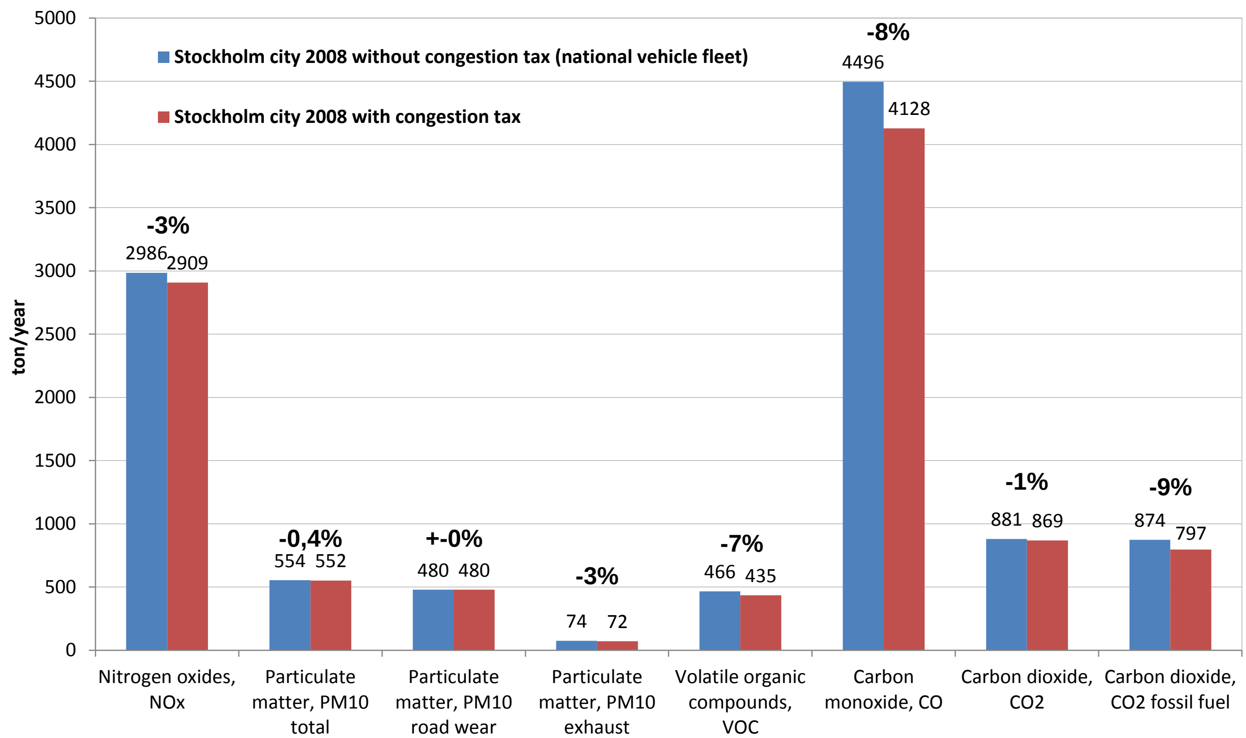


Figure 7: Comparison between emissions from the actual vehicle mix of Stockholm and that of the vehicle mix of all of Sweden.

7.3 Changes in air quality

Air pollution in Stockholm comes from a large number of emission sources, mostly road traffic, but also energy and maritime traffic. Concentrations are also affected by emissions in other counties and other parts of Sweden, as well as from other countries. Varying meteorological conditions, i.e. the weather, decide how fast air pollutants are dispersed. Since local concentrations of air pollutants are a product of many factors, it is difficult, solely on the basis of air quality measurements, to judge how much the congestion tax has affected air quality.

The city of Stockholm has three fixed monitoring stations for air quality, located on Hornsgatan, Sveavägen and Norrlandsgatan (see annual report for air quality at www.slb.nu/lvf). The city also participates in a regional cooperation within the Stockholm-Uppsala Air Quality Management Association. The monitoring station Torkel Knutsonsgatan is located at rooftop level on Södermalm and thereby represents urban background concentrations for the Stockholm region. For regional background concentrations, there is a monitoring station at Norr Malma, located in the countryside outside of Norrtälje. On behalf of the Swedish Road Administration, measurements are also carried out near Essingeleden, on the island of Lilla Essingen.

7.3.1 Changes in total concentrations

Presented below are the results from the monitoring stations in the inner city (Hornsgatan, Sveavägen and Norrlandsgatan), as well as near Essingeleden during 2005-2008. Average concentration values have been calculated separately for periods with congestion tax (January 2006-July 2006 and August 2007-December 2008), as well as periods without tax (other times during the measured period). All in all, the period encompasses two years with tax and two years without tax, and an equal number of winter, spring, summer and autumn months. Only measurements during daytime (6 am-7 pm), Monday through Thursday, have been used, so that only time periods relevant to the congestion tax (nights and weekends are tax free) are included in the comparisons. Therefore, total concentrations do not include weekends and nights, and cannot be compared to environmental quality standards spanning entire years.

Figure 8 shows unequivocally, for all substances, that average concentration values for periods with congestion tax are lower than for periods without tax, when it comes to the inner city monitoring stations. For the exempt Essingeleden motorway, however, concentrations of nitrogen oxides, NO_x, are higher during periods with tax, while concentrations of PM10 remain unchanged.

The lower concentrations measured in the inner city, with congestion tax, are partly a result of concentrations continuously decreasing due to lower traffic emissions. Since the periods with tax mostly fall within the latter part of 2005-2008, the average concentration values with tax are lower. In addition, this reduction in emissions is partly due to the implementation of the congestion tax. The decrease in traffic during periods with tax also contributes to a certain extent, especially during the period of the congestion tax trial in 2006. The higher NO_x concentrations along Essingeleden during periods with tax must be due to the fact that increased traffic volumes more than compensated for the decreased emissions from a cleaner vehicle fleet.

PM10 concentrations also depend to a high extent on meteorological conditions, which affect the moisture of the road surface and how fast it dries off in spring in different years. During the trial of spring 2006, for example, concentrations of PM10 were significantly lower than normal, mainly due to unusually large quantities of snow during late winter and spring, and not as a result of decreased traffic in relation to the congestion tax.

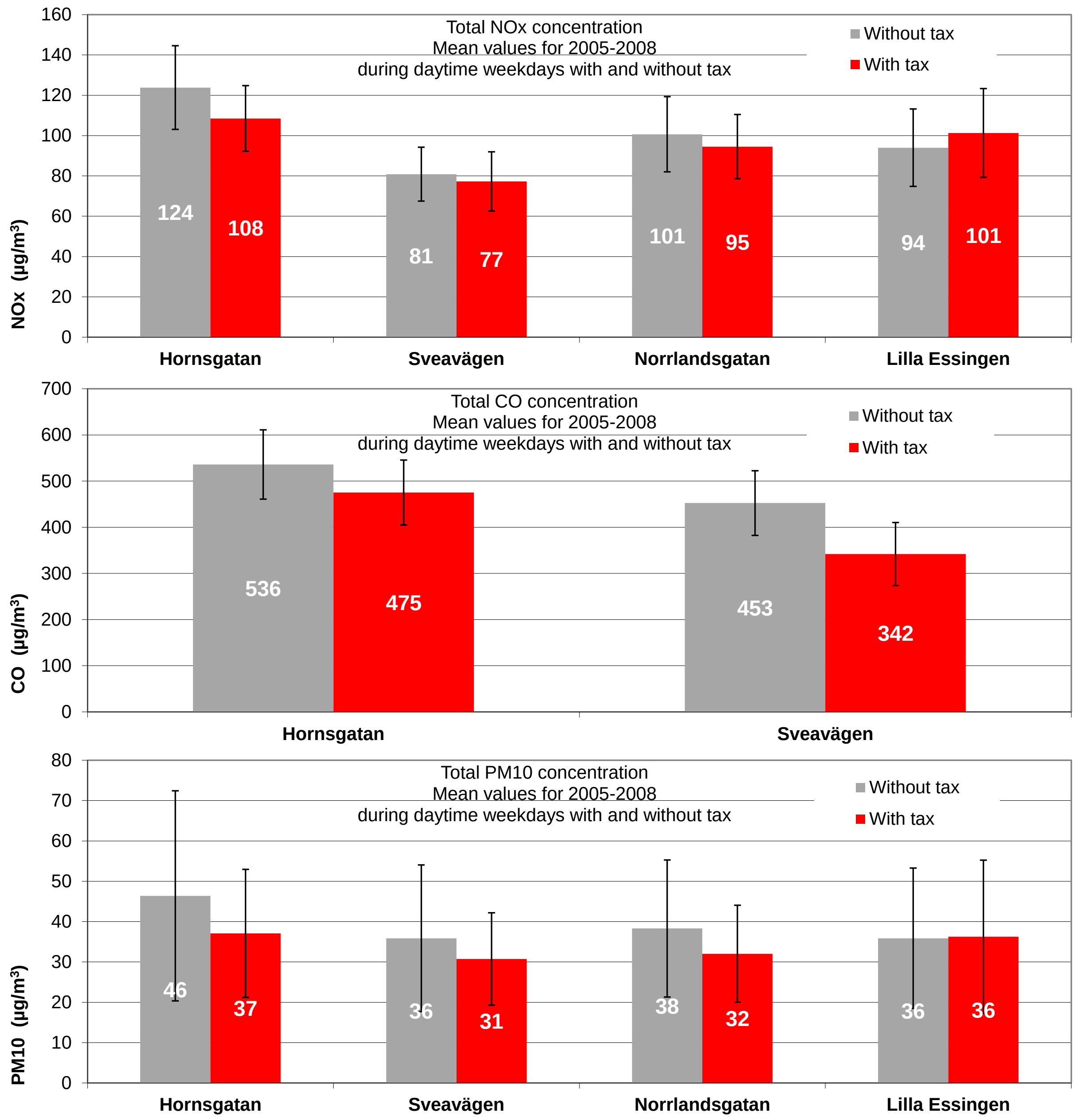


Figure 8: Total concentrations of NO_x, CO and PM10 in the inner city and along Essingeleden between 2005 and 2008; the total for two years with congestion tax and two years without. Grey columns represent average values for periods without congestion tax and red columns show average values with tax. The vertical lines show standard deviations from the average monthly levels.

7.3.2 Changes in local traffic contribution to concentrations

Local road traffic contributions to concentrations of NO_x, CO and PM10 in the inner city of Stockholm, and along the Essingeleden motorway, have been calculated by subtracting the background concentrations (at rooftop elevation) from total concentrations at the monitoring stations (Hornsgatan, Sveavägen, Norrlandsgatan and Lilla Essingen).

Figure 9 shows the average traffic contributions to NO_x concentrations during 2005-2008, divided into periods with congestion tax and periods without tax. All in all, the period spans 12 months with tax and 12 months without tax and an equal number of winter, spring, summer and autumn months. Only daytime hours (6 am-7 pm), Mondays through Thursdays, are included in the calculations.

On the streets of the inner city, NO_x concentrations were, on average, lower than during periods with congestion tax. The largest difference is noted on Hornsgatan, where total concentrations have been 13 µg/m^3 (micrograms per cubic meter) lower with tax. On Norrlandsgatan concentrations were 4 µg/m^3 lower, and on Sveavägen there is no noticeable difference. The lack of difference for Sveavägen has to do with the higher frequency of diesel buses on Sveavägen during the trial (see SLB-analys, 2006). On Lilla Essingen, concentrations were 9 µg/m^3 higher with tax. The change in contributions to NO_x concentrations is correspondingly -11%, -4% and +9% of total concentrations during weekdays, daytime, for Hornsgatan, Norrlandsgatan and Lilla Essingen.

Figure 9 shows when NO_x concentrations have been higher and lower, respectively, than the average for the period. The contributions have varied considerably. During the period of the congestion tax trial (January-July 2006), most monthly averages for inner city streets were significantly lower than the average value for the period as a whole. Apart from that, it is not possible to see any obvious, systematic trend in the deviations. As presented above, emissions have steadily decreased as a result of cleaner vehicles. Since the period of permanent congestion tax (from August 2007 until the end of the period) lies at the latter part of the studied period (2005-2008), and periods without tax mostly lie at the beginning of the period, contributions to concentrations have also been affected by the changes in emissions from the vehicle fleet. The lower emission contributions during tax periods are mainly due to decreased emissions from the vehicle fleet.

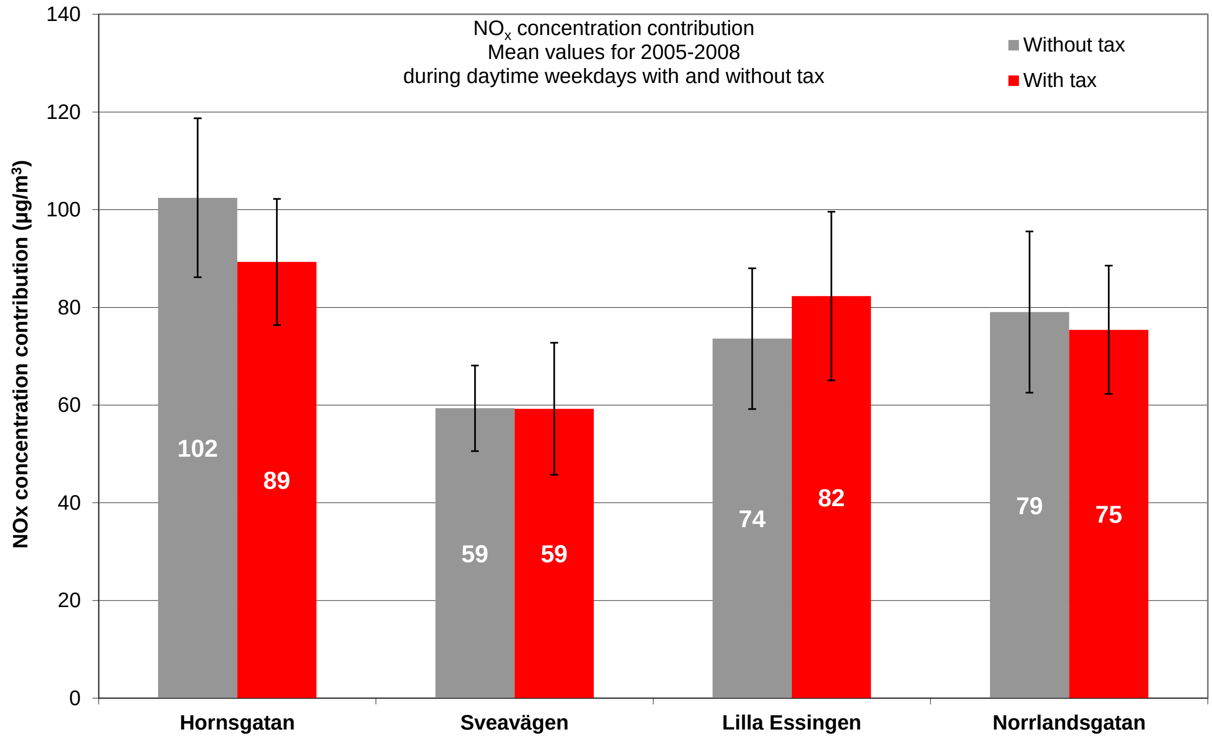


Figure 9: Average concentration values of traffic contributions for the entire period 2005-2008 with congestion tax and without tax, respectively. In total, 12 months with tax and 12 months without tax. The averages only encompass weekdays (Mondays-Thursdays) during daytime (6 am-7 pm).

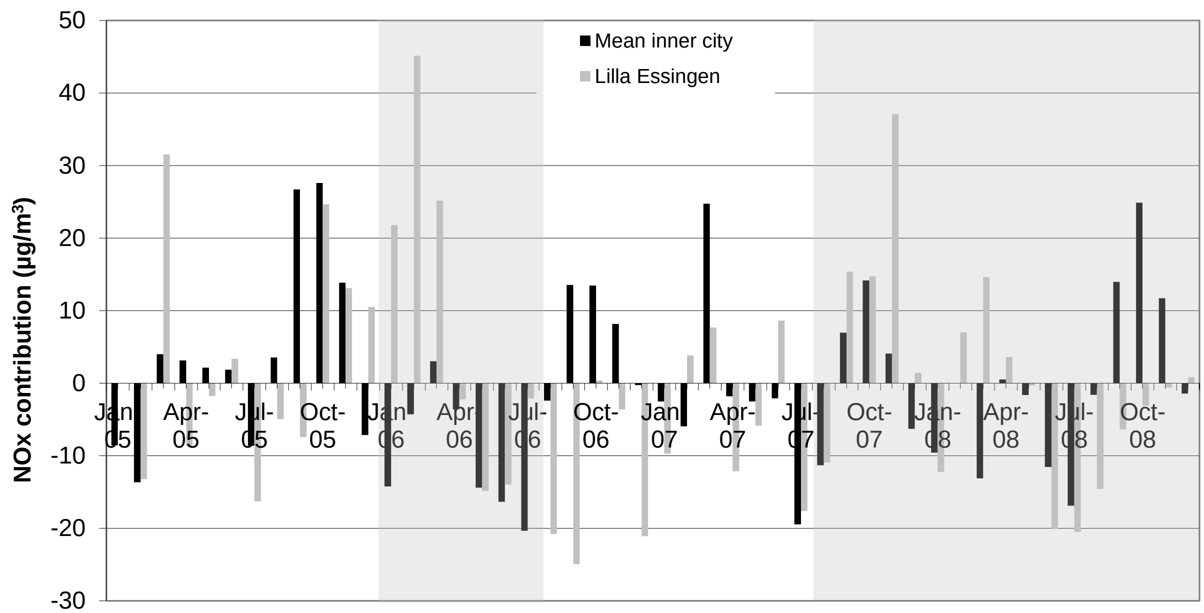


Figure 10: Divergences of NO_x contributions from the average for the whole period. The shaded areas show periods with congestion tax. The contributions make up monthly average concentrations for Mondays-Thursdays during daytime.

Figure 11 shows the average traffic contributions to CO concentrations for the period 2005-2008, divided into periods with and without congestion tax (daytime, Mondays-Thursdays). CO is only measured on the inner city streets (Hornsgatan and Sveavägen). Contributions to emissions were lower, on average, during periods with congestion tax, both on Hornsgatan and on Sveavägen. On Hornsgatan, the contribution was 43 µg/m^3 lower and on Sveavägen it was 33 µg/m^3 lower. The decreased contributions correspond to 13% and 17% respectively, of the total concentrations.

Figure 12 shows that, compared to the average concentration for the entire period, contributions were considerably lower during the congestion tax trial (January-July 2006). Both before and after the trial, contributions were above the average concentration. During the period of permanent congestion tax, most monthly averages for inner city streets were noticeably lower than the period's average. CO emissions have decreased gradually due to cleaner vehicles. A large part of the lower emission contributions during periods with tax is down to decreased emissions from the vehicle fleet. CO comes mainly from petrol-fuelled private cars. NO_x comes both from petrol-fuelled and diesel-fuelled vehicles, with a significant portion from goods vehicles. This could be the explanation as to why the effects on CO concentrations are stronger than for NO_x concentrations.

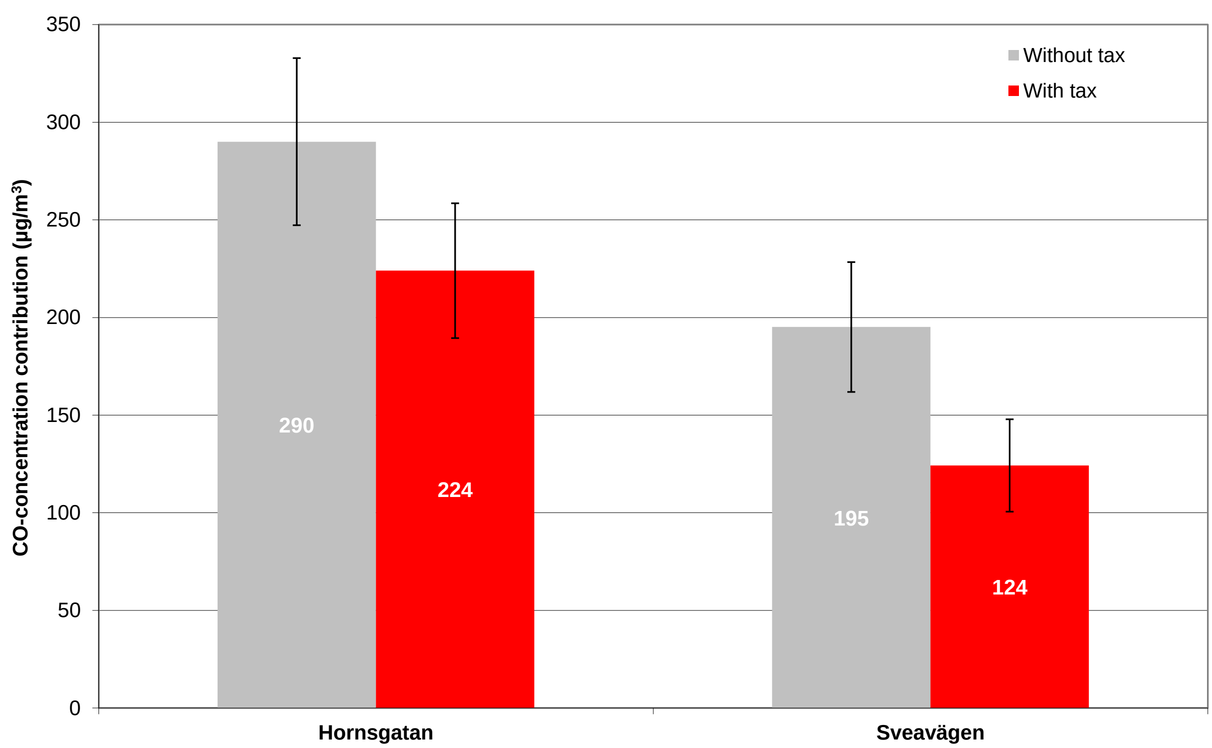


Figure 11: Average traffic contributions to CO concentrations during the entire period 2005-2008, with and without congestion tax. In total, 12 months with tax and 12 months without tax. The averages only represent weekdays (Mondays-Thursdays) during daytime (6 am-7 pm).

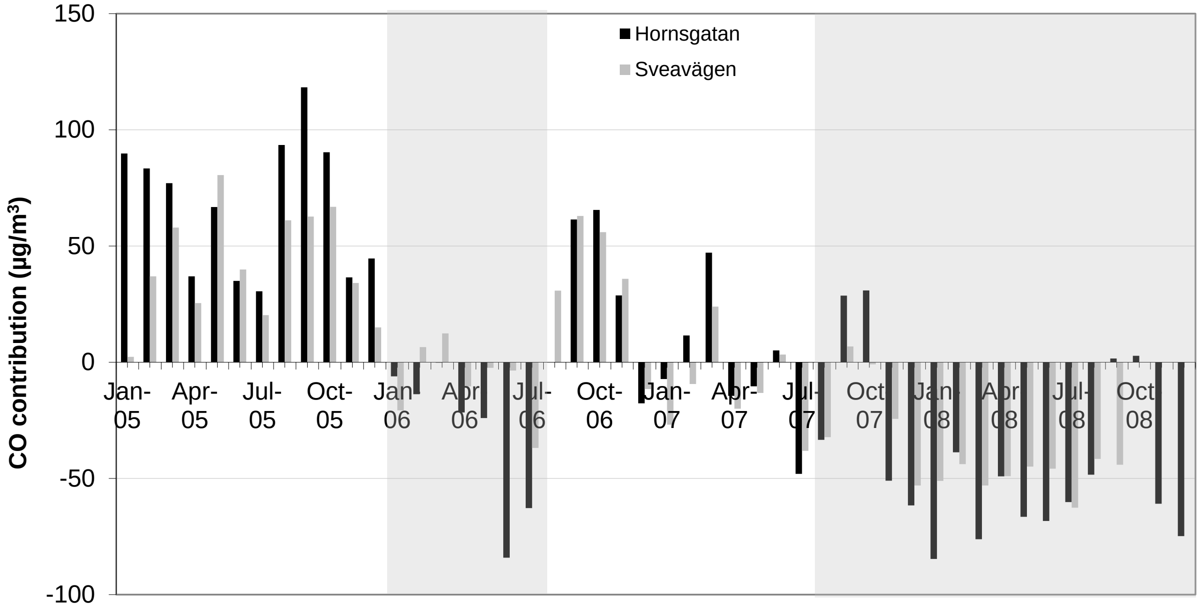


Figure 12: Deviations of CO concentration contributions from the average for the whole period. Shaded areas mark periods with congestion tax. The contributions make up monthly averages during daytime, Monday-Thursday.

Figure 13 shows the average traffic contributions to PM10 concentrations for the period 2005-2008, divided into periods with and without congestion tax (daytime, Mondays-Thursdays). Concentration contributions were, on average, around 5 µg/m^3 lower on inner city streets during periods with congestion tax, and around 2 µg/m^3 lower for Essingeleden. This represents 13% and 6% of the total concentrations in the inner city and on Essingeleden, respectively. The alterations are most likely a result of changes in traffic flows, decreased traffic in the inner city and increased traffic on Essingeleden. There is a tendency for PM10 concentrations to drop along inner city streets, which can explain the lower contributions during periods with tax (since the period with congestion tax falls mainly during the latter part of 2005-2008). But PM10 concentrations depend largely on variations in road surface dampness, due to the varying times at which roads dry up in springtime.

PM10 concentrations show a marked seasonal variation, with the highest values measured during late winter and spring, and the lowest during autumn. This is reflected in the variations in deviations from the averages (Figure 14). In relation to the average for the whole period, concentrations were high during the spring months and low during autumn/winter.

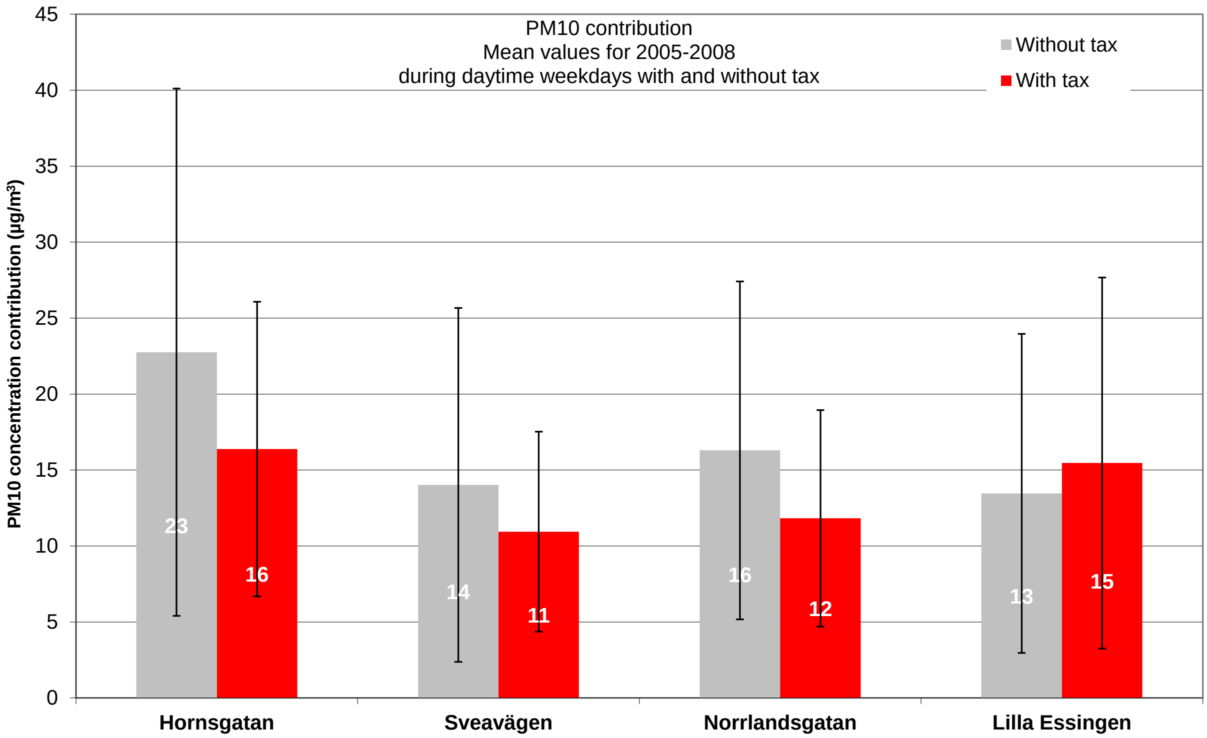


Figure 13: Average traffic contributions to PM10 concentrations for the whole period 2005-2008, with and without congestion tax. In total, 12 months with tax and 12 months without tax. The averages only represent weekdays (Mondays-Thursdays) during daytime (6 am-7 pm.)

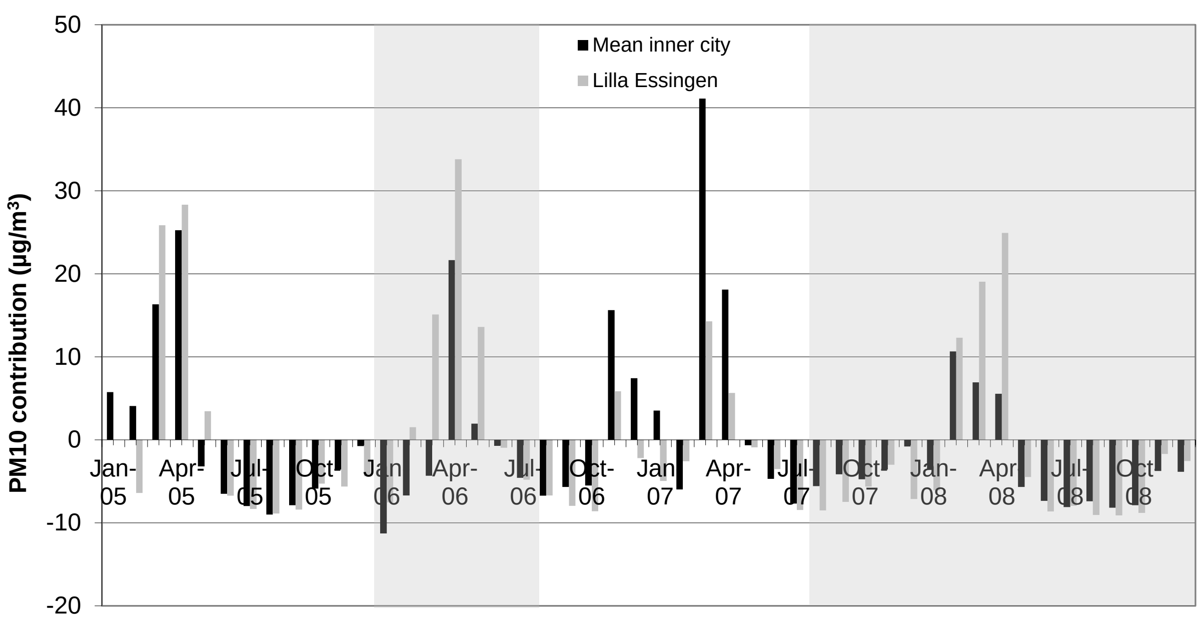


Figure 14: Deviations of the PM10 concentration contribution from the period average. Shaded areas mark periods with congestion tax. The contributions make up averages for daytime, Mondays through Thursdays.

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Appendix 1. Taxis in Stockholm city and county

At the turn of the year 2008/2009, the number of alternative fuel taxis in the county was around 1,700, which represents 30% of all the (not off-road notified) taxis. The corresponding figure for the city is 870 cars (32%). Compared to the country as a whole, the proportion of alternative fuel taxis in the county and city is high; more than 30% in the city and county compared to 15% in all of Sweden. The majority are ethanol-fuelled cars.

Table 13: Taxis in the city of Stockholm at the end of 2008, divided into fuel type.

Fuel	2008	
Petrol	182	6.8%
Diesel	1,616	60%
Ethanol	496	18%
Vehicle gas	191	6.8%
Electric hybrid/Electric	190	7.1%
Taxis in total	2,675	100%
...of which are alternative fuel vehicles[1)]	867	32%

1) Stockholm City's definition

Table 14: Taxis in Stockholm County at the end of 2007 and 2008, divided into fuel type.

Fuel	2007		2008	
Diesel (petrol)	6,471	87%	3,508 (370)	70%
Ethanol	524	7.0%	963	17%
Vehicle gas	295	4.0%	345	6.1%
Electric hybrid/Electric	139	1.9%	393	7.0%
Taxis in total	7,429	100%	5,579	100%
... of which are alternative fuel vehicles[1)]	961	13%	1,681	30%

1) Stockholm City's definition

Appendix 2. The Artemis emissions model

The Artemis emissions model (http://www.trl.co.uk/artemis/index.htm) is an internationally accepted emissions model. In the beginning of the 21st century, the Swedish Road Administration became involved in the EU project ARTEMIS. The implementation of ARTEMIS as an emissions model for national calculations has been conducted within the project SvArtemis, initiated by the Emissions Research Programme (EMFO). Emissions factors in ARTEMIS have been validated for Swedish conditions, and activity data and emissions correlations have been further developed for increased quality in the Swedish calculations. The same emissions factors are used by the Swedish Road Administration in the SIMAIR model.

Classification of vehicles

Traffic data per link are normally presented as total traffic and the proportion of heavy duty vehicles. To reach higher flexibility in certain analyses, light and heavy duty vehicles have been further divided in ARTEMIS. Light duty vehicles are divided into private cars, light goods vehicles and two-wheelers. Private cars are in turn sub-divided into petrol, diesel, FFV (flexi-fuel vehicles) and bio-fuel. Heavy duty vehicles are divided into city buses, long-distance buses, heavy goods vehicles without trailers and heavy goods vehicles with trailers. City buses are further divided in to diesel, ethanol and gas.

Classification of the road network

In ARTEMIS, roads are principally classified according to the criteria of Table 15, i.e. urban/rural, road type (function combined with design), speed limit and traffic flow class. State roads correspond to what in ARTEMIS is characterised as “National” or “Regional roads” and “Primary roads”. Municipal and private roads correspond principally to “city or district connectors”, as well as roads of lower rank.

Table 15: Principal classification or roads in Artemis. For example, code 110091 means rural motorway with speed limits of 90 km/h and free flow.

Rural/Urban	Road type (function)	Speed limits	Traffic flow class
1=rural 2=urban	10=motorway 12=semi-motorway (two plus one road) 20=national primary trunk road 21=primary city trunk road 11=motorways city 30=distributor 31=distributor (with curves) 40=local collector 41=local collector with curves 50=access road, residential	03=30 km/h 04=40 km/h 05=50 km/h 06=60 km/h 07=70 km/h 08=80 km/h 09=90 km/h 10=100 km/h 11=110 km/h 12= 120 km/h 13= 130 km/h 14= >130 km/h	1= free flow 2=heavy flow 3=congested 4=stop & go

The emissions factors of the Artemis model consist of warm, cold start and evaporative emissions. Emissions factors are available for the years leading up to 2020 (ARTEMIS version 3b). These include emissions factors for HC, CO, NO_x, exhaust particles, CO_2, methane, NMHC, SO_2, N_2O, NH_3, Pb and fuel consumption.

Emissions factors for cold start and evaporation are provided in ARTEMIS for private cars and light duty vehicles. These emissions factors are developed for an average year for the country as a whole. Evaporative emissions can be divided into running losses (g/km) during driving, hot soak (g/stop) for when the ignition is turned off, and diurnal losses (g/day and vehicle) in connection with parking.

Appendix 2. Emissions from road traffic

Road traffic emissions according to Artemis emissions factors integrated into the databases of the Stockholm-Uppsala Air Quality Management Association.

Inner city of Stockholm	**2006 tons/year**	**2007 tons/year**	**2008 tons/year**	**Change 2006 to 2008**
Nitrogen oxides, NO_X	835	776	730	-105 tons (-13%)
Particulate matter, PM10, total	134	132	130	-3.8 tons (-3%)
Particulate matter, PM10, from road wear	114	112	111	-2.6 tons (-2%)
Particulate matter, PM10, from exhaust fumes	20.1	19.6	18.9	-1.2 tons (-6%)
Volatile organic compounds, VOC	176	143	120	-56 tons (-32%)
Carbon monoxide, CO	1,730	1,403	1,153	-577 tons (-33%)
Carbon dioxide, CO_2	244,100	237,425	233,183	-10,916 tons (-4%)
Fossil fuel carbon dioxide, CO_2	233,570	222,018	214,051	-19,519 tons (-8%)

City of Stockholm	**2006 tons/year**	**2007 tons/year**	**2008 tons/year**	**Change 2006 to 2008**
Nitrogen oxides, NO_X	3,175	3,042	2,909	-266 tons (-8%)
Particulate matter, PM10, total	540	550	552	+12 tons (+2%)
Particulate matter, PM10, from road wear	467	477	480	+ 13 tons (+3%)
Particulate matter, PM10, from exhaust fumes	73	74	72	-1.3 tons (-2%)
Volatile organic compounds, VOC	597	502	435	-162 tons (-27%)
Carbon monoxide, CO	5,875	4,921	4,128	-1,748 tons (-30%)
Carbon dioxide, CO_2	866,014	871,024	868,511	+2,498 tons (+0.3%)
Fossil fuel carbon dioxide, CO_2	828,657	814,503	797,251	-31,407 (-4%)

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