



Swedish Environmental Emissions Data

# Update of gasoline consumption and emissions from leisure boats in Sweden 1990-2003 for international reporting

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## Summary

At present, gasoline consumption for gasoline leisure boats in Sweden are assumed to be 1.5 % of the national delivered amounts of gasoline per year, based on a Swedish EPA study in 1992. In 2004, Statistics Sweden performed a telephone survey to about 13 000 persons in order to gain information on the number leisure boats in Sweden 2004 and their usage. Comparisons of gasoline consumption estimation between the two sources, indicates large differences. Three approaches for estimating gasoline consumption 1990-2003 have been applied and presented in this report: Continue with the approximation of 1.5% of the delivered amount per year; assume constant consumption 1990-2004, by extrapolating the results from the 2004 survey; or interpolate the consumption 1990-2004, using 1.5% of the deliveries for 1990 and the survey result for 2004.

Due to lack of evidence of any trend in gasoline consumption between 1990 and 2004, and good quality in the results from the 2004 survey, it is recommended in this report to apply constant consumption 1990-2003, based on the 2004 survey results, for international reporting. Several figures in the report elucidate how the emission level impact on domestic navigation varies depending on approach.

In addition, gasoline consumption divided on 2-stroke and 4-stroke engines have been estimated for the whole time series 1990-2003, based on information from the two sources.

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# 1 Introduction

Leisure boats have played a big part of the layback lifestyle that many Swedes enjoy, especially during summer times. They are therefore an important source of air emissions, both on local and national level<sup>1</sup>. For international reporting to the UNFCCC<sup>2</sup>, EU monitoring mechanism and the CLRTAP<sup>3</sup>, leisure boats are included in the overall emissions from domestic navigation.

Gasoline consumption for leisure boats 1990-2003 are presently assumed to be 1.5 % (about 80 000 m<sup>3</sup> in 2003) of the national delivered amounts of gasoline per year (Swedish EPA, 2005). This assumption is based on a study of the environmental impact from leisure boats in 1990 (Swedish EPA, 1992).

Emissions of CO<sub>2</sub> and SO<sub>2</sub> from leisure boats are calculated on the basis of estimated consumption of gasoline and national emission factors, whereas emissions of NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, CO, N<sub>2</sub>O are estimated using emission factors from CORINAIR (Swedish EPA, 2005). The difference in emission factor levels for 2- and 4-stroke engines are taken into account.

In 2004, Statistics Sweden performed a survey regarding leisure boats in Sweden 2004 (Statistics Sweden, 2004). Results from the survey show that there were about 718 000 leisure boats in 2004, consuming approximately 32 500 m<sup>3</sup> gasoline, indicating that the assumption based on delivered amounts tended to highly overestimate the fuel use.

## 1.1 Aim

The aim of this project is to update the gasoline consumption and emissions from leisure boats in Sweden 1990-2003 for international reporting.

## 2 Methodology for updating gasoline consumption and emissions 1990-2003

In order to update the gasoline consumption and emissions from leisure boats 1990-2003, it is important to settle which information sources and possible estimation models are available. In this report, two studies of leisure boats have been scrutinized; Statistics Sweden's 2004 survey and the Swedish EPA report from 1992.

### 2.1 Statistics Sweden's leisure boat survey 2004

During the fall 2004<sup>4</sup>, Statistics Sweden (2004) performed a survey where 13 000 persons were interviewed by telephone. The aim of the study was to gather information on the number of leisure boats in Sweden 2004 and how they were used.

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<sup>1</sup> For example, in Sweden's Submission 2005 to the UNFCCC, 20 % of the NMVOC emissions from mobile sources derive from leisure boats in 2003.

<sup>2</sup> United Nations Framework Convention on Climate Change

<sup>3</sup> Convention on Long-Range Transboundary Air Pollution

<sup>4</sup> Since the majority of leisure boat usage happens during summer time in Sweden, the survey was executed between October and November.

The response rate was very high, about 81 % (or 10 519 persons) replied. The estimated number of boats in Sweden rounded up to about 718 000 in total (also corresponding to about 15 % of the Swedish households owning a leisure boat). The uncertainty related to this number was estimated to be +/- 66 000 boats given a 95 % interval. About 2000 answered that they had motor-driven leisure boats, which equaled about 470 000 boats with engines on the national total. Of these, roughly 200 000 boats had gasoline engines with an installed motor effect of more than 10 kW. Roughly 1300 respondents stated that they had some kind of gasoline consumption, resulting in about 100 liters per boat, or about 32 500 m<sup>3</sup> for the total gasoline consumption in Sweden during 2004. The quality of the survey results is considered to be good.

Results from the survey regarding the gasoline use for 2-stroke and 4-stroke engines showed that the relation was approximately 51/49.

## **2.2 The Swedish EPA study on environmental impact from leisure boats**

During the late eighties and the early nineties, medium and big leisure boats (>10 kW installed effect) in Sweden were registered in the 'Swedish Leisure Boats Register' (swe. Fritidsbåtsregistret). In 1990, 208 000 motor boats and 62 000 sailing boats were registered (Swedish EPA, 1992). Of these, 190 000 boats had gasoline engines.

Gasoline consumption for leisure boats in 1990 was estimated using the number of registered boats (>10 kW installed effect) and an assumption that the number of small boats (< 10 kW installed effect) in Sweden were 495 000. Assumptions on average engine operating load (% of maximum) and on average value for the annual operating hours were also made.

Estimates of gasoline consumption on installed effects on boats were used to calculate the ratio between 2- and 4-stroke engines in 1990, resulting in 79 % 2-stroke and 21 % 4-stroke engines.

## **2.3 Choosing method for estimating gasoline consumption and emissions 1990-2004**

It is clearly a large difference in gasoline consumption for leisure boats between the study by the Swedish EPA, 1992 and the 2004 survey by Statistics Sweden. Based on the information available from the two sources, three approaches for estimating the gasoline consumption are possible: Continue with the approximation of 1.5% of the delivered amount per year; assume constant consumption 1990-2004, by extrapolating the results from the 2004 survey; or interpolate the consumption 1990-2004, using 1.5% of the deliveries for 1990 and the survey result for 2004.

It is notable that the number of boats with more than 10 kW installed effect, which stands for most of the fuel consumption, is relatively similar. However, even if the total number of leisure boats can be considered to more or less equal over the years, the proportion of the boats have changed resulting in bigger and bigger boats over the years. This should imply that more fuel is used in 2004 compared to the early nineties. On the other hand, boats were more frequently used in the beginning of the times series 1990-2003 compared to the end (Bingman, 2005).

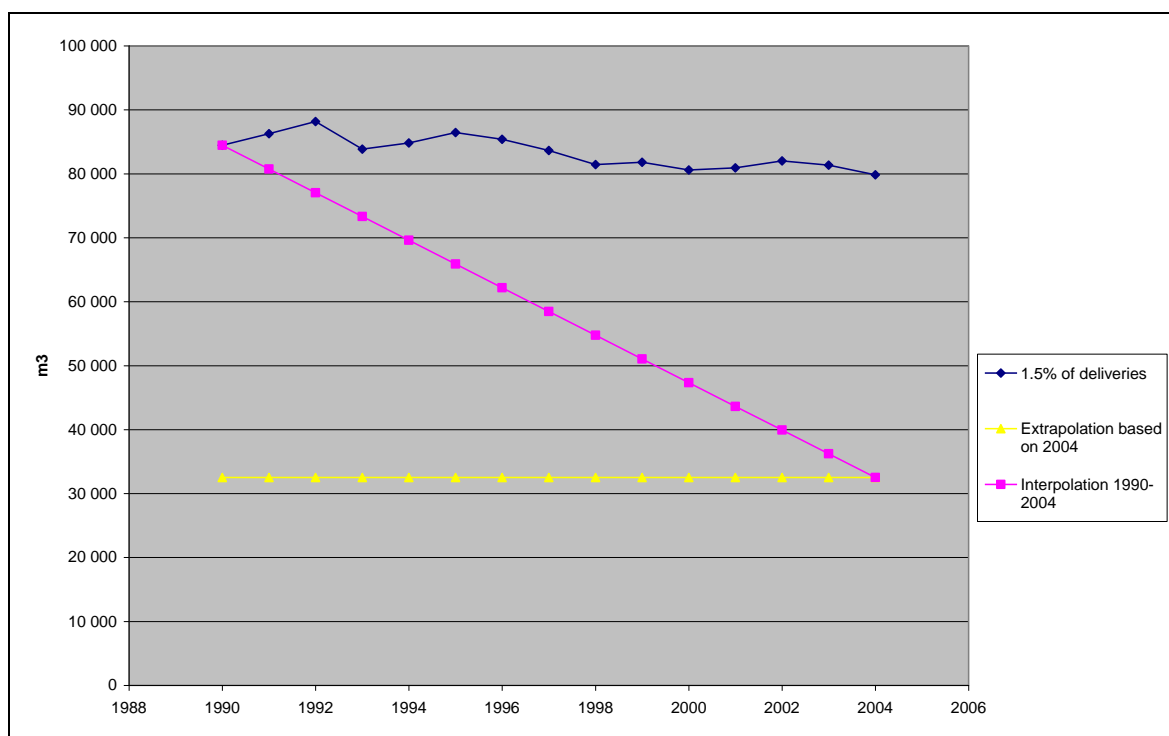
Since there is no strong evidence of any trend in gasoline consumption for leisure boats between 1990 and 2004, and the result from the 2004 survey is considered to be of good quality, we therefore recommend in this report to use the survey result as a constant for the whole time period 1990-2004. Though, fuel consumption and emissions will continuously be presented for all the three approaches.

Data from the two studies on installed effect can be considered to accurately describe the change from a majority of 2-stroke engines in 1990 to a fairly even number of 2- and 4-stroke engines in 2004. Here, it has been assumed that the progress is linear.

### 3 Results

#### 3.1 Gasoline consumption 1990-2004

Figure 1 show the estimated gasoline consumption for leisure boats 1990-2004 for the three approaches: 1.5 % of delivered gasoline, extrapolation based on the 2004 survey, and interpolation 1990-2004.



**Figure 1. Three approaches for gasoline consumption for leisure boats 1990-2004: 1.5% of deliveries, extrapolation based on the 2004 survey, interpolation 1990-2004.**

Table 1 shows the progress 1990-2004 of fuel consumption based on engine type (2-stroke and 4-stroke engines). In 1990, about 79 % of the gasoline was consumed by 2-stroke engines, whereas in 2004, the consumption had dropped to 51 %.

**Table 1. Gasoline consumption divided on 2-stroke and 4-stroke engines 1990-2004.**

Engine type	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
2-stroke	0.51	0.53	0.55	0.57	0.59	0.61	0.63	0.65	0.67	0.69	0.71	0.73	0.75	0.77	0.79
4-stroke	0.49	0.47	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.29	0.27	0.25	0.23	0.21

#### 3.2 Emissions 1990-2003

Figures 2-5 show the implications on emission levels for CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, and NMVOC on the whole sector domestic navigation 1990-2004 for the three different approaches.

Emissions for leisure boats solely for the three approaches are presented in Table I-III in Appendix 1.



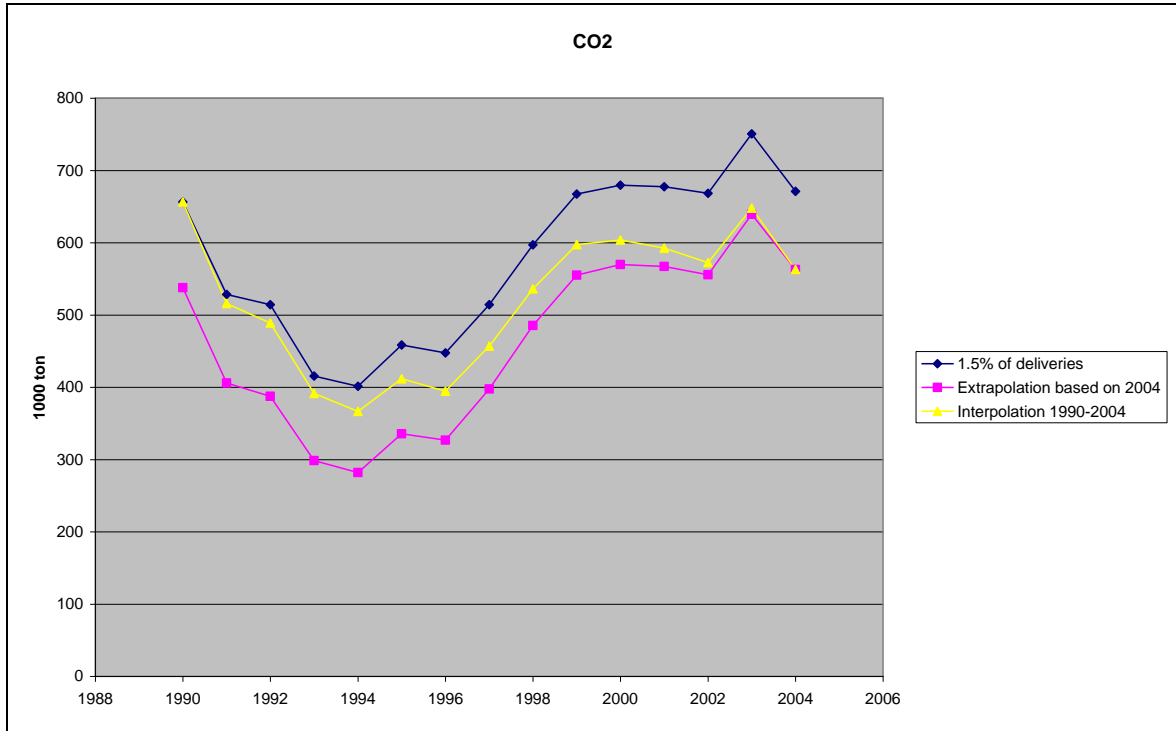


Figure 2. Emissions of CO2 for domestic navigation for the three approaches 1990-2004.

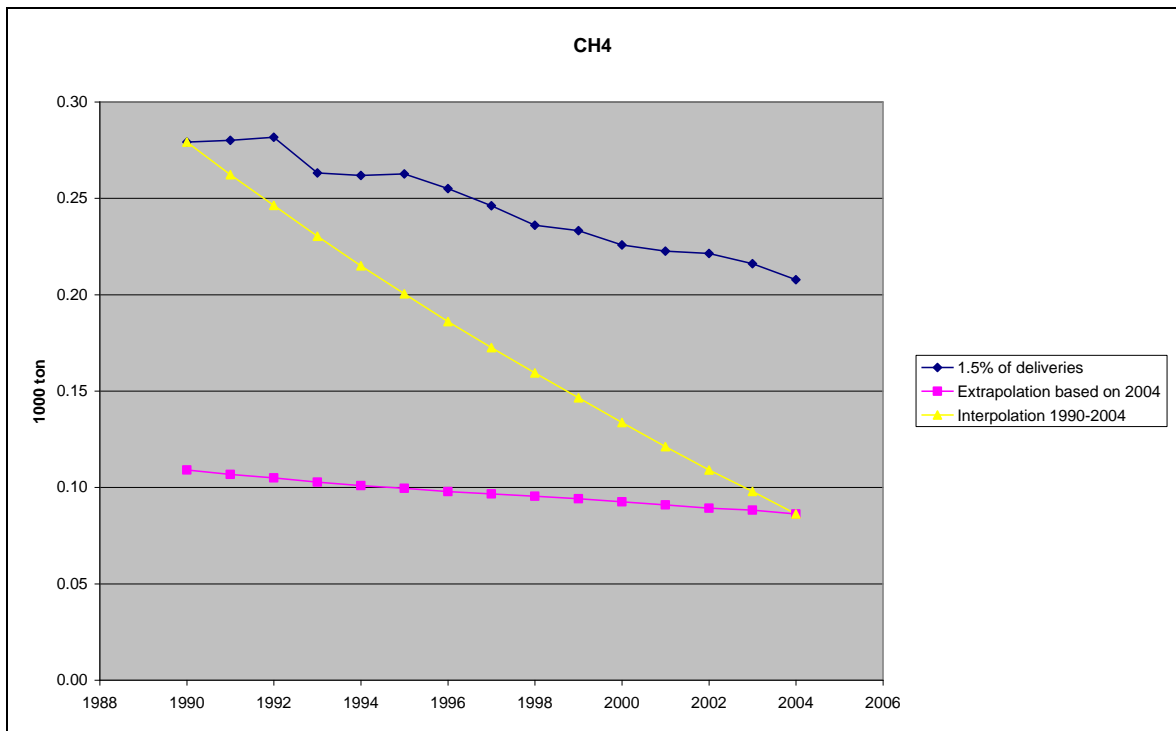


Figure 3. Emissions of CH4 for domestic navigation for the three approaches 1990-2004.

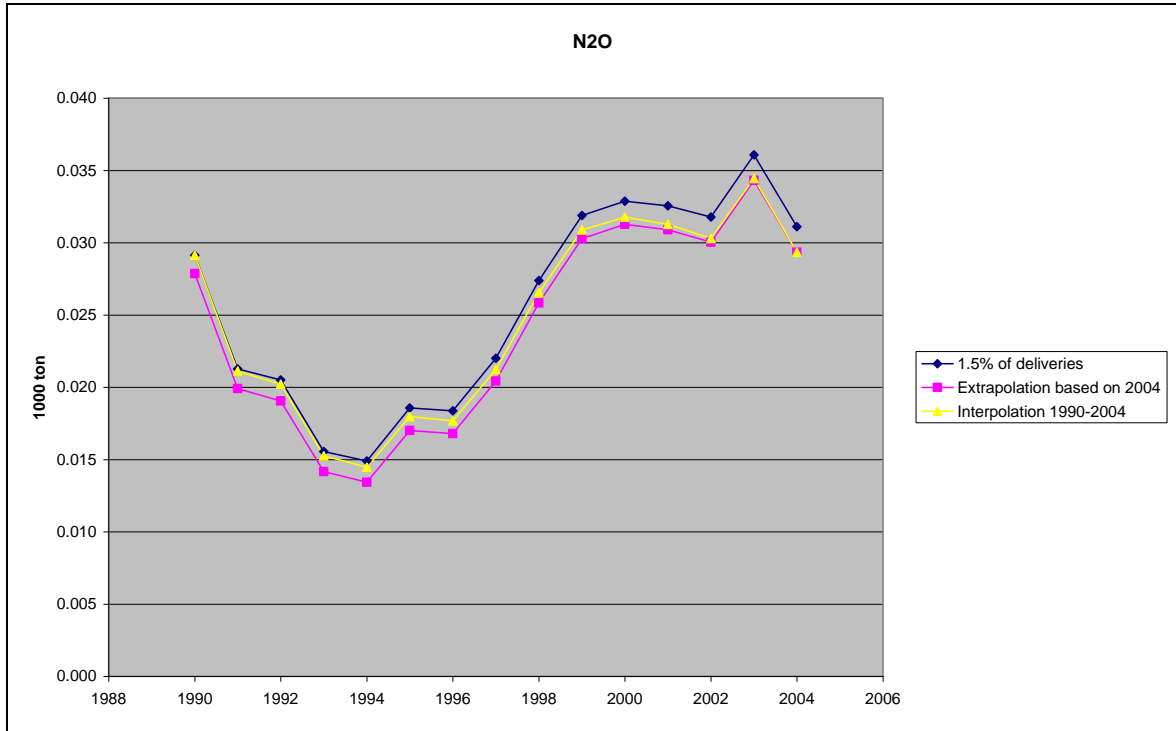


Figure 4. Emissions of N2O for domestic navigation for the three approaches 1990-2004.

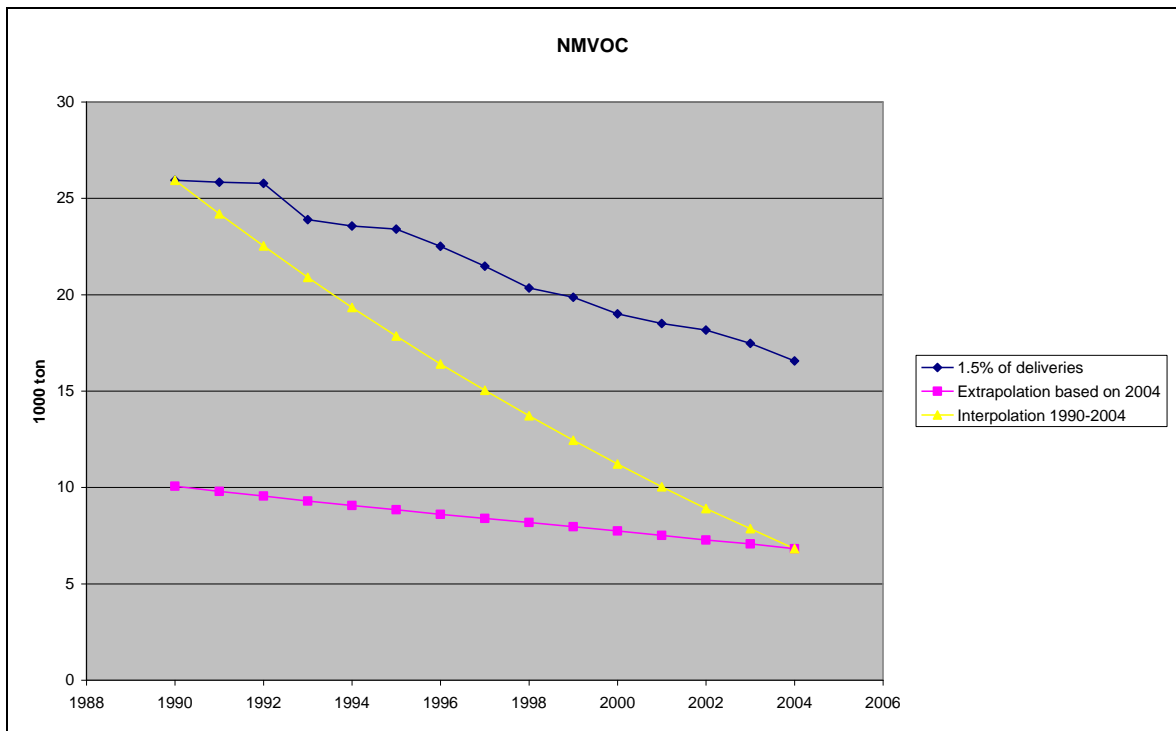


Figure 5. Emissions of NMVOC for domestic navigation for the three approaches 1990-2004.

## **4 Discussion**

### **4.1 Conclusion**

Based on the discussion in chapter 2.3 we recommend that Sweden applies the approach of extrapolation of the 2004 survey results for estimating gasoline consumption and thus emission estimates 1990-2003 (Table II in Appendix 1). In addition, the progress from 1990 to 2004 regarding gasoline consumption divided on 2- and 4-stroke engines (Table 1) should be taken into account when estimating emissions for international reporting.

### **4.2 Future improvements**

At present, only emissions from gasoline leisure boats are accounted for in the Swedish international reporting to the UNFCCC. Information on diesel oil consumption for leisure boats for 1990 is presented in Swedish EPA, 1992. In the 2004 survey, there was information about consumed diesel oil (about 12 000 m<sup>3</sup>). In order to reach full completeness regarding emissions from leisure boats, emissions from diesel oil leisure boats should be estimated and included in the domestic navigation.

In addition, the 2004 survey showed that for 2-stroke engines, about 6 % of the fuel consumption was alkylate gasoline and about 7 % other fuel, including ethanol. This information should be used in future work to improve the quality of the emission estimations.

## References

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## Appendix 1. Fuel consumption and emission estimates for three approaches for leisure boats 1990-2004.

Table I. Assumed consumption: 1.5 % of the national delivered amounts of gasoline.

Year	Fuel consumption (m3)	1000 ton								ton		
		CO2	SO2	NOX	NMVOC	CH4	CO	N2O	NH3	TSP	PM10	PM2,5
1990	84 444	193	0.06	0.26	25.80	0.277	58.216	0.002	0.0003	239	239	239
1991	86 258	197	0.06	0.28	25.74	0.278	59.637	0.002	0.0003	244	244	244
1992	88 165	201	0.07	0.29	25.69	0.280	61.129	0.002	0.0003	249	249	249
1993	83 840	191	0.06	0.29	23.83	0.262	58.295	0.002	0.0003	237	237	237
1994	84 830	193	0.06	0.30	23.51	0.261	59.151	0.002	0.0003	240	240	240
1995	86 440	197	0.06	0.31	23.34	0.261	60.443	0.002	0.0003	244	244	244
1996	85 406	195	0.06	0.32	22.45	0.254	59.888	0.003	0.0003	241	241	241
1997	83 650	191	0.06	0.32	21.39	0.244	58.822	0.003	0.0003	236	236	236
1998	81 441	186	0.06	0.32	20.25	0.234	57.428	0.003	0.0003	230	230	230
1999	81 798	186	0.01	0.33	19.75	0.231	57.841	0.003	0.0003	231	231	231
2000	80 592	184	0.01	0.34	18.89	0.223	57.147	0.003	0.0003	228	228	228
2001	80 913	184	0.01	0.35	18.39	0.220	57.534	0.003	0.0003	229	229	229
2002	81 997	187	0.01	0.36	18.05	0.219	58.466	0.003	0.0003	232	232	232
2003	81 334	185	0.01	0.36	17.32	0.213	58.153	0.003	0.0003	230	230	230
2004	79 832	182	0.01	0.37	16.43	0.205	57.236	0.003	0.0003	226	226	226

**Table II. Extrapolated consumption back to 1990, based on results from the 2004 survey.**

Year	Fuel consumption (m3)	1000 ton								ton			
		CO2	SO2	NOX	NMVOC	CH4	CO	N2O	NH3	TSP	PM10	PM2,5	
1990	32 500	74	0.02	0.10	9.93	0.106	22.406	0.001	0.0001	92	92	92	
1991	32 500	74	0.02	0.10	9.70	0.105	22.470	0.001	0.0001	92	92	92	
1992	32 500	74	0.02	0.11	9.47	0.103	22.534	0.001	0.0001	92	92	92	
1993	32 500	74	0.02	0.11	9.24	0.102	22.598	0.001	0.0001	92	92	92	
1994	32 500	74	0.02	0.11	9.01	0.100	22.662	0.001	0.0001	92	92	92	
1995	32 500	74	0.02	0.12	8.77	0.098	22.726	0.001	0.0001	92	92	92	
1996	32 500	74	0.02	0.12	8.54	0.097	22.790	0.001	0.0001	92	92	92	
1997	32 500	74	0.02	0.12	8.31	0.095	22.853	0.001	0.0001	92	92	92	
1998	32 500	74	0.02	0.13	8.08	0.093	22.917	0.001	0.0001	92	92	92	
1999	32 500	74	0.00	0.13	7.85	0.092	22.981	0.001	0.0001	92	92	92	
2000	32 500	74	0.00	0.14	7.62	0.090	23.045	0.001	0.0001	92	92	92	
2001	32 500	74	0.00	0.14	7.38	0.088	23.109	0.001	0.0001	92	92	92	
2002	32 500	74	0.00	0.14	7.15	0.087	23.173	0.001	0.0001	92	92	92	
2003	32 500	74	0.00	0.15	6.92	0.085	23.237	0.001	0.0001	92	92	92	
2004	32 500	74	0.00	0.15	6.69	0.083	23.301	0.001	0.0001	92	92	92	

**Table III. Interpolated consumption between 1990-2004, using estimates on 1990 and 2004.**

Year	Fuel consumption (m3)	1000 ton								ton		
		CO2	SO2	NOX	NMVOC	CH4	CO	N2O	NH3	TSP	PM10	PM2,5
1990	84 444	193	0.06	0.26	25.80	0.277	58.216	0.002	0.0003	239	239	239
1991	80 733	184	0.06	0.26	24.10	0.260	55.817	0.002	0.0003	228	228	228
1992	77 023	176	0.06	0.25	22.44	0.245	53.404	0.002	0.0002	218	218	218
1993	73 313	167	0.05	0.25	20.84	0.229	50.975	0.002	0.0002	207	207	207
1994	69 603	159	0.05	0.25	19.29	0.214	48.533	0.002	0.0002	197	197	197
1995	65 892	150	0.05	0.24	17.79	0.199	46.075	0.002	0.0002	186	186	186
1996	62 182	142	0.05	0.23	16.34	0.185	43.603	0.002	0.0002	176	176	176
1997	58 472	133	0.04	0.22	14.95	0.171	41.116	0.002	0.0002	165	165	165
1998	54 762	125	0.04	0.22	13.61	0.157	38.615	0.002	0.0002	155	155	155
1999	51 051	116	0.01	0.21	12.33	0.144	36.099	0.002	0.0002	144	144	144
2000	47 341	108	0.00	0.20	11.09	0.131	33.569	0.002	0.0002	134	134	134
2001	43 631	99	0.00	0.19	9.91	0.119	31.024	0.001	0.0001	123	123	123
2002	39 921	91	0.00	0.17	8.79	0.107	28.464	0.001	0.0001	113	113	113
2003	36 210	83	0.00	0.16	7.71	0.095	25.890	0.001	0.0001	102	102	102
2004	32 500	74	0.00	0.15	6.69	0.083	23.301	0.001	0.0001	92	92	92