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NO_X EMISSIONS FROM GASOLINE AND DIESEL OIL COMBUSTION IN MOBILE SOURCES IN EUROPE, 1985

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SUMMARY

This report presents calculations of the emissions of nitrogen oxides (NOx) from combustion of gasoline and diesel oil in mobile sources in Eastern and Western Europe. The mobile source categories considered are road traffic, rail traffic, internal navigation and agricultural tractors.

The calculations are based on national gasoline and diesel oil consumption data and on fuel based emission factors (kg NOx/tonne (metric) fuel).

For calculation of NOx emissions from road traffic, the following model was used for gasoline and diesel separately (Larssen, 1988):

$$Q = M \sum_i P_i \frac{l_i}{l} \frac{T_i}{T}$$

where M is total fuel consumption, P is emission factor (kg/tonne), l is specific fuel consumption (l/km) and T is traffic activity (vehicle·km). The index i sums over all specified driving modes and vehicle classes.

Concerning emission factors, P, for each vehicle class/driving mode, no differentiation was made between countries.

Available statistics is used to estimate the l_i´s and T_i´s for the various vehicle classes and driving modes in each country. The statistical data used is not always consistent, and in some cases incomplete. In such cases estimates have been made based on the available data from other countries. For Eastern European countries, a simplified model is used, due to lack of data.

The emissions have been calculated in a consistent way for all countries. Emissions from all gasoline and diesel oil consumed for road traffic, according to fuel consumption statistics, have been accounted for.

Table S1 gives the results of the calculations.

Table S1: Calculated national NOx emissions from combustion of gasoline and diesel oil in mobile sources in Europe 1985* (10^3 metric tonnes/a, as NO_2).

	Road traffic Gasoline	Road traffic Diesel	Rail traffic	Internal navigation	Agri-culture	Total
Albania	10	5			9[a]	24
Bulgaria	66	50	4	2	25	147
Czechoslovakia	63	73	17	3	35	191
GDR	90	43	14	2	33	182
Hungary	35	45	6	7	35	128
Poland	99	112	11	2	74	298
Romania	77	89	17	2	65	250
European USSR	1 754	332[e]	158		700	2 944
Yugoslavia	115	103	6	4	50	278
Total Eastern Europe	2 309	852	255		1 026	4 442
Austria	89	66	1	4	10	170
Belgium	92	81	2	15	12	202
Denmark	57	59	2	15	24	157
Finland	53	57	1	2	21	134
France	646	399	10	6	115	1 176
FRG	907	429	9	49	63	1 457
Greece	59	60	1	17	39	176
Iceland	3	1	0	11		15
Ireland	26	23	1	0.4	5	55
Italy	404	420	4	23	78	929[c]
Luxemburg	11	10	0.2	0	0.2	21
Netherlands	135	94	1	20	5	255[d]
Norway	53	37	0.3	79[b]	8	177
Portugal	29	31	1	4	18	83
Spain	219	215	4	76	111	625
Sweden	141	67	2	6	18	234
Switzerland	115	34	0.2	0.6	4	154
UK	757	359	14	75	41	1 246
Total Western Europe	3 796	2 442	54	403	572	7 267
Total Europe	6 105	3 294	712		1 598	11 709

a Estimated sum for agricultural tractors, rail and navigation.
b Official national estimate for internal navigation, including the fishing fleet.
c Plus 38 kt from LPG combustion in road traffic (OECD, 1988).
d Plus 13 kt from LPG combustion in road traffic (OECD, 1988).
e This is a careful estimate. A recent estimate of gasoline consumption in passenger cars in USSR as a whole of 24 mill. tonnes in 1984 (Wilson, 1986), results in less gasoline available for road freight transport, and thus increased diesel consumption for this transport. This estimate would increase the NOx emissions from road diesel traffic in the European USSR by about $300 \cdot 10^3$ tonnes/a.

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* The emission estimates are based on the emission factors and statistical data described in this report. The estimates may deviate considerably from emission figures reported by national authorities.

The spatial distribution of the NOx emissions from mobile sources in Eastern Europe within the EMEP grid of 150 km x 150 km is shown in Figure S1. The emissions have been distributed according to the population in each grid. Within this work it has not been possible to take account of the position of the major highway network within the grid system. If this is taken into account, it will affect the NOx distribution somewhat.

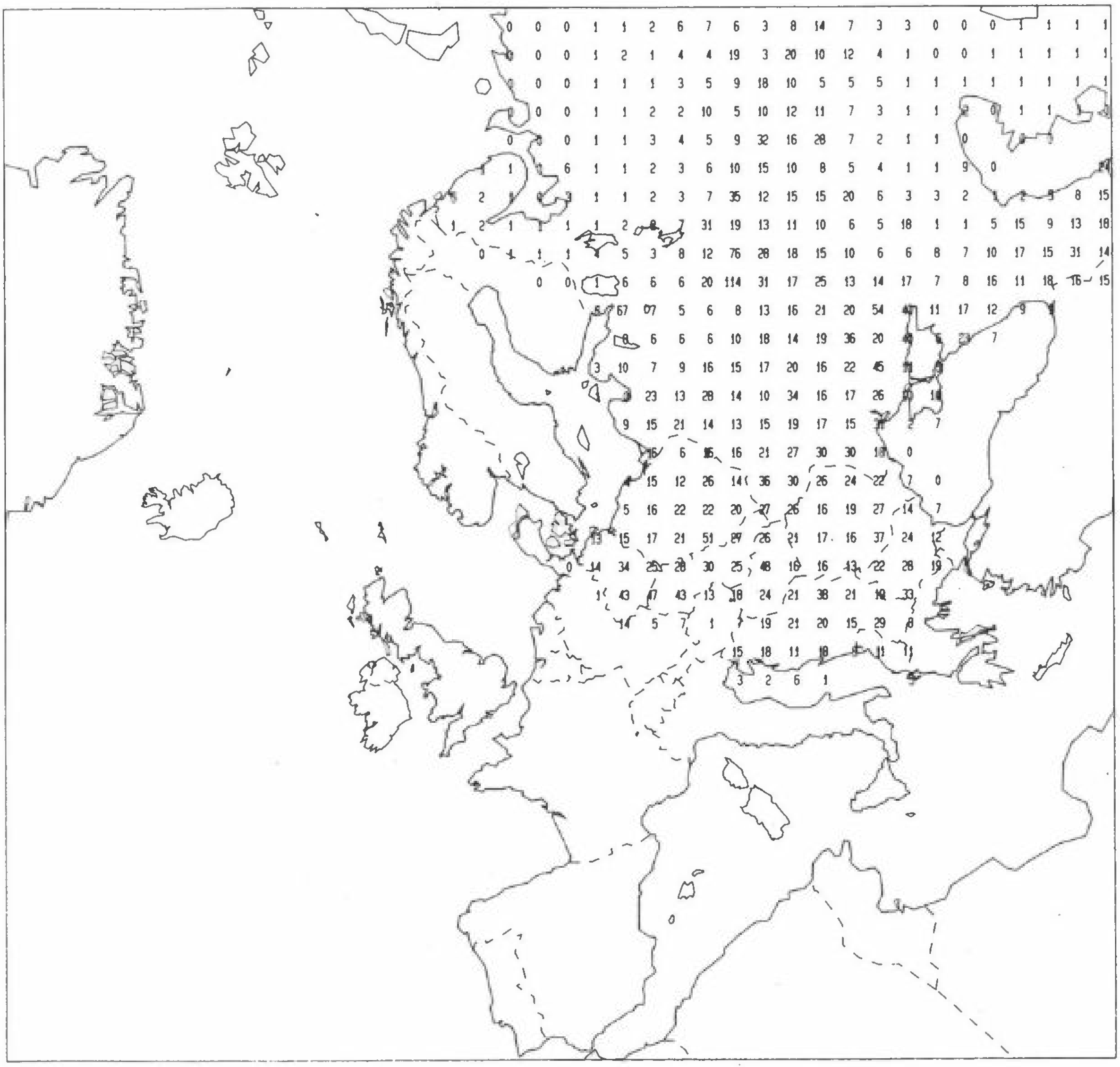

Figure S1: The distribution of NOx emissions from mobile sources in Eastern Europe, within the EMEP grid (10^3 metric tonnes/a, as NO_2).

Uncertainties in the statistical data basis are discussed to some extent in the report.

Our approach of uniform emission factors was a necessity in this project, since very detailed data on national vehicle fleet compositions were not available. Thus, there may be differences in the emission factors used here and those used by national authorities.

Several investigations indicate that the NOx emissions from Otto engines, without 3-way catalyst, increase with reduced ambient temperature in the hot stabilized mode (Larssen, 1988b). The indicated increase is in the range of 10-40% as the temperature decreases from 20^0C to 0^0C. This has not been taken into account in the presented emission figures. For countries of Northern Europe, the indicated increase in annual NOx emissions due to this temperature effect is limited to maximum 15% of the gasoline-related emissions. Thus, the temperature effect may represent 2-8% increase in total mobile NOx emissions. For countries in Central and Southern Europe, this increase will not be significant on an annual basis.

NOx emissions from international maritime navigation have not been estimated in this work. Laikin (1988) has estimated that the NOx emissions in 1983 were about 410 000 tonnes/a from international maritime navigation in European Seas. This constitutes about 3% of the total NOx emissions from mobile sources in Europe, as calculated in this work.

NOx emissions from air traffic have also not been estimated in this work. OECD (1988) has estimated the NOx emissions from air traffic in OECD Europe to be about 85 000 tonnes/a in 1980. This constitutes about 1.3% of the total NOx emissions from mobile sources in OECD Europe, as calculated by OECD.

In Table S2 the emissions calculated in this work is compared to those calculated within the OECD MAP project (OECD, 1988). The OECD emissions were calculated for 1980. The 1985 emissions have been estimated in this work, based on the 1980 emissions and the increase in gasoline and diesel oil consumption from 1980 to 1985 (an increase of 1.3% and 22% for gasoline and diesel oil respectively for OECD Europe as a whole) (OECD, 1987b).

Table S2: Comparison of NOx emissions from mobile sources in OECD Europe (excl. Iceland) calculated in this work and calculated by OECD (10^3 metric tonnes/a, as NO_2).

	This work 1985	OECD 1980	OECD 1985[a]
Road traffic			
Gasoline	3 793	3 800	3 849
Diesel oil	2 441	1 818	2 218
Other fuels		59	
Rail traffic	54	95	
Internal navigation	392	298[b]	
Agricultural tractors	572	402[c]	

a) Estimated in this work
b) "Shipping (incl. harbours)"
c) "Off highway (tractors etc.)"

For road traffic, there is good agreement with the OECD emission figures for OECD Europe as a whole. For individual countries, there are some discrepancies. For internal navigation and agricultural tractors, the emissions of this work are some 30-40% larger than the OECD figures.

CONTENTS

NOx EMISSIONS FROM GASOLINE AND DIESEL OIL COMBUSTION IN MOBILE SOURCES IN EUROPE, 1985

1 INTRODUCTION

The data basis for calculating national NOx emission figures resulting from the combustion of gasoline and motor diesel oil in mobile sources in European countries is described in Appendices A-H. Nearly all gasoline is combusted in Otto engines, mainly in passenger cars, and also in light duty trucks, in motorcycles and mopeds.

The main diesel oil consumption is in diesel engines for road transport. The largest consumption sector is freight transport on roads. Other mobile source sectors considered here are agriculture (mainly tractors and combine harvesters), locomotives and ships (internal navigation). In Western European countries and in some Eastern European countries, combustion of diesel oil ("gas oil") in stationary furnaces and units for production of heat, electricity and mechanical work represents a large consumption sector.

In some countries, notable Italy and The Netherlands, liquid petroleum gas (LPG) is used to some extent in automobiles. The NOx emission from LPG combusted in cars in OECD Europe represents an about 1% addition to the emissions from gasoline and diesel combustion in road traffic. Emissions from LPG in mobile sources are not considered further in this report.

In this report, NOx emission factors and figures should always be understood "as NO_2".

The following appendices presents the statistical data basis:

Appendix A: Car populations in Europe.
Appendix B: Driving modes for road traffic.
Appendix C: Specific fuel consumption for various road vehicle categories.

It should be added that this work is only a part of the project on NOx emissions in Europe. The other parts include: 1) the calculation of NOx emissions from stationary sources in Eastern Europe, 2) the estimation of NOx emissions from stationary combustion sources in Western Europe, and 3) a comprehensive report on NOx emissions in Europe in 1985.

2 NOx EMISSIONS FROM ROAD TRAFFIC

2.1 CALCULATION MODEL

The specific NOx emission (emission per driven length or per fuel unit consumed) from road vehicles depends mainly on the following parameters:

- Fuel type (gasoline, diesel oil)
- Vehicle category (gross vehicle weight, engine size)
- Driving mode (average vehicle speed, speed variation).

Also, investigations indicate that the ambient temperature has an effect on the NOx emissions from gasoline-powered engines in the hot stabilized mode. Emissions seem to increase considerably with decreasing ambient temperature (Larssen, 1988b). The NOx emissions during cold start are not significantly higher than with hot engine, contrary to what is the case with for instance CO og VOC.

NOx emission calculations from road traffic may be based on fuel consumption or traffic activity data. The following calculation models may be used for gasoline and diesel separately, to calculate NOx emissions on the national level (Larssen, 1988):

Fuel consumption basis: $$Q = M \sum_i p_i \frac{l_i}{l} \frac{T_i}{T}$$

Traffic activity basis: $$Q = T \sum_i q_i \frac{T_i}{T}$$

where

- i indexes the various vehicle classes and driving modes
- Q total NOx emission (kg/a)
- M total fuel consumption for road traffic (metric tonnes/a)
- T total traffic activity (vehicle-km/a)
- T_i traffic activity for the i´th vehicle class/driving mode (km/a)
- p_i NOx emission factor based on fuel consumption for the i´th vehicle class/driving mode (kg/tonne)
- q_i NOx emission factor based on driven distance for the i´th vehicle class/driving mode (kg/km)
- l specific fuel consumption, averaged over all vehicle classes and driving modes (l/km)
- l_i specific fuel consumption for the i´th vehicle class/driving mode (l/km)

For gasoline-powered engines, both models may be used to calculate Q, on the condition that M and T represent the total fuel consumed and the total traffic activity, respectively. For gasoline-powered engines, we consider the emission factors p_i and q_i to be equally well determined as a function of vehicle class and driving mode. However, it seems that statistical figures for total fuel consumption are more accurate at the national level than independently determined traffic activity figures.

For diesel-powered engines, the fuel based emission factors, p_i, are considerably more stable, i.e. vary much less with vehicle class and driving mode, than the q_i (g/km) emission factors (Larssen, 1988b). Also for diesel oil, M is considered a generally more accurate figure than T on the national level.

Thus, the national emissions are calculated using the model based on total fuel consumption, M (tonnes/a). The calculated emissions will be proportional to the national fuel consumption figures. The main uncertainties are associated with the emission factors, assuming the fuel consumption figures reported reflect real consumption. For many Eastern European countries, fuel consumption data for mobile sources are not available, hence estimates are made, extrapolating information from other countries (see Appendix H).

The distribution of fuel consumption between the different vehicle/ driving mode categories will also, if estimated incorrectly, affect the accuracy of the calculated emissions. For the model used, the calculated total NOx emissions from each fuel type are not, however, very sensitive to moderate errors in this distribution.

In our calculations, the vehicle classes and driving modes given in Table 1 are considered.

Table 1: Definition of vehicle classes and driving modes considered in our calculations.

VEHICLE CLASSES		DRIVING MODES[a]	
GASOLINE	DIESEL	PC AND LDT	HDT
Passengers cars (PC)[b]	Passengers cars (PC)	Urban (10-50 km/h)	Urban (10-50 km/h)
Light duty trucks (LDGT) (GVW < 3.5 t)	Light duty trucks (LDDT) (GVW < 3.5 t)	Rural (50-80 km/h)	Rural (50-80 km/h)
Heavy duty trucks (HDGT) Motorcycles (MC) and mopeds	Heavy duty trucks (HDDT) (GVW > 3.5 t)[c]	Highway/motorway - 80 km/h - 100 km/h - 120 km/h	Highway/motorway (80-100 km/h)

GVW: Gross vehicle weight.
a) See Appendix B.
b) Sub-categories: 4-stroke and 2-stroke.
c) In the emission factor estimation, two vehicle classes, with GVW ≷ 7 t, are considered.

For some parameters, the available data basis allow for differentiation between countries. For other parameters, the data basis is not specific enough to allow for differentiation:

- The distribution of vehicles in different categories is calculated from national vehicle statistics (Appendix A).

- In distributing the total traffic activity in driving modes, some differentiation is made for passenger cars, based on available statistics of length of motorways relative to the total road network length (see Appendix B).

- For each vehicle class/driving mode, the same emission factors are used in all countries. This implies that we do not differentiate on the basis of the distribution of vehicle models, engine size and vehicle weight and age in the national car populations. Such data are not easily available, and it is believed that corrections for differences in these distributions are, for NOx emissions, second order to the corrections made for national differences in vehicle class and driving mode distributions.

The mobile source NOx emissions calculated by this model deviate for some countries from emission figures reported by national authorities. Deviations may be caused by the following factors:

- Inaccuracies in the fuel consumption statistics and estimates used in this work.

- Differences in emission factors, due to significant deviations in national vehicle fleets from the ones our uniform emission factors are based on.

- Deviations in the distribution of driving modes from the assumed distributions.

- In many cases, national emission estimates have been derived from traffic activity data, and not from fuel consumption. Traffic activity and fuel consumption data are not easily reconciled, particularly not for heavy vehicle transport and diesel fuel.

Zierock et al. (1988) have proposed very similar methods to be used in calculating road traffic emissions within the CORINAIR project. Within that project national experts in each country are available to evaluate national data on the distribution of traffic activity between the vehicle and driving mode categories. This makes possible one further step in the model: to iterate the process of distributing the traffic work within vehicle and driving mode categories, until agreement is reached between reported fuel consumption and calculated fuel consumption for each country based on the adjusted traffic activity data and specific fuel consumption data. This last step will improve somewhat the accuracy of the emission estimates, provided the iteration process is based on real traffic activity and fuel consumption data.

2.2 NOx EMISSION FACTORS FOR ROAD VEHICLES

Table 2 shows the NOx emission factors used in the calculation of national NOx emissions. The basis for selecting these factors is given in Appendix D. When selecting the emission factors for gasoline-powered passenger cars, results of measurements made during actual driving, and measurements using actual urban driving modes have been emphasized (Larssen, 1988b).

Zierock et al. (1988) have proposed speed-dependent emission factors to be used in the CORINAIR project. Emission factors are given for different car categories according to the ECE regulations from R15-00/01 to R15-04 (and also pre 1971), and for three engine size categories (<1.4 l, 1.4-2 l, >2 l). The proposed NOx emission factors, in terms of g NOx/kg fuel, are somewhat higher than those used in this work. For gasoline cars, the gross average factor for 1.4-2 l engines is about 8% larger than used in this work as an average for all passenger cars, assuming a traffic activity distribution of 35%/35%/20%/10% in the urban/rural/highway/motorway modes respectively. Taking account of the other engine size categories will change this 8% increase only slightly. For heavy duty diesel vehicles, the gross average emission factor is some 15% larger than used in this work, assuming a distribution of 34%/33%/33% in the urban/rural/highway modes.

Table 2: Selected NOx emission factors (g/kg, as NO_2) for road vehicles.

Driving mode Average speed, km/h	URBAN 10-50	RURAL 50-80	HIGHWAY/MOTORWAY 80	 100	 120
Passenger cars					
Gasoline					
- 4 stroke	23	41	44	55	62
- 2 stroke	7 (gross average)				
Diesel	15 (gross average)				
Light duty trucks (GVW < 3.5 t)					
Gasoline	42 (gross average)				
Diesel	15 (gross average)				
Heavy duty vehicles (GVW > 3.5 t)					
Diesel trucks	50	55	60 (average)		
Diesel buses	50	60	70 (average)		
Gasoline trucks	36 (gross average)				
Motorcycles and mopeds, gasoline	5.5 (gross average)				

2.3 NOx EMISSIONS FROM GASOLINE-POWERED ROAD VEHICLES

Eastern Europe

Table 3 shows calculated NOx emissions from gasoline-powered road vehicles in Eastern European countries.

Table 3: NOx emissions from gasoline-powered road vehicles, Eastern European countries, 1985.

	Gasoline consumption 10^3 tonnes 1984 (UN, 1986)	Passenger cars		Trucks		MC/moped		NOx emissions
		p_i kg/t	$\frac{Mi}{M}$	p_i kg/t	$\frac{Mi}{M}$	p_i kg/t	$\frac{Mi}{M}$	10^3 tonnes
Albania	270	36	0.95[e]	40	g	5.5	0.05[f]	9.6
Bulgaria	1 800	36	0.45	40	0.50	5.5	0.05[f]	65.7
Czechoslovakia	1 778	36	0.95	40	0	5.5	0.05[f]	63.0
GDR	3 438	18[d]	0.53	40	0.41	5.5	0.06[h]	90.3
Hungary	1 271[a]	27[d]	0.85	40	0.10	5.5	0.05[f]	34.6
Poland	2 783[b]	36	0.54[b]	40	0.38[b]	5.5	0.08[b]	99.1
Romania	2 186	36	0.95[e]	40	g	5.5	0.05[f]	77.4
European USSR	47 000[c]	36	0.21	40	0.74	5.5	0.05[f]	1 759.4
Yugoslavia	3 295	36	0.86	40	0.09	5.5	0.05[f]	114.8

a) IRF 1985.
b) National estimates, 1985 (Jagusiewicz, 1988).
c) USSR x 0.69 (population ratio).
d) Percent 2-stroke: GDR: 65%; Hungary: 35%.
e) Passenger cars + light duty trucks.
f) estimated.
g) unknown. Included in "passenger cars".
h) DIW (1988).

The emission factor for passenger cars with 4-stroke engine is based on a driving mode distribution of 35%/35%/30% in the urban/rural/highway (80-100 km/h) modes respectively, as estimated for Western European countries with less than 0.5% motorways (Appendix B).

For Eastern European countries, a simplified model is used:

$$Q = \sum_i p_i M_i$$

since little is known about the traffic activity of the various vehicle classes.

The fraction of total gasoline consumption (M_i/M) used by passenger cars has been estimated from the number of cars (Table A6), data on annual average distance driven (AADD, Table E4) and specific fuel consumption (Table 7). Where AADD data are not available, 10 000 km/a has been used. For Albania and Romania, where no estimate on car population is available, all gasoline is considered used in passenger cars, except the 5% used by MC/mopeds (estimated based on GDR and Polish national data). For USSR, an estimate of 17.5 mill. cars have been used.

The rest of the gasoline is assumed used in trucks, for freight transport. These estimates result in a large portion of the gasoline consumed in Bulgaria, GDR and the USSR being used in trucks for freight transport.

Table 4 shows the calculated per capita consumption of gasoline in each country, total, in passenger cars, and in trucks. The rest is used in motorcycles/mopeds. The gasoline consumption in trucks in the USSR covers most of the energy needed for the reported road freight work (see Section 1.4 and Appendix H).

Table 4: Calculated per capita consumption of gasoline. The total is based on UN statistics for 1984 (UN, 1986).

	kg gasoline/capita		
	total	consumed by passenger cars	consumed by trucks
Albania	90	86	0
Bulgaria	196	88	98
Czechoslovakia	114	108	≈ 0
GDR	206	109	84
Hungary	118	100	12
Poland	75	41	29
Romania	90	85	0
USSR	247	52	183
Yugoslavia	143	123	13

Western Europe

Tables 5 and 6 show calculated NOx emissions in Western European countries for passenger cars and for light duty trucks and MC/mopeds respectively.

The fuel consumption figures are from OECD statistics (OECD, 1987b) or from national statistics.

The emission factors used are given in Table 2. Table 7 gives the specific fuel consumption figures used (see Appendix C).

The estimated distribution of traffic activity in urban/rural/highway modes for passenger cars, are given in Table B3 in Appendix B, for each country.

The traffic activity distribution between vehicle classes used for each country is based on the statistics given in Appendix E, and is shown in Table 8. The diesel car percentage enters into this calculation. For passenger cars, we have estimated that the diesel car percentage in 1985 is 70% higher than reported to OECD for 1980 (OECD, 1987), based on some national data (see Table A5 in Appendix A). We have assumed that the annual average distance driven is 60% larger for diesel cars than for gasoline cars (see Table A5 in Appendix A).

Table 5: NOx emissions from gasoline-powered passenger cars, Western European countries, 1985.

	Gasoline consump. 10^3 tonnes	Urban				Rural				Highway (80-100)				Motorway (120)				$Q_{PC,gas}$ 10^3 t
		p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_U 10^3 t	p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_R 10^3 t	p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_H 10^3 t	p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_M 10^3 t	
Austria	2 405	23	1.29	0.90·0.35	22.5	41	0.82	0.90·0.25	18.1	50	0.82	0.90·0.20	17.7	62	0.93	0.90·0.2	25.0	83.3
Belgium	2 501	23	1.29	0.93·0.35	26.0	41	0.82	0.93·0.30	23.7	50	0.82	0.93·0.25	24.1	62	0.93	0.93·0.1	13.5	86.3
Denmark	1 502[a]	23	1.29	0.85·0.35	13.2	41	0.82	0.85·0.30	12.9	50	0.82	0.85·0.25	13.1	62	0.93	0.85·0.1	7.4	46.6
Finland	1 504	23	1.29	0.93·0.35	14.6	41	0.82	0.93·0.35	16.5	50	0.82	0.93·0.30	17.2	62	0.93	0.93·0.0	0	48.3
France	17 776	23	1.29	0.82·0.35	149.2	41	0.82	0.82·0.30	147.0	50	0.82	0.82·0.25	149.4	62	0.93	0.82·0.1	84.0	529.6
FRG	22 940[a]	23	1.29	0.95·0.35	226.2	41	0.82	0.95·0.20	146.5	50	0.82	0.95·0.20	178.7	62	0.93	0.95·0.25	314.2	865.6
Greece	1 736	23	1.29	0.89·0.35	16.0	41	0.82	0.89·0.35	18.1	50	0.82	0.89·0.30	19.0	62	0.93	0.89·0.0	0	53.1
Iceland	99	23	1.29	0.95·0.35	1.0	41	0.82	0.95·0.35	1.1	50	0.82	0.95·0.30	1.1	62	0.93	0.95·0.0	0	3.2
Ireland	841	23	1.29	0.92·0.35	8.0	41	0.82	0.92·0.35	9.1	50	0.82	0.92·0.30	9.5	62	0.93	0.92·0.0	0	22.6
Italy	11 103	23	1.29	0.84·0.35	97.9	41	0.82	0.84·0.20	63.4	50	0.82	0.84·0.20	77.4	62	0.93	0.84·0.25	136.1	370.4
Luxemburg	303	23	1.29	0.92·0.35	2.9	41	0.82	0.92·0.30	2.8	50	0.82	0.92·0.25	2.9	62	0.93	0.92·0.1	1.6	10.2
Netherlands	3 389	23	1.29	0.90·0.35	32.0	41	0.82	0.90·0.20	20.7	50	0.82	0.90·0.20	25.3	62	0.93	0.90·0.25	44.4	122.4
Norway	1 518[a]	23	1.29	0.89·0.35	14.0	41	0.82	0.89·0.35	15.9	50	0.82	0.89·0.30	16.6	62	0.93	0.89·0.0	0	46.5
Portugal	854	23	1.29	0.98·0.35	8.7	41	0.82	0.98·0.35	9.8	50	0.82	0.98·0.30	10.2	62	0.93	0.98·0.0	0	28.7
Spain	5 894[a]	23	1.29	0.92·0.35	56.3	41	0.82	0.92·0.30	54.6	50	0.82	0.92·0.25	55.6	62	0.93	0.92·0.1	31.3	197.8
Sweden	3 801[a]	23	1.29	0.95·0.35	37.5	41	0.82	0.95·0.30	36.4	50	0.82	0.95·0.25	37.0	62	0.93	0.95·0.1	20.8	131.7
Switzerland	3 026	23	1.29	0.83·0.35	26.1	41	0.82	0.83·0.25	21.1	50	0.82	0.83·0.20	20.6	62	0.93	0.83·0.2	28.0	96.7
UK	20 403	23	1.29	0.92·0.35	194.8	41	0.82	0.92·0.30	189.3	50	0.82	0.92·0.25	192.4	62	0.93	0.92·0.1	108.2	684.7

a Data from national sources, 1985.

Table 6: NOx emissions from gasoline-powered light duty trucks and motorcycles/mopeds, Western European countries, 1985.

		Light duty trucks				Motorcycles/mopeds			
	Total gasoline consumption 10^3 t	$\frac{l_1}{l}$	$\frac{T_i}{T}$	p_i kg/t	$Q_{LDGT, gas}$ 10^3 t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	P_i	Q_{MC} 10^3 t
Austria	2 405	1.40	0.04	42	5.7	0.2	0.06	5.5	0.16
Belgium	2 501	1.40	0.04	42	5.9	0.2	0.03[b]	5.5	0.08
Denmark	1 502[a]	1.40	0.12	42	10.6	0.2	0.03	5.5	0.05
Finland	1 504	1.40	0.05	42	4.4	0.2	0.02	5.5	0.03
France	17 776	1.40	0.11	42	115.0	0.2	0.07	5.5	1.37
FRG	22 940[a]	1.40	0.03	42	40.5	0.2	0.02	5.5	0.50
Greece	1 736	1.40	0.06	42	6.1	0.2	0.05	5.5	0.09
Iceland	99	1.40	0.03	42	0.2	0.2	0.02	5.5	0.002
Ireland	841	1.40	0.06	42	3.0	0.2	0.02	5.5	0.02
Italy	11 103	1.40	0.05	42	32.6	0.2	0.11	5.5	1.34
Luxemburg	303	1.40	0.06	42	1.1	0.2	0.02	5.5	0.006
Netherlands	3 389	1.40	0.06	42	12.0	0.2	0.04	5.5	0.15
Norway	1 518[a]	1.40	0.07	42	6.3	0.2	0.04	5.5	0.07
Portugal	854	1.40	0.00	42	0.0	0.2	0.02	5.5	0.02
Spain	5 894[a]	1.40	0.06	42	20.9	0.2	0.02	5.5	0.13
Sweden	3 801[a]	1.40	0.04	42	8.9	0.2	0.01	5.5	0.04
Switzerland	3 026	1.40	0.10	42	17.8	0.2	0.07	5.5	0.23
UK	20 403	1.40	0.06	42	72.0	0.2	0.02	5.5	0.54

a) Data from national sources, 1985.
b) Assumed.

Table 7: Specific fuel consumption figures, gasoline.

	1/100 km
Passenger cars (4 stroke), average	10.7
- urban	13.8
- rural	8.8
- highway 80-100 km/h	8.8
- motorway 120 km/h	9.9
Passenger cars (2 stroke)	5
Light duty trucks	15
Heavy duty trucks	30
MC/mopeds	2.25

Table 8: Traffic activity distribution (%), gasoline-powered road vehicles, Western European countries.

	Passenger cars	Light duty trucks	Motorcycles/ mopeds
Austria	90	4	6
Belgium	94	3.5	2.5 (estimated)
Denmark	85	11.5	3.5
Finland	93	5	2
France	82	11	7
FRG	95	3	2
Greece	89[a]	6[a]	5[a]
Iceland	95	3	2[a]
Ireland	92[a]	6[a]	2[a]
Italy	85	4	11
Luxemburg	92[a]	6[a]	2[a]
Netherlands	90	6	4
Norway	89	7	4
Portugal	98	0	2
Spain	93	5.5	1.5
Sweden	95	4	1
Switzerland	83	10	7
UK	92	6	2

a estimated

When calculating gasoline consumption based on traffic activity and the specific consumptions from Table 7, the result is for some countries (Belgium, Denmark, Finland, France, Italy, Netherlands, Spain) a higher consumption than that reported to OECD (see Appendix G, Table G1). Reasons for this discrepancy may be that for some of these countries the average specific consumption for PC´s of 10.7 l/100 km is too large, and also that for some smaller countries, tanking and driving abroad may contribute somewhat to the discrepancy. These discrepancies have only a minor influence on the calculated total gasoline NOx emissions, provided the OECD consumption figures are correct, since there is little difference in emission factor for the major gasoline-powered vehicles (PC and LDT).

2.4 NOx EMISSIONS FROM DIESEL-POWERED ROAD VEHICLES

Eastern Europe

Table 9 shows calculated NOx emissions from diesel-powered road vehicles in Eastern European countries. The simplified model is used:

$$Q = \sum_i p_i M_i$$

National estimates of diesel oil consumption for road traffic as a whole are available for Czechoslovakia, GDR, Hungary and Poland (Table G5). For the other Eastern European countries, the diesel oil consumption by road traffic is estimated based on the consumption data for the above countries, and also on data from Western European countries, and on the freight work and bus passenger transport volume reported by each country (see Appendix H). Then account is taken of the gasoline consumed by road freight traffic, as calculated in Section 1.3.

Emission factors, p_i, are based on Table 2. The category "trucks" includes both light duty and heavy duty vehicles. There is no data on the light/heavy duty truck distribution in Eastern European countries, except for Czechoslovakia, where IRF gives 23% light duty trucks out of total number of trucks. In Austria, Belgium, Denmark, Finland, France, FRG, Netherlands, Norway and Sweden, the average figure is 17% light duty trucks out of the total number of trucks. Using 20% for Eastern European countries, the resulting gross average emission factor for "trucks" is 47 g/kg. We have then assumed a traffic activity distribution of 34%/33%/33% in the urban, rural and highway modes respectively.

For buses, a traffic activity of 45%/45%/10% in urban/rural/highway modes is assumed. This gives an average emission factor of 57 g/kg.

Table 9: NOx emissions, diesel-powered road vehicles, Eastern European countries, 1985.

	PC			Trucks			Buses			
	M 10^3 t	p_i kg/t	Q 10^3 t	M 10^3 t	p_i kg/t	Q 10^3 t	M 10^3 t	p_i kg/t	Q 10^3 t	Q_{diesel} 10^3 t
Albany	14	15	0.2	90	47	4.2	14	57	0.8	5.2
Bulgaria	50	15	0.8	736	47	34.6	247	57	14.1	49.5
Czechoslovakia	89	15	1.3	1 078	47	50.7	366	57	20.9	72.9
GDR	0	15	0	640	47	30.1	218	57	12.4	42.5
Hungary	64	15	1.0	639	47	30.0	251	57	14.3	45.3
Poland	209	15	3.1	1 945	47	91.4	314	57	17.9	112.4
Romania	109	15	1.6	1 561	47	73.4	240	57	13.7	88.7
European USSR	2 350	15	35.3	2 850	47	134.0	2 850	57	162.5	331.8
Yugoslavia	165	15	2.5	1 758	47	82.6	319	57	18.2	103.3

The quality of the diesel oil consumption estimates in Table 9 is dependent upon the quality of the freight and passenger transport work data reported by each country, and on the assumption that the energy consumption per work unit is the same as the average for Western European countries.

The estimated emissions from the USSR are uncertain, since there is very little available information on the car population. However, annual production of passenger cars during the period 1975-1984 was 1.2-1.5 million. Assuming on average car life of 12-13 years, and neglecting car export, it can be estimated that there are 15-20 mill. passenger cars in the country. With an annual average distance driven of 10 000 km, and an average fuel consumption of 11 l/10 km, this represents a gasoline consumption of 12-16 10^3 metric tonnes, or 45-60 kg/capita. The rest (except 5% used in MC/mopeds) is assumed used in trucks, representing about 180 kg/capita for freight work (Table 4). Based on the estimates of total energy requirement for road freight transport given in Appendix H, it is found that only about

15 kg diesel oil per capita is needed in addition to the gasoline. There is no basis available for evaluating whether this is correct. In this way, however, the energy required for the road transport work in the USSR is taken into account, and the resulting total NOx emissions from road traffic is the best available estimate.

Western Europe

Table 10 shows calculated NOx emissions from diesel-powered road vehicles in Western European countries.

The fuel consumption data are from OECD statistics (OECD, 1987b) or from national statistics.

The traffic activity for each vehicle class in each country is calculated from AADD data (OECD, 1987) (Appendix E) and 1985 data for vehicle populations (Appendix A). For heavy duty trucks, we have assumed the traffic activity distribution 34%/33%/33% in the urban/rural/highway mode, respectively.

Table 10: NOx emissions from diesel powered road vehicles, Western European Countries, 1985.

	Total diesel consump. road traf. 10^3 tonnes	PC				LDDT				HDDT				BUS				
		p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_{PC} 10^3 t	p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_{LDDT} 10^3 t	p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_{HDDT} 10^3 t	p_i kg/t	$\frac{l_i}{l}$	$\frac{T_i}{T}$	Q_{BUS} 10^3 t	Q_{diesel} 10^3 t
Austria	1 459	15	0.46	0.43	4.3	15	0.68	0.11	1.7	55	1.58	0.40	50.7	57	1.84	0.06	9.2	65.9
Belgium	2 391	15	0.64	0.71	16.3	15	0.95	0.08	2.7	55	2.19	0.19	54.7	57	2.55	0.02	7.0	80.7
Denmark	1 331[a]	15	0.40	0.20	1.6	15	0.59	0.27	3.2	55	1.36	0.45	44.8	57	1.59	0.08	9.6	59.2
Finland	1 299	15	0.46	0.45	4.0	15	0.68	0.12	1.6	55	1.58	0.33	37.3	57	1.84	0.10	13.6	56.5
France	10 520	15	0.52	0.38	31.2	15	0.76	0.31	37.2	55	1.76	0.27	275.0	57	2.06	0.045	55.6	399.0
FRG	11 645[a]	15	0.59	0.65	67.0	15	0.87	0.10	15.2	55	2.00	0.21	269.0	57	2.33	0.05	77.3	428.5
Greece	1 200	15	0.35	0.11	0.8	15	0.52	0.20	2.2	55	1.21	0.59	47.1	57	1.41	0.10	9.6	59.7
Iceland	32	15	0.47	0.52	0.14	15	0.70	0.08	0.03	55	1.60	0.19	0.54	57	1.87	0.21	0.72	1.4
Ireland	516	15	0.43	0.29	0.1	15	0.64	0.23	1.2	55	1.48	0.40	16.8	57	1.72	0.08	4.0	23.0
Italy	11 388	15	0.57	0.59	57.4	15	0.84	0.14	20.1	55	1.95	0.22	268.7	57	2.27	0.05	73.7	419.9
Luxemburg	184	15	0.34	0.15	0.2	15	0.51	0.05	0.1	55	1.17	0.70	8.3	57	1.37	0.10	1.4	10.0
Netherlands	2 660	15	0.59	0.65	15.3	15	0.87	0.11	3.8	55	2.00	0.19	55.6	57	2.33	0.055	19.4	94.1
Norway	594[a]	15	0.40	0.28	10.0	15	0.59	0.18	0.9	55	1.36	0.40	17.8	57	1.59	0.15	8.1	36.8
Portugal	1 244	15	0.62	0.20	2.3	15	0.92	0.69	11.8	55	2.13	0.09	13.1	57	2.48	0.02	3.5	30.7
Spain	5 500	15	0.51	0.42	17.7	15	0.76	0.25	15.7	55	1.75	0.27	142.9	57	2.05	0.06	38.6	214.9
Sweden	1 409	15	0.40	0.37	3.2	15	0.59	0.05	0.7	55	1.36	0.49	51.7	57	1.59	0.09	11.4	67.0
Switzerland	671	15	0.35	0.18	0.7	15	0.52	0.12	0.7	55	1.20	0.51	22.6	57	1.40	0.18	9.6	33.6
UK	7 106	15	0.36	0.20	9.2	15	0.53	0.12	8.1	55	1.22	0.51	243.2	57	1.42	0.17	97.8	358.3

a Data from national sources, 1985.

For passenger cars, we have taken account of the following, when calculating the diesel car traffic activity:

- % diesel cars in 1985 was 70% larger than reported to OECD for 1980 as an average for five countries for which data are available (Appendix A, Table A5).

- the AADD for diesel passenger cars was 60% higher than for gasoline passenger cars, as an average for three countries for which data are available (Appendix A, Table A5).

The specific diesel fuel consumption figures (l_i) used, are the following:

Passenger cars	: 8.8	l/100 km
Light duty trucks	: 13	l/100 km
Heavy duty trucks	: 30	l/100 km
Buses	: 35	l/100 km

The gross average specific fuel consumption figure (l) for each country was calculated by weighting l_i with traffic activity for each vehicle class. Results are shown in Table 11.

Table 11: Calculated gross average diesel consumption (l/100 km).

	l/100 km		l/100 km
Austria	19	Italy	17
Belgium	14	Luxemburg	27
Denmark	21	Netherlands	15
Finland	19	Norway	22
France	17	Portugal	23
FRG	15	Spain	17
Greece	25	Sweden	22
Iceland	19	Switzerland	29
Ireland	20	UK	25

When calculating diesel consumption based on traffic activity and specific fuel consumption for the various vehicle categories, this calculated consumption is for some countries (Austria, Belgium, Italy, Luxemburg, the Netherlands and Spain) smaller than that reported to OECD (see Appendix G, Table G4). Traffic activity data may be inaccurate. For some smaller countries, tanking by foreign trucks in transit may also explain some of the discrepancy. Luxemburg is a clear example, and possibly also Austria, Belgium and the Netherlands to some extent. These discrepancies may affect the calculated total road diesel NOx emissions to some extent, if the traffic activity of one of the light duty or heavy duty truck categories is underestimated more than the other, since there is a large difference in NOx emission factor from light duty and heavy duty trucks.

3 NOx EMISSIONS FROM RAIL TRAFFIC, NAVIGATION AND AGRICULTURE

The consumption of diesel oil for rail traffic, internal navigation and agriculture in Western European countries is given by OECD statistics (Appendix G, Table G3).

The basis for estimating diesel oil consumption in these sectors in Eastern European countries is described in Appendix H.

Table 12 shows the emission factors we have used in our calculations (Appendix D). We have no basis for differentiating between countries.

Table 12: NOx emission factors used for diesel consumption in locomotives, ships and agricultural tractors.

	NOx emission factor kg/t
Rail traffic	20
Internal navigation	70
Agricultural tractors	50

In Tables 13 and 14 the NOx emissions from these sectors have been calculated.

NOx emissions from international maritime navigation have not been estimated in this work. Laikin (1988) have estimated that the NOx emissions from international maritime navigation in European seas (excluding Norwegian Sea and Barents Sea) in 1983 was approximately 410 000 tonnes/a, distributed as follows:

Black Sea	8 670	tonnes/a
Mediterranean Sea	211 310	"
Eastern Atlantic Ocean (incl. English Channel)	110.600	"
North Sea	56 960	"
Baltic Sea	21 060	"
Sum	408 600	tonnes/a

Table 13: NOx emissions from rail traffic, internal navigation and agriculture, Eastern European countries, 1985.

	Rail			Internal navigation			Agriculture		
	M 10^3 t	p kg/t	Q 10^3 t	M 10^3 t	p kg/t	Q 10^3 t	M 10^3 t	p kg/t	Q 10^3 t
Albania							142[a]	60	8.5
Bulgaria	217	20	4.3	30	70	2.1	500	50	25.0
Czechoslovakia	859	20	17.2	46	70	3.2	700	50	35.0
GDR	705	20	14.1	21.5	70	1.5	650	50	32.5
Hungary	280	20	5.6	95	70	6.7	700	50	35.0
Poland	546	20	10.9	31	70	2.2	1 476	50	73.8
Romania	853	20	17.0	31	70	2.2	1 300	50	65.0
USSR	9 800[b]	20			70		27 800	50	1 390
European USSR	6 300[b]	25[d]	158				14 000[c]	50	700
Yugoslavia	314	20	6.3	50	70	3.5	1 000	50	50.0

a estimated rail + agriculture + internal navigation.

b estimated rail + internal navigation (33 300 tonnes/ 10^6 cap.).

c estimated 50% of agricultural land in European USSR.

d estimated average emission factor for rail and internal navigation.

Table 14: NOx emissions from rail traffic, internal navigation and agriculture, Western European countries, 1985.

	Rail			Internal navigation			Agriculture		
	M 10^3 t	p kg/t	Q 10^3 t	M 10^3 t	p kg/t	Q 10^3 t	M 10^3 t	p kg/t	Q 10^3 t
Austria	53	20	1.1	50[a]	70	3.5	200	50	10.0
Belgium	109	20	2.2	212	70	14.8	242	50	12.1
Denmark	114	20	2.3	215	70	15.0	473	50	23.7
Finland	71	20	1.4	34	70	2.4	425	50	21.3
France	483	20	9.7	78	70	5.5	2 300	50	115.0
FRG	470	20	9.4	699	70	48.9	1 260	50	63.0
Greece	52	20	1.0	236	70	16.5	787	50	39.4
Iceland	-	20		156	70	10.9		50	
Ireland	43	20	0.9	5	70	0.4	100	50	5.0
Italy	213	20	4.3	329	70	23.0	1 557	50	77.9
Luxemburg	9	20	0.2		70		3	50	0.15
Netherlands	40	20	0.8	292	70	20.4	90	50	4.5
Norway	15[a]	20	0.3	577	70	40.4[b]	153	50	7.7
Portugal	57	20	1.1	52	70	3.6	367	50	18.4
Spain	180	20	3.6	1 078	70	75.5	2 212	50	110.6
Sweden	82	20	1.6	81	70	5.7	355	50	17.8
Switzerland	11	20	0.2	9	70	0.6	70	50	3.5
UK	718	20	14.4	1 071	70	75.0	825	50	41.3

a Estimated.

b The official national emission estimates for internal navigation are as follows, based on the fuel consumption figures of Table G3 in Appendix G (Ministry of Environment, 1988):
Internal navigation: $49.4 \cdot 10^3$ tonnes.
Fisheries : $29.6 \cdot 10^3$ tonnes.

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The calculations presented here are based on the best information available to the author and may deviate from official national data.

APPENDIX A

Car populations in Europe

A1 WESTERN EUROPEAN COUNTRIES

The principal data sources used are OECD data from 1980 (OECD, 1987), International road federation (IRF) data from 1985 (IRF, 1987) and national statistics from some countries.

Tables A1-A4 give populations of passenger cars (PC), light duty trucks (LDT), heavy duty trucks (HDT), total trucks (LDT+HDT) and motorcycles (MC)/mopeds respectively. Table A5 gives data on the diesel part of the PC and LDT vehicles and traffic activity for 1980 and 1985 for some countries.

There is generally good agreement between the data sources, but the IRF "Goods vehicles" data are somewhat inconsistent with the HDT data from OECD and national sources. This is probably to some extent due to different vehicle definitions.

There is not agreement between the OECD data and the IRF and National data for the following countries:

	OECD, 1980	IRF, 1985	Ntl. data, 1985
Italy, total trucks :	279 000	1 788 000	
Norway, LDT :	25 000		147 000
Portugal, total trucks:	179 000	492 000 (1984)	413 000

Data from the International Transport Union (IRU, 1985) support the IRF data for Italy and national data for Portugal.

A2 EASTERN EUROPEAN COUNTRIES

The principal data sources are IRF (1987), IRU (1985) and national statistics from some of the countries. Rijkeboer (1987) has provided some data and views concerning the Eastern European car population.

Table A6-A7 show a summary of the available data on Eastern European car populations. There is generally good agreement between the data sources.

We have no data for Albania, Romania and USSR, and for truck data for Bulgaria. Data are also largely lacking on LDT/HDT partition, and gasoline/diesel partition for trucks.

The production of passenger cars in USSR has during the last 10 years been about 1.3 mill. cars/a. Assuming the same ratio between car production and car fleet as in Czechoslovakia, the number of passenger cars in USSR is 15-20 mill. This corresponds to the total number of cars produced in the USSR in the last 12-15 years.

Table A1: Number of passenger cars, Western Europe (thousands).

Country	OECD, 1980[1] No.	OECD, 1980[1] % diesel	IRF[2] 1983	IRF[2] 1985	National data No.	National data % diesel
Austria	2 247	4	2 414	2 531		
Belgium	3 159	10	3 263	3 343		16.3[9]
Denmark	1 390	4	1 390	1 546	1 500 (1985)[3]	3.3
Finland	1 226	5	1 410	1 546	1 546 (1985)[4]	8.5
France	18 400	4	20 600	20 940		
FRG	23 192	5	24 690[c]	26 100[c]	25 845 (1985)[5]	9.0
Greece	863	0	1 043	1 264		
Iceland	86	0	96	103	114 (1985)	~5
Ireland	736	3	719	710		
Italy	17 686	10	19 616[a]	22 398		
Luxembourg	133	5	141	152[d]		
Netherlands	4 240	4	4 770	4 901		
Norway	1 234	2	1 383	1 514	1 472 (1985)[7]	2.9
Portugal	1 269	0	1 269[b]	1 185[e]	1 702 (1985)[10]	7.0
Spain	7 557	0	8 714	9 274	8 874 (1984)[11]	6.0
Sweden	2 883	4	3 007	3 151	3 151 (1985)[8]	4.1
Switzerland	2 253	0	2 521	2 617		
UK/GB	15 356 (UK)	1	15 854	16 453 (GB)	18 101 (UK, 1986)[6]	0.3

a 1982.
b 1980.
c Incl. W. Berlin, also incl. "Vans (Kombi u. Lieferwagen)".
d Incl. "commercial vehicles".
e Incl. "minibuses".

References:
1. OECD (1987)
2. IRF (1987)
3. Automobil-importørenes sammenslutning (1986)
4. Finnish Road Association (1987)
5. Enderlein (1987)
6. Rogers (1984)
7. Opplysningsrådet for veitrafikken (1987)
8. Bilindustriföreningen (1987)
9. Van Rompaey (1987)
10. Carneiro (1989)
11. LABEIN (1986)

Table A2: Number of light duty trucks, Western Europe (thousands).

Country	OECD, 1980[1] (GVW < 3 t) No.	% diesel	IRF, 1985[2] ("Vans")		National data No.	% diesel	Used in our calculations for 1985
Austria	124	40					130
Belgium	146	35	168		273 (1985)[9]	58	273
Denmark	169	30			GVW <3.0t:173 (1985)[3]	36.5	173
Finland	105	41	128	(1986:136)	GVW <3.5t:140 (1986)[4]	31	130
France	2 259	38	2 895	(GVW <5 t)			~2 700
					Load cap. 1980 1985[5]		
FRG	831	45	227		< 1 t: 321 435		~ 850
					1-4 t: 656 573		
Greece	343	45					~ 350
Iceland	4.3	30			7.7 (1985)	27	~ 5
Ireland		40					
Italy	221	45					~ 250
Luxemburg	1.3	40	5.1				~ 5
Netherlands	212	26	280				~ 280
Norway	25	24	146	(1986)	GVW <3.5t:147 (1985)[7]	29 (1984)[7]	~ 140
Portugal	136	45			GVW <3.5t:418 (1985)[10]	100	~ 418
Spain	1 065	45					1 100
Sweden	121	30			GVW <3.5t:124 (1985)[8]	15 (1984)[8]	124
Switzerland	121	10	130	(1983)			
			159	(1986)			159
					1911 (1983)[6]	86	
UK	1 334	40			incl. 155 "heavy vans"	40	~1 500
					incl. 179 "4x4 utility"	45	

References 1-10, see Table A1.

Table A3: Number of heavy duty trucks and buses, Western Europe (thousands).

Country	Heavy duty trucks: OECD, 1980[1] (GVW > 3 t) No.	% d.	IRF, 1985[2] "Goods vehicles" excl. "vans" No.	National data No.	% d.	Used in our calculations for 1985	Buses: IRF, 1985[2] No.	National data No.	% d.
Austria	68.4	100				~ 70	9.2		
Belgium	91.2	100	105	208 (1985)[9,i]	88	208	16.8	14.9 (1985)[9]	95
Denmark	82.6	81	195[e]	>3.5t: 86.5 (1985)[3]	89	67.5	8.0	8.0 (1985)[3]	99
Finland	49.9	98	51.7	>3.5t: 50.0 (1986)[4]	99	50	9.0	9.0 (1985)[4]	100
France	314	100	330			330	64.0		
				Load cap. 1980 1985[5]					
FRG	516	100		1-4 t: 656 573		~525	69.2	69 (1985)[5]	
				> 4 t: 300 273					
				Semitrailers: 60 64					
Greece	72.5	100				~ 75	18.6		
Iceland	5.4	100		5.0 (1985)	95	~ 6	1.4		
Ireland	2.7	100				~ 3	4.7[c]		
Italy	58.2	100					75.3		
Luxemburg	4.3	100				~ 4	0.7		
Netherlands	138	91	84			84	11.6		
Norway	60.3	100	119[f]	>3.5t: 62 (1985)[7]	97	63	17.1	16.6 (1984)[7]	77
Portugal	42.7	100		>3.5t:95.2 (1985)[10]	100	95	10.4[a]	6.9 (1985)[10]	100
Spain	316	100				~320	41.6		
Sweden	70.2	100		>3.5t: 94 (1985)[8]	95	94	13.7	13.6 (1988)[8]	91
Switzerland	50.1	100	48.3[f]			48	10.8[d]		
UK	579	100		556[h] (1983)[6]	92	~600	120[b]	99[g] (1983)[6]	95

a 1984.
b Incl. taxis.
c Incl. school buses.
d Incl. small buses.
e GVW > 2 t.
f 1986.
g Buses and metropolitan taxis.
h Trucks excl. vans.
i "Trekkers, Landbouwtrekkers, Speciale voertuigen".

References 1-10, see Table A1.

Table A4: Number of trucks (LDT + HDT) and motorcycles/mopeds, Western Europe (thousands).

Country	TRUCKS				MC/MOPEDS
	OECD, 1980[1] No.	IRF, 1985[2] "Goods vehicles" + "vans"	National data No.	% d.	IRF, 1984
Austria	192	207			109/ 530
Belgium	237	273	480 (1985)[9]	71	126/ 379
Denmark	252	195 (GVW > 2t)	Total: 259.5 (1985)[3]		
			GVW>3t: 85.5	54	39/
Finland	155	180	190 (1986)[4]		48/ 170
France	2 573	3 225			650/4 000
			Load cap. 1980	1985	
			< 1 t: 321	435	
FRG	1 347	1 508	1-4 t: 656	573	876/2 074
			> 4 t: 360	337	
			Semitrailers: 60	64	
Greece	416	572			164/
Iceland	9.7	11.8			1/
Ireland		93			25 (total)
Italy	279	1 788			961/3 500
		1 519 (IRU, 1981)			
Luxemburg	5.6	9.3 (1986)			2/
Netherlands	350	364			126/ 650
Norway	85	233	196 (1984)[7]		43/ 130[5]
			215 (1985)[7]		
Portugal	179	492 (1984)	513 (1985)[10]	100	94/
		399 (IRU, 1981)			
Spain	1 381	1 529	1 445 (1984)[11]	61	1 310/
Sweden	191	218	218 (1985)[8]	46	19/ 90
Switzerland	171	201			187/ 675
UK/GB	1 913(UK)	2 622 (GB)			816/474(GB)

References 1-11, see Table A1.

Table A5: Percentage diesel (of no. of cars and traffic activity) and annual average driving distance (AADD, 10^3 km) of gasoline and diesel-powered cars in some countries.

COUNTRY	PERCENTAGES DIESEL OF			
	NO. OF PASSENGER CARS		PASSENGER CAR TRAFFIC ACTIVITY (vehicle·km)	
	1980	1985	1980	1985
Denmark	1.5	3.5	-	-
Finland	5	8.5	-	-
FRG	5	9	8	15
Norway	2.0	2.9	3.1	5.0
Sweden	3.9	4.1	5.6	-
UK	0.3 (1983)	-	-	-

COUNTRY	AADD, PC		AADD, LDT	
	Gasoline	Diesel	Gasoline	Diesel
Norway, 1985	11.4	20.1	11.4	17.4
Sweden, 1980	13.6	19.8		
FRG, 1985	11.3	20.1		

Table A6: Number of passenger cars, Eastern Europe (thousands).

Country	IRU 1982[12]	IRF 1985[2]	National data		
			No.	% 2-stroke	% diesel
Albania					
Bulgaria		1 030			ca. 5
Czechoslovakia	2 442		2 640[c] (´84)		
GDR	2 922		3 020[13] (´83)	ca. 65[13]	Small
			3 306[14] (´85)		
Hungary	1 182	1 436	1 436[15] (´85)	35	
Poland	3 534[a]	3 671	3 671[16] (´85)	ca. 10	d
Romania					
USSR - Eur.			15-20x10^6[e]		
Yugoslavia	2 771[b]	2 874	2 874 (´85)	Small	

a 1981.
b 1983.
c Incl. taxis.
d 8.4% of total fuel (gasoline + diesel) consumption in PC + LDT is diesel (Cofala et al., 1987).
e estimate (see text).

References:
12 IRU (1985)
13 DIW (1988)
14 DDR (1986)
15 Hungary (1985)
16 Poland (1985)

Table A7: Number of motor vehicles, Eastern Europe (thousands).

		NO. OF MOTOR VEHICLES, in thousands					
		Light vans	Trucks[h] (IRU: Lorries) (IRF: Goods veh.)	Trucks for spec. purposes	Buses (IRF: incl. coaches)	Tractors	Motorcycles/ mopeds
Albania							
Bulgaria	IRF ´83				27		423 (total)
	IRF ´85				27.5		469 (total)
Czechoslovakia	Ntl ´84		295[g]	118			
	IRF ´81		298		32	193[a]	670/ 874
	IRU ´82	61	193[f]	103	32		
GDR	Ntl ´85		361[d]	130[e]	53[e]	516	1 300/2 500[e]
	IRU ´82		356		53	234	
	DIW ´83		223[g]	130	53		1 307/2 500
Hungary	Ntl ´85		151[c]		25[c]	55	
	IRF ´82		146		25	26[a]	630 (total)
	IRF ´85		167		25	46[d]	396 (total)
	IRU ´82		119		25		
Poland	Ntl ´85		780[b]		23	919	
	IRF ´83		655		77		1 624 (total)
	IRF ´85		780		83		1 546 (total)
	IRU ´81		639		68		
Romania							
USSR							
Yugoslavia	Ntl ´84		613				
	IRF ´82		211		26		167 (total)
	IRF ´85		193		26		158 (total)
	IRU ´83		217	33	28		

a Excl. agricultural tractors.
b Diesel: 70% (1983).
c Diesel: 60%.
d Incl. "special trucks".
e 1983.
f Excl. light vans.
g Excl. "special trucks".
h Incl. light vans, unless otherwise noted.

APPENDIX B

Driving modes for road traffic

The exhaust emission of NOx and other pollutants from motor vehicles is a function of traffic parameters such as average speed and speed variation. In an effort to take account of this variation in emissions, the traffic activity is divided into three basic driving modes, as follows:

Driving mode:	URBAN	RURAL	HIGHWAY/MOTORWAY		
Range of average speeds (km/h):	10-50	50-80	80	100	120

Very little data are available on the distribution of the total traffic activity into these driving modes. Table B1 shows the estimates available to us.

Table B1: National estimates of distribution of total traffic activity in various driving modes.

<table>
<tr><th rowspan="2">Country</th><th colspan="4">Percent of total traffic activity</th><th rowspan="2">Reference</th></tr>
<tr><th>Urban</th><th>Secondary highway</th><th>Main highways</th><th>Motorways</th></tr>
<tr><td>FRG</td><td>31.7</td><td>18.9</td><td>23.3</td><td>26.1</td><td></td></tr>
<tr><td>Norway</td><td>30</td><td colspan="2">70[a]</td><td></td><td></td></tr>
<tr><td>Netherlands</td><td>36</td><td colspan="2">42</td><td>22</td><td></td></tr>
<tr><td>Finland</td><td>31</td><td colspan="2">69[a]</td><td></td><td></td></tr>
<tr><td>Sweden</td><td>51</td><td colspan="2">49[a]</td><td></td><td></td></tr>
<tr><td>UK</td><td>41.5</td><td colspan="2">46.2</td><td>12.4</td><td></td></tr>
</table>

a) Highways and motorways.

The percentage of urban driving varies within 30-51% in these estimates. The definitions of the driving modes may differ.

Table B2 shows the total length of road networks in European countries, and the percentage of motorways.

Table B2: Total length (km) of road networks, and percentage of motorways, 1985 (reference: IRF, 1987).

Country	Road network 10^3 km	% motorways	Country	Road network 10^3 km	% motorways
Austria	104.5	1.5	Bulgaria	37.6	0.6
Belgium	127.9	1.1	Czechoslovakia	73.8	0.65
Denmark	58.5	1.0	Hungary	90.7	0.35
Finland	76.1	0.3	Poland	300.6	0.07
France	804.7	0.8	Romania	72.8	0.13
FRG	491.2	1.7			
Great Britain	348.3	0.8			
Greece	34.5	0.3			
Iceland	11.6	0			
Ireland	92.3	0.01			
Italy	301.3 (1984)	2.0			
Luxemburg	5.2	1.1			
Netherlands	112.7	1.8			
Norway	85.9	0.1			
Portugal					
Spain	319.0	0.6			
Sweden	130.7	0.7			
Switzerland	70.6	1.5			

Based on these data, we have made the following estimates of the distribution of passenger car traffic activity into driving modes (Table B3).

Table B3: Estimate of the distribution of total traffic activity into driving modes, passenger cars.

Country	Urban 10-50	Rural 50-80	Highway 80-100	Motorway > 100
Austria	35	25	20	20
Belgium	35	30	25	10
Denmark	35	30	25	10
Finland	35	35	30	0
France	35	30	25	10
FRG	35	20	20	25
Greece	35	35	30	0
Iceland	35	35	30	0
Ireland	35	35	30	0
Italy	35	20	20	25
Luxemburg	35	30	25	10
Netherlands	35	20	20	25
Norway	35	35	30	0
Portugal	35	35	30	0
Spain	35	30	25	10
Sweden	35	30	25	10
Switzerland	35	25	20	20
UK	35	30	25	10
East European countries	35	35	30	0

The 35% urban driving is close to the average of the estimates in Table C1. The percentage of motorway driving has been estimated as follows:

Motorway % of road network	Motorway traffic activity, %	
> 1.5	25	(as estimated in FRG and Netherlands)
1.5	20	
0.5-1.5	10	(UK estimate: 12.4%)
< 0.5	0	

For other vehicle categories, the driving mode distribution will be different, with less motorway driving.

APPENDIX C

Specific fuel consumption for various road vehicle categories

GASOLINE-POWERED PASSENGER CARS

Specific fuel consumption measurements are often performed in connection with emission measurements in emissions test laboratories or during actual driving. Figure C1 shows examples of measured specific fuel consumption as a function of driving mode and average driving speed for 4-stroke engines (Larssen, 1988).

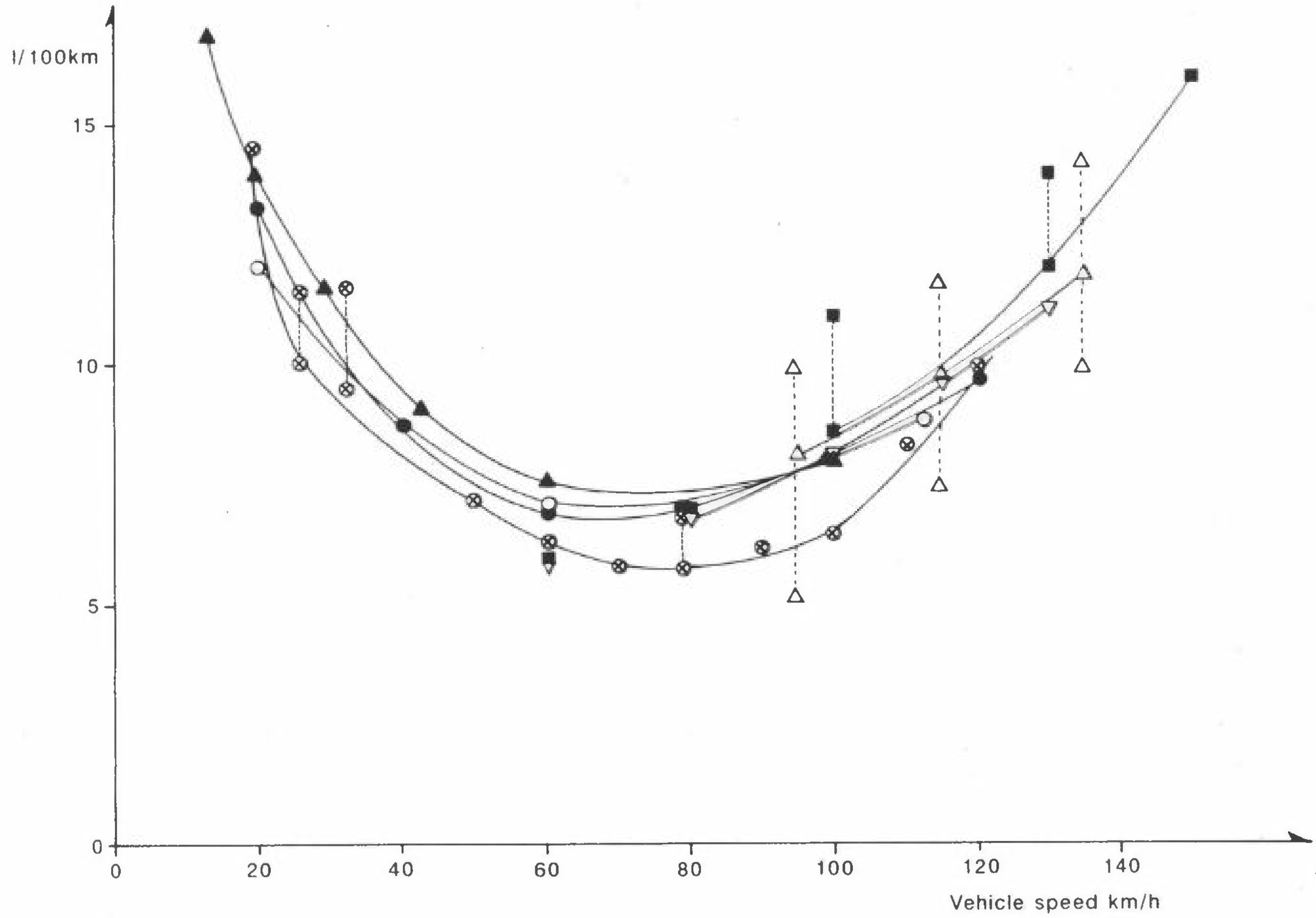

Figure C1: Specific fuel consumption (l/100 km) for light duty gasoline powered cars.
For explanation of symbols: See Table D1.

From this the consumption figures in Table C1 can be selected for "urban", "rural" and "highway" driving modes.

Table C1: Selected specific fuel consumption for gasoline-powered passenger cars (4-stroke engines).

Mode:	URBAN	RURAL	HIGHWAY/MOTORWAY		
Speed (km/h)	10-50	50-80	80	100	120
Fuel consumption 1/100 km	17.5-7.5	7.5	7.5	8.5	10

For FRG, the gross average fuel consumption for gasoline-powered passenger cars has for 1985 been estimated to 10.9 1/km (DIW, 1987).

For an estimated distribution of total traffic activity in FRG of 35%/20%/20%/25% for urban/rural/highway/motorway driving modes respectively, the fuel consumption figures in the table above give a gross average consumption of 10.0 1/100 km, about 10% less than the FRG estimate.

Other independent data on specific fuel consumption for larger car populations are not available to us.

The measurements shown in Figure C1 represent for the most part 20^0C ambient temperature. At lower temperatures during winter conditions, the fuel consumption will tend to increase somewhat.

In the subsequent calculations, we use 10.7 1/100 km as the gross average gasoline consumption in passenger cars, and use the relative variation between the driving modes as given in Table C1.

DIESEL-POWERED PASSENGER CARS (DPC)

Diesel-powered light duty cars have a somewhat less fuel consumption than gasoline cars. Gross average fuel consumption for light duty diesel cars in FRG is 8.8 1/100 km, for 1985 (DIW, 1987).

Veldt (1986) gives the following consumption estimates for diesel powered passenger cars:

Speed km/h	10	50	80	100	120
1/100 km	18	6.5	6.5	7	8.5

LIGHT DUTY TRUCKS (LDT) (GVW < 3.5 t)

Very little information on the specific fuel consumption of light duty trucks is available to us. An estimate for Norway is 15 1/100 km for gasoline and 13 1/100 km for diesel (Rosland, 1987).

In the OECD MAP project, 15 1/100 km was used to convert emission factors from g/kg to g/km (OECD, 1987).

Veldt (1986) has estimated the following fuel consumption figures for gasoline and diesel LDT´s alike:

Speed km/h	10	50	80	100	120
1/100 km	17.5	8.0	8.5	10.5	15

For a distribution of traffic activity into 40%/30%/30% in urban/ rural/highway (80-100) driving modes, respectively, this gives the following gross average fuel consumption figures:

gasoline: 12.4 1/100 km
diesel : 11.1 1/100 km.

We have chosen to use 15 1/100 km for gasoline powered and 13 1/100 km for diesel powered light duty trucks.

HEAVY DUTY DIESEL TRUCKS (HDDT)

In Norway, the estimated gross average fuel consumption is:

- 30 l/100 km for HDT
- 35 l/100 km for buses.

In the OECD MAP project, 30 l/100 km is used (OECD, 1987).

Veldt (1986) has given the following estimates (l/100 km):

Speed km/h	10	50	80	100	Average
GVW 3.5- 5.5	27	13	16.5	21.5	18
GVW 5.5-12.0	37	19.5	21.5	26	24
GVW 12.0-15.0	45	25.5	27	31	30
GVW > 15.0	~55	36.5	36.5	40	40

The average figures were calculated based on a traffic activity distribution of 0.34/0.33/0.33 in the urban (10-50)/rural (50-80)/highway (90) driving modes, respectively.

For a GVW distribution similar to that of the HDT population in Norway, this gives a gross average fuel consumption of 30.9 l/km.

Data on total fuel consumption in vehicles, and traffic activity in the FRG (DIW, 1987) offer an opportunity to calculate the average fuel consumption for buses and road freight traffic, which are:

28 l/100 km for freight traffic
34 l/100 km for buses.

Based on the above, we have chosen to use the following specific fuel consumption figures:

Heavy duty trucks: 30 l/100 km.
Buses : 35 l/100 km.

APPENDIX D

NOx emission factors

D1 ROAD TRAFFIC

D1.1 Passenger cars

D1.1.1 Western Europe

Gasoline

Results from measurements of NOx emission factors for gasoline-powered passenger cars in Europe have been reviewed (Larssen, 1988b).

Detailed information is available on the NOx emission factors for light duty gasoline (LDG) vehicles. A selection of emission factor data is presented in Figure D1 as a function of vehicle speed. Fleet emission factors proposed by Veldt (1986) are included as well as other data that indicate the effect of various parameters on NOx emissions.

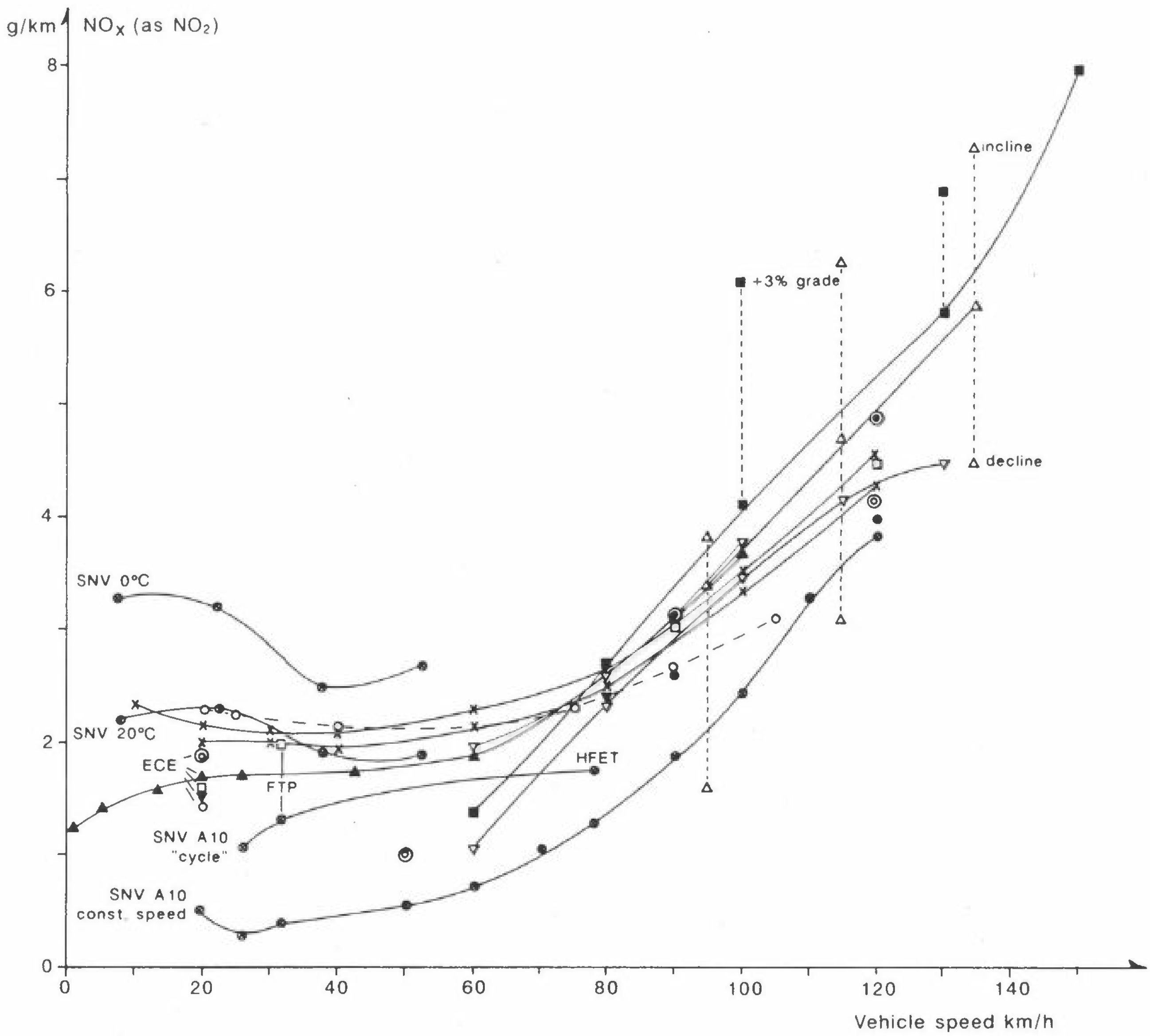

Figure D1: NOx emission factors (g/km) for light duty gasoline powered cars, as a function of vehicle speed (Larssen, 1988b). For explanation of symbols: See Table D1.

Table D1: Explanation to Figure D1.

X	CORINE (proposed, Veldt & Bakkum, 1987) (1.4-2 l engines). Upper curve: 1980. Lower curve: 1985.
○	Warren Springs Lab (Potter and Savage, 1983) Measurements during actual driving in traffic. Average of 20 cars, 1975-82. ECE R15-01, 02, 03.
⊗	Vehicle emissions lab, Studsvik, Sweden, Swedish National Environmental Protection Board (SNV) SNV 20^{0}C/0^{0}C: 22 cars, 1971-78, hot engines, at amb. temp. 20^{0}C and 0^{0}C (Bertilsson, 1979; Persson, 1980). SNV A-10 : 60 cars, 1977-87, complying with the Swedish A-10 emissions regulation (Egebäck, 1986).
◉	TNO, Netherlands, 1984. Const. speed. R15-03.
■	TNO, Netherlands, 1984. Const. speed. R15-04.
▽	Switzerland, 1981. 52 cars. Lower curve: Const. speed.
◎	Czechoslovakia, 1985. 4 cars, 1980-84 (ECE, 1985).
▲	Rheinland, TUV (1980). 100 km/h: Const. speed. <100 km/h: "Fahrmodus 2-7".
■	Rhein.Westph., TUV (1984). 20 cars. Const. speed.
▼	Norway, 1983. 47 cars, 1961-82. ECE cycle and 80 km/h const. speed (Melhus, 1983).
□	ECE (1987b) "Baseline factors".
△	Abgas-Grossversuch. Vd TUV (1986).
●	Veldt (1986). (Figure C1 only.)

At average speeds less than 60 km/h, there are essentially four classes of information:

- Measurements at constant speed at 20^{0}C. This gives fairly low NOx emission factors, less than 1.5 g/km. The Swedish measurements (Egebäck, 1986) on cars made to comply with the Swedish A-10 emission requirements, show very small emissions.

- Measurements of emissions from the ECE R15 and FTP-75 test cycles at 20^{0}C. Such emission factors are in the range 1.5-2 g/km.

- Measurements in actual traffic (Potter and Savage, 1983) or representing actual urban driving pattern (Persson, 1980). Such emission factors are higher, 1.9-2.3 g/km. Veldt´s suggested emission factors are in this range.

- Measurements representing an actual urban driving pattern at 0^{0}C (Persson, 1980). These factors are in the range 2.5-3.3 g/km.

At speeds higher than 60 km/h, most measurements have been done at constant speeds. Exceptions are the Warren Springs laboratory (WSL) measurements at 75 km/h (actual rural driving), the Swedish SNV measurements at 78 km/h (HFET driving cycle) and the German "Abgas-Grossversuch (Vd TUV, 1986).

The emissions from the Swedish A-10 cars increase considerably at high speeds, but still seem to be somewhat lower than the ECE 15-03 and ECE 15-04 cars. Surprisingly, the WSL mesurements in actual traffic fall a little below the other measurements. This may in part be due to relatively small average engine size of the cars used in that experiment.

Reported measurements from Czechoslovakia agree fairly well with results from Western European countries.

The measurements from "Abgas-Grossversuch" indicate that road decline reduces the NOx emissions as much as or more than road incline increases it. This indicates that various degrees of "hilliness" do not affect the average NOx emission factor very much.

Based on this review, the following emission factors were proposed for the urban, rural and highway driving modes (Table D2).

Table D2: Proposed emission factors for NOx, gasoline-powered passenger cars, at 20^0C ambient temperature.

Mode	Urban	Rural	Highway/motorway 80	100	120
Emission, g/km	2.2	2.3	2.5	3.5	4.3-5.0
Emission, g/kg	23	41	44	55	57-67

Several studies have shown that the NOx emissions from gasoline-powered cars increase with decreasing ambient temperature, in the hot stabilized mode (Larssen, 1988b).

Table D3 shows a summary of results from several investigators. The ratio between emissions at 0^0C (q_{0^0C}) and emissions at 20^0C (q_{20^0C}) is in the range 1.0-1.4. A ratio of 1.4 has been reported from Swedish and Canadian studies, using ECE R15 or FTP warm start test cycles.

Table D3: Effect on NOx emissions of low ambient temperature.

Sweden (Bertilsson, 1979) 22 cars, 1971-78 models	$\frac{q_{0^0C}}{q_{20^0C}}$	~ 1.4 (ECE R15 warm start) ~ 1.2 (ECE R15 cold start)
Canada (Ashby, 1974) 1967-74 models	$\frac{q_{-7^0C}}{q_{20^0C}}$	~ 1.4 (FTP warm start) ~ 1.3 (hot stab. mode) ~ 1.0 (FTP cold start)
Norway (Bang, 1983) 2 cars	$\frac{q_{-20^0C}}{q_{20^0C}}$	~ 1.3 (ECE R15 cold start)
USA (Eccleston, 1978) 4 cars, ox. cat + EGR	$\frac{q_{-7^0C}}{q_{20^0C}}$	~ 1.15 (FTP hot transient)
Canada (Ostrouchov, 1978) 1974-75 models, various emission controls	$\frac{q_{-7^0C}}{q_{20^0C}}$	~ 1.1-1.4 (FTP hot transient)

Diesel

Diesel-powered passenger cars contribute only a very small fraction of the total NOx emissions from mobile sources.

The following emission factor estimates are available to us:

					Reference
OECD:		1.5 g/km/20 g/kg			(OECD, 1987)
		Urban	Rural	Highway	
C. Veldt	g/km:	1.2	1.1	1.3	(Veldt, 1986)
Sweden	g/km:	0.74	0.62		(Olsson, 1983)
Norway	g/km:	1.0	1.5		(Rosland, 1987)
	g/km:	0.9 (ECE R15-03)			(Melhus, 1982)
FRG	g/km:	0.68	0.54(75 km/h)	0.94(105 km/h)	(Hassel et al., 1987)
	g/kg:	12.0	12.7 (75 km/h)	15.5 (105 km/h)	

Average fuel consumption estimates varies from 8.8 l/100 km (Enderlein, 1987) to ca. 8 l/100 km (Veldt, 1986) and 7 l/100 km (Rosland, 1987).

Based on the above, we propose the following gross average emission factors for diesel-powered light duty cars:

1.0 g/km and 15 g/kg.

D1.1.2 Eastern Europe

For 4-stroke gasoline powered engines, the NOx emission factor for passenger cars in Eastern Europe is considered to be about the same as in Western Europe.

A test in Czechoslovakia of 4 cars gave an average of 1.9 g/km with the ECE R15 test cycle (ECE, 1985). This is similar, or somewhat higher, than usually obtained in Western European tests. A test of 14 cars of various makes (ref. mass about 1 000 kg, except 3 cars with mass 1 460-1 790 kg) with the US Highway driving cycle (HFET) and at 77.6 km/h constant speed gave an average of 3.22 and 2.93 g/km for the HFET cycle and 77.6 km/h, respectively (ECE, 1986). This is somewhat higher than similar tests on Western European cars (see Figure D1).

A USSR test of a 1 130 kg car gave about 2 g/km with the ECE test cycle, and a fuel consumption of 10.6 l/100 km (ECE, 1980). This gives an emission factor for the ECE cycle of about 25 g/kg.

For 2-stroke gasoline powered engines, Bethkenhagen et al. (1988) give the following NOx emission factors:

Urban	Rural
0.2 g/km	0.3 g/km

With an average fuel consumption of 5 l/100 km for the Trabant, this gives an estimated average emission factor of about 7 g/kg fuel for that make. We propose to use that emission factor for all passenger cars with 2-stroke engines.

D1.2 Light duty trucks (< 3.5 t GVW)

Only a limited amount of data on light duty truck emission factors is available to us.

Gasoline (LDGT)

Veldt (1986) has proposed the following factors:

	Urban	Rural	Highway	
			80	100
g/km	2.9	3.3	3.6	4.9
l/100 km	15	9	9	11
g/kg	26	49	53	59

A traffic activity distribution of 40%/30%/30% in the urban/rural/highway modes respectively gives a gross average emission factor of 42 g/kg, which is proposed to be used for light duty gasoline-powered trucks in the study.

Table D4 gives measured emission factors for FRG for various driving modes (Hassel et al., 1983).

Table D4: NOx emission factors (g/kg) for light duty trucks (gasoline- and diesel-powered), FRG, as a function of driving mode.

Driving mode	Average speed km/h	Gasoline	Diesel
K85	85.0	45	14
M2	60.0	36	13
M3	42.4	28	12
M4	26.6	20	11
M0	19.5	17	11
M5	13.5	13	11
M6	6.3	10	12
M7	1.2	7	13
Idle	0.0	6.5	13
Calculated urban mode (0.65 M3 + 0.35 M4)		25	11.5

The emission factors for the urban mode and 85 km/h constant speed are similar to those estimated by Veldt (1986).

Diesel (LDDT)

From the emission factors and fuel consumption data estimated by Veldt (1986), and based on a traffic activity distribution of 40%/30%/30% in the urban/rural/highway driving modes, respectively, a gross average emission factor of about 14 g/kg can be calculated for light duty diesel-powered trucks.

The FRG measurements in Table D4 give an emission factor of 11.5 g/kg for urban driving, and 14 g/kg for 85 km/h constant speed.

Emission measurements performed in Norway (Melhus, 1982) give the following emission factors:

Passenger cars	(n = 16):	0.82 g/km
Light duty trucks	(n = 7):	1.23 g/km

Fuel consumption was not measured during these tests. They show a 50% larger emission factor for light duty trucks than for passenger cars. Similarly, FRG emission tests show an approximately 75% increase in fuel consumption for light duty trucks compared to passenger cars. This gives a fuel-based NOx emission factor for light duty trucks somewhat lower, maybe 15% lower than for passenger cars.

With a view to the emission factors proposed by Veldt and the measurements reported from FRG, and to the fact that only limited data are available, we have chosen to use the same gross average emission factor for LDDT as for PC, 15 g/kg, although it may in fact be somewhat lower.

D1.3 Heavy duty trucks (HDT > 3.5 t (GVW) and buses

D1.3.1 Diesel (HDDT)

Based on emission measurements on a total of 80 HDDT performed in Sweden (Berthilsson et al., 1987) the emission factors in Figure D2 were calculated (Larssen, 1988b). These results suggest the emission factors listed in Table D5.

Veldt (1986) has proposed HDDT emission factors in terms of g/km. Based on this and his proposed fuel consumption data for constant speed driving, the fuel based emission factors (g/kg) in Table D6 may be calculated.

These last factors are larger than the Swedish factors, especially for the rural and highway modes. The reason for the discrepancy may be that the Swedish data consider constant speed, while the factors proposed by Veldt may represent actual driving modes.

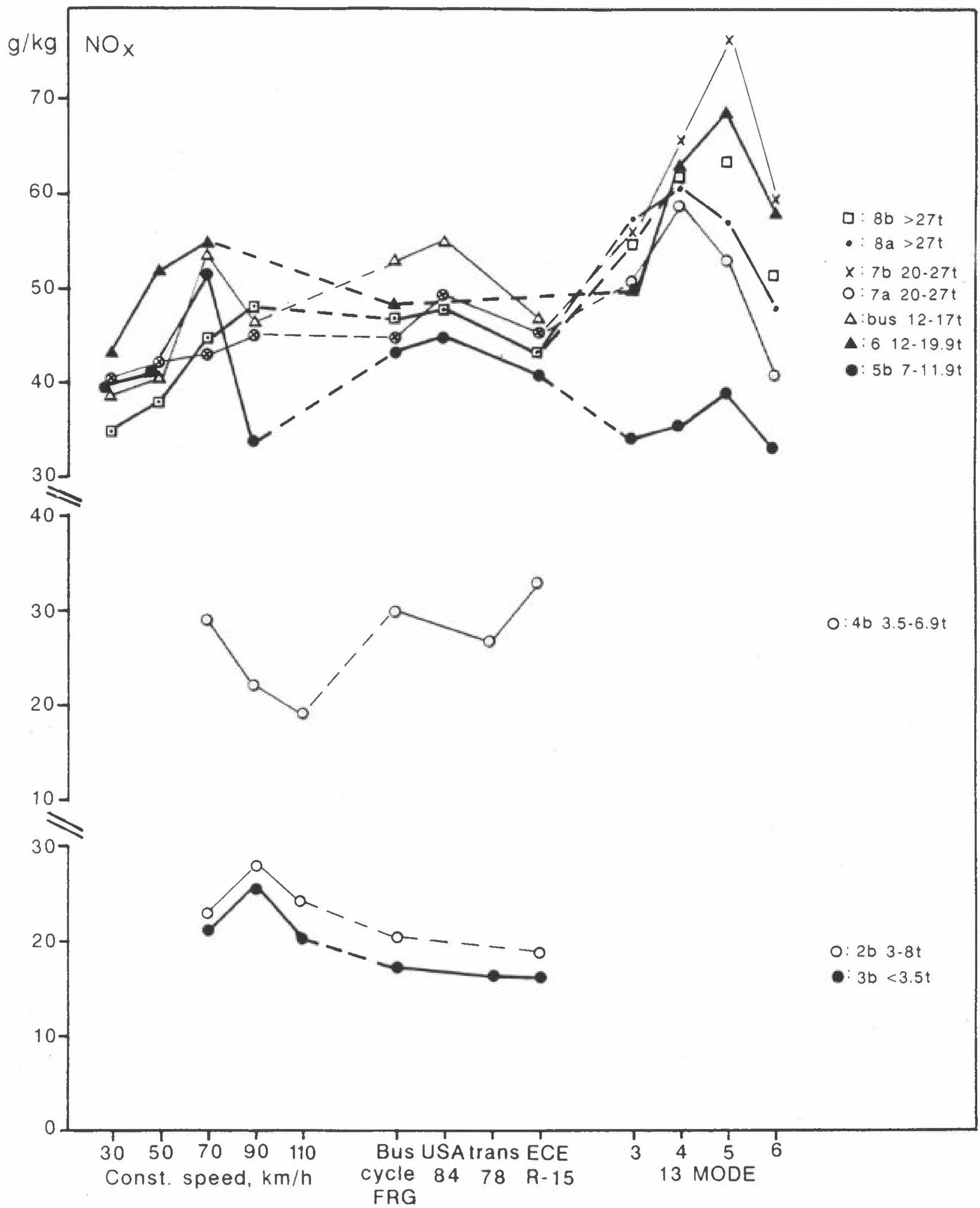

Figure D2: NOx emission factors (g NOx/kg fuel) for diesel vehicles, as a function of vehicle speed. Results of Swedish measurements (Berthilsson, 1987).

Table D5: NOx emission factors (g/kg) derived from measurements on a total of 80 HDDT in Sweden (Berthilsson et al., 1987).

GVW, t	Urban cycles	Rural 50-70 km/h const. speed	Highway 90 km/h const. speed	No. of vehicles
3.5-7 t	30			3
> 7 t	50	45	45	77

Table D6: NOx emission factors (g/kg) for HDDT, derived from Veldt (1986).

GVW, t	Urban	Local 60 km/h	Highway 80 km/h
5.5-12	40	63	72
12-15	43	62	67
> 15	50	67	83

Emission factors reported by TÜV Rheinland (Hassel et al., 1983) are summarized in Table D7. Based on these data, and the GVW distribution of FRG trucks, the following average emission factors (g/kg) can be calculated:

GVW, t	Urban	"Autobahn" (motorway)
3.5-7	52	51
7-14	50	79 (?)
> 14	54	65

Based on this material, we have chosen the following NOx emission factors (g/kg) for HDDT:

GVW, t	Urban	Rural	Highway
3.5-7	50	50	50
> 7	50	60	70
incl. buses			

The distribution between trucks with GVW less or larger than 7 tonnes, is shown in Table D8 for six countries for which data are available to us.

On the average, about 25% of the trucks have a GVW larger than 7 tonnes. They use about twice as much fuel per km (Veldt, 1986), and probably have a somewhat larger annual average driving distance than the lighter trucks. A fair assumption is that about 50% of the HDDT fuel consumption is used by the > 7 t GVW trucks. These assumptions lead to the following emission factor estimates (g/kg) for HDDT as a whole:

	Urban	Rural	Highway
HDDT	50	55	60
Buses	50	60	70

Table D7: NOx emission factors (g/kg) reported by TÜV Rheinland (Hassel et al., 1983).

Driving modes	"Solofahrzeuge"	"Lastzüge"
Urban		
M2	57	65
M3	55	63
M4	51	59
M0	44	60
M5	44	56
M6	41	48
M7	22	28
Autobahn	64	69
Buses	72	

	Driving mode				
	2	3	0	6	K 85
"Solofahrzeuge"					
3.5-7	56	54	42	34	51
7 -10	55	50	46	41	90(?)
10 -14	57	58	51	43	63
14 -16	58	55	52	44	61
16 -22	60	59	22(?)	44	66
"Lastzüge					
22-32	67	63	61	48	69
32-38	63	62	59	48	69
"Busse"	59	59	54	46	72

Table D8: Distribution of HDDT with GVW $\lessgtr$ 7 t.

	< 7 t	> 7 t	% > 7 t
FRG, 1985	573	338	37
Norway, 1985	145.5	50.5	26
Finland, 1986	145	42	22
Sweden, 1985	155	63	29
Denmark, 1985	219	39	15

D1.3.2 Heavy duty gasoline trucks (HDGT)

The US Environmental Protection Agency has given the following nation-wide fleet emission factors (EPA, 1978):

Model year	g NOx/km
pre 1970	5.5
1970-73	8
1974-78	6.6
1979-84	5.7

In Europe, gasoline powered heavy duty vehicles are used mainly in Eastern European countries. For these countries we propose to use 8 g NOx/km. With an average specific fuel consumption of 30 l/100 km, we arrive at an emission factor of about 36 g/kg, which we have chosen to use in our calculations.

D1.4 Motorcycles and mopeds

Veldt (1986) has proposed the emission factors presented in Table D9.

Table D9: NOx emission factors (g/km) proposed by Veldt (1986).

	Urban	Rural	Highway
Mopeds			
- 2-stroke	0.05	0.05	
- 4-stroke	0.1	0.1	
MC			
- 2-stroke	0.1	0.1	0.25
- 4-stroke	0.2	0.2	0.5

Based on the following assumptions concerning MC/moped distribution, fuel consumption (see Appendix A and C) and traffic activity distribution:

- 80% mopeds (2-stroke)/20% MC (50% 2-stroke/50% 4-stroke)
- Traffic activity:
  - Mopeds: 50% urban/50% rural
  - MC: 40%/30%/30% in urban/rural/highway
  - Fuel consumption: MC: 0.03 l/km/Moped: 0.015 l/km

a gross average emission factor can be calculated to 5.5 g/kg.

D2 RAIL TRAFFIC, INTERNAL NAVIGATION AND AGRICULTURE

D2.1 Rail

OECD has recommended the following NOx emission factors:

Passenger trains	11.4 g/km
Freight trains	36.6 g/km

Based on statistics of rail traffic activity in Norway ($12 \cdot 10^6$ train-km in 1984), subdivided into several train categories, data on average specific diesel consumption for each category and the total fuel consumption for the railroads ($15 \cdot 10^3$ t in 1984), the gross average fuel based NOx emission factor for the Norwegian railroads has been calculated to 20 g/kg (Rosland, 1987).

Canada and Finland has reported an emission factor of 44 kg/m^3 (52.4 kg/t) for railroads (ECE, 1987). It is unclear whether this is for freight trains or for average railway traffic. The factor recommended by OECD for freight trains (36.6 g/km) corresponds to about 28 kg/m^3 (34 kg/t), if a fuel consumption of 1.3 l/km i used, as reported for Norwegian railroads. The OECD factor for passenger trains corresponds to about 12 kg/t.

There is a discrepancy between these sources of information on emissions from diesel locomotives.

We have at present no basis for evaluating this discrepancy. We propose to use a composite factor of 20 g/kg for passenger and freight trains, as calculated for Norway, based on the OECD emission factors. This factor is considerably lower than those used for heavy duty diesel trucks and for navigation. It may represent an underestimate of NOx emissions from rail traffic.

D2.2 Internal navigation

Table D10 gives emission factors recommended by OECD and EPA, and those used in Canada and Finland.

Table D10: NOx emission factors for water navigation, reported by various countries.

	Diesel	Residual oil/ heavy fuel oil	Ref.
Canada (kg/m^3)	33	6.7 (res. oil)	ECE, 1987
Finland (kg/m^3)	37 (inland)	32 (sea, heavy fuel oil)	ECE, 1987
OECD (kg/t)	35		OECD, 1984
EPA (kg/t)	37		EPA, 1977

Investigations in Norway involving a review of the literature, and also measurements of NOx emissions from diesel engines on board ships, yield emission factors in the range 40-100 kg/t, dependent upon ship/ engine type and engine load (Melhus, 1986; 1988). Table D11 shows estimated NOx emission factors resulting from this investigation.

Table D11: Summary of NOx emission factors (g/kg).
Source: Melhus, 1986; 1988.

		Propulsion engine		Power generation, auxiliary engine
		Full speed	Harbour speed	
1. Tank/bulk carrier international navig.	< 5 000 brt	80-100	70- 80	40-50
	> 5 000 brt	65- 90	80-120	30-80
2. Coastal navig. Scheduled routes (all types)	< 500 brt	60-100	40- 70	30-40
	> 500 brt	80-100	70- 80	40-50
3. Transport for hire or on own accord	< 500 brt	60-100	40- 70	30-40
	> 500 brt	80-100	70- 80	40-50
	Supply and tug boats	80-100	70- 80	40-50
4. Fishing boats	< 500 brt	40-100	40- 70	-
	> 500 brt	70- 90	70- 80	40-50
5. Pleasure boats				
- Ottoengines	Outboard	2- 5	1- 2	-
	Inboard	10- 30	5- 10	-
- Diesel engines	Inboard	60-100	40- 70	-

A gross average emission factor for Norwegian coastal navigation has on this basis been estimated to 70 kg/t (Rosland, 1987), about twice the emissions recommended by OECD and EPA. In this work we propose to use this emission factor, since it is based on recent measurements and a recent literature survey, including literature from EPA.

Table D12 shows the distribution between types and ships and local conditions which was used to arrive at the average emission figure.

Table D12: Distribution of diesel fuel consumption on types of boats and engine load.
Source: Rosland, 1987.

	Total	Total	Full speed	Harbour speed	Aux. engine
TOTAL	100				
COASTAL TRANSPORT	64				
Scheduled					
< 500 brt	17	100	60	15	25
> 500 brt	19	100	60	15	25
HIRE, OWN ACCORD					
< 500 brt	14	100	60	15	25
> 500 brt	6	100	60	15	25
supply and tug boats	8	100	60	15	25
FISHING BOATS	36				
< 500 brt	18	100	70	30	0
> 500 brt	18	100	60	15	25

We believe NOx emission factors for internal navigation (rivers, lakes) will not differ much from those used for coastal navigation. We have thus chosen to use 70 g/kg as an average emission factor for all diesel oil used for navigation in Europe.

D2.3 Agriculture

Table D13 gives emission factors for agricultural tractors used in some countries, and those recommended by OECD and EPA.

There is fair agreement between the information sources. We have chosen to use 50 kg/t in our calculations.

Table D13: NOx emission factors for agricultural tractors.

	kg/t	Ref.
Austria	40.68	ECE, 1987
Canada	40.20	ECE, 1987
Finland	40	ECE, 1987
Norway	50	ECE, 1987
OECD	53	OECD, 1984
EPA	48	EPA, 1977

APPENDIX E

Road traffic activity

E1 ANNUAL AVERAGE DISTANCE DRIVEN (AADD)

E1.1 Western Europe

Data on AADD are available from OECD (1987) and from IRF (1987), and for some countries, additional national data are available.

The basis for estimating AADD may differ from country to country. The basis may be independently estimated, based on actual AADD statistics, or it may be calculated from total national fuel consumption, no. of cars and spesific fuel consumption.

Table E1 gives data for passenger cars. It is unclear whether light duty diesel cars are included in the data for all countries. The national data indicate that they are included in the FRG and Norwegian data for 1985 and in the Swedish data for 1980.

There is fair agreement between the OECD and IRF data, mostly with a somewhat increased AADD from 1980 (OECD) to 1985 (IRF). Noteworthy exceptions are Italy, Sweden and Switzerland, with seemingly decreased AADD from the 1980 OECD data to the 1985 IRF data.

Table E2 gives AADD data for trucks. There is fair agreement (less than ± 20% difference) between OECD and IRF data for Belgium, Denmark, France, FRG, Netherlands, Norway and Spain, and large disagreement for the other countries, especially for Austria, GB/UK, Italy, Sweden and Switzerland. The national data point to inconsistencies also for Denmark and Norway. Further analysis of total truck traffic work sheds some light on the disagreements (see section E2).

Table E3 gives AADD data for buses.

Table E1: Annual average distance driven (km).
Passenger cars, Western European countries.

	OECD 1980 (OECD, 1987)	IRF 1985 (IRF, 1987)	National data
Austria	10 764	11 000	
Belgium	9 867	13 000	
Denmark	15 473	15 200	
Finland	18 500	17 200	17 200 (1985)[d]
France	13 000	12 500	
FRG	12 824	13 600	Gas.: 11 300 (1985)[e]
			Diesel: 20 100
Great Britain		14 000	
Greece	12 111	16 500	
Iceland	11 800	11 500	
Ireland	20 115		
Italy	11 400	9 900	
Luxemburg			
Netherlands	13 880	14 600	
Norway	11 659	13 500	Gas.: 11 400 (1985)[f]
			Diesel: 20 100
			Taxis: 67 000
Portugal		15 000[a]	Gas.: 6 700 (1985)[g]
			Diesel: 20 000
Spain	7 497	9 100[b]	
Sweden	14 382	12 000	Gas: 13 600 (1980)[h]
			Diesel: 19 800
Switzerland	14 237	12 500[c]	

a 1982.
b "Natl. road network".
c 1983.
d Ref.: Finnish road association, 1987.
e Ref.: Enderlein, 1987.
f Ref.: Rosland, 1987.
g Ref.: Carneiro, 1989.
h Ref.: Olsson, 1983.

Table E2: Annual average distance driven (km).
Trucks, Western European countries.

	1980 (OECD) (OECD, 1987) LDT	HDT	Average[a]	1985 (IRF) (IRF, 1987) "Trucks"	National data LDT	HDT
Austria	15 136	35 180	22 200	50 000		
Belgium	13 321	16 516	14 550	17 000		
Denmark	24 483	29 691	26 170	26 000	26 000 (2-6 t)[d]	57 000 (> 6 t)[d]
Finland	19 344	34 706	24 340	47 000	16 500[e]	47 000[e]
France	19 823	55 340	24 160	20 000		
FRG	18 143	29 527	23 680	23 700	22 800[f]	
Greece	7 587			46 900		
Iceland	10 237	6 221	7 950	20 500		
Ireland		41 205		34 000		
Italy	69 465	50 700	65 470	21 600		
Luxemburg		6 215				
Netherlands	17 920	27 816	21 820	24 165		
Norway	18 820	26 425	24 170	20 000	13 200[g]	20 600[g]
Portugal				10 700[b]	20 000[10]	11 000
Spain	8 585	14 836	10 010	11 100		
Sweden	17 242	33 849	23 350	44 000[c]	15 000[h]	31 260[h]
Switzerland	27 269	39 522	30 850	40 000		
UK (GB)	15 802	26 387	19 000	49 000 (GB)		

a Calculated, based on OECD data on no. of LDT and HDT.
b 1983.
c 1986.
d Estimated data 1985. Ref.: Automobil-importørenes sammenslutning (1986).
e 1985. Ref.: Finnish Road Association (1987).
f "Lastkraftwagen". Ref.: Enderlein (1987).
g 1985. Ref.: Rosland (1987).
h 1980, Estimate. Ref.: Olsson (1983).

Table E3: Annual average distance driven (km).
Buses, Western European countries.

	1985 (IRF) (IRF, 1987)	National data
Austria	45 000	
Belgium	23 000[a]	
Denmark	62 000	65 000 (1985)
Finland	74 100	74 100 (1985)
France	48 000	
FRG	53 300	53 300 (1985)
Great Britain	43 000	
Greece		
Iceland	29 100	
Ireland	38 400	
Italy	51 900	
Luxemburg		
Netherlands	52 300	
Norway	36 000	37 100 (1984)
Portugal		40 000 (1985)
Spain	25 400	
Sweden		42 100 (1980)
Switzerland	58 000[b]	

a 1982.
b 1983.

E1.2 Eastern Europe

IRF (1987) and other sources provide AADD data for some Eastern European countries. They are shown in Table E4. They fall within the range of Western European AADDs, except for PC in Poland, with a calculated AADD of only 5 500 km.

Table E4: Annual average distance driven (km), 1985.
Eastern European countries.

	PC	Trucks	Buses	MC	Moped
Czechoslovakia[1]		35 200			
GDR[2]	10 000			3 500	1 750
Poland[1]	5 500[3]	24 000[3]	57 000[3]		
Yugoslavia[1]	12 500	40 000	58 000		

1 IRF (1987)
2 DIW (1987)
3 Based on fuel consumption.

E2 TOTAL TRAFFIC ACTIVITY

E2.1 Western Europe

Data on total traffic activity are available from OECD (1987) and IRF (1987), and for some countries, additional data are available.

As is also the case for AADD data, it is not clear whether the basis for the traffic activity data is specific traffic work data, or they are derived from fuel consumption.

Table E5 shows traffic work data for passenger cars. There seems to be consistency between the data sources.

Tables E6 and E7 show traffic work for trucks. Table E6 for total trucks (LDT+HDT) shows fair agreement between data sources. Noteworthy exceptions are Austria and Italy, where IRF gives more than twice the traffic activity than OECD.

In Figure E1 the total truck traffic activities are plotted against population. From this, the following is indicated:

- Austria: The OECD figure of $4.3 \cdot 10^9$ km/a seems the most correct.
- Italy : The IRF figure of $40.5 \cdot 10^9$ km/a seems the most correct.

In the case of Italy, the OECD figure for LDT traffic activity seems correct, while the OECD figure for HDT activity seems much too low.

In Figure E1, France has a very large truck traffic activity compared to other countries. Table E7 indicates that the HDT activity is "normal", while the LDT activity is very large compared to other countries. OECD and IRF data agree on the larger total traffic acitivity figure for France.

Table E8 shows traffic activity for buses.

Table E5: Traffic activity (10^9 km/a), passenger cars. Western European countries.

	1980 (OECD, 1987)	1985 (IRF, 1987)	National data
Austria	24.2	27.5	
Belgium	31.2	43.4	
Denmark	21.5	24.2	1980: 21.5 1985: 24.2 (PC and LDT)
Finland	22.7	26.0	1980: 22.2 1985: 26.0
France	239	262	
FRG	297	313	1980: 297, 8% diesel 1985: 313, 15% diesel
Great Britain/UK	202 (UK)	228 (GB)	1981: 203.6 1985: 229.5 98% gasoline for "cars and taxis" (Rogers, 1984)
Greece	10.4	4.4[b,f]	
Iceland	1.0	1.0[c]	
Ireland	14.8		
Italy	202	214	
Luxemburg	-	2.0[a,g]	
Netherlands	58.9	71.5	
Norway	14.4	17.7	1985: 17.7 1980: 15.4
Portugal	-	21.2[a]	
Spain	56.7	56.3	
Sweden	41.5	52.9	1980: 39.9 5.6% diesel
Switzerland	32.1	31.5	

a 1984.
b 1982.
c 1981.
d 1983.
e Calc. based on no. of cars and km/car-year (IRF).
f "Inter city traffic".
g "Incl. foreign vehicles".

Table E6: Traffic activity (10^9 km/a), trucks.
Western European countries.

	1980 (OECD, 1987) LDT + HDT	1985 (IRF, 1987)	National data
Austria	4.29	10.3	
Belgium	3.45	4.5	
Denmark	6.59	5.0	1985: 5.2 (>2-3 t GVW)
Finland	3.77	4.5	1986: 3.7
France	62.2	63.0	
FRG	38.3	31.8	1980: 35.8 1985: 37.4
Great Britain/UK	36.4(UK)	43.0(GB)	
Greece	2.6 + ?	-	
Iceland	0.077	0.18	
Ireland	0.70	-	
Italy	18.3	40.5	
Luxemburg	? + 0.027	0.2	
Netherlands	7.64	9.2	
Norway	2.06	3.4	1985: 3.39
Portugal	? + 0.28	2.0[a]	
Spain	13.82	17.6	
Sweden	4.46	-	1980: 4.05
Switzerland	5.29	-	

a 1983.

Table E7: Traffic activity (10^9 km/a), LDT and HDT, Western European countries.

	LDT		HDT	
	1980 (OECD, 1987)	National data	1980 (OECD, 1987)	National data
Austria	1.88		2.41	
Belgium	1.94		1.51	1986: 1.98
Denmark	4.14	1985: 3.8 (2-6 t GVW)	2.45	1985: 1.4 (> 6 t GVW)
Finland	2.04	1986: approx. 1.7	1.73	
France	44.8		17.4	
FRG	15.1		23.2	
Greece	2.60			
Iceland	0.044		0.033	
Ireland	0.59		0.11	
Italy	15.3		2.95	
Luxemburg			0.027	
Netherlands	3.80		3.84	
Norway	0.47	1985: 1.73	1.59	1985: 1.66
Portugal			0.28	
Spain	9.14		4.68	
Sweden	2.08	1980: 1.81 (estim.)	2.38	1980: 2.24
Switzerland	3.31		1.98	
UK	21.1	1980: 21.3 1985: 23.3[a]	15.3	

a 1983: 15% diesel (Rogers, 1984).

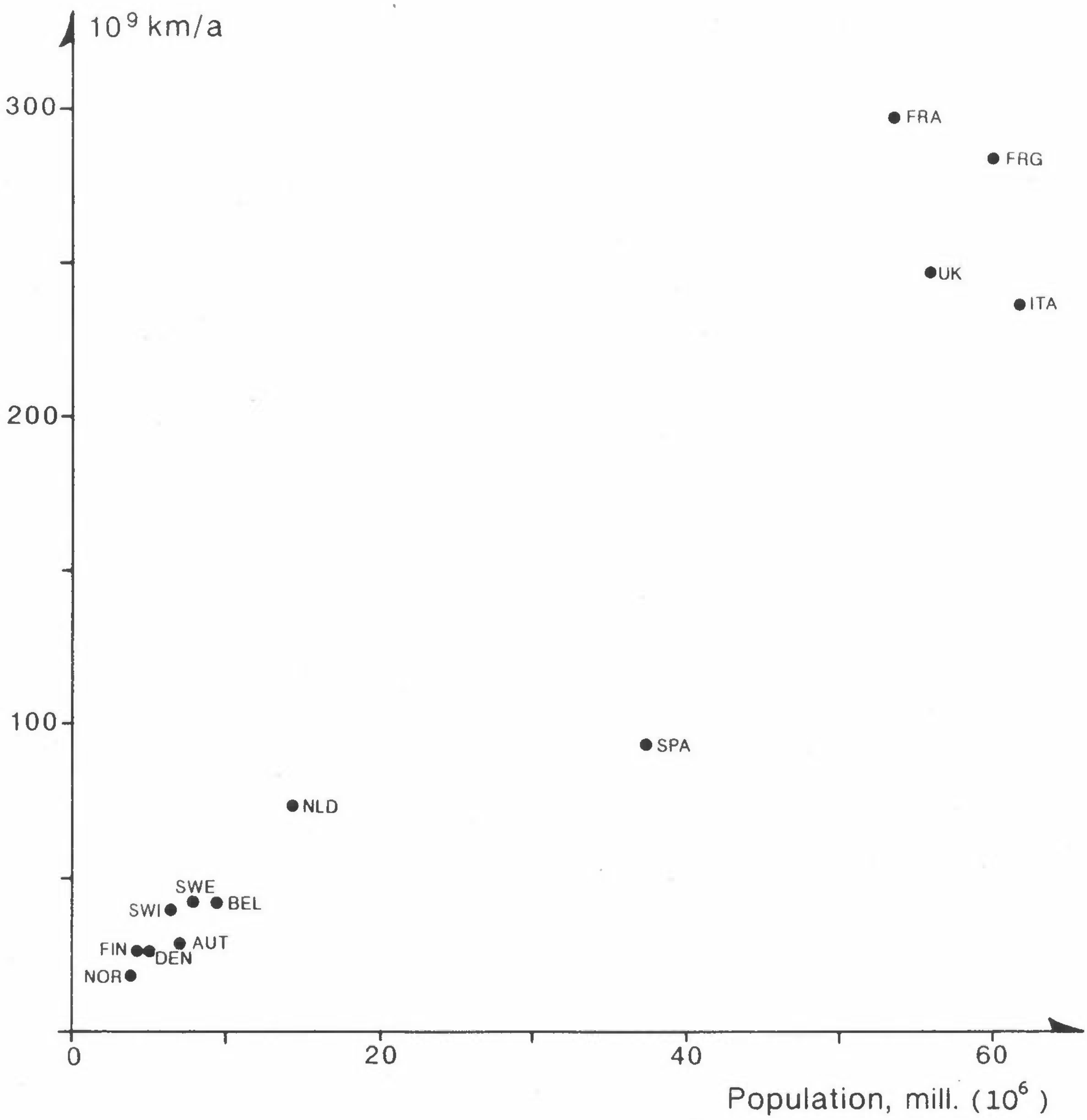

Figure E1: Annual truck traffic activity vs. population.

Table E8: Traffic activity (10^9 km/a), buses and 2-wheeled vehicles, Western European countries.

	Buses		2-wheeled veh.
	1985 (IRF, 1986)	National data	1980 (OECD, 1987)
Austria	0.41		1.67
Belgium	0.39		
Denmark	0.50	1985: 0.49	0.91
Finland	0.67	1985: 0.67	0.60
France	3.0		2.0
FRG	3.3	1980: 3.2 1985: 3.3	5.7
Great Britain (UK)	3.0 (GB)	1985: 2.57 (UK) 1983: 95% diesel traffic act. (Rogers, 1983)	6.02 (UK)
Greece	0.42[a,b]		
Iceland	0.04		
Ireland	-		0.34
Italy	3.7		24.88
Luxemburg	0.04[c]		
Netherlands	0.56		2.50
Norway	0.55	1985: 0.55	0.71
Portugal	0.4		
Spain	1.2		1.55
Sweden		1980: 0.53	0.37
Switzerland			3.03

a 1982.
b "Inter city traffic".
c "Incl. foreign vehicles".

E2.2 Eastern Europe

IRF (1987) provides some data on traffic activity in Eastern European countries. We have calculated traffic activities for some countries from car population data and AADD data. Finally, Laikin (1987) has presented estimates of traffic activities. These data are all presented in Table E9.

The traffic activity data from Eastern Europe are far from complete, and we have no basis for evaluating the quality of the data.

Table E9: Estimated traffic activity (10^9 km/a), Eastern European countries.

	PC			Trucks			Buses			MC		
	IRF	Calc	Laikin[i]	IRF	Calc	Laikin	IRF	Calc	Laikin	IRF	Calc	Laikin
Albania												
Bulgaria		10.3[g]	4.8			3.6	0.75[c]		1.0		1.2[h]	1.1
Czechoslovakia		24.8[g]	21.2	1.91[b]	9.2[d]	4.6	1.07[b]		1.3		3.9[h]	1.7
					13.3[e]							
GDR		33.0[a,g]	26.8			5.3			1.0		4.6[a,h]	3.3
Hungary		14.4[g]	10.1			2.9			0.9		1.6[h]	1.7
Poland	20.2[a]	20.2[f,a]	18.4	18.7[a]	18.7[f,a]	1.5	4.7[a]	4.7[f,a]	2.3	3.9[a]	4.1[h]	4.3
Romania			2.4			2.9			1.0			12.5
USSR			82.5			86.4			15.6			
Yugoslavia		35.9[b]	36.5		7.7[b]	7.6		1.5[b]	1.4		0.4[h]	0.3

a 1985, DIW (1987).
b 1986.
c 1983.
d Trucks.
e Trucks + spec. vehicles.
f Based on fuel consumption.
g Assumed AADD 10 000 km.
h Assumed AADD 2 500 km.
i Laikin (1987).

APPENDIX F

Statistics on freight and passenger transport,
road and rail traffic and internal navigation

Statistics on freight transport on roads, rail and waterways may be used to estimate fuel consumption in these sectors. Such statistics is available from national sources, from IRU and IRF.

F1 FREIGHT TRANSPORT ON ROADS

Tables F1 and F2 give such data for Western and Eastern European countries.

For Western European countries, there is fair agreement between IRU and IRF statistics. For Eastern European countries, a distinction is often made between "professional" freight and "private" freight, sometimes called "on own account". Discrepancies between data sources may often be explained by one source taking account of both freight classes, and the other only the professional freight.

F2 PASSENGER TRANSPORT ON ROADS

Tables F3 and F4 show such statistics for Western European and Eastern European countries, respectively.

F3 FREIGHT AND PASSENGER TRANSPORT ON RAIL AND INTERNAL WATERWAYS

IRU (1985) gives such statistics, shown in Tables F5 and F6.

Table F1: Freight transport on roads, Western European countries.

	FREIGHT TRANSPORT ON ROADS				
	10^6 tonnes		10^9 tonne-km		Average tonnes pr vehicle
	1985 IRF (1987)	1982 IRU (1985)	1985	1982	
Austria	15.6[a,f]	110[l]	8.4[a,f]	6.7[f]	
Belgium	349[b]	321	19.6[b]	19.7	4.4
Denmark	199[g]		9.4[h]	8.4	
Finland	400		22	14.8[d]	4.9
France	1 243	1 203	106		1.7
FRG	2 311	2 251	132	120	4.2
GB	1 444		107		2.5
Greece					
Iceland					
Ireland					
Italy			144		3.6
Luxemburg	14[c]		0.2[a]		1.0[i]
Netherlands	344	358	18.4	17	2.0
Norway	219[b]	208[e]	6[b]	5.1	3.2(1.8)
Portugal	151[a,j]		7.2[a,j]		3.6
Spain			108[k]		(6.1)
Sweden	327	358	21.2	21.1	
Switzerland	318	307[e]	6.6	6.2[e]	

a) 1983
b) 1984
c) 1982
d) 1976
e) 1981

f) "Long distance transport only (> 80 km)"
g) "Domestic trucks > 6 t GVW"
h) "Trucks > 2 t GVW"
i) "Incl. foreign vehicles"
j) "Over 1 ton loading capacity"
k) "On national road network"
l) Estimate of "short distance traffic for hire or reward".

Table F2: Freight transport on roads, Eastern European countries.

	FREIGHT TRANSPORT ON ROADS					
	10^6 tonnes			10^9 tonne-km		
	Ntl. stat.	IRU	IRF	Ntl. stat.	IRU	IRF
Albania		62[a]			1.3[a]	
Bulgaria	816[a] 914[f] 330[h]	837[b]	316[b] 330[f] 324[g]	15.9[a] 17.1[f]	17.1[b]	11.2[b] (prof.) 10.6[f] 10.3[g]
Czechoslovakia	350[h]	1 280[c]	339[g]		21.0[c] (prof.+priv.)	11.7[g]
GDR	730[a] 138[h]	608[c]		21.0[a] 15.0[g]	16.3[c] (prof.+priv.)	6.9[f] (prof.)
Hungary	240[b] 227[h]	238[c,d] 340[c,e]	578[c] 548[g]	6.2[b] 6.6[f]	6.3[c,d] 5.7[c,e]	11.8[c] 9.7[g]
Poland	2 170[a] 1 390[g] 124[h]	1 553[b]	1 576[b] 1 394[f]	44.5[a] 36.6[g]	36.1[b] 20.6 (prof.) 15.4 (priv.)	36.8[b] 36.6[f]
Romania	1 877[a] 2 187[g] 418[h]	479[c]		27.7[a] 27.9[g]	11.2[c]	
USSR	25 900[g] 6 357[h]	25 217[c]		476.0[g]	464[c]	
Yugoslavia		188[c]	188[c] 229[f] 221[g]	20.2[f]	19.3[c]	23.0[g]

a) 1980
b) 1981
c) 1982
d) "Lorry transport enterprises"
e) Goods carried "on own accord"
f) 1984
g) 1985
h) Jahrbuch der DDR (1986), data for 1984.

Table F3: Bus passenger transport on roads, Western European countries.

	BUS PASSENGER TRANSPORT ON ROADS 1985							
	10^6 pass. IRU	Pass./cap, year	Pass./bus, year $\times 10^3$	10^9 pass. km IRU	10^9 pass. km IRF	pass. km/cap·year IRF	pass. km/bus, year $\times 10^3$ IRF	pass./bus average IRF
Austria								
Belgium	540	55	30	4.9	4.9	495	270	13
Denmark				7.8[b]	8.3	1 610	1 060	17
Finland	477[c]	99	52	7.0[c]	8.6	1 760	950	13
France	4 990	92	62		60[a]	1 100	750	20
FRG	6 528[b]	107	92	73.7	61.5	1 000	870	19
GB/UK				40[b] (UK)	42[a] (GB)	760	620	14
Greece, interurban	174[d]	18	54 (interurban and urban)	5.8[d]	0.6[b]			
" , urban	846[d]	86						
Iceland	0.49	2		0.03			25	1
Ireland	246[e]	69	3.5					
Italy					41	720	610	11
Luxemburg								
Netherlands					12.0	830	1 000	21
Norway	324	79	22	4.3[d]	3.8[a]	930	250	7
Portugal					8.2	820	960	21
Spain, regular lines	566	15	110 (regular lines and urban)		31	800	700	26
" , urban	4 305	111						
Sweden								
Switzerland					3.0	470	270	
Average		91[f]	53			940	690[f]	17

a) 1984
b) 1982
c) 1983
d) 1981
e) 1980
f) excl. Iceland.

Table F4: Bus passenger transport on roads, Eastern European countries.

	BUS PASSENGER TRANSPORT ON ROADS								
	10^6 passengers				10^9 passenger-km				
	Ntl. stat.	IRU	Pass. / Cap,year	Pass. / Bus,year x 10^3	Ntl. stat.	IRU	IRF	Pass. km / Cap,year	Pass. km / Bus,year x 10^3
Albania		133[a]	48[a]			1.42[a]		470	
Bulgaria	730[a] 853[f]	769[b]	93		15.4[a] 17.9[e]	15.9[b]	22.4[b] 24.0[e] 24.7[f]	1 950	
Czechoslovakia		2 196[c]	140	68	33.8[a] 35.9[f]	33.7[c]	36.6[f]	2 320	1 100
GDR	3 500[a,h] 3 600[f,h]	1 990[c]	215	67	50.0[a] 51.0[f]	21.7[c]		3 050	960
Hungary		709[c,g] 1 833[c,h]	240	102	21.9[a] 22.9[f]	14.0[c,g]	21.8[b] 25.1[f]	2 140	920
Poland	2 380[a] 2 430[f]	2 340[b]	66	32	49.2[a] 52.1[f]	48.5[b]	48.5[b] 52.1[f]	1 410	680
Romania	1 034[a]	1 000[c]	45		24.0	24.2[c]		1 050	
USSR	6 341[f]	2 053[c,g] 43 701[c,i]	23[g] 164[i]		447.0[f]	45.6[c,g] 12.7[c,i]		1 600	
Yugoslavia		1 016[d]	45		33.5[e]	31.2[d]	30.3[b] 33.9[e] 31.9[f]	1 460	
Average			117	67				1 705	920

a) 1980
b) 1981
c) 1982
d) 1983
e) 1984
f) 1985

g) Long distance only
h) Local
i) "Public road traffic"
j) Except urban.
k) Incl. trams and local trains

Table F5: Freight and passenger transport on rail and internal waterways, Western European countries.
(Source: IRU, 1985.)

	RAIL				INTERNAL WATERWAYS (incl. coastal)			
	Tonnes 10^6	Ton.km 10^9	Pass. 10^6	Pass.km 10^9	Tonnes 10^6	Ton.km 10^9	Pass. 10^3	Pass.km 10^6
Austria[a]	50.0		170.0	7.2	6.6		564	27
Belgium[a]	63.5		177.0 + urban	6.95 + urban	90.6	5.0		
Denmark[a]		1.0				2.0		
Finland[b]	29.7	8.4		3.3				
France[a]	184	61.2	714	56.8	76	10.2		
FRG[a]	318	58.8	1 157	40.6	222	49.4		
Greece[c]	3.0	0.7	10.4	1.5				
Iceland								
Ireland[a]	3.6[d]	0.39[d]	12.8	1.0[d]				
Italy[d,e]	60.7	18.4	373	39.2				
Luxemburg								
Netherlands[a]	18.2	2.9	209	9.4	68.4	6.2		
Norway[c]	8	1.65	38	2.3	60.0	8.9	51[f]	0.63[f]
Portugal	3.7	1.0	213	5.9				
Spain[a]		10.9	283	15.9				
Sweden[a]	44	14.3	93[g]	6.6[g]				
Switzerland[a]	54		316	11.6				
UK[a]	143	15.9		31.3				

a) 1982
b) 1983
c) 1981
d) 1980
e) "State railway only"
f) Ferry and other regular services
g) State + private.

Table F6: Freight and passenger transport on rail and internal waterways, Eastern European countries.
(Source: IRU, 1985.)

	RAIL				INTERNAL WATERWAYS			
	Tonnes 10^6	Ton.km 10^9	Pass. 10^6	Pass.km 10^9	Tonnes 10^6	Ton.km 10^9	Pass. 10^6	Pass.km 10^6
Albania	5.8[a]							
Bulgaria[b]	82	18.1	97.3	7.0	5.0	2.5	0.4	41
Czechoslovakia[c]	289	71.6	413	19.0	11.4	3.8		
GDR[c]	323	54.0	623	24.8	16.8	2.3 + 55.7 (maritime)		
Hungary	127	23.3	266[d]	13.1	4.2	7.9	3.4	0.07
Poland[b]	1 114	48			16.6	1.9	9.0	0.1
Romania[c]	271	71.1	375	25.6	14.2	2.55	1.9	0.07
USSR			3 578	348				
of which "suburban"			3 205	97				
Yugoslavia[c]	85.7	26.2	111	11.3	21.7 + 21.8 (maritime)	4.2		0.03

a) 1980
b) 1981
c) 1982
d) "Long distance" (exl. urban)

APPENDIX G

National fuel consumption statistics

UN and OECD statistics are available on national consumption of gasoline and motor diesel oil (United Nations, 1986; OECD, 1987b). For Western European countries, data are also available on diesel consumption in various sectors such as road traffic, rail, agriculture, etc.

Total fuel consumption may also be calculated from traffic activity and specific fuel consumption data (l/km). We are aware that traffic activity data in some cases may be derived from the total fuel consumption statistics, so that comparing these two figures for total fuel consumption may be misleading.

G1 GASOLINE

Table G1 gives OECD data for annual gasoline consumption in Western European countries. Included are also the fuel consumption calculated from the traffic activity data from Appendix E and the following specific fuel consumption figures (Appendix B):

Passenger cars	: 10.7	l/100 km
Light duty trucks	: 15	l/100 km
Motorcycles/mopeds:	2.25	l/100 km

One correction has been made in the traffic activity data:
For LDT in Italy, the OECD figure for AADD is 69 900 km/a. The corresponding figures for the other Western European countries fall within the range 8 600-27 300 km/a. We have used an estimated figure of 17 500 km/a for Italy, based on AADD figure from France, FRG and GB.

Table G1: Annual gasoline consumption (10^3 metric tonnes), 1985.

	OECD, 1985	Calc. from traffic activity[d]
Austria	2 405	2 287
Belgium	2 501	3 323
Denmark	1 513	2 201
Finland	1 504	2 151
France	17 776	23 930
FRG	23 430	22 950
Greece	1 736	1 875
Iceland	99	105
Ireland	841	
Italy	11 103	15 975
Luxemburg	303	
Netherlands	3 389	5 342
Norway	1 565	1 571
	1 682[a]	
	1 544[b]	
Portugal	854	875
	821[c]	
Spain	5 894	6 632
Sweden	3 750	3 563
Switzerland	3 026	3 190
UK	20 403	21 879

a Annual gasoline cons. National statistics (Central Bureau of Statistics of Norway, 1987).
b Gasoline cons., road transport. National statistics (Central Bureau of Statistics of Norway, 1987).
c Gasoline for road transport. National statistics (Carneiro, 1989).
d LPG-powered cars represent only a very minor part of the traffic activity except for some countries, where the traffic activity figures have been reduced with the following percentages, to represent only gasoline powered activity:
Denmark: - 2% Netherlands: -10%
Italy : - 6% Spain : - 3%
The estimated reductions are based on OECD data (OECD, 1987; OECD, 1988).

Noteworthy disagreements in Table G1 are the following:

	OECD	Calc. from traffic act.	
Belgium	2 501	3 323	+ 33%
Denmark	1 513	2 201	+ 45%
Finland	1 504	2 151	+ 43%
France	17 776	23 930	+ 35%
Italy	11 103	15 975	+ 44%
Netherlands	3 389	5 342	+ 58%

From a plot of gasoline traffic activity vs. population (Figure G1) the traffic activity data for the above countries seem to fall in line with the other countries, except France is a bit high. On the other hand, there is no reason to question the OECD fuel consumption data.

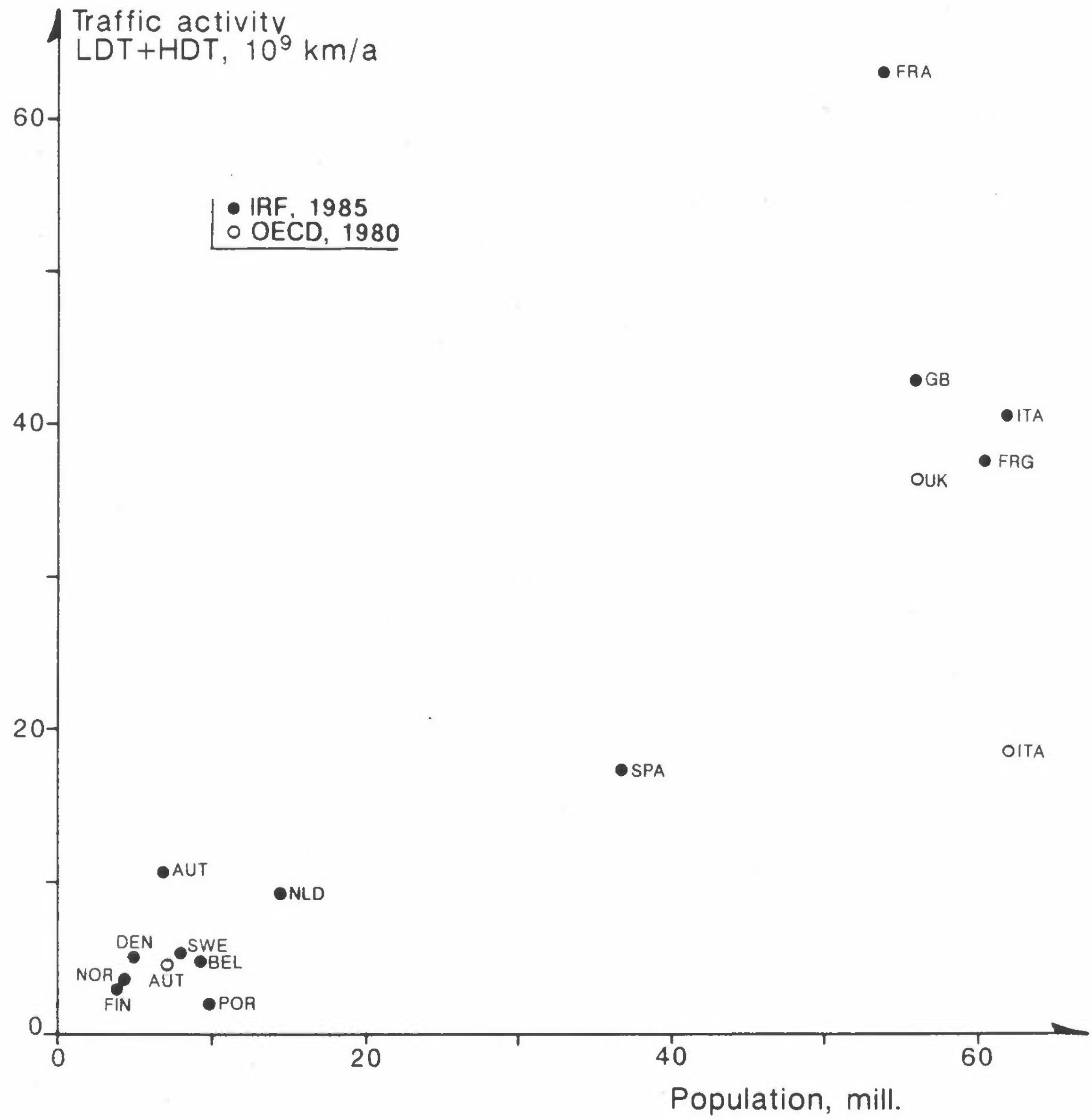

Figure G1: Traffic activity, gasoline vs. population.

The main probable reasons for the disagreements are the following:

- The specific fuel consumption of 10.7 l/100 km for passenger cars is probably an overestimate for countries such as Denmark, France, Italy, The Netherlands, with a large population of small cars.

- For smaller countries such as Denmark and the Netherlands tanking and driving abroad may contribute somewhat to the discrepancies.

The gasoline consumption for Eastern European countries is shown in Table G2, from UN statistics. Included is also some data from national sources, and from IRF.

The IRF data for Czechoslovakia seem erroneous. For Yugoslavia, gasoline consumption can be calculated based on the reported AADD of 12 500 km. This gives an annual consumption of around 2 800 10^3 tonnes. Thus, the IRF figure for Yugoslavia seems to be low.

Table G2: Annual gasoline consumption, Eastern European countries (10^3 metric tonnes).

	UN, 1984	IRF, in road veh.	National data
Albania	270		
Bulgaria	1 800		
Czechoslovakia	1 778	256 (1986)	
GDR	3 438		2 475 (1983) (DIW 1987)
Hungary	1 219	1 271 (1985)	
Poland	2 981		2 783 (1985) (Jaguzievicz, 1988)[a]
Romania	2 186		
USSR	68 000		
Yugoslavia	3 295	1 770 (1984)	

a) 14% used in 2-stroke engines.

G2 DIESEL

Table G3 gives diesel oil consumption data for Western European countries from OECD, UN and IRF. For Norway, revised national data are also given for diesel oil and heavy oil consumption for internal navigation and for the fishing fleet.

There is a large discrepancy between the total consumption data from OECD and UN for the following countries:

	OECD, 1985	UN 1984
Austria	2 565	3 833
Netherlands	4 647	6 303

There is fair-to-excellent agreement between the OECD and IRF data for all countries, as far as road traffic diesel consumption is concerned.

Generally, the sum of diesel consumption in the various sectors in Table G3 is less than the total consumption reported to OECD. The difference may be used in military vehicles, road working and construction machinery and in combustion in stationary machinery. In some countries, as in Norway, consumption in road and construction machines is listed under the commercial/public sector.

In Table G4 the OECD road transport diesel data can be compared with those calculated from traffic activity data and the following specific fuel consumption figures (see Appendix B):

Passenger cars	:	8.8 l/100 km
Light duty trucks	:	13 l/100 km
Heavy duty trucks	:	30 l/100 km
Buses	:	35 l/100 km

Table G3: Annual diesel oil consumption, Western European countries.

	DIESEL OIL CONSUMPTION (10^3 tonnes)										
	OECD 1985								UN 1984[d]	IRF 1984	
	Total	Road transport	Rail-ways	Internal navig.	Agri-culture	Comm. public	Resi-dential	Other	Total	Motor fuel	In road vehicles,%
Austria	2 565	1 459	53				1 053		3 833	1 522	?
Belgium	7 623	2 391	109	212	242	830	3 535		6 863	2 391	100
Denmark	5 073	1 118	114	215	473	329	1 881	302	4 716	2 654	46
Finland	4 009	1 299	71	34	425		1 641		4 310	1 299	100
France	33 068	10 520	483	78	2 300	15 236		386[b]	33 351	10 900	96.5
FRG	51 890	11 645	470	699	1 260	9 971	23 221	569	50 742	14 556	80
Greece	3 567	1 200	52	236	787		942	104	3 595	3 689	29
Iceland	240	42[e]		156			22		207	241	17
Ireland	1 287	516	43	5		241	105		1 273	1 292	30
Italy	25 750	11 388	213	329	1 557	790	10 293		24 978	24 941	53
Luxemburg	523	184	9		3		282		484	547	34
Netherlands	4 647	2 660	40	292	90		272	876	6 303	4 658	57
Norway	2 878	594	20	577	153	436[a]	318		3 161	932[c]	73
	3 879[c]			1 092[f]							
Portugal	1 818	1 136	57	52	367	69	5		1 955	1 775	67
		1 244[g]									
Spain	10 963	5 500	180	1 078	2 212	604	1 001		10 795	5 371	100
Sweden	5 874	1 409	82	81	355		3 268	80	5 053	2 455	60
Switzerland	6 772	671	11	9	70	1 321	3 639	43[b]	6 427	864	72
UK	16 923	7 106	718	1 071	825	2 816	423	713	17 312	6 750	100

a) $86 \cdot 10^3$ tonnes in this sector is used in construction vehicles
b) Road traffic
c) National statistics (Central Bureau of Statistics of Norway, 1987)
d) "Gas-diesel oils"
e) Incl. 10^4 tonnes used in construction machines (Gisladottir, 1988)
f) Revised, national data (10^3 metric tonnes) (Central Bureau of Statistics of Norway, 1987):

	Diesel-gas oil	Heavy oil
Internal navig.	453	186
Fisheries	448	5

g) National statistics (Carneiro, 1989).

Table G4: Annual road transport diesel consumption, Western European countries (10^3 metric tonnes). OECD data and calculated consumption from traffic activity data reported to OECD.

	OECD, 1985	Calculated from traffic activity
Austria	1 459	1 083
Belgium	2 391	1 815
Denmark	1 118	1 100
Finland	1 299	1 116
France	10 520	9 842
FRG	11 645	9 231
Greece	1 200	1 437
Iceland	32[a]	23.5
Ireland	516	405
Italy	11 388	8 981
Luxemburg	184	33.5
Netherlands	2 660	1 391
Norway	594	578
Portugal	1 136	1 380
	1 244[b]	
Spain	5 500	2 991
Sweden	1 409	1 130
Switzerland	671	691
UK	7 106	7 029

a National data (Gisladottir, 1988)
b National data (Carneiro, 1989).

There are larger discrepancies (> 20% difference) for the following countries:

	OECD	Calc. from traffic act.	
Austria	1 459	1 083	- 25%
Belgium	2 391	1 815	- 24%
Italy	11 388	8 981	- 21%
Luxemburg	184	33.5	- 78%
Netherlands	2 660	1 391	- 48%
Spain	5 500	2 991	- 46%

We have no specific explanations for the disagreements. The traffic activity data, especially the AADD data, may be inaccurate.

Annual diesel production and consumption in Eastern European countries are shown in Table G5. No data on diesel consumption in the various consumption sectors are available to us, except national data and IRF for road transport diesel consumption in Czechoslovakia, GDR, Hungary and Poland.

Table G5: Annual diesel oil consumption, Eastern European countries.

	DIESEL OIL, 10^3 tonnes					
	National statistics, 1985	UN statistics, 1984[a]			IRF statistics, 1984	National data
	Production	Production	Consumption Total	Consumption per cap (kg/cap)	Consumption	Consumption in road vehicles
Albania		380	380	127		
Bulgaria		3 400	4 000	436		
Czechoslovakia		3 688	3 138	201	2 916[g] (75% in rd. veh.)	
GDR	6 350[b]	6 162	5 313	319		858[f]
Hungary	3 533	3 522	3 638	337	887[c,d] (72% in rd. veh.)	
Poland	4 833[b]	4 694	5 568	150		2 468[h]
Romania	6 842	6 809	4 094	179		
USSR		120 000	90 100	327		
Yugoslavia	3 650	3 656	3 585	156	2 988[d]	

a) "Gas-Diesel Oils"
b) "Oil for high pressure engines"
c) 1985
d) Unspecified, but probably consumption in motor road vehicles
e) Road traffic: Buses: 9 000 tonnes
f) Bethkenhagen, et al. (1988)
g) 1986
h) Gis and Radzimirski (1987).

APPENDIX H

Estimates of diesel fuel consumption in various sectors, Eastern European countries

- H1 Road freight traffic
- H2 Bus traffic
- H3 Rail traffic
- H4 Internal navigation
- H5 Agriculture

Very little data is available on diesel oil consumption in various consumption sectors in Eastern European countries.

For Poland, national data are available for all transportation sectors and agriculture. For Czechoslovakia, GDR and Hungary estimates of road traffic diesel consumption are available, either national estimates (GDR) or from IRF (see Appendix G).

A good basis for estimating diesel consumption in the various mobile source sectors is not available. It is, however, possible to use consumption statistics from Western European countries, together with statistics on freight volume and agricultural area for all countries. The uncertainty associated with such estimates will of course be fairly large, but a better method is not available. However, with this method we do account for the energy required to transport the freight volume reported by each country, assuming the energy requirement per unit freight is the same in Eastern Europe as in Western Europe. Since little information is available on the gasoline/diesel partition of trucks and buses in Eastern Europe, we may not by this method differentiate correctly between gasoline and diesel consumption for road freight work. This is especially true for the USSR. However, the total NOx emissions from road traffic (diesel + gasoline) are not affected to a large extent by such errors.

The resulting estimates of diesel consumption in the various sectors in Eastern European countries are given in Table H1. The basis is described in the following sections.

The column called "Rest" in Table H1 is arrived at by subtracting the estimated consumption in road and rail traffic, internal navigation and agriculture from the total consumption given in UN statistics (UN, 1986). This rest may be diesel consumed in stationary machines (which is the case in Poland) (Jagusiewicz, 1988), marine navigation, small combustion furnaces, and other sectors.

It is seen from the Table H1 that the "Rest" is negative for Czechoslovakia, Romania and Yugoslavia. This indicates the level of uncertainty of our estimates of diesel consumption in the various sectors. In the subsequent calculations of NOx emissions, we have chosen to reduce the diesel consumption in heavy duty trucks, which is the largest sector, so that the negative "Rest" in these countries is reduced to zero.

Table H1: Diesel consumption in various sectors, East European countries, 1985 (10^3 metric tonnes).

	Total (UN, 1986) (1)	Road traffic Trucks (2)	Buses (3)	PC[a] (4)	Rail (5)	Internal navig. (6)	Agriculture (7)	Rest (8)
Albania	380	90[b]	14[c]	14				262
Bulgaria	4 000	736[b]	247[c]	50	217[h]	30[i]	500[i]	2 220
Czechoslovakia[f]	3 138	1 732	366[c]	89	859[h]	46[i]	700[i]	- 654
GDR	5 313	640[d]	218[d]	0[d]	705[d]	21.5[d]	650[i]	3 078
Hungary	3 638	639[k]	251[c]	64	280[h]	95[i]	700[i]	1 609
Poland	5 568	1 945[e]	314[e]	209[e]	546[e]	31[e]	1 476[e]	1 047
Romania	4 094	2 070[b]	240[c]	109	853[h]	31[i]	1 300[i]	- 509
USSR	90 100	4 125[b]	4 130[b]	3 400	9 200[j]		27 800[i]	41 445
Yugoslavia[g]	3 585	2 504	319[c]	165	314[h]	50[i]	1 000[i]	- 746

a) 5% of gasoline consumption, except Poland (8.4%) and GDR (0%)
b) Based on Western Europe estimate (see section H1)
c) Based on GDR estimate: 10 t diesel/10^6 pass.km
d) National statistics (DIW, 1987)
e) National statistics (Gis and Radzimirski, 1987)
f) Columns 2+3+4 equals IRF data for total diesel consumption in road vehicles (2 187 · 10^3 tonnes)
g) Columns 2+3+4 equals IRF data for total diesel consumption in road vehicles (2 988 · 10^3 tonnes)
h) Based on Western Europe estimate: 12 kg/10^3 ton.km (freight)
i) Based on Western Europe estimate: 120 kg/ha
j) Based on average consumption in other Eastern European countries: 33 300 tonnes/10^6 capita
k) IRF (1987).

H1 ROAD FREIGHT TRAFFIC

Figure H1 shows fuel consumption per capita in light and heavy duty trucks versus freight volume per capita (ton km/cap).

Fuel consumption is calculated as "diesel equivalents" (= kg diesel + 0.65 x kg gasoline. We have estimated that the fuel efficiency of large diesel engines is some 50% higher than for similar gasoline engines). A linear relationship is estimated in the Figure. There is a considerable spread around the indicated relationship, due to variable data quality and transport efficiency of the country (for example average weight carried on each vehicle).

In Figure H2 similar data are plotted for the Eastern European countries for which data are available (CZ, HUN, GDR, POL and YUG). The consumption data are presented in Table 4 and in Table G5. The five Eastern countries have an average fuel consumption for road freight which is somewhat larger than Western countries with the same freight volume. However, considering that freight volume data are not very accurate, and also the assumptions made when estimating the gasoline consumption for road freight, we can only conclude that the energy consumption for per capita unit road freight is about the same in Eastern and Western European countries. We thus have a basis for estimating the total fuel consumption for road freight in ALB, BUL, ROM, and USSR, and thus the diesel consumption, since the gasoline consumption has been estimated earlier (Section 1.3).

This is estimated in Table H2. The table shows that according to our estimates, most of the energy for road freight in the USSR is covered by the gasoline consumption.

Table H2: Estimate of per capita consumption of diesel for road freight work, as the difference between total diesel_{eqv}/cap and gasoline_{eqv}/cap.

	ALB	BUL	ROM	USSR
Total kg diesel_{eqv}/cap (from Figure H2)	30	140	90	130
Gasoline_{eqv}/cap (kg gasoline x 0.65) (from Table 4)	$\approx 0^{a}$	60	$\approx 0^{a}$	115
Kg diesel/cap	30	80	90	15

a) estimated.

H2 BUS TRAFFIC

Figure H3 shows a plot of diesel consumption per capita in buses vs. pass.km/capita·year for Western European countries. Data for Poland and GDR are also included.

	$t/10^6$ pass.km
Western Europe	~ 25 (range: 17-50)
Poland	6
GDR	10.3

There is a large range in calculated diesel consumption per pass.km, based on the available data. The low consumption for Poland and GDR points towards a larger average passenger load on buses than in Western European countries. This is also indicated by statistics showing pass.km/ bus·year, which is $690 \cdot 10^3$ in Western European countries, and $920 \cdot 10^3$ in Eastern European countries (Czechoslovakia, GDR, Hungary, Poland) (see Tables F3 and F4).

We choose to use the GDR estimate for other Eastern European countries as well, 10 kg/10^3 pass. km. This gives the bus diesel consumption figures in Table H1.

H3 RAIL TRAFFIC

Figure H4 shows annual data for rail diesel consumption per capita vs. tonne-km freight per capita for Western European countries, as well as for Poland and GDR. Especially Denmark, UK and Ireland reports very large diesel consumption per capita, relative to their reported freight work. Obviously, two parameters will tend to distort a relationship between diesel consumption and freight work:

- the distribution in each country between diesel and electric rail traffic activity
- the distribution in each country between diesel powered freight transport and passenger transport work.

We have not collected data on these parameters. However, the reasonably good relationship in Figure H3 (again except UK, Ireland and Denmark) justifies an estimate of rail diesel consumption based on data on total rail freight work.

We estimate the rail diesel consumption to be about 12 kg/10^3 tonne-km. Using that estimate, we arrive at the rail consumption figures for Eastern European countries given in Table H1.

H4 INTERNAL NAVIGATION

Figure H5 shows a plot of annual data for diesel consumption per capita vs. freight tonne-km per capita for Western European countries. Data for GDR and Poland are also included. Here, Denmark, Norway, Belgium and Netherlands have large diesel consumption relative to the freight volume. This may be explained by the large portion of coastal navigation in these countries. Based on the other countries, we estimate the diesel consumption for non-coastal internal navigation to be about 12 kg/10^3 ton km, the same estimate as for rail traffic. This gives the diesel consumption for non-coastal internal navigation given in Table H1.

H5 AGRICULTURE

Figure H6 shows a plot of diesel consumption in agriculture in Western European countries, as a function of agricultural area (FAO, 1984). Data for Poland (Jagusievicz, 1988) are included. In the reference, there are two independent estimates for agricultural diesel consumption in Poland. The lowest estimate fits fairly well with the estimates from Western European countries.

There is a fairly good linear relationship between diesel consumption and agricultural area. Based on this, we estimate the diesel consumption in agriculture to be 120 kg/ha. This gives the agricultural diesel consumption estimates for Eastern European countries given in Table H1.

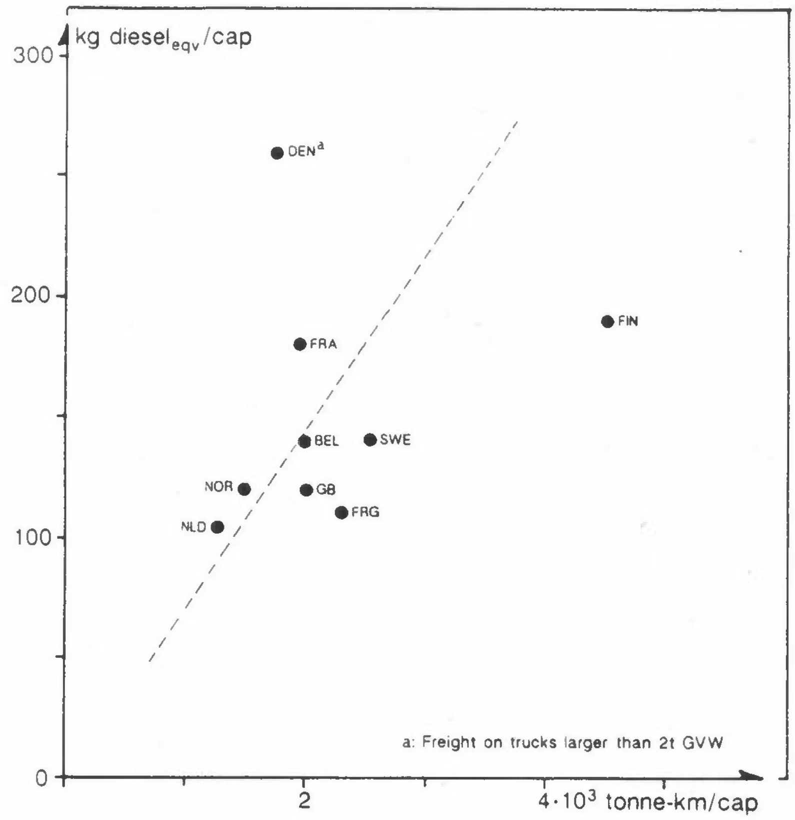

Figure H1: Road freight diesel consumption (kg/cap.) vs. freight volume (tonne-km/cap.), Western European countries.

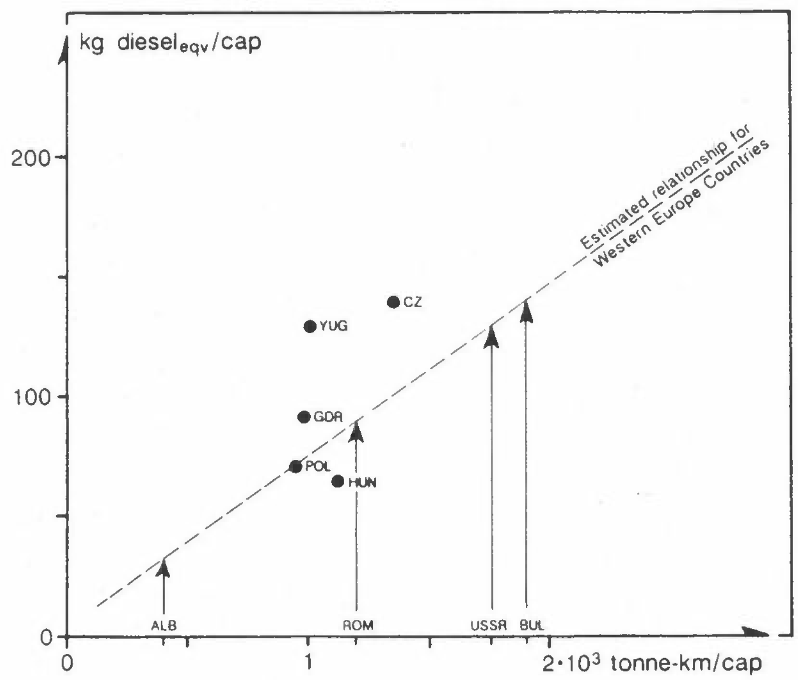

Figure H2: Road freight diesel consumption (kg/cap.) vs. freight volume (tonne-km/cap.), Eastern European countries.

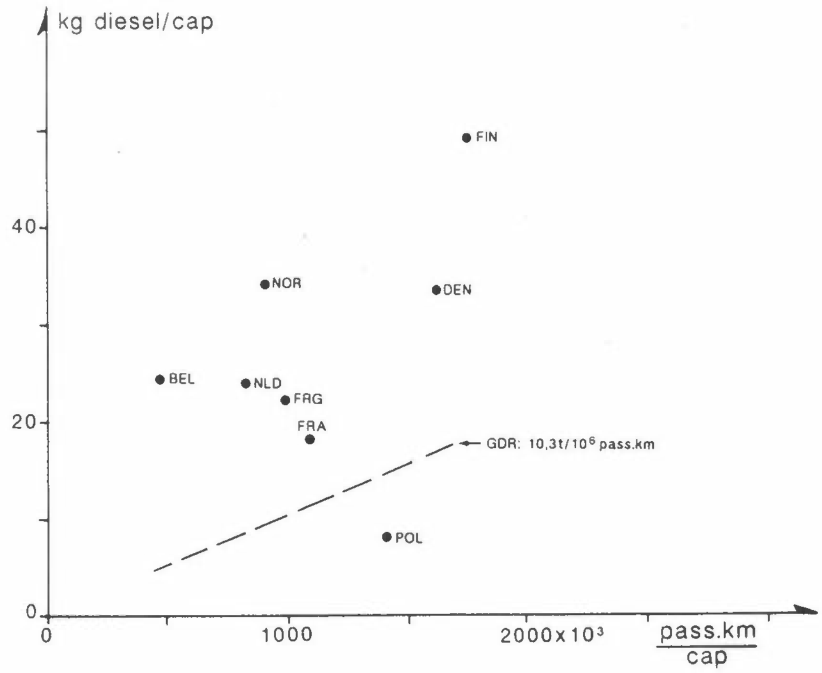

Figure H3: Bus diesel consumption (kg/cap.) vs. passenger freight volume (pass.km/cap.).

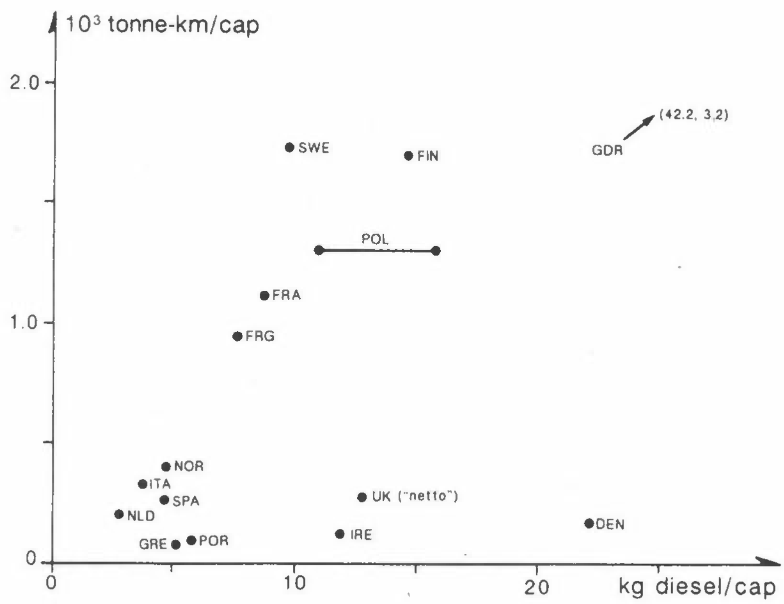

Figure H4: Rail diesel consumption (kg/cap.) vs. rail freight volume (tonne-km/cap.).

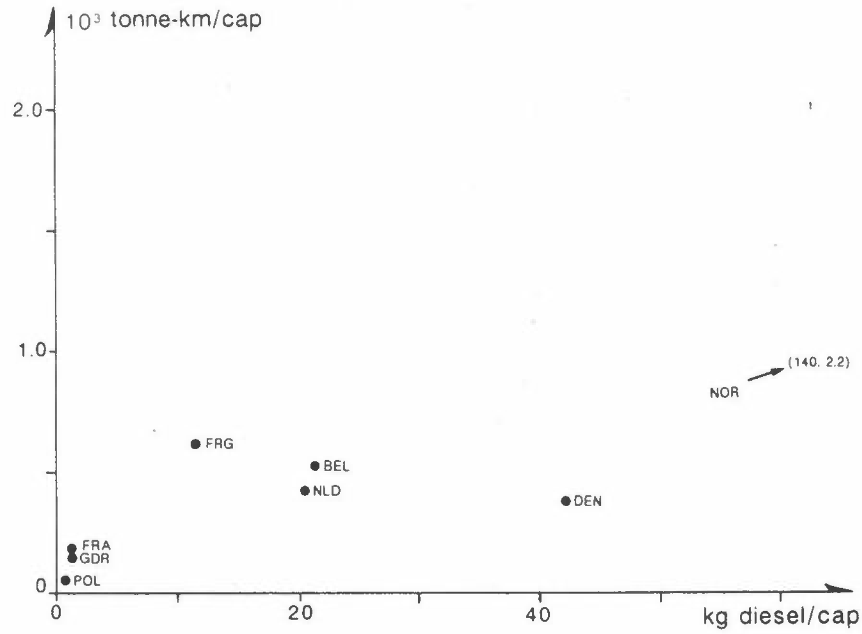

Figure H5: Diesel consumption for internal navigation (kg/cap.) vs. freight volume (tonne-km/cap.).

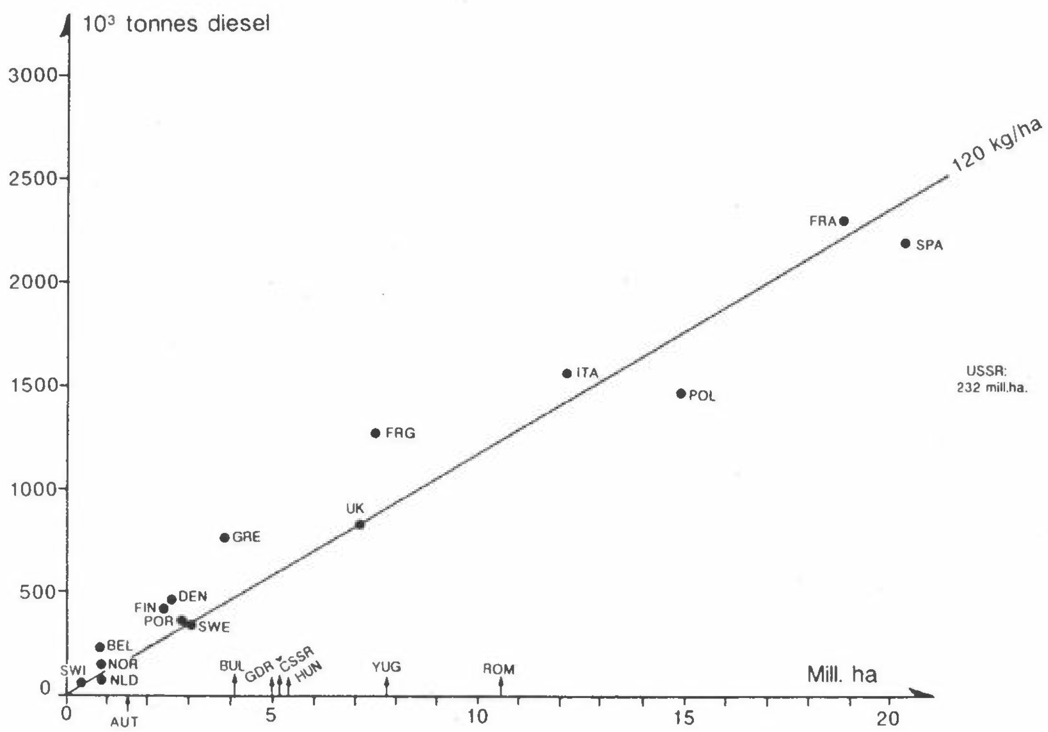

Figure H6: Diesel consumption in agriculture vs. agricultural area.

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TITTEL NOx emissions from gasoline and diesel oil combustion in mobile sources in Europe, 1985		PROSJEKTLEDER A. Semb	
		NILU PROSJEKT NR. O-8668	
FORFATTER(E) S. Larssen		TILGJENGELIGHET A	
		OPPDRAGSGIVERS REF. FE-Vorhaben "NOx-Emissionen in Europa"	
OPPDRAGSGIVER (NAVN OG ADRESSE) Umweltbundesamt Bismarkplatz 1 D-1000 Berlin 33			
3 STIKKORD (à maks. 20 anslag) Nitrogenoksider	Utslipp	Mobile kilder	

REFERAT (maks. 300 anslag, 7 linjer)

Rapporten presenterer metode for og beregning av utslipp av NOx fra mobile kilder (biltrafikk, tog, innenriks sjøfart og jordbrukstraktorer) for de enkelte land i Øst- og Vest-Europa for 1985.

TITLE

ABSTRACT (max. 300 characters, 7 lines)

The report presents the method and results of calculations of emissions of NOx from mobile sources (road traffic, rail traffic, internal navigation and agricultural tractors) for each country in Eastern and Western Europe in 1985.

* Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C