Scenarios for Transboundary Air Pollutants from the Transport Sector in Europe

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Abstract

Scenarios for the European transport sector are used to examine the impact on transboundary air pollution of a range of vehicle emission standards, technologies and demand management measures and to produce estimates of national emissions in the UN/ECE region. This paper demonstrates the possible reductions in emissions of nitrogen oxides and volatile organic compounds which could be achieved using different policy instruments.

Keywords

Business-as-usual, Europe, environmentally sustainable transport, long-range transboundary air pollution, transport scenarios, technology, UN/ECE region

Introduction

Air pollution from the transport sector has important health and environmental effects. It is a main source of nitrogen oxides (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter (PM) and carbon monoxide (CO), and is a major emitter of carbon dioxide (CO_2) and other greenhouse gases. The transport sector is a main contributor to global, regional and local air pollution. The rates of growth in road and air transport both regionally and globally are indicative of a non-sustainable trend.

The long-range movement of air pollutants from the transport sector, such as emissions of sulphur and nitrogen oxides, has resulted in acid deposition. Transboundary air pollution has caused widespread acidification of terrestrial and aquatic ecosystems, which has had impacts on human health, crop productivity, forest growth, biodiversity and man-made materials. The United Nations' Economic Commission for Europe (UN/ECE) Convention on Long-range Transboundary Air Pollution (LRTAP) (1979) provides the framework for controlling and reducing damage to human health and the environment caused by transboundary air pollution. The Convention came into force in 1993 and has been extended by five specific protocols on nitrogen oxides, sulphur and volatile organic compounds.

This paper is based on a study funded by the Swedish Environmental Protection Agency on air pollution from the transport sector in Europe (Haq and Bailey, 1998). The study was commissioned as a contribution to the UN/ECE Task Force on Integrated Assessment Modelling (TFIAM), which supports the LRTAP Convention. The final results of the study were presented at the twenty-second meeting of the TFIAM which was held in London in December 1998.

This paper examines how emissions of transboundary air pollutants (excluding greenhouse gases) from the transport sector can be reduced in Europe through the application of different vehicle emission standards, technologies and demand management measures. Scenario analysis is used to produce estimates of national emissions of transboundary air pollutants in the UN/ECE region.

Traffic growth

Since the early 1980s the road transport of freight and passengers in the European Union has increased by roughly 45% and 41% respectively. In contrast, the transport of freight by rail has decreased while passenger rail transport has increased by 10%. In the period 1970-1993 passenger transport in the member states of the European Union (EU) grew at an annual rate of 3.2%. The average distance travelled every day by each European citizen in this period increased from 16.5 km to 31.5 km. This growth in the demand to travel has been met mainly by the motor vehicle, which now accounts for 75% of all kilometres travelled in the EU. Car ownership in the period 1975-1995 grew from 232 per 1000 people to 435 per 1000 people (EC,

Table 1: Contribution of road transport to total anthropogenic NO_x emissions (1990)

Country	*Road traffic*
Austria	68%
Belgium	55%
Denmark	37%
Germany	62%
Finland	44%
France	65%
Greece	21%
Ireland	38%
Italy	46%
Luxembourg	40%
Netherlands	47%
Portugal	48%
Spain	41%
Sweden	47%
United Kingdom	50%

Source: Corinair (1990)

1995). Table 1 presents the contribution of road transport to total anthropogenic NO_x emissions in 1990.

In Western Europe forecasts in transport growth for a business-as-usual scenario indicate that the demand for freight and passenger transport by road could double between 1990 and 2010. The number of cars could increase by 25 – 30% and annual car kilometres travelled could increase by 25%. The growth rate in air transport is also expected to increase by 182% during the period 1990-2010 (EC, 1992). This growth, together with the expected expansion in mobility and car ownership in Central and Eastern European (CEE) countries, will mean a significant increase in energy consumption and transport-related air pollution.

Transport scenarios for Europe

To examine how emissions of transboundary air pollutants from the transport sector can be reduced in Europe through the application of different policy measures, three scenarios for the transport sector were developed:

- a business-as-usual scenario (focusing on the years 2010 and 2030);
- a technology scenario (2010 and 2030); and
- an environmentally sustainable transport scenario (2030).

In the development of the scenarios, datasets of activity levels and energy used by the transport sector in UN/ECE countries, which have been built up over a number of years at the Stockholm Environment Institute (SEI), were used. The datasets have been used for estimating future emissions from the transport sector (Bailey, 1995) and for constructing abatement cost curves for use in integrated assessment models (Bailey, 1996).

The scenarios focus mainly on road transport (motorcycles, light duty and heavy-duty vehicles), boats, ships and trains. Aircraft and off-road machinery are not included in the scenarios. The scenarios examine the impact on air pollution of a range of vehicle EU emission standards (the so called Euro I, II, III and IV standards) and technologies to produce estimates of national emissions of transboundary air pollutants in the UN/ECE region. EC Directive 70/220/EEC lays down the technical requirements for light duty motor vehicles and the limit values for carbon monoxide and unburnt hydrocarbon emissions from the engines of motor vehicles. Over the past 25 years these requirements have been made more stringent by a series of amendments. Euro I limits came into effect in 1993 and meant that all new petrol cars needed to be fitted with a three-way catalytic converter; Euro II, which were separate limits for petrol and diesel cars, came into force in 1997; Euro III standards are expected to come into force in 2000; and Euro IV emission limits are expected to come into force in 2005. The exact limits for Euro III and Euro IV have yet to be approved.

Business-as-usual scenario

The business-as-usual scenario (BAU) for 2010 and 2030 is based on a continuation of present trends in transport taking into consideration expected changes in vehicle emission legislation. It can thus be considered as a base case scenario. The key assumptions for the BAU 2010 and 2030 scenario are:

- an increase in total vehicle kilometres travelled according to OECD (1995) figures presented in Table 3;
- no significant change in occupancy rate;
- no significant change in modal shift;
- all vehicle categories meet SEI's interpretation of the forthcoming Euro III standards;
- a reduction in the sulphur content of fuel;
- an improvement in fuel efficiency for petrol cars of 5 litres/100 km and 4.5 l/100 km for diesel engines; and
- a 10% increase in fuel efficiency for heavy duty vehicles.

Technology scenario

The 2010 technology scenario assumes that technology will be used to improve fuel efficiency, fuel quality and meet SEI's interpretation of the forthcoming Euro III and Euro IV emission standards. The technologies used in this scenario are aimed at reducing

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the transboundary air pollutants and are not directed at reducing greenhouse gases such as carbon dioxide. A technology scenario for 2030 is undertaken for a selected number of countries. The technology 2030 scenario has the same assumptions as the 2010 scenario, except all the vehicle categories meet Euro IV standards. The key assumptions for the technology scenarios are:

- traffic growth as predicted in the business-as-usual scenario (2010 and 2030);
- 50% of each vehicle category meets Euro emission standards III and IV. For the 2030 scenario all vehicle categories meet Euro IV standards;
- a 15% shift from petrol to diesel for light duty vehicles. It is assumed that this is motivated by climate change policy concerns (although it does have potentially negative implications for local air quality);
- an improvement in fuel efficiency for petrol cars of 5 l/100 km and 4.5 l/100 km for diesel engines;
- a 10% increase in fuel efficiency for heavy duty vehicles;
- a reduction in the sulphur content of fuel;
- 6% of the vehicle fleet uses alternative fuels (electric (1%) and hybrid cars (5%));
- all urban buses run on compressed natural gas (approximately 5% of heavy duty vehicles are diesel buses). The use of natural gas is the favoured option in many European countries; however, others are considering biofuels (such as alcohols or fuel derived from oilseed rape). This scenario simply assumes that compressed natural gas will be favoured.

Environmentally sustainable transport

What actually constitutes an environmentally sustainable transport (EST) system has been discussed widely in the literature (Roberts *et al.*, 1992; RCEP, 1994; SEPA, 1997; Haq, 1997; Whitelegg, 1997). In 1996 the OECD initiated a study on EST and defined it as transportation which does not endanger public health or ecosystems and meets needs for access consistent with:

1. use of renewable resources at below the rate of regeneration; and
2. use of non-renewable resources below the rates of development of renewable substitutes (OECD, 1996).

The OECD identified a number of objectives for an EST:

- an 80% reduction in carbon dioxide emissions between 1990-2030;
- a 90% reduction in nitrogen oxide emissions between 1990-2030;
- a 90% reduction in volatile organic compounds between 1990-2030;
- a 90% reduction in particulate matter (PM_{10}) between 1990-2030;
- a negligible level of noise nuisance by 2030;
- stabilisation of direct land use for transport outside urban areas between 1990 and 2030; a good living climate inside urban areas in 2030; indirect land use in 2030 represents half of the 1990 level.

The EST scenario adopts the OECDs targets for NO_X and VOCs.

Table 2: Annual growth rates in motor vehicle stock (%)

	1990-2000	*2000-2010*	*2010-2020*	*2020-2030*
Europe	2.4	2.0	1.0	1.0
CEE Countries	5.1	4.5	3.7	3.5

Source: OECD, 1995

Table 3: Annual growth rates of motor vehicle kilometres travelled (%)

	1990-2000	*2000-2010*	*2010-2020*	*2020-2030*
Europe	2.6	2.1	1.1	1.0
CEE Countries	4.9	4.5	4.0	3.6

Source: OECD, 1995

Calculation of vehicle emissions

In the development of the scenarios OECD (1995) growth rates were used. This was done to give consistency across Europe instead of using national sources of forecasts. In practice, very few countries produce such forecasts in a readily accessible form (if at all) and the use of the OECD study has the advantage that an estimate is automatically available for all countries. The OECD growth rates used are perhaps over-pessimistic of what is generally suggested in many studies. However, this is offset by the improvement in fuel efficiency for petrol cars of 5 l/100 km and 4.5 l/100 km for diesel engines and a 10% increase in fuel efficiency for heavy duty vehicles, which is probably an optimistic interpretation of what is possible.

Emission factors

The emission factors used in each scenario were EC standards for Light Duty Vehicles (LDVs) and Heavy Duty Vehicles (HDVs) (Greening, 1998; *pers comm.*). Tables 4 and 5 present the limits for HDVs and LDVs as a percentage of the initial EC standard. For HDVs Euro IV is taken as an 85% reduction. HDV gasoline have the same percentage

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Table 4: HDV emission reductions (gasoline and diesel) as a percentage of initial EC standard

Standard	*Year*	*NO_x*	*HC*	*CO*	*PM*
Reg. 49	1980	0	0	0	0
Euro I	1991	56%	56%	68%	0
Euro II	1993	61%	56%	71%	58%
Euro III	2000	72%	74%	85%	72%
Euro IV	2005	85%	85%	85%	85%

Table 5: LDV emission reductions (gasoline) as a percentage of initial EC standard

Standard	*Year*	*NO_x*	*HC*	*CO*	*PM*
EC 1504	1983	0	0	0	0
Euro I	1991	82%	82%	87%	48%
Euro II	1996	91%	91%	89%	63%
Euro III	2000	94%	94%	91%	81%
Euro IV	2005	97%	97%	96%	89%

Table 6: LDV emission reductions (diesel) as a percentage of initial EC standard

Standard	*Year*	*NO_x*	*HC*	*CO*	*PM*
EC 1504	1983	0	0	0	0
Euro I	1991	82%	87%	89%	48%
Euro II	1996	83%	88%	96%	63%
Euro III	2000	90%	92%	97%	81%
Euro IV	2005	94%	96%	98%	89%

Table 7: Summary table of oxides of nitrogen tail pipe emissions (NO_2 equivalents) (Kilotonnes)

Country	*1990**	*BAU 2010*	*Change*	*Tech 2010*	*Change*
Austria	154	36	-76%	28	-82%
Belgium	190	76	-60%	53	-72%
Denmark	102	49	-52%	31	-70%
Finland	119	30	-75%	22	-82%
France	1038	278	-73%	208	-80%
Germany	1630	415	-75%	307	-81%
Greece	114	78	-32%	53	-53%
Ireland	44	17	-61%	13	-71%
Italy	946	215	-77%	164	-83%
Luxembourg	9	7	-17%	6	-35%
Netherlands	272	125	-54%	90	-67%
Portugal	107	36	-67%	27	-75%
Spain	512	260	-49%	179	-65%
Sweden	163	42	-74%	32	-81%
United Kingdom	1383	435	-69%	316	-77%
EU 15	6783	2099	-69%	1529	-77%
Belarus		34		18	
Bulgaria**	137	13	-91%	9	-93%
Croatia**	28	18	-36%	8	-71%
Czech Republic**	143	40	-72%	23	-84%
Estonia**	40	14	-65%	9	-78%
Hungary**	94	35	-63%	26	-72%
Latvia**	25	18	-28%	13	-48%
Lithuania**	53	16	-70%	13	-75%
Macedonia		6		3	
Moldova		2		1	
Norway	84	67	-20%	40	-52%
Poland**	243	70	-71%	51	-79%
Romania**	50	44	-12%	25	-50%
Russian Federation		1582		893	
Slovakia**	56	7	-88%	5	-91%
Slovenia**	34	3	-91%	2	-94%
Switzerland	101	37	-63%	30	-70%
Ukraine		341		251	

* Corinair
** Road transport only

reductions as HDV diesel. The reductions in Table 6 for light duty diesel vehicles appear to be large because the baseline of Regulation 15.04 is used. In practice, many LDV diesel vehicles outperformed the 15.04 standard. This is not a problem for the study methodology, as emission factors in g/km are used for the different Euro standards to estimate vehicle emissions for each scenario.

Emissions from trains, boats and ships are estimated on the basis of fuel use in 1994 (or an earlier year such as 1992 if later data were not available). This parameter has not been projected to the year 2010 or 2030 and it is simply assumed that present fuel levels by rail and marine traffic remain constant. Emissions from boats and ships relate to domestic (i.e. national) marine transport activity emissions from marine activity in the North Sea, Baltic Sea and Atlantic Ocean are not estimated.

Methodological considerations

A large amount of data is required to produce estimates for all European countries. In some cases data are not available although this situation has improved considerably in the last five years as more statistics for CEE countries have been collated by international bodies such as UN/ECE. The availability of traffic data for CEE countries was still limited in some cases, especially for the Russian Federation and Ukraine.

Overall, the accuracy of the results for European Union countries is probably not constrained by the availability of data - the methodology is probably the limiting factor here. This is the situation for other countries, for example, Norway, Switzerland and even some CEE countries such as Poland or the Czech Republic. However, it is more likely that data quality has a larger impact on the remaining countries and that, overall, the quality of the estimates of future emissions for these countries is poorer. One general point is concerned with 1990 emission data. These data were used both for 1990 transport sector NO_x and VOCs emissions in the EST scenario. The 1990 emission data were necessary to provide a reference level for emission reductions. Occasionally, the data were only available at the national level or the pedigree of the data has been questioned elsewhere. Any errors in these 1990 reference level emission data have implications for the target levels in the various scenarios and the results should be interpreted with this in mind.

Table 8: Summary table of VOCs tail pipe emissions (Kilotonnes)

Country	*1990**	*BAU 2010*	*Change*	*Tech 2010*	*Change*
Austria	114	29	-75%	22	-81%
Belgium	189	40	-79%	29	-85%
Denmark	99	24	-76%	17	-83%
Finland	73	21	-71%	16	-78%
France	1170	224	-81%	170	-85%
Germany	1234	286	-77%	238	-81%
Greece	137	43	-69%	34	-75%
Ireland	62	9	-85%	7	-89%
Italy	954	199	-79%	152	-84%
Luxembourg	10	6	-40%	5	-54%
Netherlands	184	57	-69%	43	-77%
Portugal	81	24	-71%	18	-78%
Spain	449	127	-72%	93	-79%
Sweden	154	32	-79%	24	-84%
United Kingdom	982	216	-78%	159	-84%
EU 15	5892	1337	-77%	1027	-83%
Belarus		16		10	
Bulgaria**	74	12	-84%	9	-88%
Croatia**	37	8	-78%	5	-86%
Czech Republic**	53	24	-55%	16	-70%
Estonia**	28	5	-82%	3	-89%
Hungary**	79	23	-71%	17	-78%
Latvia**	33	6	-82%	5	-85%
Lithuania**	45	8	-82%	7	-84%
Macedonia		3		2	
Moldova		1		1	
Norway	88	24	-73%	16	-82%
Poland**	248	47	-81%	35	-86%
Romania**	76	15	-80%	10	-87%
Russian Federation		682		525	
Switzerland	88	31	-65%	25	-72%
Slovakia**	40	4	-90%	3	-93%
Slovenia		2		2	
Ukraine		162		126	

* Corinair

** Road transport only

Results

In the Business-as-usual (2010) scenario present trends and agreed legislation should give emission reductions of approximately 70% for NO_x and 75% for VOCs compared to 1990 levels; however, many countries are likely to experience an increase in CO_2 emissions. Tables 7 and 8 presents the emissions of VOCs and NO_x for each of the BAU and technology scenarios.

The technology scenario assumes that new emissions technology, aimed at reducing transboundary air pollutants, will be implemented on a wide basis and will perform effectively in service. If this is the case, many countries could achieve an 80 – 85% reduction in NO_x emissions. This scenario has concentrated on technologies for reducing regional pollutants; therefore, compared to the BAU scenario CO_2 emissions are not reduced significantly.

The environmentally sustainable transport scenario highlights that technology alone is unlikely to be sufficient to achieve reductions in polluting emissions. A wide range of other policy measures has been applied (often at a local scale) in many European countries. These provide evidence of how the demand and need to travel can be reduced and how transport can become more sustainable.

The EST scenario assumes that a 90% reduction in the emissions of NO_x and VOCs by 2030 and that the national Kyoto targets are achieved. The EST scenarios for Sweden and Hungary are presented here.

Sweden

Tables 9 and 10 present the NO_x and VOC emissions for Sweden. The lowest reduction in NO_x (69%) and VOC (75%) emissions is achieved in the BAU 2030 scenarios. The highest reduction in NO_x (83%) and VOC (87%) emissions is achieved in the technology 2030 scenario. A further 7% reduction in NO_x and 3% reduction in VOC emissions are required in order to meet the EST target (Figure 1).

Table 9: NO_x emissions (Kilotonnes)

Sweden

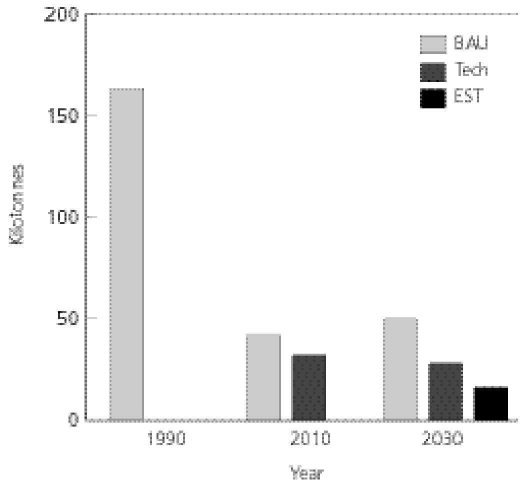
Scenario	*1990*	*2010*	*2030*	*Reduction 2010*	*Reduction 2030*
BAU	163	42	50	74%	69%
Tech	-	32	28	81%	83%
EST	-	-	16	-	90%

Table 10: VOC emissions (Kilotonnes)

Sweden

Scenario	*1990*	*2010*	*2030*	*Reduction 2010*	*Reduction 2030*
BAU	154	32	39	79%	75%
Tech	-	24	21	84%	87%
EST	-	-	15	-	90%

Figure 1: Sweden: Emissions of nitrogen oxides



Hungary

Tables 11 and 12 present the NO_x and VOC emissions for Hungary. The lowest reduction in NO_x (28%) and VOC (41%) emissions is achieved in the BAU 2030. The highest reduction in NO_x (78%) and VOC (83%) emissions is achieved in the post-Kyoto 2030 scenario. A further 12% reduction in NO_x and 7% reduction in VOC emissions are required in order to meet the EST target (Figure 2).

Table 11: NO_x emissions (Kilotonnes)

Hungary

				Reduction	
Scenario	*1990*	*2010*	*2030*	*2010*	*2030*
BAU	94*	35	68	63%	28%
Tech	-	26	38	73%	60%
EST	-	-	9	-	90%

* Road transport only

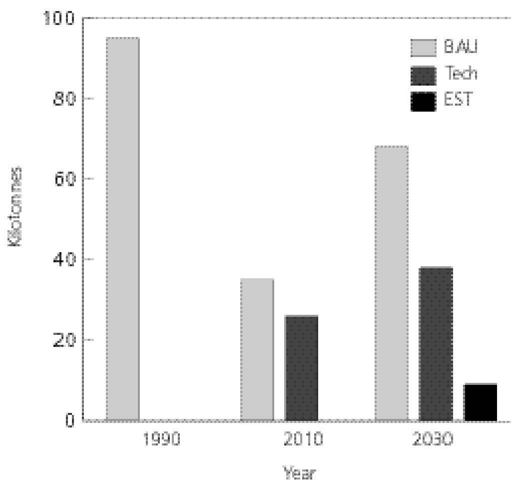
Table 12: VOC emissions (Kilotonnes)

Hungary

				Reduction	
Scenario	*1990*	*2010*	*2030*	*2010*	*2030*
BAU	79*	23	47	70%	41%
Tech		17	25	78%	69%
EST			8		90%

* Road transport only

Figure 1: Hungary: Emissions of nitrogen oxides



Conclusion

Transport has important implications for air pollution and human health. In Western Europe forecasts in transport growth indicate that the demand for freight and passenger transport by road could double between 1990 and 2010. The number of cars could increase by 25 – 30% and annual car kilometres travelled could increase by 25% (EC, 1992). Improvements in vehicle technology can, to a certain extent, reduce vehicle-related pollution; however, this will not be enough to meet EST targets such as a 90% reduction in NO_x and VOCs emissions by 2030.

The projected increase in car ownership and use in Europe and the reliance on fossil fuels mean that, in the absence of policy measures directed towards reducing the need and demand to travel, there will be a considerable increase in oil-based fuel consumption and vehicle-related pollution. High rates of growth in both freight and passenger traffic in Europe are indicative of a non-sustainable trend. This will have significant implications for emissions of NO_x and VOCs, and regional air pollution.

The scenarios examined provide a comprehensive attempt at exploring futures for regional air pollutants from the transport sector in Europe. Although the methodology used in the scenario analysis was less detailed compared to many national studies, the scenarios do provide useful data for comparing the implications of certain policy measures in different European countries on a broadly consistent basis. The availability of data for Central and Eastern European has improved over the last five years; however, there still remains a number of gaps in data which influenced the calculations of emissions for some CEE countries in this study.

Stricter emission standards, fuel quality standards and implied technological controls do appear to have an important role to play in reducing regional air pollution, assuming that technologies perform in service and that advances are made in emission controls for diesel vehicles in the next five to ten years. However, other policy measures are required as the expected increase in mobility and car ownership will reduce the benefits achieved with the introduction of new technologies. A greater scope exists for adopting policy measures directed towards reducing the need and demand to travel. A number of measures (e.g. car free zones, park and ride, reduced car parking and increased provision and use of public transport) are already being implemented successfully at the local level, usually as a direct result of experiencing poor air quality, congestion and other effects caused by traffic.

Transport has important implications for national CO_2 reduction targets under the Kyoto protocol. A reduction in the use of motorised transport will not only have the benefits of reducing vehicle-related air pollution, but also noise pollution, congestion and road accidents as well as improving the overall quality of life in towns and cities.

The transport sector will continue to be a significant source of air pollution into the next century. The adoption of new technology, stricter standards and policies to reduce the use of the motor vehicle and to encourage the use of more environmentally friendly modes of transport will be important if reductions in vehicle-related pollutants are to be achieved. The scenarios demonstrate the possible reductions in NO_x and VOCs and other pollutants which could be achieved using different policy instruments. They also highlight the potential for further action which could be taken within the transport sector in order to achieve a reduction in regional air pollution within the next twenty-five years.

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