Unclassified **ENV/EPOC/PPC/T(97)1/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

OLIS : 23-Sep-1999
Dist. : 24-Sep-1999

English text only

ENVIRONMENT DIRECTORATE
ENVIRONMENT POLICY COMMITTEE

ENV/EPOC/PPC/T(97)1/FINAL
Unclassified

Working Party on Pollution Prevention and Control
Working Group on Transport

ENVIRONMENTALLY SUSTAINABLE TRANSPORT

FINAL REPORT ON PHASE II OF THE OECD EST PROJECT
Volume 1: Synthesis Report

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Acknowledgements

The OECD would like to acknowledge the important assistance and support provided by government officials and experts from OECD Member countries during the preparation of this report. In particular, the wealth of information contained in this document and its annex would not have been possible without contributions from the following: Robert Thaler and Romain Molitor from Austria; Julie Charbonneau, Philip Kurys and Lee Sims from Canada; Dominique Dron, Alain Morcheoine and Bertrand Chateau from France; Norbert Gorissen, Hedwig Verron, Andreas Pastowski and Axel Friedrich from Germay; Martin Kroon, Karst Geurs and Bert van Wee from the Netherlands; Eli Marie Åsen, Harald Minken and Farideh Ramjerdi from Norway; Stefan Andersson and Peter Steen from Sweden; and finally, Harald Jenk and André Schrade from Switzerland.

Each of the six case studies involved a great number of experts and staff in the eight participating countries. Without their generous assistance and input, the case studies would be devoid of any value. Their contribution is gratefully acknowledged.

A very special acknowledgement is due to Richard Gilbert of the Canadian Centre for Sustainable Transport who wrote this report and helped to fashion the thinking behind the project. The main responsibility for this work rested with Peter Wiederkehr of the OECD Working Party on Pollution Prevention and Control. He was assisted by a number of past and present staff including Freda O'Rourke, Lyndia Levasseur, Cilla Cerrado-Williamson and Philippe Crist.

This report has been revised by the experts associated with the project on Environmnetally Sustainable Transport. It has been reviewed and approved by the OECD's Working Group on Pollution Prevention and Control under the Environmental Policy Committee

Foreword

Conventional approaches to mitigating transport's environmental impacts have used observed and projected transport trends and sought to assess the environmental impact of these developments ex-post. This approach has led to important efficiency gains and has helped to reduce certain environmental and health risks stemming from the transport sector. It has not - and likely will not - however, lead us towards meeting long-term environmental objectives.

A new policy approach is needed which places environmental criteria up front along with other policy goals. Recognising this need, the OECD Environmental Policy Committee's Task Force on Transport initiated the project on Environmentally Sustainable Transport (EST) in 1994 to give some precision to the concept through the use of criteria which can be quantified and have environmental significance. The overall objectives of the project are to provide an understanding of EST, its implications and requirements, and to develop methods and policy guidelines towards its realisation. The core of the EST approach is to develop long-term scenarios and identify instruments and strategies capable of achieving it. Unlike conventional approaches to transport system development, the EST project is a backcasting exercise. One or more desirable futures are defined and policy development is guided by an assessment of what is required to achieve them.

The EST project comprises four phases:

- Phase 1 involved a review of relevant activities of Member countries as well as the development of the definition and criteria for EST.

- Phase 2 has focused on the identification of the gap between current and projected trends and the EST criteria through scenario-development for 2030. During this phase participants have constructed a "business-as-usual" (BAU) trend forecast scenario and three scenarios consistent with the EST criteria.

- Phase 3 is to be the "back-casting" exercise. It comprises the identification of packages of policy instruments whose implementation would result in achieving the EST scenarios. Phase 3 will also involve the assessment of the social and economic implications of the BAU and EST scenarios.

- Phase 4 will refine the criteria for achieving EST and develop policy guidelines for governments towards environmentally sustainable transport.

The work is being carried out by six teams of experts from eight countries, each with a separate geographical focus to describe how this environmentally desirable objective may be achieved. The six case studies include Sweden, the Netherlands, Germany, the Quebec-Windsor corridor in Canada, the greater Oslo region and the Alpine region comprising parts of France, Switzerland and Austria.

This report presents the results of Phase 2 of the project. It comes in two volumes: i) the synthesis report of the case studies with the different scenarios, and ii) as an annex volume, the compilation of the six case studies prepared by the participating eight countries. A brief project summary and some of the reports and expert papers of Phase 1 and Phase 2 of the project are also available on OECD's Internet site (http.//www.OECD.org/env/trans/).

Table of CONTENTS

1 Introduction

1.1 The EST Project: Overview

This report describes Phase 2 of the four-phase project on Environmentally Sustainable Transport (EST) and provides an overview and some analysis of the results.

The overall purposes of the OECD EST project are to characterise EST (see Sections 1.2 and 1.3) and to establish guidelines for the development of policies that would result in the achievement of EST. The basic techniques used are scenario construction and backcasting, explained in Section 1.4 and the work organised in 4 broad phases.

- **Phase 1,** of the EST project—completed in 1996—involved a review of relevant activities of Member countries as well as the development of the definition of and criteria for EST noted above.
- **Phase 2,** reported here, has been the scenario-development phase. It has mainly comprised construction by participating Member countries of a business-as-usual (BAU) scenario and three scenarios for 2030 consistent with the EST criteria. It has also involved some preliminary consideration of the backcasting and other analyses to be undertaken during Phase 3.
- **Phase 3**, to be conducted during the remainder of 1997 and early 1998, will comprise the core of the backcasting exercise. It will mostly consist of identification of packages of policy instruments whose implementation would result in achieving the scenarios constructed during Phase 2, with a focus on the EST3 scenario (see Section 6 for a description of this scenario, known too as the optimum-combination scenario). Phase 3 will also involve refinement of the EST3 scenario and assessment of the social and economic implications of the BAU and EST3 scenarios.
- **Phase 4**, to be conducted during 1998, will comprise refinement of the definition and the criteria for achieving EST

and the establishment of guidelines for policy development in connection with environmentally sustainable transportation.

The purposes of the EST project—characterisation of EST and development of guidelines for its achievement—are not an attempt to develop goals, objectives, targets or standards to which OECD Members and other countries should adhere. Rather, the project is an attempt to give some precision to the concept of environmentally sustainable transportation through the use of criteria that can be quantified and have environmental significance. The project will also provide Member countries with practical advice on achieving EST.

The EST project seeks to demonstrate what an environmental framework for strategies to achieve EST might look like, taking into account environmental issues that manifest their effects at very different geographic scales (global, regional, and local). It is an attempt to establish a basis upon which a diverse range of policy-makers and economic actors can communicate, and a framework within which goals, objectives, targets or standards could be set by governments and actions initiated.

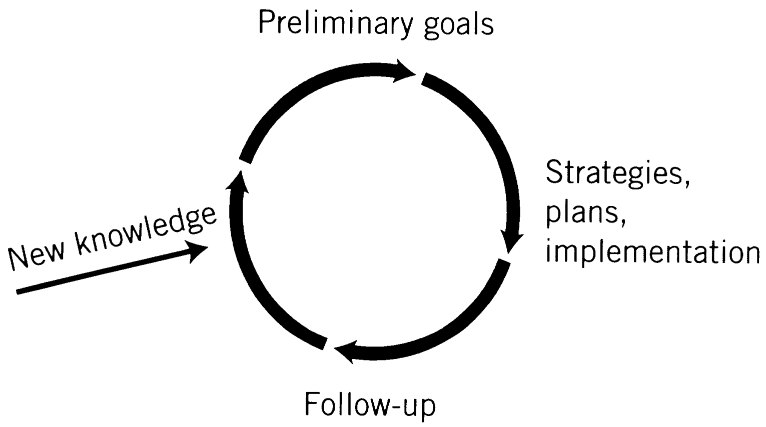


Figure 1
The Swedish EST-circle: an iterative method for developing goals

Above all, this project is being conducted as support for the strategy of setting long-term goals in the transportation areas. Is a contribution to what has been described by the Swedish participants in the present project as the “EST circle”, with an expectation of impact somewhere between “New knowledge” and “Preliminary goals” (see Figure 1).

1.2 Environmentally Sustainable Transport (EST): Definition

The report on Phase 1 of the EST project[1] contains a discussion of the some of the meanings of EST and its relationship to the broader concept of sustainable development. The discussion concluded that the achievement of sustainability will require that each major sector of human activity become sustainable, consistent with the outcome of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. Transportation, as a major part of human activity, should accordingly become sustainable.

Transportation is presently unsustainable on three counts: first, it constitutes the major use of a non-renewable resource, oil, for which renewable substitutes are not being developed at a commensurate rate; second, in several respects—perhaps most persistently in terms of raised atmospheric levels of the radiatively active substance carbon dioxide—transportation results in emissions that appear to exceed the assimilative capacity of the environment; and third, many of the local and regional impacts of transport activity damage the health of humans and other organisms and affect the integrity of ecosystems. Moreover, present trends are for transport activity to increase and, consequently, for the impacts of transportation to worsen unless action is taken that more than offsets these trends.

For transportation to be sustainable, and thus play its part as a component of sustainable development, it should at least not result in exceedances of generally accepted objectives for environmental quality (such as those of the World Health Organization concerning air pollutants and noise); it should not reduce the integrity of ecosystems; and it should not contribute to potentially adverse global phenomena such as climate change and stratospheric ozone depletion.

Consistent with the foregoing, a brief definition of EST was developed during Phase 1, as follows:

Definition of EST

Transportation that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources at below their rates of regeneration, and (b) use of non-renewable resources at below the rates of development of renewable substitutes.

1.3 Environmentally Sustainable Transport: Criteria

The definition of EST was elaborated in terms of criteria for the attainment of EST. This elaboration took into account several factors including environmental quality and health protection objectives, knowledge of impacts established by the World Health Organization and other bodies that have formed the basis of the work of several international conventions such as the UN/ECE

Convention on Long-Range Transboundary Air Pollution (LRTAP), and related matters such as full life-cycle impacts and total material requirements. The elaboration considered impacts on air and water from local, regional, and global perspectives. It also considered impacts on land, and the particular nature of these impacts whereby the character of land is changed to accommodate transportation, which facilitates patterns of development that result in further demand for transport, and further changes in the character of land, all of which are generally adverse from an environmental perspective.

Six criteria were developed during Phase 1 as being the minimum number required to address the wide range of transportation impacts at the local, regional and global level. The criteria were chosen in response to the following specific considerations with respect to the environment.[2]

LOCAL AND REGIONAL IMPACTS OF ATMOSPHERIC EMISSIONS

Of most concern among this type of emissions are those that raise the concentration of tropospheric **ozone** (O_3) and breathable **particulate matter** (PM) near ground level. Ground-level ozone is formed as a result of the action of sunlight on mixtures of **nitrogen oxides** (NO_x) and **volatile organic compounds** (VOCs), which are both components of the emissions from motor vehicles. Other regional concerns include acidification and eutrophication through the deposition of sulphur and nitrogen compounds. Accordingly, criteria were used concerning each of NO_x, VOCs, and PM.

- **Ozone** is formed from emissions by photochemical action. In temperate climates, high ambient levels of ground-level ozone (which comprises 90 per cent or more of what is known as summer smog) comprise the most pervasive air pollution problem associated with transportation. Smog episodes can result in the immediate hospitalisation of vulnerable people. The recent assessment made under the UN ECE Convention on Long-Range Transboundary Air Pollution showed that “critical levels” for ozone, i.e., “the concentrations above which adverse effects on plants, ecosystems or materials may occur”, were exceeded by a factor of four.[3] The most effective control strategy to reduce peak ozone levels involves reducing emissions of both NO_x and VOCs, and thus the criteria used in the EST project address these pollutants. It is important to note that linear reductions of precursor emissions will not result in a similar effect on ozone; generally a great degree of reduction of precursor emissions is required.[4]
- In addition to the contribution to ozone formation, there are several reasons for considering a criterion based on emissions of **nitrogen oxides**. Nitrogen oxides are produced whenever air is involved in high-temperature combustion processes.

Ambient nitrogen dioxide (NO_2) causes respiratory problems in humans and damage to plants. Emissions are an important contributor to acid rain, acid deposition, and eutrophication, which can alter the ecosystems of water bodies, forests, and meadowlands. In addition to local and regional effects, NO_x emissions can have global effects in that nitrogen oxides can contribute to global warming, directly and indirectly. In the United States, transportation accounts for 43 per cent of NO_x emissions; in Europe it accounts for 60 per cent.[5]

- In addition to the contribution to ozone formation, there are several reasons for considering a criterion based on emissions of **volatile organic compounds**. Many VOCs have direct toxic effects on humans and animals, including carcinogenesis and neurotoxicity, and are harmful to plants.[6] Some VOCs (e.g., methane) are radiatively active and thus contribute to potential climate change. In the United States, transportation accounts for 48 per cent of emissions of VOCs; in Europe it accounts for 50 per cent.[7]

  The need for a criterion concerning emissions of VOCs is based on the supposition that carbon compounds, whether renewable or not, might continue to be used as fuels. Emissions of VOCs can occur whenever there is combustion of carbon compounds, the result of incomplete combustion, spillage or evaporative emissions.[8]

- The need for a criterion concerning suspended **particulate matter** is also based on the supposition that carbon-based fuels might continue to be used. (Particulate matter from motor vehicles usually consists of numerous compounds absorbed on a solid carbonaceous core, but sulphates, nitrates and other compounds can be implicated; secondary particulate matter can result from the transformation in the atmosphere of gaseous combustion products.) A criterion concerning particulate matter is of importance because of the following factors: (i) current trends involving substitution of diesel for gasoline as a transportation fuel on account of the higher energy efficiency of diesel engines; (ii) the much higher rate of emission of particulate matter from diesel engines; and (iii) observations that suspended particulate matter is the most severe air pollution problem affecting the world's largest cities.

LOCAL AND REGIONAL IMPACTS NOT RESULTING FROM ATMOSPHERIC EMISSIONS

The remaining two criteria concerned **noise** and **land use**. In many places, notably in parts of Europe, noise is the most important transport-related problem. In some places, the amount of land used for transportation is perceived to be a key issue in that it is often both a factor generating transport activity and a contributor to environmental stress.

- A criterion reflecting the extent of **the use of land for motorised transport** may be the only novel type of criterion among the six proposed here. Such a criterion could capture a range of adverse impacts including those arising from urban sprawl, inhospitality towards pedestrians and bicycle users, and excessive paving that results in distortions of local heat balances, diversion of precipitation, creation of barriers to the normal migration of plants and animals, and disturbance of their habitats.
- The proposed criterion concerning **noise** reflects the potential for any mechanised system to cause adverse impacts through noise, affecting health of humans and possibly that of other organisms. Noise may become especially important with the application of the criterion concerning land use, which could bring mechanised transport systems and everyday human activity into closer proximity.

GLOBAL IMPACTS OF ATMOSPHERIC EMISSIONS

Directly and indirectly, fossil fuels provide the energy for almost all transport activity. The recent Second Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) has reactivated interest in the global impacts of fossil fuel use. It states that "the atmospheric concentrations of the greenhouse gases [such as] carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have grown significantly ... [and] these trends can be attributed largely to human activities, mostly fossil fuel use, land-use change and agriculture ... . The balance of evidence suggests a discernible human influence on global climate." [9] Carbon dioxide (CO_2) is the transport emission of greatest concern in respect of global impacts on account of its likely involvement in climate change. Carbon dioxide is a major component of vehicle exhaust; accordingly, one of the criteria used here concerned CO_2 emissions. Carbon dioxide emissions are also a surrogate for use of fossil fuel, which is the major non-renewable resource consumed in connection with transportation. Unlike CO_2 emissions from other fossil-fuel-using sectors, CO_2 emissions from transportation continue to increase globally. Emissions of CO_2 and other radiatively active compounds from aircraft, at high altitudes, are of special concern because of their high potential rate of impact on climate change per unit of transport activity.

Accordingly, **the six criteria for EST developed during Phase 1 that will have to met in the long-term (by 2030) were formulated as follows:**

EST Criteria

- *Transport-related emissions of* ***nitrogen oxides (NO_x)*** *have been reduced to the extent that the air quality objectives for ambient NO_2 and for ozone levels as well as for nitrogen deposition are achieved.*

- *Emissions of* ***volatile organic compounds (VOCs)*** *have been reduced to the extent that excessive ozone levels are avoided, and emissions of carcinogenic VOCs from vehicle transportation have been reduced to meet acceptable human health risk levels.*
- *Emissions of* ***particulates*** *have been reduced to the extent that harmful ambient air levels are avoided.*
- *Climate change is being prevented by achieving per-capita* ***carbon dioxide*** *emissions from fossil fuel use for transportation consistent with the global protection goals for the atmosphere.*
- ***Land*** *surface in urban areas is used for the movement, maintenance, and storage of motorised vehicles, including public transport vehicles, such that the objectives for ecosystem protection are met.*
- ***Noise*** *caused by transportation should not result in outdoor noise levels that present a health concern or serious nuisance.*

The EST definition and criteria developed during Phase 1 are general in nature and extremely preliminary. They are to be developed further during and after the EST project. The six EST criteria have been quantified during Phase 2 of the EST project, in the manner set out below in Section 2.

It should be stressed that although the six criteria do address local, regional and global issues, they do not encompass the entire range of environmental impacts related to environmental sustainability. Absent, for example, are criteria concerning depletion of stratospheric ozone, biodiversity, globally bioaccumulating substances, and pollution of fresh and salt water and soil.

During Phase 1, 2030 was selected as the year for achieving EST; it was a compromise between earlier and later dates proposed by participating experts. Part of the justification for selecting 2030 is that current problems have mostly been generated during one or two generations and may require the same amount of time for a solution. To wait longer would bring additional challenges associated with increased population levels in developing countries, and consequently higher demand for transportation. Use of an earlier date would imply a more rapid rate of change, which would also pose great difficulties particularly in OECD countries. Moreover, the choice of 2030 was consistent with the most distant projections of motor vehicle activity developed in recent OECD work,[10] and also with the target date of some of the backcasting work that has been carried out in Member countries.[11]

1.4 Scenario Construction and Backcasting

Policy development can be shaped in the light of present circumstances or future goals. In the former case, forecasts based on current trends provide the basis for determining what may be required to accommodate or counteract those trends. In the latter case, goals are set and there is a working backwards (backcasting) from the goals to determine what must be done to reach them. The former kind of policy development results in doing what is possible to avoid an unwanted future. The latter kind results in doing what is necessary to achieve a wanted future.

Policy developments often involve both approaches, although usually with more emphasis on present circumstances than on goals for the future. Engaging in forecasting rather than backcasting is especially appealing when setting goals may be controversial or when desired goals may appear to be unattainable. Moreover, an approach based on forecasting is likely to be incrementalist and responsibly cognisant of current realities. By contrast, an approach based on backcasting may involve large and even disruptive changes, and may appear quixotically idealistic.

A backcasting approach may nevertheless be preferable if effective change is sought. Transportation may well be a sector for which such an approach could be especially valuable. Current policies and measures—many based on forecasting—have not significantly reduced the overall environmental impacts of transportation, even though such reductions are desired. The environmental benefits of technological improvement have in many respects been offset by the environmental costs of increased activity.

An approach based on backcasting may be capable of generating the fresh policy directions needed if transportation is to become environmentally sustainable. Moreover, because such methods highlight discrepancies between current trends and desirable futures, they may be capable of generating the motivation needed to implement fresh policy directions.

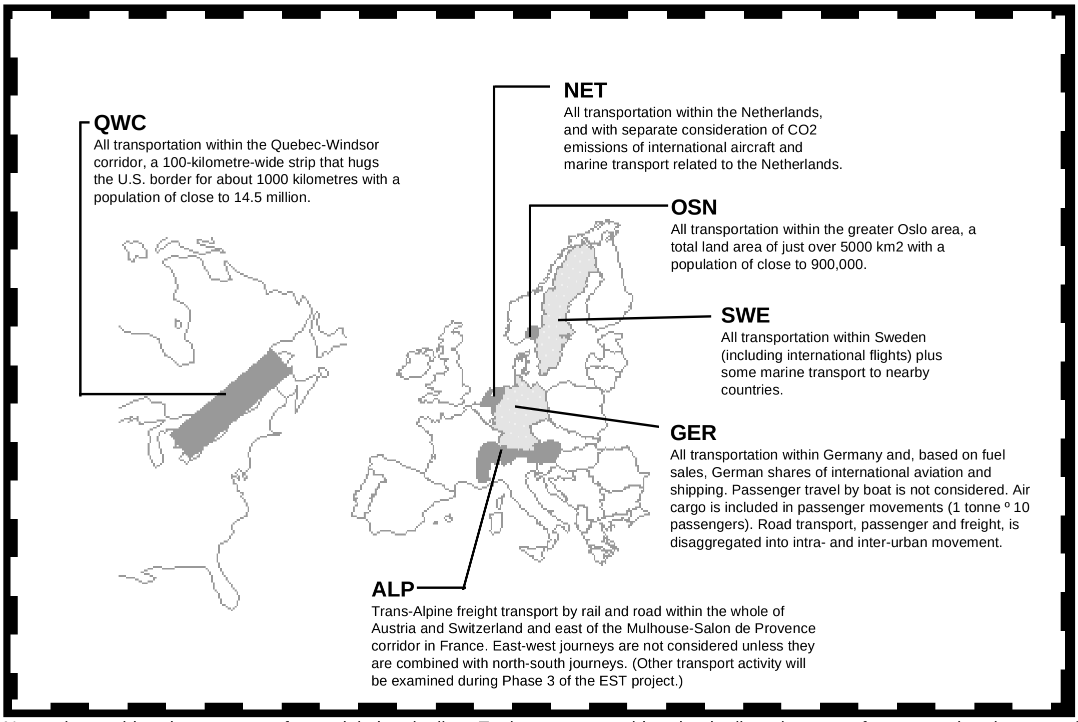
In the long-term, the potential to influence development in desired directions is relatively large. Major obstacles to important changes are often perceptions of what is possible or reasonable to achieve based on current situations. The scenarios of a backcasting exercise are not limited by the constraints of current policies. They can therefore broaden the scope of solution-finding.

Scenario development is a necessary preliminary to a backcasting exercise. A future or several alternative futures (scenarios) must be described with rigour if there is to be a valid exercise of identifying policy instruments whose implementation might lead to the achievement of one or another of the scenarios.[12] Thus the core of the EST project comprises two substantial items of work: one is construction of scenarios and the other—the backcasting exercise—is identification of the actions that would need to be taken to ensure attainment of the scenarios.

2 The EST Project: Phase 2 design

2.1 The EST Case Studies

Phase 2 has been designed as a collaborative effort among eight Member countries to explore and develop methodology with respect to identification and attainment of environmentally sustainable transportation:



No study considered movement of materials by pipeline. Each country considered only direct impacts of transport; i.e., impacts of production of vehicles, fuels, and infrastructure, and of disposal of vehicles and infrastructure were ignored.

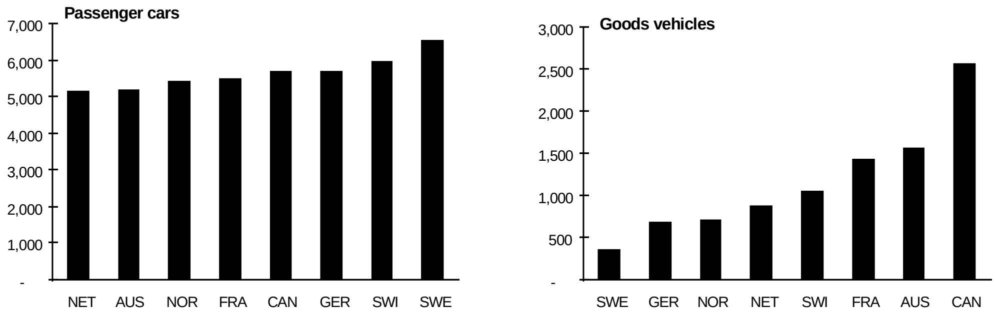
Figure 2
EST case studies: Geographic scope and transport modes considered.

Germany (GER)[13], **The Netherlands** (NET), and **Sweden** (SWE) have developed scenarios for their respective countries.

Canada (QWC) and **Norway** (OSN) have studied parts of their respective countries: the Quebec City-Windsor corridor in the case of Canada and the greater Oslo region in the case of Norway.

Austria, **France**, and **Switzerland** (ALP) have collaborated within the EST project to develop scenarios and identified instruments for the Alpine region (ranging from Vienna to Geneva to Ventimiglia).

Figure 2 provides information on the geographic scope of each of studies and about the modes of transportation considered. Figure 3 provides key comparative transport-related data on the participating countries for 1990 or the next previous year; Appendix A provides more such data.



*For the source of these data see the explanatory note at the beginning of Appendix A.

Figure 3.
*Road-vehicle-kilometres travelled per capita per year in participating countries**

Reports on their work in connection with Phase 2 of the EST project have been prepared by Member country study teams for five of the six studies. The Swedish contribution differs from the others in that it is an adaptation of ongoing related work rather than a new study done for the EST project; different base years and scenario-construction years are used, as well as different criteria.[14] The work of the Alpine team during Phase 2 has concerned long-distance, trans-Alpine freight transport only; other kinds of transport activity are to be addressed during Phase 3 of the EST project.

2.2 Quantification of the EST Criteria

The criteria for EST had to be precise enough to allow the development of scenarios consistent with the criteria. Thus the work of Phase 2 involved quantification of the criteria for the purposes of the EST project only. A strategic decision was made to quantify three of the criteria in a manner common to the participants—for NO_x, VOCs, and CO_2—and to leave the quantification of the other three criteria to the individual study teams. This sub-section is primarily concerned with presenting the cases for the particular quantifications of the three common criteria. It builds on the arguments provided in the report on Phase 1 of the EST project.[15]

Quantification of the NOx Criterion

A first consideration for quantification of the criterion for nitrogen oxides was the kind of reductions in emissions that might have to be implemented to prevent exceedance of the current air quality guidelines of the World Health Organization, including those for ozone, for which NO_x and VOCs are precursors.[16] For NO_2, the one-hour guideline is a mean of 200 micrograms per cubic metre (µg/m^3). Peak hourly means in excess of 600 µg/m^3 have been recorded in major cities.[17] Similar or greater proportional exceedances are noted with respect to annual average concentrations. In city centres, about 70 per cent of monitoring sites in Western Europe, 60 per cent in the United States, and 65 per cent in Japan exceed the revised WHO chronic health effect criterion (40 µg/m^3, annual average).[18]

For ozone, WHO provided a one-hour guideline until 1996: a mean of 150-200 µg/m^3. Peak hourly means of up to 600 µg/m^3 have been noted in several areas in the 1990s, with higher levels being noted in earlier years and levels of up to 1200 µg/m^3 in some regions in the 1990s.[19] The revised WHO guidelines include only an 8-hour guideline (120 µg/m^3). This guideline is exceeded at almost all urban residential and rural monitoring sites in OECD countries.[20]

A second consideration for the quantification of the criterion for NO_x was based on the critical loads of this pollutant. A *critical load* has been defined as "the highest deposition of a compound that will not cause chemical changes leading to long-term harmful effects on ecosystem structure and function." Thus, a critical load is an indicator for sustainability of an ecosystem in that it provides a value for the maximum allowable load of a pollutant at which risk of damage to an ecosystem is reduced. By measuring or estimating certain physical and chemical properties of an ecosystem, its sensitivity to deposition of pollutants can be calculated. For NO_x, acidification and eutrophication are of particular significance. In many parts of Europe, critical loads for acidification and eutrophication are exceeded by a factor of two to four, indicating that ecosystems are at risk of being damaged and their sustainability endangered. Consideration of depositions of nitrogen compounds across Europe in relation to critical loads has indicated that for many areas even reduction of NO_x emissions from transportation to zero would not be sufficient to meet critical loads for deposition of nitrogen compounds in many areas. Critical levels for ozone would also be exceeded.[21]

The considerations in the previous two paragraphs led the experts involved in the EST project to conclude that a criterion for transport-related emissions of NO_x consistent with attainment of environmentally sustainable transportation would be emissions totalling no more than 10 per cent of such emissions in 1990 across the area of investigation. Determination of whether the criterion would be met would involve determination of total NO_x emissions associated with transportation in 1990 and estimation of total NO_x emissions from transportation in 2030.

It should be noted, that a similar line of reasoning led the participants in the Swedish EST study to select similar criteria for reductions in total emissions of NO_x from transportation. The Swedish criteria were with reference to emissions in 1980 and spoke to reductions of 50 per cent by 2005 and 80 per cent by 2020, with differing degrees of reduction according to transport mode.[22]

Quantification of the VOC Criterion

Regarding volatile organic compounds, consideration was given to critical levels for ozone, as for NO_2,[23] but a more important factor in the quantification of the criterion was the belief that there is no safe level for many of these pollutants due to their carcinogenic properties; for these total elimination should be the goal. Notwithstanding this belief, study participants recognised the practicability of setting a criterion short of total elimination and followed a common practice of setting a similar emission reduction criteria for NO_x and VOCs.[24] Thus the basic criterion used here for VOCs was that for NO_x: a reduction in total emissions from transportation to 10 per cent of the total of such emissions in 1990. However, study participants agreed that greater reductions should apply in respect of carcinogenic and genotoxic VOCs. The criteria for VOCs used in the Swedish study called for overall reductions of 70 per cent by 2005 and 85 per cent by 2020 from 1988 levels.[25]

Quantification of the CO_2 Criterion

The quantification of the criterion for carbon dioxide was based on the work of the Intergovernmental Panel on Climate Change (IPCC) concerning what is required to return atmospheric concentrations of this gas to current levels and maintain them there (i.e., to stabilise them). To this end, the first assessment of the IPCC argued for "immediate reductions in emissions from human activities of over 60 per cent."[26] The IPCC's second assessment noted that the evidence for a discernible influence of human activity on climate had become stronger but was less forthright on the matter of what reductions in emissions might be required to remove such an influence.[27] The second assessment reports nevertheless contain further evidence for the statement about needed reductions that was made in the first assessment report.[28]

In setting the criterion for CO_2 reductions, participants in the EST project also took into account the argument that the relative reductions in CO_2 emissions required in OECD countries may have to be greater than otherwise necessary in order to allow opportunities for further economic development by non-OECD countries. Accordingly, the participants concluded that an objective for transport-related emissions of CO_2 consistent with attainment of environmental sustainable transportation would be to stabilise CO2 concentrations at current levels -- thus requiring that CO2 emissions from transport activity be 20 per cent of their levels in 1990 across the area of investigation. The criterion was to apply only to emissions of CO_2 from the use of fossil fuels; emissions from the use of other vehicle fuels, e.g., ethanol from biomass, may not add to the atmospheric load of CO_2.

Calling for reductions of 90 per cent (NO_x and VOCs) and 80 per cent (CO_2) may seem extreme, particularly in the light of evidence that CO_2 emissions from transportation are *increasing* in OECD countries and elsewhere.[29] The particular criterion for CO_2 emissions developed here should be set against the parts of the latest IPCC report identified in Footnote 28, and also current proposals for a four-fold increase in energy efficiency,[30] for a ten-fold increase in energy and resource productivity,[31] and for a twenty-fold increase in eco-efficiency.[32]

OECD Environment Ministers have taken particular note of the proposal for a ten-fold increase in energy and resource productivity made by the "Factor 10 Club", a group of leading individuals from academic, business, and environmental circles. At their meeting in May 1997, the Ministers noted the growth in international interest in the potential of "Factor 10" to provide challenging numerical targets against which progress can be monitored. The Ministers are to receive a report on eco-efficiency in 1998.

The criteria for CO_2 used in the Swedish study were less strict than the EST criterion. The Swedish study spoke to overall reductions of 10 per cent by 2005, 20 per cent by 2020, and 60 per cent by 2050. The development of the case for these criteria included this argument: "If an even distribution of the global per capita emissions of carbon dioxide is desired, an industrial country like Sweden must reduce its emissions in the region of 50-80 per cent."[33] However, the report suggested that "inertia will set in when it comes to introducing measures to reduce carbon dioxide emissions within the transport sector". Accordingly, less stringency should be required, especially for the early decades of the next century.

The German study also considered scenarios defined by less stringent CO_2 criteria along with the regular EST1, EST2, and EST3 scenarios. These scenarios were variants of the EST3 scenario. They are not reported on here; information about them can be found in the report on the German study.

Participants in the EST project have been acutely aware of the difficulties inherent in large reductions of CO_2 emissions from transportation. The decision was made to stay with the criterion of an 80-per-cent reduction suggested by the logic of environmental and social sustainability, at least for Phase 2 of the project. A less stringent criterion might be considered during Phase 3, perhaps one closer to the Swedish criteria or one of the two additional German criteria. The IPCC work suggests, however, that unless reductions of more than 60 per cent are eventually achieved there will be no stabilisation of CO_2 emissions.[34] Thus a more relaxed criterion for 2030 should be seen as a milestone for the attainment later in the 21st century of reductions consistent with stabilisation of atmospheric CO_2 levels.

In 1990, transportation was responsible for 22 per cent of CO_2 concentrations from fossil-fuel use[35] and higher proportions, noted above, of emissions of NO_x and VOCs. There are other major sources of all three types of emission. The reductions in emissions required for environmental sustainability apply to all emissions. The assumption made for the EST project is that the reductions required for transportation will be no more nor less than those required for all contributing emission sources.

In summary, the three common criteria were set as follows:

EST Targets

- **Nitrogen oxides**
  Total emissions of NOx from transport in 2030 should not exceed 10% of total emissions of NOx from transportation in 1990.

- **Volatile organic compounds**
  Total emissions of VOCs from transport in 2030 should not exceed 10% of total emissions of VOCs from transportation in effect in 1990. (Greater restrictions would apply to carcinogenic or genotoxic VOCs.)

- **Carbon dioxide**
  Total emissions of CO2 from transport in 2030 should not exceed 20% of the total emissions of CO2 in 1990.

The other EST criteria were left to be quantified or otherwise specified in more detail during Phase 2 by the participating countries themselves, using national and international standards where appropriate. Table 1 describes the activities of the participating countries in this respect. Some countries chose not to use some or all of the optional EST criteria during Phase 2.

Table 1
Development of the optional EST criteria during Phase 2

	PARTICULATES	LAND USE FOR TRANSPORTATION	NOISE
QWC	Not used.	Not used.	Not used.
OSN	Not used.	No more land to be used for transport purposes than approved in 1996.	Not used.
GER	A 99% reduction in total emissions of PM_{10} from diesel engines in urban areas between 1990 and 2030.	*For urban areas:* A criterion still has to be developed; it needs to take account of population density as well as access to public transit. In sprawl areas the percentage of land use for transport should be very low, while it could be considerably higher in city regions. An average value is considered to be 5 % of the land in cities. *For rural areas:* no additional transport infrastructure is to be constructed after 2010 in conservation areas, in surrounding buffer zones and in areas larger than 100 square kilometres with low traffic densities not yet divided by transport infrastructure (excluding roads with less than 3.000 vehicles per day).	Noise levels from transport in 2030 do not impair health and are thus in all places below 65 dBA and below 55 dBA during the day and 45 dBA at night in residential areas.
NET	A 90% reduction in total emissions of PM_{10} from transportation between 1990 and 2030 (i.e., as for NO_x and VOCs).	*Direct land use* (land used for moving and storing vehicles) to be no more in 2030 than in 1990, with a much improved environment for living and working. *Indirect land use* (land unfit for living and working on account of proximity to transport corridors) to be reduced by 50%.	A negligible level of serious noise nuisance in 2030 is met when road traffic noise emissions are reduced from 1990 levels by 10 dBA, rail traffic by 7 dBA and civil aviation by 8 dBA, with trade-offs allowed between modes.

Table 1: Continued

	PARTICULATES	LAND USE FOR TRANSPORTATION	NOISE
SWE	An intermediate goal for 2005 was used specifying a 50% reduction in total emissions of PM_{10} between 1990 and 2005. A long-term goal is under development.	So far specified only in qualitative terms, as follows: (i) access to parklands and natural areas must not decrease; (ii) the total area of infrastructure is to be reduced; (iii) restrictions on classified areas are to be respected; and (iv) there must be no further fragmentation.	Average noise levels from transport in 2030 are not higher than 55 dBA outdoors and 30 dBA indoors. Maximum values are 70 dBA outdoors and 45 dBA indoors
ALP	[under development]	[under development]	Noise levels in residential areas in 2030 should not rise above 55 dBA during the day and above 45 dBA at night.

2.3 Scenario Construction

The first part of the work for Phase 2 involved establishing four scenarios for 2030. One was a business-as-usual (BAU) scenario, which served as a reference scenario. The other three were constructed so as to meet the EST criteria described in Section 2.2. The four scenarios were as follows:

- ***BAU*** **The "business-as-usual" scenario** characterised the transport system for each of the areas under study and its activity for that area in 2030, as projected from demographic and economic trends and other considerations. It assumed present and planned technology and legislation supplemented by changes considered likely to occur.

- ***EST1*** **The high-technology scenario,** assumed that the amount of passenger and freight transport was to be the same as determined for the BAU scenario for the particular area of study. The EST criteria were to be achieved entirely through technological change, identified in the characterisations of EST1.

- ***EST2*** **The capacity-constraint scenario,** assumed that the level of technology was to be the same as for the respective BAU scenarios. The EST criteria were to be achieved entirely through managing and reducing the demand for passenger and freight transport; the amounts and types of the reductions were identified in the characterisations of EST2.

- ***EST3*** **The optimum-combination scenario,** assumed that the EST criteria were to be achieved through a combination of technological change and demand management. The nature and extent of the changes were included in the characterisations of EST3. (The word *optimum* in the name of this schedule refers to what may be practically or politically optimum rather than to what is optimum in a technical sense. The development of the EST3 scenarios did *not* involve formal optimisation procedures.) The relationships between each of the three EST scenarios and the BAU scenario are summarised in Table 2.

	EST1	EST2	EST3
Technological progress	*significantly greater than BAU*	*equal to BAU*	*greater than BAU*
Transport activity	*equal to BAU*	*significantly less than BAU*	*less than BAU*

Table 2.
How the three EST scenarios differed from the BAU scenario

A significant feature of the present project has been the development of two extreme scenarios, the high-technology scenario (EST1) and the capacity-constraint scenario (EST2). The legitimate comment might be made that neither of these scenarios is realistic and that effort might be more productively employed in focusing on the more realistic optimum-combination scenario (EST3).

Several points can be made in response. The most important is that development of EST1 and EST2 scenarios is reported by participants in the EST project as being a valuable exercise that expands thinking about transportation and specifically about the character of EST. Another point is that the pure cases *are* sometimes advanced: that transportation problems can be solved entirely through technology or entirely through restricting demand. Such proposals deserve analysis even if only to understand better how they might be inappropriate.

The point could also be made that many would consider even the EST3 scenarios to be unrealistic. Certainly, major costs and social impacts might be expected from the implementation of EST3 scenarios, but they could well be less, even much less, than the impacts that would result from continuing towards the BAU scenarios. The present project is designed to cast light on these matters.

For each study, assumptions were made regarding demographic and economic factors. These are summarised in Table 3. The six studies all assumed moderate economic growth (about 2 per cent per year, or just over 120 per cent over a 40-year period). They also assumed low population growth (less than 0.5 per cent per year, or less than 25 per cent over the period), but a near doubling of the proportion of people aged over 65 years, and commensurate relative reductions in the proportions of other age groups.

Table 3: *Assumptions common to all scenarios*

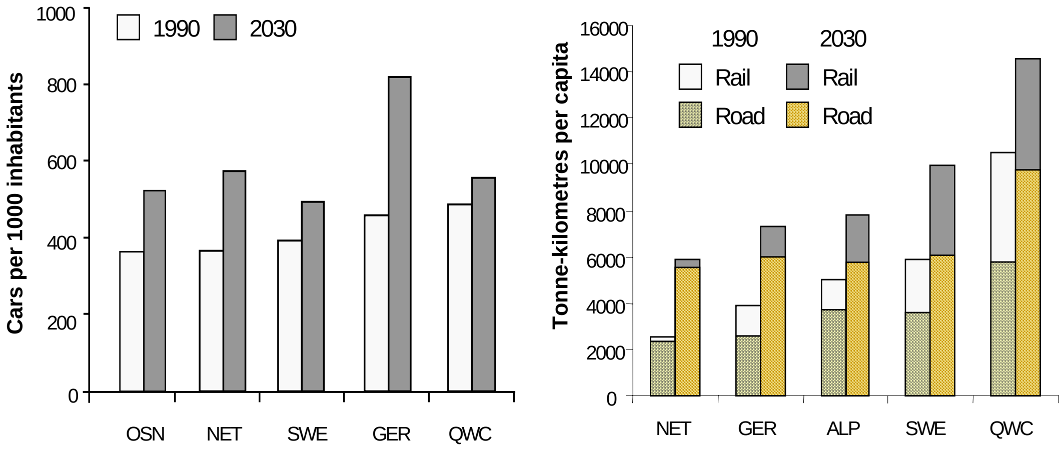
	Economic growth	Population growth	Age distribution	Employment	Other
QWC	Annual 2.2% increase in GDP.				Progressive harmonisation of policies and standards within Canada and within North America.
OSN	Real economic growth of about 2%/y between 1990 and 2030.	Population and employment both grow at close to 0.41%/y until 2000, then at 0.25%/y.	Very slight decrease in proportion aged 20-64.	To increase by 16% and 19% respectively for men and women by 2030.	
GER	Declining real GDP growth rates of with still growing GDP per capita; a steeper decline in growth rate after 2010 on account of decreasing population. Impacts of the scenarios themselves ignored.	Slight growth 1990-2010 (79.4 to 84.9 million), then decreasing until 2030 (81.1 million).	Increase in proportion of population of driving age.	Not considered.	
NET	2-2.5%/y (each year until 2030).	13.7% increase (1995-2030), annual rate declining.	Fewer young (<20y: 24.3-21.9%, 1995-2030) and more old people (>64: 13.1-24.4%).		
SWE	1.7%/y for each year until 2030.	From 8.7m in 1993 to 9.2m in 2010 to 9.4m in 2020.	Relatively fewer people aged 0-55 years and more aged over 55 years.	Labour force participation rate to increase from 72% in 1994 to 78% in 2020.	
ALP	2.3%/y for Switzerland and Austria; 2/2%/y for France.				Freight traffic appears inherently linked to growth in GDP of Alpine and neighbouring countries.

3 Business-as-Usual (BAU) Scenarios

3.1 Development of the BAU scenarios

Development of the BAU scenarios involved assumptions concerning both transport activity and emissions control—the latter to be achieved by anticipated technological advances or required by changed regulatory standards. These assumptions are summarised respectively in Table 4 and in Table 5, and provided in more detail in Table 13B to Table 15B, inclusive.[36] The specific assumptions concerning changes in the ownership of private automobiles under the various BAU scenarios are shown in Figure 4. (Three of the five BAU scenarios concerning passenger transport anticipate no change in use per automobile; the BAU scenario for the Oslo region anticipates a decline of 12 per cent in use per automobile between 1990 and 2030; the equivalent German decline is 14 per cent.)

Figure 4
BAU scenarios: Ownership of private automobiles and freight transport per capita in 2030 compared to 1990 levels



The assumptions concerning activity were used to estimate overall transport activity in 2030 in relation to levels in 1990. The assumptions concerning emissions were used to estimate emissions factors for the four types of atmospheric emissions that were considered: NO_x, VOCs, PM_{10}, and CO_2. These projections were then combined and used to estimate the variance of the scenarios from the EST criteria in the manner described in Section 3.2.

FACTOR	ASSUMPTION
Car ownership and use	Substantial increases in both ownership and use. (See Figure 2 for detailed projections concerning ownership.)
Van and truck use	Substantial increases in use.
Rail	Some increases in both passenger and freight movement.
Aviation	Very large increases in passenger and freight movement.
Inland and coastal shipping	Modest increases.
Modal splits	General shift to automobile use for passenger movement; little change respecting freight.
Transport-related infrastructure	Current rate of provision of infrastructure continues.
Fuel prices	Slight real increases in most countries. (See Table 15B for detailed projections concerning gasoline prices.)
Other	Continuation of present trends concerning increased dispersion of urban regions and reduced occupancy of passenger vehicles.

These summaries are very general and do not necessarily represent individual characterisations of the BAU scenario. Particulars about the characterisations can be found in Table 13B and in the reports on the individual studies.

Table 4
*BAU scenarios: Summary of assumptions about factors concerning transport activity**

Regarding noise, the German, Netherlands, and Swedish teams have provided analysis to this point. For the German study, estimates were made of the numbers of people affected by noise levels above target levels, distinguishing between rail and road noise, on the one hand, and day-time and night-time noise, on the other hand. In the Netherlands study, noise impacts in 2030 were estimated by extrapolating from the process of assumed compliance with European standards in 2010 in a way that takes into account the expected large increase in aircraft movements. In the Swedish study the focus was on setting long-range environmental goals, but impacts were also estimated.

Table 5
*BAU scenarios: Factors concerning transport emissions**

FACTOR	ASSUMPTION
Emission standards and performance	Emissions standards for all vehicles will be at least equal to EURO3 standards. Fuel efficiency will increase.
Road vehicle types	Most road vehicles will be of present types, with some electric and hybrid vehicles in use.
Alternative fuels for road vehicles.	Gasoline and diesel oil remain fuels of preference, with some use of LPG and natural gas—the latter particularly by urban buses.
Other modes	There will be a general increase in fuel efficiency across all modes, and reductions in emissions.
Electric power generation	Improvements in efficiency and reduction in NO_x emissions.
Other factors, in-cluding energy use	There will be relatively more traffic outside urban areas.

These summaries are very general and do not necessarily represent individual characterisations of the BAU scenario. Particulars about the characterisations can be found in Table 15B and in the reports on the individual studies.

The German and Netherlands studies also provided some consideration of the land-use criterion. In the Netherlands study, changes in direct land use were estimated from expected changes in the housing stock in urban areas.

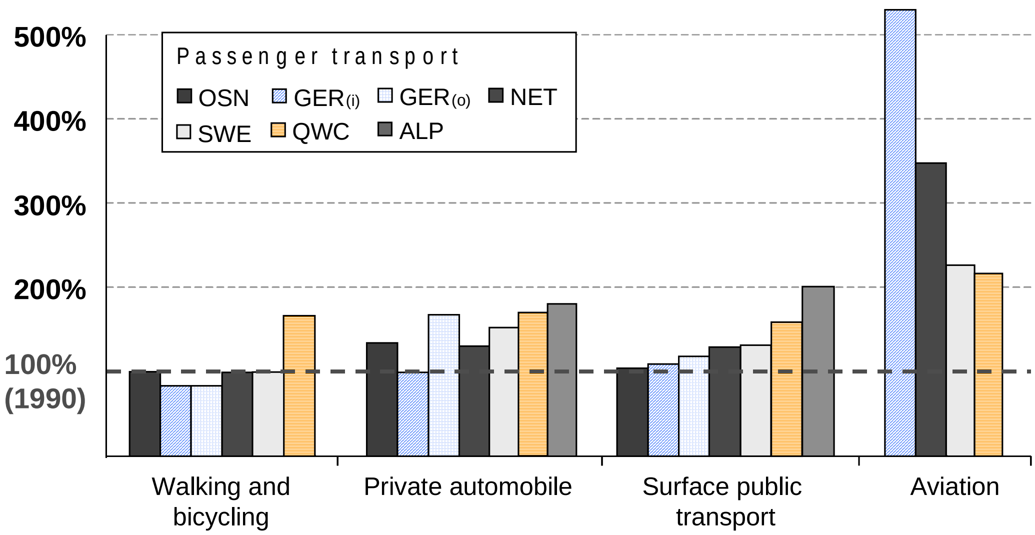
3.2 Features of the BAU scenarios

The key results from the construction of the BAU scenarios are the projected overall activity levels in 2030 portrayed in Figures 5a and 5b and the estimated emission factors portrayed in Figure 6. From the activity levels and emission factors the resulting overall changes in emissions between 1990 and 2030 can be estimated, and thus the deviations of the BAU scenarios from the EST criteria shown in Figure 7.

Figures 5a and 5b indicate the following about transport activity levels in the BAU scenarios for 2030: use of non-motorised transport (walking, bicycling) will be at a similar or slightly lower level than in 1990 except for Canada where higher levels are projected; car use will be substantially greater, particularly outside of urban areas; use of surface public transport will be greater, but at lower levels than those for car use; very large increases in aviation activity are expected; increases in road freight activity will be generally two to three times as large as those for automobile use, with smaller increases in other types of freight activity.

Figure 6 portrays the expected improvements in all emission factors (i.e., the reduction in emissions per unit of activity) in the BAU scenarios for 2030 in comparison with 1990. The improvements are mostly much greater for NO_x, VOCs, and PM than for CO_2.

Figure 5a
*BAU scenarios: Expected changes in passenger movement: activity in 2030 as a percentage of activity in 1990**

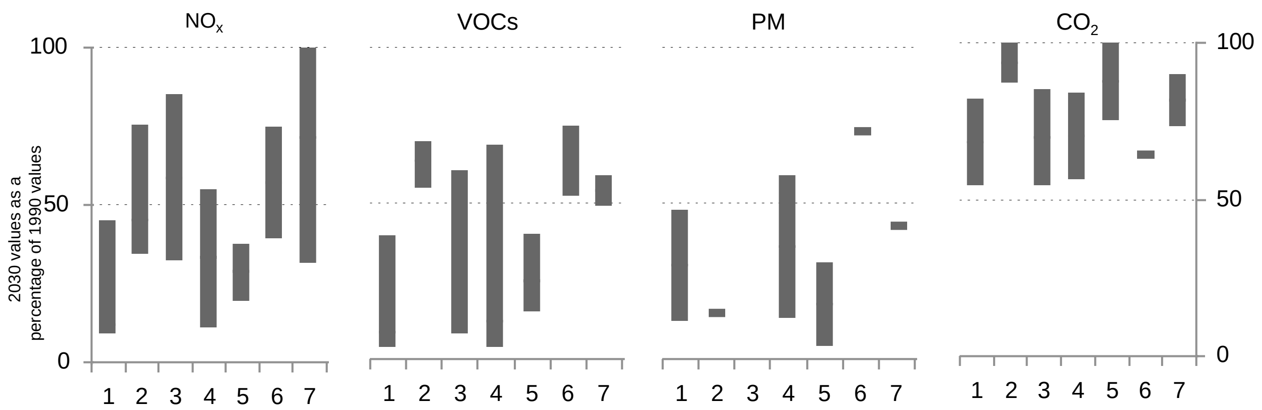


**The data represented here come from Table 16B. Ratios of passenger-kilometres or tonne-kilometres are represented where available; otherwise, ratios of vehicle-kilometres are shown. What is included in the transport categories for each study is detailed in Table 34B together with other relevant information.*

**The data represented here come from Table 16B. Ratios of passenger-kilometres or tonne-kilometres are represented where available; otherwise, ratios of vehicle-kilometres are shown. What is included in the transport categories for each study is detailed in Table 34B together with other relevant information.*

***Figure 5b**.*
*BAU scenarios: Expected changes in freight movement activity in 2030 as a percentage of activity in 1990**

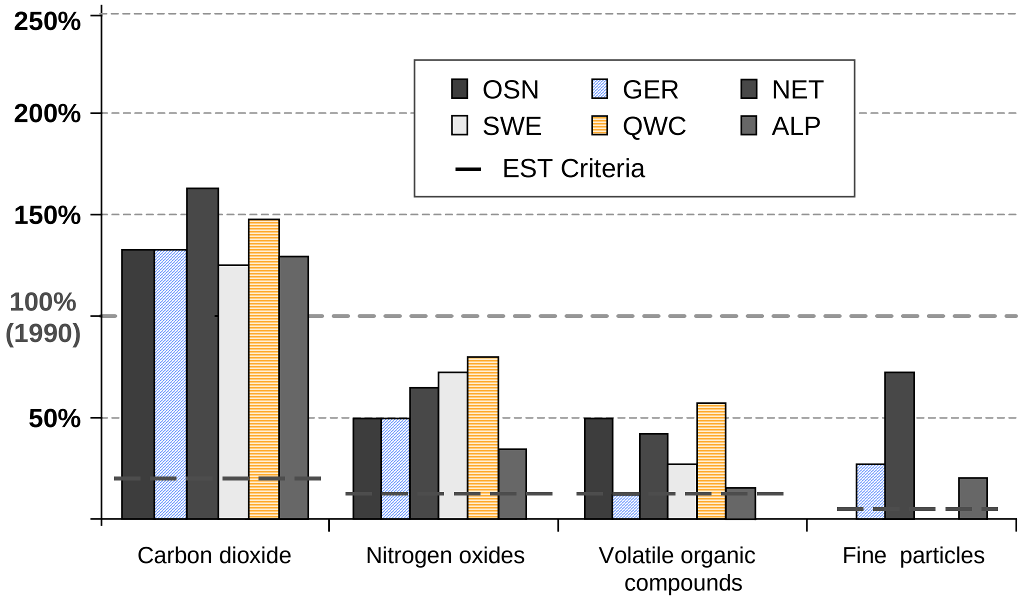
Figure 7 shows that, except for the anomaly of emissions of VOCs in Germany, total emissions in the BAU scenarios are projected to be far above the EST criteria. For carbon dioxide, they are expected in every case to be even above 1990 values. For the other types of emissions, the 2030 values will be below the 1990 values but, in most cases, much above the criterion levels.



1=private automobiles 2=surface public transport 3=aviation
4=light-duty road freight 5=heavy-duty road freight 6=rail freight
7=water-borne freight.

Figure 6
*BAU scenarios: Ranges of changes in emission factors, 2030 to 1990**

**This figure indicates the ranges of improvement in emissions anticipated in connection with the BAU scenarios. It summarises the information in Table 17B to Table 20B, inclusive. Each of the four panels shows for the indicated type of emission the unit emissions per vehicle-kilometre or per passenger- or tonne-kilometre in 2030 as a percentage of the equivalent emissions in 1990. A single point is shown where there is relevant information from only one study or where there is no variation among studies.*



**The criteria for CO_2, NO_x, and VOCs common to all studies in the EST project are shown by the dotted lines near the base of each group of bars. There was no common criterion for particulates.*

Figure 7
*BAU scenarios: Total emissions in 2030 as a percentage of total emissions in 1990, in comparison with EST criterion ratios**

For carbon dioxide, BAU emissions in 2030 are expected to be six to more than ten times greater than the level specified in the EST criterion for CO_2. For nitrogen oxides, BAU emission levels are expected to be five to eight times higher than the levels specified in the NO_x criterion. As time passes between 1990 and 2030, the contribution of different transport modes to the exceedances of the criteria would change. In general, there would be declines in the relative contributions of private automobiles, increases in the contributions of freight traffic, and marked increases in the contributions of aircraft.

Large reductions in emissions on account of improvements in technology are projected (for example, an 85- to 90-per-cent reduction in NO_x emissions from cars, as shown in Figure 6). Implementation of the anticipated improvements is projected to be enough to offset increases in transport activity in the case of NO_x, VOCs, and PM, but mostly not enough in the case of CO_2. However, the expected technological improvements are in no case sufficient to ensure that the EST criteria are met.

Some preliminary results regarding the other criteria (concerning noise and land use) are available from the German, Netherlands, and Swedish studies. Projections of noise impacts for the Netherlands BAU scenario are for slight reductions in impacts resulting from road and rail traffic and large increases in impacts from aviation, including increases by 150 per cent in the incidence of serious noise nuisance. The increases will more than offset the reductions. Because substantial proportions of the population would be exposed to serious noise nuisance from road traffic and aviation and, to a lesser extent, rail traffic, the EST noise criterion would not be met under the BAU scenario. In the German BAU scenario a small overall reduction in noise levels is anticipated, but not enough to meet the German criterion of 65 dB(A). Likewise, the Swedish study estimated improvement under the BAU scenario, but far from enough to meet the proposed environmental goals, which would require further 10-15 dB reductions for all transport modes.

Projections in the Netherlands based mostly on expected changes in housing stock suggest that if the BAU scenario were to prevail, there would be increases in road length in the Netherlands of approximately 40 per cent inside urban areas and 16 per cent elsewhere. The Netherlands EST criterion for direct land use is for no increase in land use for transportation over 1990 totals. If there is to be no compensating reduction in road surface per kilometre of road, or in associated uses (e.g., for access, parking, vehicle maintenance), then the criterion will be breached.

Regarding indirect land use for transportation, the Netherlands study team suggested that the most important factor is noise. Because there will be an overall increase in noise levels from transportation under the BAU scenario there will thus be an increase in transport's indirect impacts on land use. The Netherlands EST criterion for indirect land use is that there be a 50-per-cent reduction from 1990 levels. Thus the projection is that the criterion will be breached under the BAU scenario.

3.3 Conclusions from construction of the BAU scenarios

With one anomalous exception, none of the EST criteria in any of the six studies is met in the various BAU scenarios. For nitrogen oxides and volatile organic compounds, and for particulate matter (where examined), the projected changes in total emissions between 1990 and 2030 are towards the respective criteria for sustainability. The changes in respect of land use and noise seem to be away from sustainability; but these impacts were examined for only two study areas at this time.

The most important conclusion from construction of the BAU scenarios is this: In every study the projected changes concerning emissions of carbon dioxide were away from sustainability, i.e. more CO_2 will be emitted in 2030 than in 1990, as much as 110 per cent more—in the Alpine study, which has concerned freight *only—even though the criterion for CO_2 is for an 80-per-cent reduction with respect to 1990 levels in order to attain sustainability*.

The criterion for carbon dioxide concerns global (as opposed to local or regional) environmental impacts and is thus regarded by some as the most important of the six criteria.[37] Hence the seriousness of the conclusion concerning CO_2 emissions.

Further analysis of the results from the BAU scenarios for the six studies is constrained by the variety of methods used and the indicators chosen for making the projections about transport activity and emissions. Variety was encouraged for Phase 2 of the EST project to help determine the most fruitful approaches.[38] A challenge for subsequent work is to identify and use the best tools for construction of BAU and other scenarios.

4 High-Technology Scenarios (EST1)

4.1 Features of the high-technology scenarios (EST1)

The basic task in the development of the EST1 scenarios was to identify technological improvements that would be effective enough to reduce the impacts of transportation at least to the levels set in the EST criteria, while providing for the levels of transport activity projected in the BAU scenarios. (These levels of activity have been summarised in Figures 5a and 5b, which show the increases in activity projected in the BAU scenarios for each mode in each study area.)

Table 6
*EST1 scenarios: Summary of features**

MODE	EST1 FEATURES
Light duty road vehicles (including cars)	Except for Sweden (for which the CO_2 criterion is less stringent), almost all conventional vehicles would be replaced by electric vehicles of one of three kinds: battery-powered, fuel-cell-powered or hybrid combustion-electric (See Table 8).
Heavy-duty road vehicles	Almost all conventional vehicles replaced by hydrogen-based, fuel-cell-powered vehicles. (See Table 9).
Rail	All electrified, light-weight systems with numerous technological improvements—regenerative braking, advanced control devices, etc.—and more efficient utilisation.
Inland and coastal shipping	Improved vessels, perhaps using hydrogen-based fuel cells.
Aviation	Hydrogen will be used as a fuel, in fuel cells or directly. In one study, use of airships is proposed for shorter journeys.
Electric power generation	Almost all electric power is produced without use of fossil fuels, mostly using renewable means.
Other	Noise is reduced through design features. Widespread use of information technology helps improve vehicle efficiency and utilisation.

** These summaries are very general and do not necessarily represent individual characterisations of the scenario*

Table 6 summarises the features of the EST1 scenarios, with further details on the proposed nature of light- and heavy-duty road vehicles set out in respectively in Table 7 and Table 8.

The changes in emission factors achieved by implementing the EST1 scenarios are shown in Figure 8. This figure indicates that the EST criteria would *not* be met in respect of many of the individual transport modes even though, because of the requirements of the scenarios, they were met by each transport system taken as a whole.

Table 7
EST1 scenarios: Percentage shares of types of heavy-duty road vehicles in use in 2030

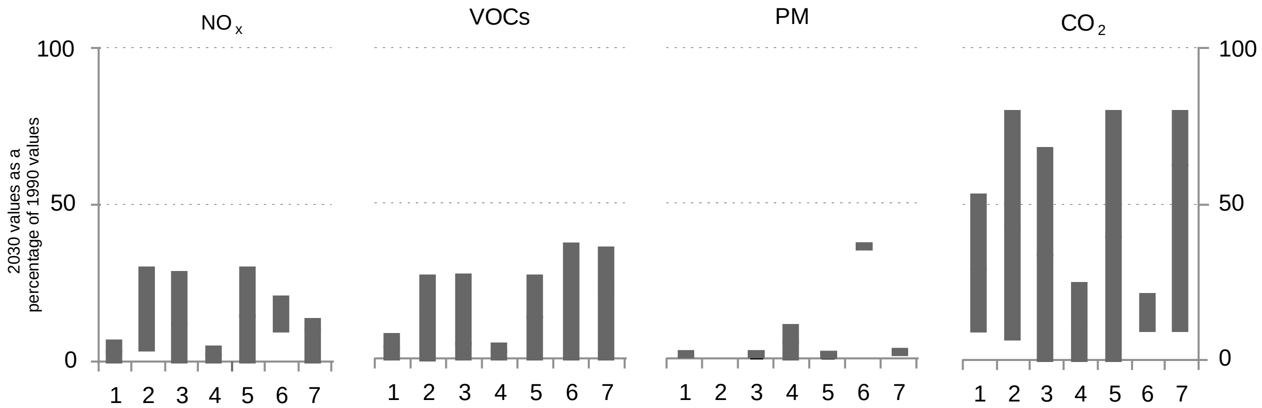
Vehicle (power system)	OSN	GER	NET	ALP
Fuel cell (hydrogen-based)		100	80	90
Conventional				10
Hybrid	100		20	

Table 8
EST1 scenarios: Percentage shares of types of personal automobile in use in 2030

Vehicle (power system)	OSN	GER	NET	SWE
Hybrid combustion-electric	60	100	20	
Electric	40		80	
Fuel cell				
Conventional				100*

**80 per cent use of biofuels*

Comparisons among the proposed EST1 features shown in Table 7 and Table 8 show more common features for freight—i.e., hydrogen-based fuel cells—than for personal transportation. Other features of the EST1 scenarios include substantial improvements in efficiency of fuel use and in pollution control, and a greater reliance on electric power, much of which would be produced from sustainable—i.e. renewable—sources.



1=private automobiles *2=surface public transport* *3=aviation*
4=light-duty road freight *5=heavy-duty road freight* *6=rail freight*
7=water-borne freight.

Figure 8.
*EST1 scenarios: Ranges of changes in emission factors, 2030 to 1990**

**This figure indicates the ranges of improvement in emissions anticipated in connection with the BAU scenarios. It summarises the information in Table 22B to Table 25B, inclusive. Each of the four panels shows for the indicated type of emission the unit emissions per vehicle-kilometre or per passenger- or tonne-kilometre in 2030 as a percentage of the equivalent emissions in 1990. A single point is shown where there is relevant information from only one study or where there is no variation among studies.*

Although Phase 2 concerned scenario construction and not examination of the economic and social implications of implementing the scenarios, study participants made comments about the likely impacts of the various scenarios. The EST1 scenario was described as being extremely expensive to implement. This was in part on account of its reliance on the production, treatment, and storage of hydrogen, which was described as "highly fuel-consuming and inefficient," with high costs of implementation and use.

5 Capacity-Constraint Scenarios (EST2)

5.1 Features of the capacity-constraint scenarios (EST2)

The basic task in developing the EST2 scenarios has been to describe sets of circumstances in which the EST criteria were met with no technological progress beyond that established for the BAU scenario—chiefly because much lower levels of transport activity were assumed. The task was not to describe how the scenarios were attained (this is the work of the backcasting exercise in Phase 3) but rather what some aspects of human activity would be like in these circumstances. The general idea, as with the other scenarios, was to sustain to the extent possible the comfort, convenience, and efficiency of present life in the study areas, in this case while meeting the EST criteria through reducing transport activity.

Table 9
*EST2 scenarios: Summary of features**

ITEM	EST2 FEATURES
Private automobiles	Much lower use or no use of private automobiles, with reductions in use sustained by regimes of high levels of taxation of fuel, road use, and parking. Moped and motorcycles may also not be used.
Other passenger transport	Most passenger transport is by collective means, particularly using rail. There is much new supporting infrastructure—also for facilitation of non-motorised modes. Efficiency improved through logistical organisation.
Freight movement	Much less reliance on road vehicles, with more use of rail and, possibly, water-borne modes. Logistical reorganisations in place to avoid transport—reversal of trend to "just-in-time," for example, and load optimisation. Transport of goods also reduced by increasing the use of locally produced products and by reducing the volume of materials circulating per unit of GDP.
Aviation	Travel by air is very much reduced or negligible. Long-distance travel is mostly replaced by telematics.
Land use	Settled areas are redeveloped to the extent possible to reduce the need for motorised travel, particularly by increasing residential densities. Work practices are changed to the same end.
Telecommunications	There is much more use of teleworking and teleconferencing, and other activities that can reduce the need for travel, together with the necessary infrastructure.
Economic activity	Economic development and freight transport have been decoupled. However, the macro-economic projections of the BAU scenarios cannot be sustained, at least not without profound changes in the structure of the global economy sufficient to obviate simple comparison with BAU scenarios.
Other	A high level of public education and information is in place to sustain the reductions in activity. Several other activities are restructured, notably tourism and vacation-taking.

**These summaries are very general and do not necessarily represent individual characterisations of the scenario.*

Table 9 sets out some of the prominent features of each study team's EST2 scenario. Figures 9a and 9b show in relation to 1990 levels the changes in transport activity considered necessary to ensure achievement of the EST2 criteria. What may be of most interest in each scenario are the provisions for motorised road transport for passengers and freight. Figure 9a shows that use of personal automobiles is mostly expected to be less than 25 per cent of 1990 levels. By contrast, projections for the BAU scenario, portrayed in Figure 5a, indicate *increases* of more than 50 per cent in the use of cars. Likewise, use of trucks (lorries) in the EST2 scenario is expected to be more than 70 per cent lower than 1990 levels. This is also in contrast to the BAU scenario, which indicates a more than doubling of truck use.

Figure 9a indicates that the reductions in personal automobile use in the EST2 scenarios would be to some degree compensated by increases in the use of public transport, particularly rail modes powered by sustainably produced electricity, and by increases in the use of non-motorised modes. The reductions in truck use would be to some degree compensated by increases in the use of rail freight and inland shipping, the former also powered by sustainably produced electricity.[39] Other features of the EST2 scenarios are shifts to local and regional production of food and manufactured goods and massive substitution of telecommunications for the movement of people and goods. Long-distance travel would be severely constrained.

Study participants noted that even before conducting a proper analysis of social and economic implications it was evident that implementing the EST2 scenario would be a wrenching experience for residents of OECD countries. This could be as much on account of the changes in the trade of goods as on account of the changes in personal mobility. The EST2 scenario could have profound economic ramifications. The effect on economic activity would not necessarily be adverse overall, but the scope of changes in details could be huge.

A key challenge in the selection and testing of instruments in a backcasting exercise would be management of the profound social and economic changes that any implementation of the EST2 scenarios might bring. Thus, perhaps much more than for the other scenarios, a backcasting exercise in respect of the EST2 scenarios, if conducted, should give continuing consideration of social and economic impacts and their interactions, as well as focusing on the requirements to reduce transport volume and to change patterns of transport activity.

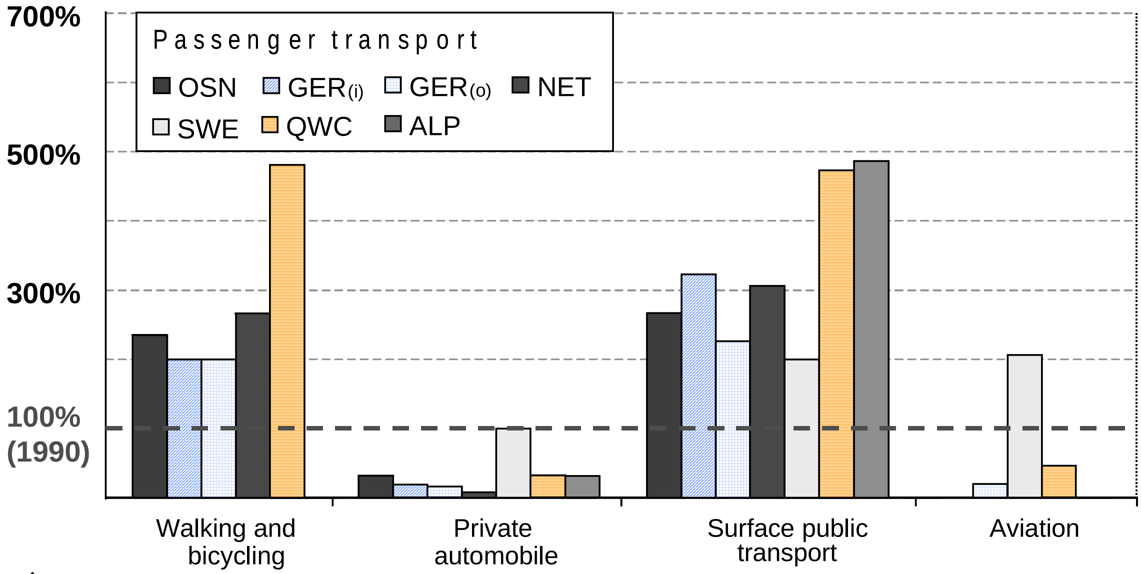
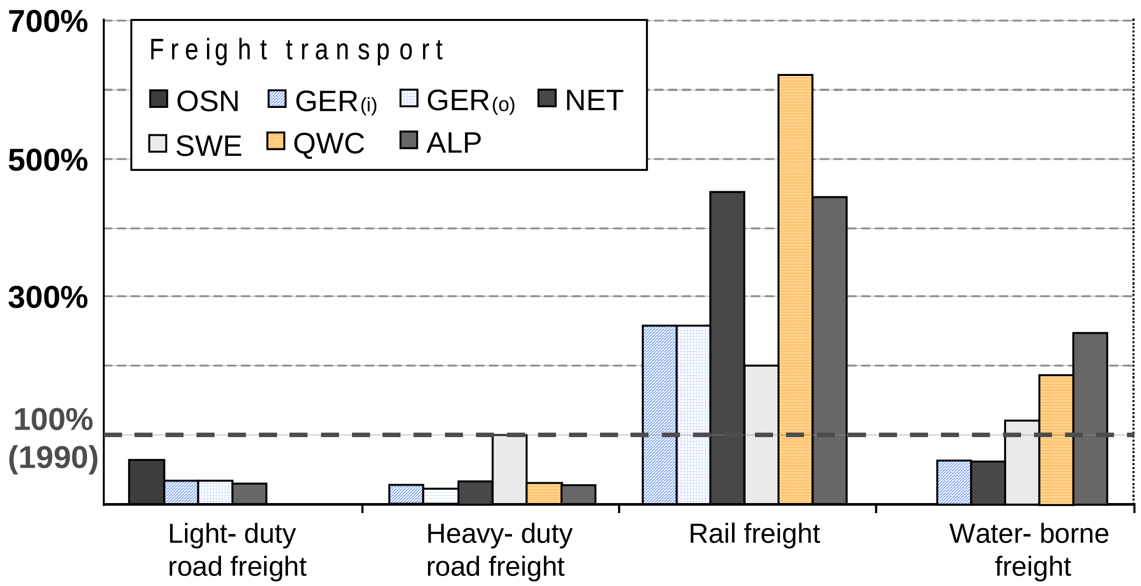


Figure 9a.
*EST2 scenarios: Expected changes in passenger movement: activity in 2030 as a percentage of activity in 1990**

Figure 9b
*EST2 scenarios: Expected changes in freight movement: activity in 2030 as a percentage of activity in 1990**



**The data represented here come from Table 27B. Ratios of passenger-kilometres or tonne-kilometres are represented where available; otherwise, ratios of vehicle-kilometres are shown. What is included in the transport categories for each study is detailed in Table 34B together with other relevant information.*

6 Optimum-Combination Scenarios (EST3)

6.1 Features of the optimum combination scenarios (EST3)

The basic task in developing the EST3 scenarios has been to determine the features of situations in which the EST criteria are met through what are regarded by the individual study teams as optimum combinations of technological change and reductions in transport activity—in other words, features that could be implemented with maximum social and economic advantage.

Table 10 sets out the strategies for optimising the features of EST3, in relation to those selected for EST1 and EST2, used by the project participants. General features of the EST3 scenarios are summarised in Table 11. The associated levels of transport activity are reported in Figures 11a and 11b. Changes in emission factors in relation to 1990 levels are reported in Figure 10.

Although the EST3 scenarios are optimum combinations—i.e. beneficial compromises between the extremes—their often dramatic nature should not be overlooked. For example, Figure 11a shows that major reductions in the use of cars—of close to 50 per cent compared with 1990 levels—are features of the EST3 scenarios. Thus, in this significant respect the EST3 scenarios are closer to the EST2 scenarios than to the EST1 or the BAU scenarios. Similar observations apply to truck traffic.

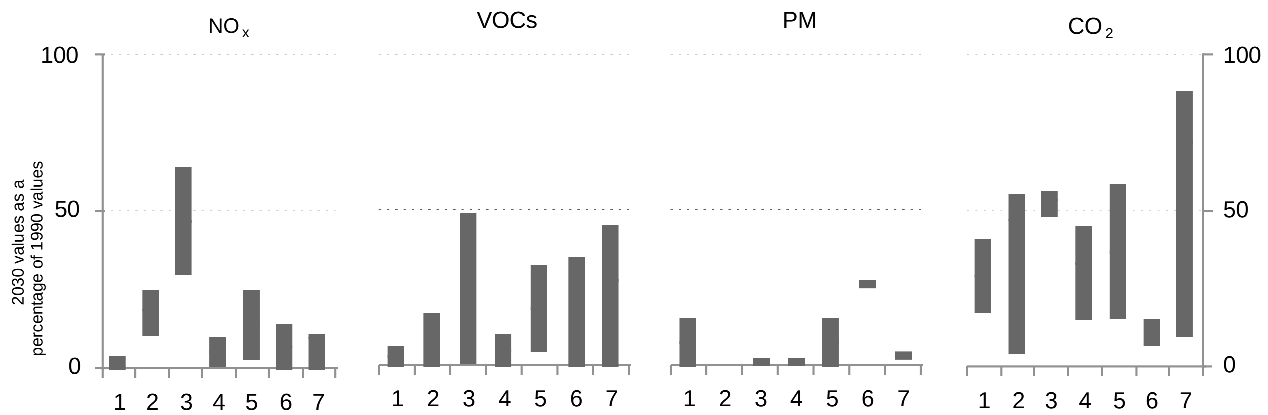
Table 10
EST3 scenarios:
Strategies for optimisation

STUDY	STRATEGY FOR EST3
QWC	EST3 contains most of the elements of EST1 and EST2, but omits those that are less feasible; some of the elements are used more conservatively.
OSN	Generally, freight transport is given more emphasis than passenger transport in the construction of EST3 (because of difficulties revealed during construction of EST1 and EST2). Specific objectives of EST3 are to reduce total amount of freight transport, to reduce use of private automobiles, and for both freight and passenger transport to reduce the number and length of trips, rationalise vehicle loads, reduce emissions, and improve efficiency.
GER	Features of EST3 are selected from those used in EST1 and EST2 according to technological, economic, and political feasibility.
NET	EST3 combines features of EST1 and EST2 omitting those that have the most adverse impacts on society.
SWE	The features of EST3 are the result of a scenario study that describes a possible, politically legitimate path to an EST.
ALP	EST3 combines features of EST1 and EST2 omitting the most restrictive measures.

Table 11
*EST3 scenarios: Summary of features**

ITEM	EST3 FEATURES
Private automobiles	There is a decrease in car ownership and use, but not as drastic as in EST2. More hybrid-electric cars are used than in EST1.
Other passenger transport	There is a focus on reducing long-distance travel, and on much greater use of non-motorised means together with supporting infrastructure. There is some emphasis on rail.
Freight movement	Large reductions in transport distances are evident, although not as much as in the EST2 scenario. Hydrogen may be widely used as a fuel, directly and in fuel cells.
Rail	Rail is all-electric, with high-speed modes and increases in efficiency.
Inland and coastal shipping	More efficient, less polluting vessels are used; hydrogen may be used as a fuel.
Aviation	Long-distance air travel is substantially reduced. Aircraft in use are more efficient, conventional types. Rigid airships may be used for shorter journeys.
Electric power for transport	This is made with great efficiency using high proportions of renewable fuels.
Land use	Modest changes in the form or settlements have been implemented to reduce the need for movement of people and freight.
Telecommunications	Extensive use is made of telecommunications to obviate travel and movement of goods.
Economic activity	Regionalisation of production occurs to avoid long-distance freight movement; volumes of production are reduced.
Other	Aggressive public education is required to sustain lower levels of travel.

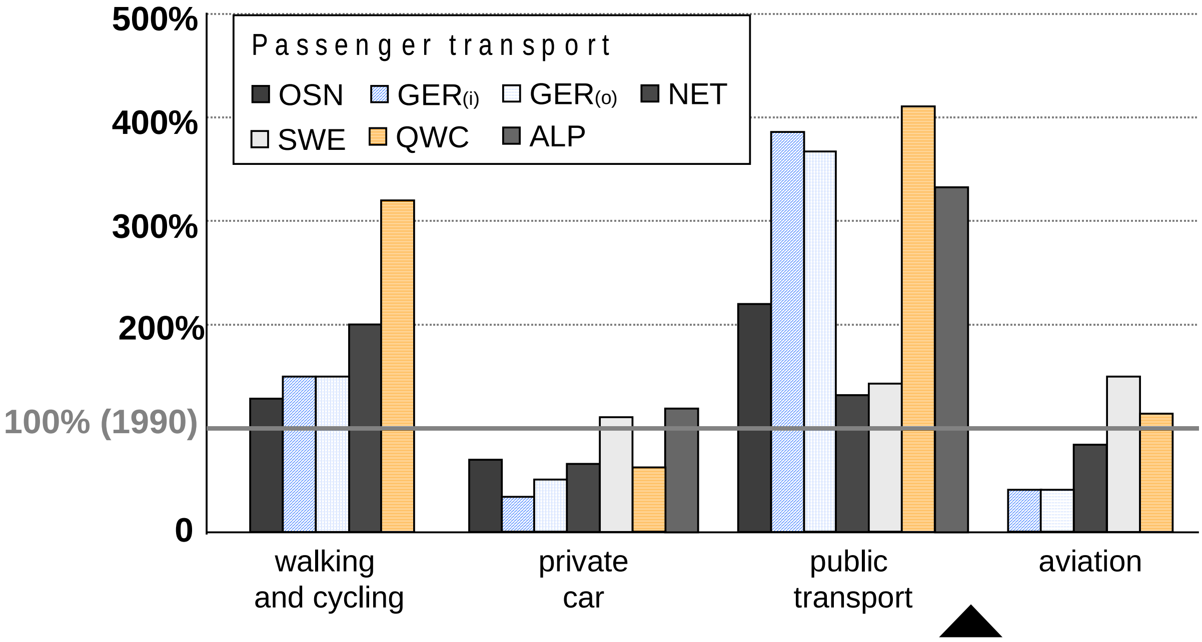
**These summaries are very general and do not necessarily represent individual characterisations of the scenario.*



1=private automobiles 2=surface public transport 3=aviation 4=light-duty road freight 5=heavy-duty road freight 6=rail freight 7=water-borne freight.

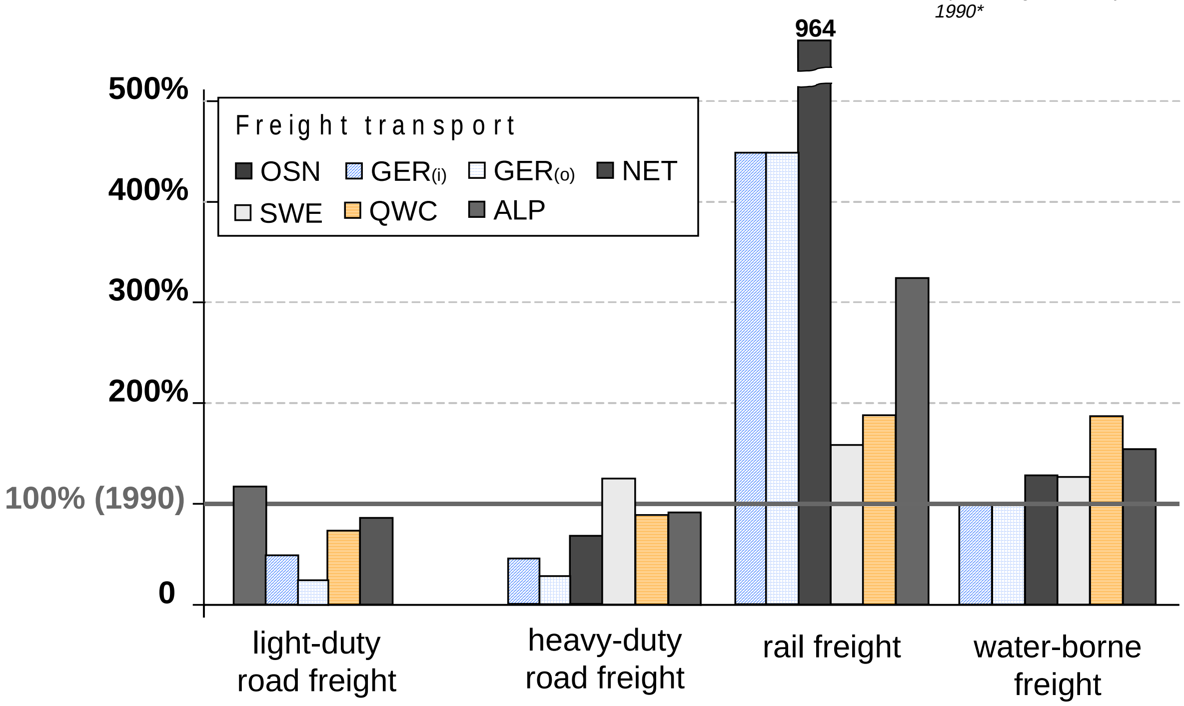
Figure 10
*EST3 scenarios: Ranges of changes in emission factors, 2030 to 1990**

*This figure indicates the ranges of improvement in emissions anticipated in connection with the BAU scenarios. It summarises the information in Table 29B to Table 32B, inclusive. Each of the four panels shows for the indicated type of emission the unit emissions per vehicle-kilometre or per passenger- or tonne-kilometre in 2030 as a percentage of the equivalent emissions in 1990. A single point is shown where there is relevant information from only one study or where there is no variation among studies.



**The data represented here come from Table 29B. Ratios of ratios of passenger-kilometres or tonne-kilometres are represented where available; otherwise, vehicle-kilometres are shown. What is included in the transport categories for each study is detailed in Table 34B together with other relevant information.*

Figure 11a
*EST 3 scenarios: Expected changes in passenger movement: activity in 2030 as a percentage of activity in 1990**



**The data represented here come from Table 29B. Ratios of passenger-kilometres or tonne-kilometres are represented where available; otherwise, ratios of vehicle-kilometres are shown. What is included in the transport categories for each study is detailed in Table 34B together with other relevant information.*

Figure 11b
*EST 3 scenarios: Expected changes in freight movement: activity in 2030 as a percentage of activity in 1990**

Perhaps the more significant features of the EST3 scenario in comparison with the EST1 and EST2 scenarios are the greater use of public transport, on the one hand, and the much greater rail freight activity, on the other hand. The study teams appear to have sought to optimise transport activity by applying technological advances mostly to these modes. However, as suggested in the previous paragraph and noted more particularly in the next section, the stronger emphasis in construction of the EST3 scenarios appears to be on activity reduction rather than on technological improvement.

The backcasting exercises for the EST3 scenarios will comprise all the elements of those for the EST1 and EST2 scenarios, plus the task of optimising between measures to enhance technology and measures to reduce activity. The present plan is that the backcasting exercises to be conducted during Phase 3 focus on implementation of the EST3 scenarios rather than EST1 or EST2. However, just as development of the extreme EST1 and EST2 scenarios has been of value in determining the elements of the optimum EST3 scenarios, so may consideration of implementation of the extreme scenarios be of value in working out the best way to implement the EST3 scenarios.

7

Relative Contributions of Reductions in Transport Activity and Unit Impact to Attaining the Scenarios

Transport's impact on the environment changes when the level of transport activity changes or when the impact of each unit of activity changes, or when both happen. If transport activity increases—most directly expressed in vehicle-kilometres[40]—there will be an increase in transport's impact on the environment, unless there is counterbalancing reduction in unit impact, i.e., in emissions per vehicle-kilometre. Likewise, if unit impact increases, perhaps because more powerful vehicles are used to carry the same load, there will be an increase in transport's impact on the environment, unless there is a counterbalancing reduction in activity. Manipulation of these two components was the basis for the design of scenarios during Phase 2 of the present project; levels of transport activity were held constant in the construction of the EST1 scenarios and levels of unit impact were held constant in the construction of the EST2 scenarios.

The present section provides an assessment of the contributions of these components during the construction of the BAU and EST3 scenarios. *It should be stressed that the assessment concerns how the study teams constructed the scenarios rather than actual transport phenomena.*

	Ratios: 2030/1990			
	BAU	EST1	EST2	EST3
Carbon dioxide:				
Overall impact	1.50	0.20	0.20	0.20
Activity	*2.00*	*2.00*	*0.27*	*0.50*
Unit impact	*0.75*	*0.10*	*0.75*	*0.40*
Nitrogen oxides:				
Overall impact	0.60	0.10	0.10	0.10
Activity	*2.00*	*2.00*	*0.27*	*0.50*
Unit impact	*0.30*	*0.05*	*0.30*	*0.20*

Table 12
Estimated contributions of transport activity and unit impact to attainment of the four scenarios with respect to carbon dioxide and nitrogen oxides

The initial assessment appears in Table 12. It involved two emissions—carbon dioxide and nitrogen oxides—for which common criteria had been specified, and very rough estimates of what had been set as overall transport activity and overall unit impact. These rough estimates amounted to no more than the gaining of *impressions* of overall average changes through inspection of the relevant figures in preceding sections.[41]

Table 12 suggests that even though the criterion for NO_x was more stringent than that for CO_2 the NO_x criterion was considered to be more readily attainable through reductions in unit impact. This can be concluded from the large average reduction in NO_x (about 70 per cent) anticipated for the BAU scenarios. Consequently, the CO_2 criterion is in effect a more restrictive criterion than the NO_x criterion. Thus, it is likely (but not certain) that if the CO_2 criterion is met the NO_x criterion will also be met. Accordingly, the balance of this section concerns attainment of the CO_2 criterion only.

Regarding the CO_2 criterion, Table 12 can be understood as follows: Overall transport activity was expected by the teams to double between 1990 and 2030 (BAU scenarios). Because CO_2 emissions per unit of activity were projected to decline by 25 per cent, the resulting net increase in CO_2 emissions was 50 per cent. For the EST1 and EST2 scenarios, unit impact of activity and activity were respectively reduced to meet the criterion of an 80 per cent reduction in CO_2 emissions. For EST3, the teams proposed on average a 67 per cent reduction in activity (from twice the 1990 level to two thirds of that level). They proposed a 60 per cent reduction in unit impact (from 75 per cent of the 1990 level to 30 per cent of that level).

Accordingly, the following may be concluded from this preliminary assessment of the balance of effort applied by the teams in moving from the BAU to the EST3 scenarios: About half the effort concerned changes in activity and about half concerned unit impact, with slightly more emphasis on activity change.

7.2 Analysis of the contributions of four factors

A more sophisticated analysis was then performed to provide a more precise account of how the teams had constructed their EST3 scenarios. This analysis took four factors into account:

1. Reduced emissions per unit of transport activity, i.e., passenger-kilometres or tonne kilometres, from the same vehicle type through **technological change** or from **vehicle downsizing**.[42]
2. **Reduced transport activity**, i.e., fewer passenger-kilometres or tonne kilometres.
3. Reduced emissions per unit of transport activity through use of more efficient vehicle types, i.e., through **mode shifts**.

4. Reduced emissions per unit of transport activity through using the same vehicle type more efficiently, i.e., **higher occupancy** of vehicles for the movement of people and **higher loading** for the movement of freight.

The specific purpose of the analysis was to attach a percentage value to each of the four factors so that it could be said that a particular scenario provided that A% of the effort towards achieving the difference in CO_2 emissions between the EST3 and BAU conditions was contributed by technological change or vehicle downsizing; likewise, B% of the effort came from reducing overall transport activity, C% from shifting to more fuel-efficient transport modes, and D% from using vehicles more efficiently. It follows that the sum of A, B, C, and D should be 100.

The principle behind what became known as the "balance-of-effort" (BoE) analysis was this: **The relative contribution to the total reduction in CO_2 emissions of each of the four components acting together can be derived from estimates of their separate contributions.** The method involved estimating each of the four separate contributions, calculating their total, and then deriving each estimate's percentage of the total. However, it must be borne in mind that the various contributions towards reducing CO_2 emissions interact. For example, vehicles use energy according to their occupancy, a factor that is not taken into account when the elements of the balance of effort are considered separately. Some interactions may be stronger than others. For example, reduced energy use through technology tends to encourage activity. This interaction between elements may well be stronger than the interaction of occupancy and energy use.

Taking all such factors into account would be an enormously complex matter. It would not be justified, given the insubstantial foundation on which any BoE analysis must be based. **The relatively simple approach proposed here may be as much as the available data can reasonably support.**

The individual components of the effort in reducing CO_2 emissions to attain EST3 rather than BAU were estimated separately for the movement of people and the movement of freight for each of the pairs of scenarios as follows:[43]

1. Reduced emissions per unit of transport activity from same vehicle type through technological change or vehicle downsizing. The change in CO2 emissions resulting from this factor was estimated for each mode by multiplying emissions under BAU by the proportionate change in emissions per vehicle-kilometre (vkm) between the EST3 and BAU scenarios. This gave the change in CO2 emissions that could be expected for that mode if only the CO2 intensity (emissions per vkm) were to change.

2. Reduced transport activity, i.e., fewer passenger-kilometres or tonne kilometres. Here the proportionate change in overall transport activity was applied to the total BAU emissions for each mode. This gave the change in CO_2 emissions that could have been expected if each mode had experienced the degree of overall change in transport activity.

3. Reduced emissions per unit of transport activity through use of more efficient vehicle types, i.e., through mode shifts. This estimation was based on the assumption that any change in passenger- or tonne-kilometres for a mode that does not reflect a change in overall activity must reflect a shift in mode. Applying for each mode the estimated emissions per unit of activity to this difference provided an estimate of the change in CO_2 emissions due to a shift towards or away from the mode.

4. Reduced emissions per unit of transport activity through using the same vehicle type more efficiently, i.e. higher occupancy or loading. Here the change in occupancy or loading between the BAU and EST3 scenarios was applied to the BAU emissions providing estimates what would have been the change in CO_2 emissions if only the occupancy or loading had changed.

The above four calculations provided for each mode and each type of factor an estimate of the changes in kilotonnes of CO2 that would have been emitted if the factor had operated in isolation, for modes involving the movement of both people and freight. To estimate the shares attributable to each factor when operating together, the individual changes in CO_2 emissions were summed across modes, and the sum for each factor was expressed as a percentage of the grand total of CO_2 changes, corresponding to the percentages A, B, C, and D noted above.

The results of the analysis are provided in Figure 12 on the next page .

Several things are apparent:

- In every case except for the movement of freight in Germany, the component labelled ‘technology’ was the most significant component of the effort to meet the CO_2-reduction requirements of EST3. This component on average amounted to just over 50 per cent of the effort in the case of movement of people and just under 50 per cent in the case of the movement of freight. As noted, this component embraces not only reductions in CO_2 emissions through technological change but also reductions in emissions through simple downsizing of vehicles, i.e., performing a task by using smaller vehicles of the same kind. Because it is reasonable to suppose that attainment of EST3 will involve a considerable amount of downsizing of vehicles, especially passenger vehicles, it follows that the contribution of technology will be

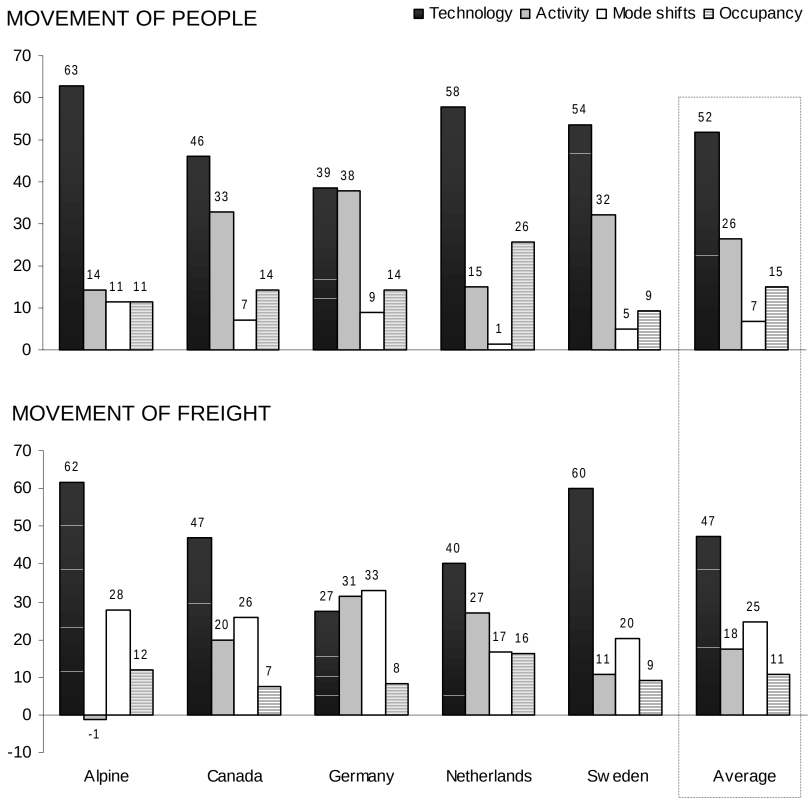


Figure 12
Percentage contribution of four types of method of reducing CO_2 emissions to the construction of the EST3 scenarios of five of the Member country teams.

somewhat less than the percentages provided in Figure 12, i.e., somewhat less than the indicated values of close to 50 per cent.

- For the movement of people, reduced activity was on average the second most significant component of the effort. For the movement of freight, the second most significant component was shifting to more efficient vehicle modes (usually from road to rail).
- Although four of the five Member country teams represented in Figure 12 are European, and European approaches to transportation are believed to differ from North American approaches, it is the non-European country, Canada, that has the closest-to-average distribution of the balance of effort, for the movement of both people and freight. **Even this small sample of European countries displays a wide variety of strategies for attainment of EST3.**

The divergence in strategies could be linked to differing assumptions about the BAU and EST3 values of the basic indicators. For example, a dependence on technology might be associated with assumptions about high CO_2/vkm values for the BAU scenarios. This kind of possibility was investigated by assessing the relationships between the teams’ strategies and their assumptions. No suggestion of a link was found with respect to either the movement of people or the movement of freight.

7.3 Conclusions from the Balance-of-Effort analysis

The above quantitative analysis of how the EST3 scenarios were constructed during Phase 2 of the EST project suggests that on average they were designed to provide that close to half of the effort required to meet the EST criterion for carbon dioxide emissions would involve reductions in the intensity of emissions of individual vehicles types. Some of these reductions would come from downsizing of vehicles (e.g., using smaller cars or trucks to carry the same loads). Another component of the reductions in emissions intensity would involve technological improvements to vehicles and their drive trains, fuels, and infrastructure.

The corollary of above conclusion is that technological improvements will account for somewhat less than half of the effort required to achieve EST, according to the Member country study teams. About half of the effort will have to some from reductions in or other changes in transport activity. This conclusion applies to the movement of both people and freight.

The balance of effort regarding transport activity is projected by the study teams to differ between the movement of people and the movement of freight. For the movement of people, there is more emphasis on overall reductions in activity than on shifting activity to more environmentally benign modes (e.g., from car to train). For the movement of freight the emphasis is on mode shifts rather than on overall reductions in activity. The third activity-related factor examined—increasing the average occupancy or loading of vehicles—was given a relatively minor role for the movement of both people and freight.

This balance-of-effort analysis reveals marked differences in the strategies adopted by the individual Member country study teams. Nevertheless, the above general statements appear to have some validity as an overall description as to how the teams behaved.

8 Conclusions

Construction of the four scenarios during Phase 2 (BAU and EST1, EST2, and EST3) has been an extraordinarily complex and productive exercise whose implications may not be fully absorbed until subsequent phases of the study have been completed. For the moment, several interim conclusions can be drawn, as follows:

- The basic strategy of the project—developing BAU and EST scenarios for 2030, then determining how to achieve the EST scenarios, and then developing policy guidelines as to how to move toward environmentally sustainable transportation—remains sound and productive. A particular feature of this project, the construction of extreme scenarios, also appears to be a sound and productive strategy.
- Although substantial further improvements in emissions control and in attenuation of other environmental impacts can be expected, continuation of the present rate of changes in policy and technology (i.e., “business as usual”) would likely *not* result in achievement of environmentally sustainable transportation.
- Emissions of nitrogen oxides and volatile organic compounds (and therefore ground-level ozone), and also particulate matter, would decline substantially with “business as usual” but to levels that are mostly still several times higher than the present study’s criteria for environmental sustainability.
- With “business as usual,” emissions of carbon dioxide would increase compared with present levels; thus, in this respect transport systems will be moving away from rather than towards sustainability.
- One of the studies also suggested that “business as usual” transport systems would also be moving away from rather than towards sustainability in respect of noise. Two other studies were slightly more optimistic regarding noise, but gave no comfort than a reasonable criterion would be achieved with “business as usual.”
- Thus the overall conclusion must be that continuation of present trends in transportation and transport policies would be environmentally unsustainable. (The German and Swedish

work suggests that this conclusion would appear to hold even if more relaxed criteria for CO_2 emissions are used.)

- The work during Phase 2 has indicated that transportation could, at least in theory (i.e., ignoring costs and social impacts) become environmentally sustainable through application of advanced technology (the EST1 scenarios); or through massive reductions in transport activity with respect to the movement of both people and freight (the EST2 scenarios); or through combinations of the two approaches (the EST3 scenarios).

- In constructing the EST3 scenarios, the study teams appeared to make more use of reductions in activity than of improvements in energy efficiency and other forms of emissions control. (However, the actual strategies used in developing the EST3 scenario may well have initially emphasised technological improvements and then looked to activity reduction to secure attainment of the EST criteria.)

- Even before conducting a proper analysis of social and economic implications, it is apparent that implementation of the EST1 scenarios would be extraordinarily expensive, and implementation of the EST2 scenarios would be extraordinarily disruptive of the social fabric. Thus the focus of the backcasting exercise and analyses of implications proposed for Phase 3 should be on the implementation of the EST3 scenarios.

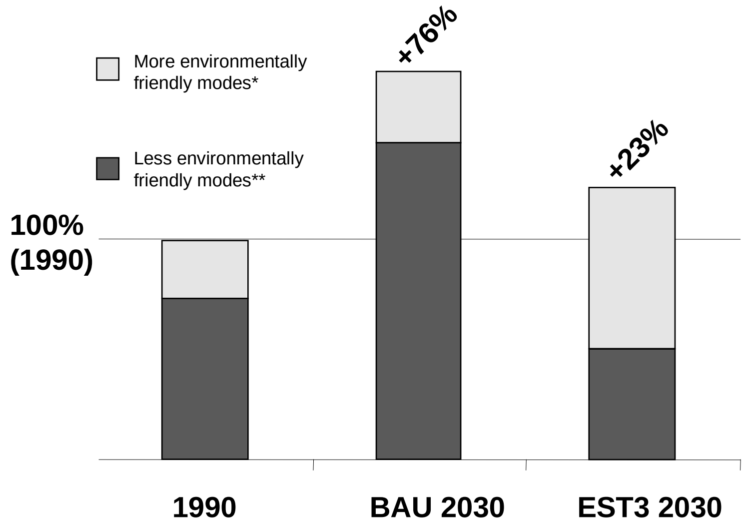
- However, construction of the EST1 and EST2 scenarios has been of considerable value during Phase 2 in determining possible features of EST; further work on these scenarios, to the extent that resources permit, would be fruitful.

- The main difficulties in meeting the EST criteria are likely to concern carbon dioxide and noise. Provision might well be made during Phase 3 for considering the implications of requiring less stringent reductions of carbon dioxide and noise by extending the time frame for achievement of the respective EST criteria.

- Notwithstanding possible implementation difficulties, environmentally sustainable transportation, as defined and described in Phase 1 and as quantified and further characterised in Phase 2, appears to be an objective that could be achieved through a mix of technological improvements and changes in practices regarding passenger and freight transport.

- It seems more difficult to achieve EST criteria for freight transport, particularly in urban areas. It will likely require significant changes in production and consumption patterns. The regionalisation of consumption and production is a necessary policy objective to bring about these changes.

- A key feature of transport under the EST scenario is illustrated in Figure 13. Transport activity, while less than under the BAU, is more in 2030 under the EST scenario than in 1990. This is made possible by much greater use of transport modes that are more respecting of the environment. Thus, attainment of EST does not necessarily mean a reduction in transport activity, only a reduction in certain types of transport activity.



* non-motorised and public transport, rail and water-borne freight.
** automobiles, light trucks, aviation, light-duty and heavy-duty road freight.

Figure 13
Transport volume index: growth and modal split from 1990 to 2030 for the BAU and EST3 scenarios

Several points raised during Phase 2 have been flagged for further examination during Phase 3. They include the following:

- The need for better assignment of CO_2 and other emissions from aviation and maritime shipping.
- The need for exploration of the concept of "uncoupling" of transport activity and economic activity and its relevance to sustainability.
- The relative lack of attention to criteria concerning noise and land use during Phase 2 and the need for further work during Phase 3.
- The relative lack of attention to life-cycle impacts during Phase 2, the possible the need for their inclusion in analyses conducted for Phase 3, and whether including them would materially affect the results obtained.

Although the EST project is far from complete, informal reports from participating Member countries suggest that it is already having an impact on policy development. The project's focus on an objective of environmentally sustainable transportation and what shape it might take appears to have contributed to interest in recognising such an objective in transportation plans. These reports have encouraged hope that the ultimate aim of the project, to develop useful guidelines for policy development in the areas of transportation and environment, will be achieved.

9 Next-Steps

9.1 Goals of Phase 3

The essence of the approach in the EST project is first to describe one or more desirable futures and then to work out how to reach it or them. Phases 1 and 2 involved characterisation of transportation systems in 2030 that will be sustainable according to environmental criteria. The main tasks for Phase 3 are as follows, in order of importance:

① Work out how the EST3 scenarios might be reached, i.e., which instruments might be deployed by governments and how they might be deployed.

② Examine the economic and social implications of deploying the instruments, and assess the appropriateness of the instruments in light of this examination. Compare the economic and social implications of moving towards and attaining the EST3 scenario with those of moving towards and attaining the BAU scenario.

③ Refine the criteria for environmentally sustainable transportation and the characterisations of EST that flow from the criteria.

The overall objectives of the project continue to be: (i) increasing understanding of what EST might comprise, and (ii) providing policy guidelines for the attainment of EST.

9.2 Identifying and testing the instruments

Given the nature of the challenge and the available resources, the most promising method for the identification and testing of the instruments would appear to be what can be called *structured brainstorming*. This is a process involving expert judgement supported by traditional forecasting methods.[44] A form has been developed to provide structure to the brainstorming activities. It can be found in Appendix C. A very preliminary list of instruments that might be considered by the teams also appears in Appendix C.

9.3 Economic and social implications of EST

Consideration of the relative social and economic implications of moving towards and attaining the BAU and EST scenarios is essential if the guidelines arising out of the EST project are to have practical value. To date the work has focused on environmental implications; there has been almost no consideration of social and economic factors. This is to be remedied during Phase 3.

The work on economic implications will include answering the following with respect to each study area:

- In what ways would the economy be different if the EST3 scenario were attained rather than the BAU scenario?
- What would be the relative economic costs and benefits of the two scenarios for individuals and households, for businesses of all sizes, and for local, regional, and national governments?
- How would employment levels differ between the BAU and EST3 scenarios?

In economic terms, who would be the winners and who would be losers if the EST3 rather than the BAU scenario were attained, particularly in terms of age groups, income groups, and geographic regions?

The work on social implications will include answering the following with respect to each study area:

- In what ways would the social fabric be different if the EST3 scenario were attained rather than the BAU scenario, both from an individual and from a societal perspective?
- What would be the relative social costs and benefits of the two scenarios for individuals and households, for businesses of all sizes, and for local, regional, and national governments? Among factors that might be considered are family cohesion, democratic activity, social polarisation, alienation, criminal activity, and what is loosely known as “lifestyle.”
- In social terms, who would be the winners and who would be losers if the EST3 rather than the BAU scenario were attained?
- In general, would people experience more freedom (or have more freedom) under the BAU scenario or the EST3 scenario?

APPENDIX A

COMPARATIVE TRANSPORT-RELATED DATA FOR PARTICIPATING MEMBER COUNTRIES

For a list of graphs and tables in the report
and in this appendix see Appendix D.

Note Concerning Figure 14A to Figure 18A

The graphs on the next three pages provide comparative data on transportation-related matters for the eight countries participating in Phase 2 of the EST project: Austria, Canada, France, Germany, the Netherlands, Norway, Sweden, and Switzerland.

The main purpose in providing these data is to demonstrate the range of variability among the countries in respect of indicators of possible relevance. For example, Figure 13A suggests that there is relatively little variability among countries in the number of passenger cars in use but much variability in the number of goods vehicles in use, when both kinds of total are corrected for population differences. Likewise, Figure 17A suggests that there is less variation in emissions of volatile organic compounds and nitrogen oxides than in emissions of particulate matter.

These graphs are based on data represented in *OECD Environmental Data: Compendium 1995.* They are for 1990 or for the next previous year for which data are provided. **Many of the data are presented in the *Compendium* with strong qualifications, which should be carefully heeded when making specific comparisons between countries.**

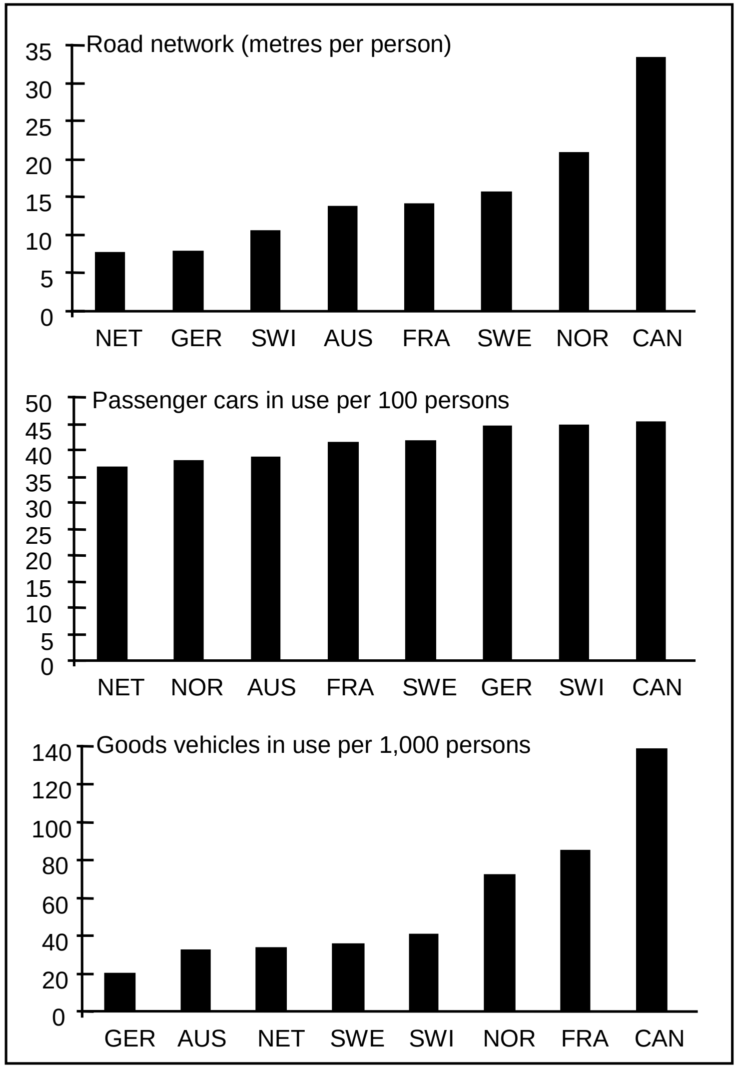


Figure 14A: Road network and vehicles in use

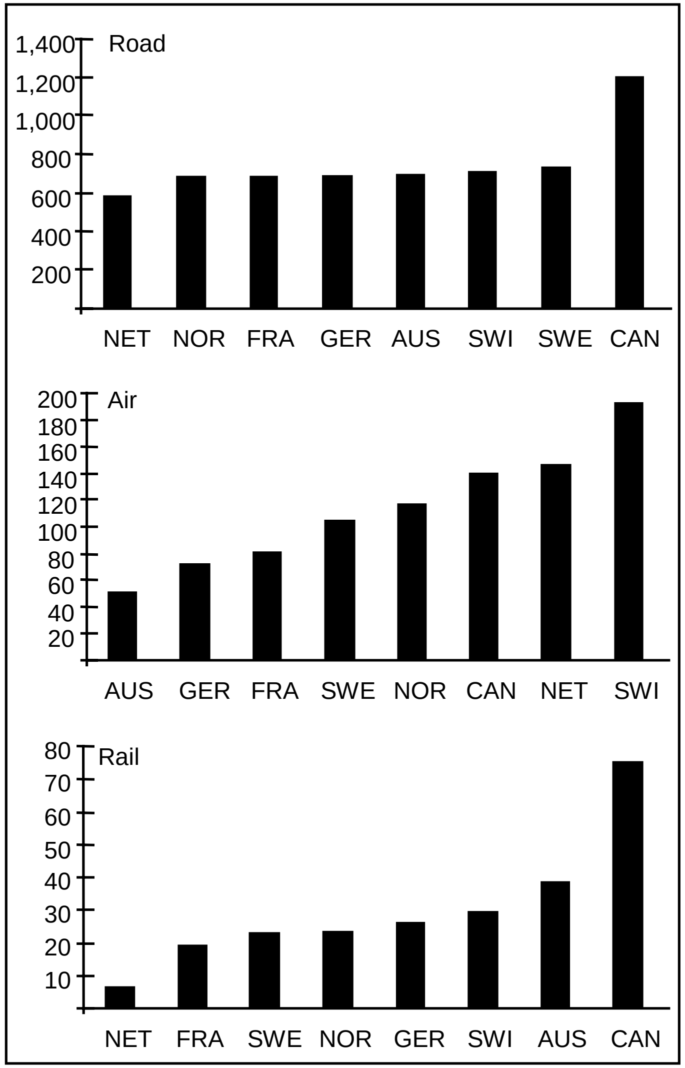


Figure 15A: Final energy consumption in kilograms of oil equivalent per person per year

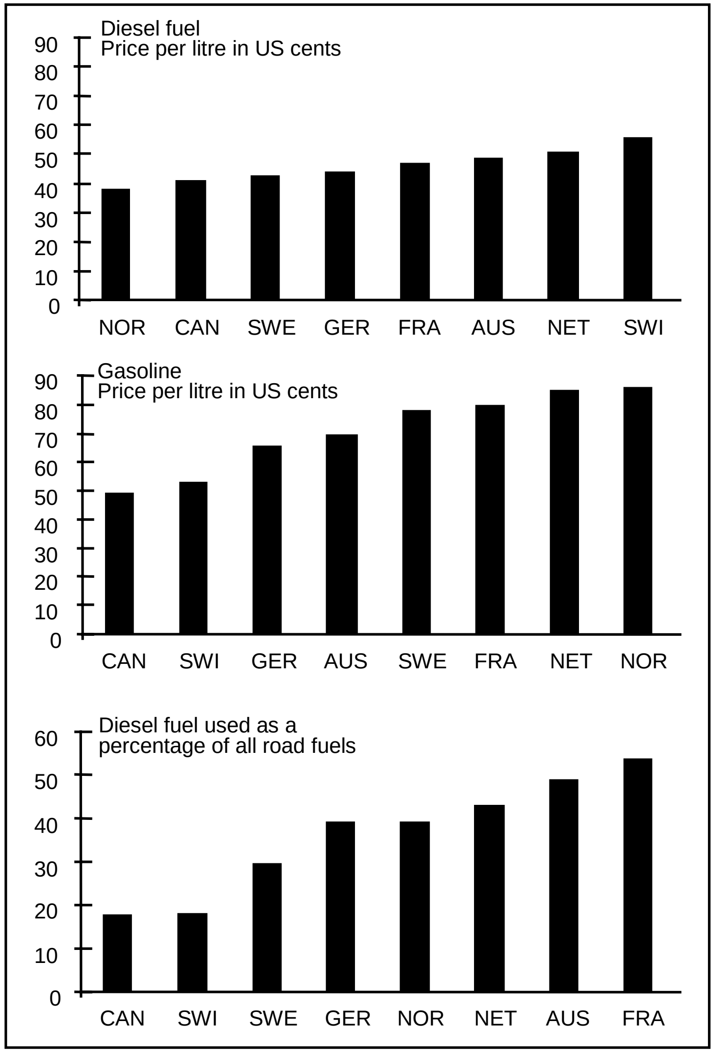


Figure 16A: Prices of diesel fuel and percentage use of diesel

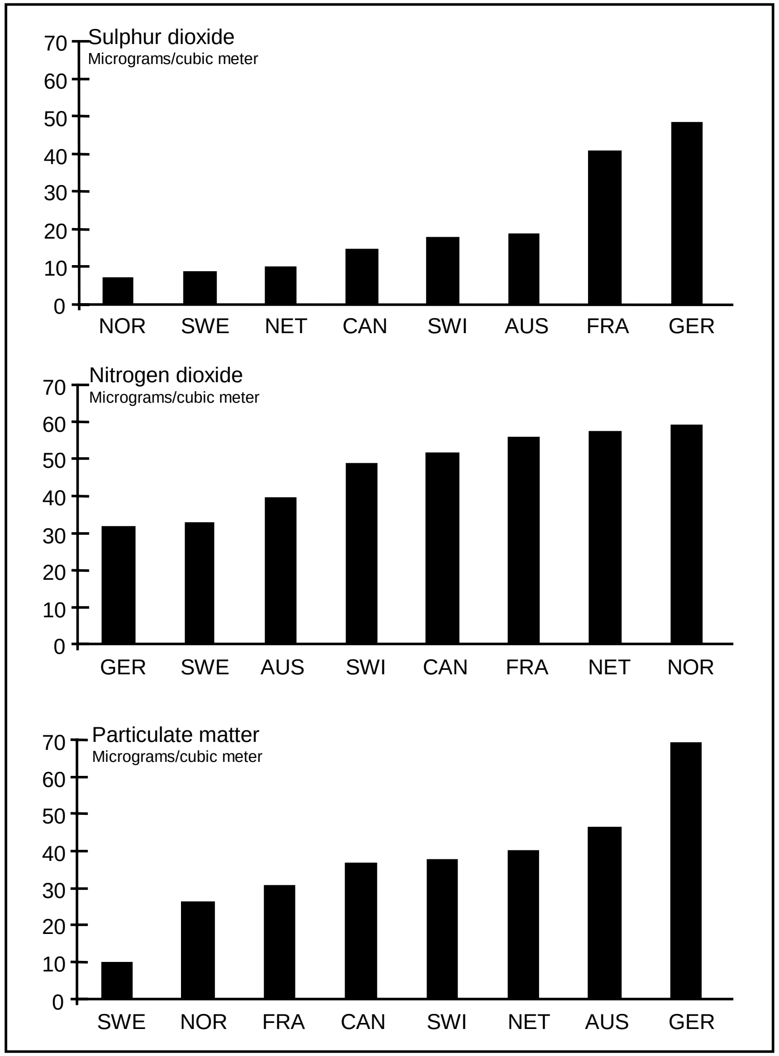


Figure 17A: Air pollutant levels of major in the EST project[3]

*Vienna, Montréal, Paris, Berlin, Amsterda, Oslo, Göteborg and Zurich

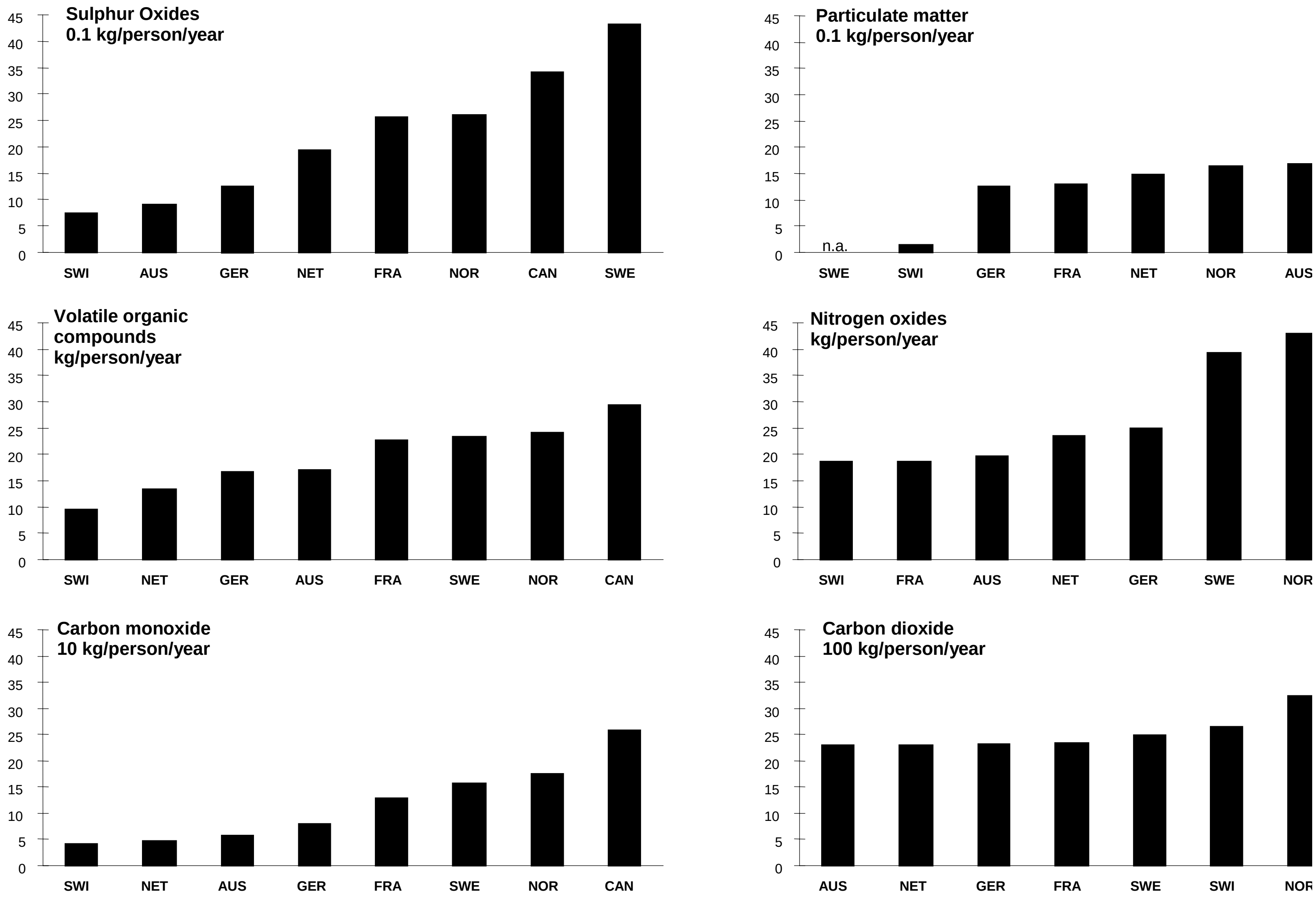


Figure 18A: Annual per-capita emissions of indicated substances from mobile sources

APPENDIX B

DETAILED TABLES

For a list of tables in the report and in this appendix see Appendix D.

Table 13B. BAU scenarios: factors concerning activity

FACTOR	QWC	OSN	GER	NET	SWE	ALP
Car ownership and use	Moderate increase in car ownership, use increases .02 % per annum. Light truck (Sport Utility Vehicle) ownership increases at a faster rate than cars at 2.6% per annum, avg. annual distance travelled decreases slightly.	Car ownership increases substantially; use per vehicle declines. Number and length of trips increase, but at a lower rate than ownership.	Car ownership almost doubles by 2030. Overall distance travelled increases by 131% outside and by 17% inside urban areas; corresponding increases for passenger kilometres are 101% and 9%.	Growth in ownership continues but rate of change diminishes on account of saturation. Use increases at a higher rate than ownership.	Car ownership increases, but use increases at a higher rate.	
Van and truck use (i.e., tonne-kilometres moved)	Trucks continue to increase their market share of freight movement, diesel truck fuel efficiency increases by 10%.	Only road transport used for freight, all carried by medium/light-duty trucks. Increases in vkt and tkt of 150% are expected.	Large increase in tonne-kilometres: 159% outside and 88% inside urban areas.	High (≈ 3.5%/y) rate of increase to 2010, then lower; higher rates for international than national.	To increase by 41% to 2020.	Estimated by applying macroeconomic assumptions to present traffic volumes.
Rail	Near doubling of urban passenger rail passenger kms., very slight increase of non-urban passenger rail. No high speed rail in Québec-Windsor corridor.		32% increase in passenger-kilometres; freight unchanged.		Passenger transport to increase by 73%; freight transport by 37%.	Estimated by applying macroeconomic assumptions to present traffic volumes.
Aviation	Air travel will continue to increase its market share of medium and long distance travel at the expense of rail.		540% increase in overall activity, including cargo.		International flights to increase by 145%; domestic flights by 49%.	
Inland and coastal shipping	Decrease in demand until 2000, marginal increase thereafter.		Inland shipping up by 51% by 2030; coastal shipping up by 78%.	Low annual growth rate on account of low growth in movement of heavy goods.	Marine transport to increase by 22%.	
Modal splits	Cars retain their dominance as in the 1990 mode split for passenger travel, trucks retain dominance in the freight mode split.	Little change in public transport use or in walking/ bicycling; thus a shift to car use.	Shift to car use; decline in walking and bicycling.	Bicycle and public transport use remain as in 1990; therefore shift to car use.	No changes in efficiency or load factors assumed, with little change in modal splits.	Road and rail shares of freight to remain about the same until 2030: 64:36 in 1990; 63:37 in 2030 (road:rail).
Transport-related infrastructure	Will continue 1990 trends, no impact on mode-split trends.	As approved up to 2000 with some further changes.	Currently proposed projects are implemented.	Quality maintained (implies significant investments).	Presently decided and proposed projects are implemented.	Infrastructure expands to meet demand.

...Table continues from previous page

FACTOR	QWC	OSN	GER	NET	SWE	ALP
Fuel prices [Also see Table 14B]		Real public transport prices to increase slightly.	Moderate real increases (assuming a slight shift from direct to indirect taxation).	Continued sufficient supply of fossil fuels.	Unchanged in real terms.	
Other	No major shift in current land-use patterns or population concentration patterns.	Continuation of present trend in decentralisation of residences and employment. Car occupancy falls from 1.6 to 1.3 by 2030.	Continuing trend of urban sprawl and decentralisation.	Car occupancy down from 1.60 to 1.25 by 2010 and continues at 1.25.		

Table 14B. BAU scenarios: Gasoline and diesel prices in 1993*

FEATURE	QWC	OSN	GER	NET	SWE	ALP1†	ALP2†	ALP3†
Price of gasoline in 1993	49	86	66	85	78	80	80	53
Price of diesel fuel in 1993	41	38	44	51	43	47	47	56

* Prices are in current U.S. cents. †ALP1 is Austria; ALP2 is France; ALP3 is Switzerland.

Table 15B. BAU scenarios: factors concerning emissions

FACTOR	QWC	OSN	GER	NET	SWE	ALP
Emission standards and performance	Current and planned legislation regarding emission standards have been taken into account (incl. vehicle inspection and maint. programmes).	Scenarios of the Institute of Transport Economics. (These are consistent with those of the German UBA, based on EURO2 standards.)	Stringent EURO3/4 standards will apply (as under discussion). Passenger cars will be comparable to ULEV. Fuel consumption will be 20-35% lower.	CO_2 emissions consistent with European Renaissance Scenario #2. NO_x and VOCs emissions of all vehicles meet or exceed EURO3 (2010) and EURO4 (2030).	All road vehicles will conform to EURO3 standards.	Factors for direct emissions based on German UBA proposal, which is based on EURO2. Indirect emissions are being accounted for.
Road vehicle types	No major shift from 1990 fleet composition, dominance of ICE engines, some efficiency improvements.	Electric and hybrid vehicles used in niche markets only.	10% of the passenger fleet will be electrically powered, with a reduced annual vehicle-kilometres travelled of half present values. Urban buses will be powered by natural gas.	Electrical and hybrid vehicles will be used in niche markets only.	As today.	
Alternative fuels for road vehicles.		No significant change.	Moderate changes: 5% of cars' vehicle-kilometres travelled will be by electric vehicles, and 30% of scheduled bus kilometres travelled will be fuelled by natural gas.	No use of H_2 or CH_4. Use of diesel and LPG remain at current proportions.	Diesel and gasoline will be used at current proportions. Other fuels will be used in niche markets only.	No changes.
Other modes			Energy efficiency of aeroplanes will rise by 45%, of ships by 25%, of trains by 10-25%. Emissions of diesel trains/ships will be reduced: NO_x by 40%; HC by 20%; CO by 20-40%.		Continuous phasing out of old aircraft and vessels will lead to more energy-efficient fleets.	

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FACTOR	QWC	OSN	GER	NET	SWE	ALP
Electric power generation	62% from hydro., 26% from nuclear, remainder coming from coal, oil and natural gas.		70% of fuel will be fossil fuel, 25% nuclear, and 5% renewable.	Efficiency increases from 40% to 50%; no use of renewable fuels. No VOCs emissions from plants. All plants equipped with de-NO_x catalysts by 2010.	Not stated. (In 1993, 52% of production was hydroelectric; 42% was nuclear.)	Minor changes. Indirect impacts of generation considered only for CO_2 emissions.
Other factors, including energy use			Increase in proportion of traffic outside of urban areas.	Remain as in 1990.		No changes.

Table 16B. BAU scenarios: Expected changes in movement—transport activity figures and ratios 2030 to 1990[1*]

BAU Ratio of activity 2030 to 1990

MODE	QWC	OSN	GER(i)	GER(o)	NET	SWE	ALP
Non-motorised	*1.69*	1.01	*0.84*		*1.00*	1.00	
Private automobiles	*1.70*	1.35	0.*99*	*1.69*	*1.31*	*1.52*	*1.79*
Surface public transit	*1.70*	1.05	*1.09*	*1.19*	*1.30*	*1.34*	*2.00*
Aviation	*2.19*		*5.28*		3.5**	*2.30*	
All personal travel	*1.75*	1.25	*1.78*		*1.29*	*1.54*	*1.82*
Light-duty road freight	*1.95*	*2.52*	2.27	2.84	3.25		*1.35*
Heavy-duty road freight	*2.41*		*1.88*	*2.58*	*2.75*	*1.48*	*1.76*
Rail freight	*1.49*		*1.00*		*2.00*	*1.40*	*1.70*
Water-borne freight	*1.45*		*1.51*		*1.75*	*1.27*	*0.93*
All freight transport	*1.89*	*2.52*	*1.86*		*2.23*	*1.39*	*1.69*

[1]Note: Ratios are based on vehicle-kilometres (normal font) and passenger- or tonne-kilometres (italic font)
*What is included in each of the transport categories for each study is explained in Table 34B, together with other relevant information
** Dutch data for Aviation are expressed in total number of passengers

Absolute number of billion passenger/tonne kilometers 1990

MODE	QWC	OSN	GER(i)	GER(o)	NET	SWE	ALP
Non-motorised	1.24		53.2		12.8		
Private automobiles	178.5		231.2	473.4	138.4	90	214
Surface public transit	14.8		37.6	106.7	22.2	14.9	42.7
Aviation	22.2		100.3			7.4	
All personal travel	216.57		1002.4		173.4	112.3	256.7
Light-duty road freight	.68					.	12
Heavy-duty road freight	83.79		50.5	151.7	35.33	29	67.9
Rail freight	67.94		104.4		3.07	20	28.7
Water-borne freight	37.4		56		35.7	26	1.5
All freight transport	190.3		362.6		74.1	75	110.1

Absolute number of billion passenger/tonne kilometers BAU 2030

MODE	QWC	OSN	GER(I)	GER(o)	NET	SWE	ALP
Non-motorised	2.1		44.9		12.8		
Private automobiles	303.6		229.5	802.6	181.91	136.6	383.6
Surface public transit	25.15		41.2	126.9	28.86	20	85.4
Aviation	48.63		529.7			16.6	
All personal travel	379.49		1774.8***		223.57	173.2	469
Light-duty road freight	1.33						16.2
Heavy-duty road freight	202.71		95.1	392.3	97.16	58.4	119.8
Rail freight	101.07		104.4		6.13	36.9	48.7
Water-borne freight	54.38		84.6		62.48		1.4
All freight transport	361		676.4		165.77	95.3	186.2

*** Germany also accounted for motorcycle travel (17.6 bill. pkm inside urban areas, 7,7 bill. pkm outside of urban areas)

Table 17B. BAU scenarios: Ratios of unit emissions of nitrogen oxides, 2030/1990[2]

MODE	QWC	OSN	GER(i)	GER(o)	NET	SWE	ALP
Private automobiles	0.47	*0.15*	0.13 *0.14*	0.11 *0.13*	0.14	0.10	
Surface public transit	0.21*	*0.56*				0.35	
Aviation	*0.60*		*0.33*			*0.85*	
All personal travel		*0.32*					
Light-duty road freight	0.44	0.55	0.21 *0.21*	0.12 0.12	0.33		
Heavy-duty road freight	0.32		0.23 *0.23*	0.25 *0.25*	0.30	0.35	0.25 *0.25*
Rail freight	*0.57*				*0.75*		*0.40*
Water-borne freight	*0.32*		*0.44*		*0.80*	*1.00*	
All freight transport		0.55					*0.31*

[2] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)
* Bus only (expressed in grams per veh. km). Other ratios for Surface Public Transport are 0.85 for Rapid Transit (expressed in grams per passenger km.) and 0.60 for Passenger Rail (expressed in grams per passenger km.)

Table 18B. BAU scenarios:
Ratios of unit emissions of volatile organic compounds, 2030/1990[1]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.43	*0.16*	0.01 *0.01*	0.02 *0.02*	0.17	0.10	
Surface public transit	0.52*	*0.58*				0.70	
Aviation	*0.60*					*0.10*	
All personal travel		*0.32*					
Light-duty road freight	0.68	0.60	0.01 *0.01*	0.02 *0.02*	0.24		
Heavy-duty road freight	0.36		0.32 *0.32*	0.32 *0.32*	0.16	0.35	0.32 *0.31*
Rail freight	*0.52*						*0.73*
Water-borne freight	*0.60*		*0.59*			0.50	
All freight transport		0.60					*0.47*

[1] Note: Ratios based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)
* Bus only (expressed in grams per veh. km). Passenger Rail = 0.55 (expressed in grams per passenger km.)

Table 19B. BAU scenarios:
Ratios of unit emissions of particulates, 2030 to 1990[2]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles			0.44 *0.48*	0.25 *0.29*	0.13		
Surface public transit						0.15	
Aviation							
All personal travel							
Light-duty road freight			0.14 *0.14*	0.14 *0.14*	0.59		
Heavy-duty road freight			0.06 *0.06*	0.05 *0.05*	0.31	0.15	0.07 *0.07*
Rail freight							*0.73*
Water-borne freight			*0.43*				
All freight transport							

[2] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)

Table 20B. BAU scenarios:
Ratios of unit emissions of carbon dioxide, 2030 to 1990[1]

MODE	QWC	OSN	GER(i)	GER(o)	NET	SWE	ALP
Private automobiles	0.77	*0.82*	0.55 *0.59*	0.60 *0.68*	0.75	0.80	
Surface public transit	0.85*	*0.88*				1.00	
Aviation	*0.60*		*0.55*			*0.85*	
All personal travel		*0.84*					
Light-duty road freight	0.77	0.84	0.59 *0.59*	0.57 *0.57*	0.78		
Heavy-duty road freight	0.85		0.76 *0.76*	0.78 *0.78*	0.84	1.00	0.78 *0.77*
Rail freight	*0.65*						*0.64*
Water-borne freight	*0.72*		*0.74*			*0.90*	
All freight transport		0.84					*0.72*

[1] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)
* Bus only (expressed in grams per veh. km). Other ratios for Surface Public Transport are 0.86 for Rapid Transit (expressed in grams per passenger km.) and 0.66 for Passenger Rail (expressed in grams per passenger km.)

Table 21B. Features of EST1 scenarios: proposed technological and other changes

FEATURE	QWC	OSN	GER	NET	SWE	ALP
Light duty road vehicles	Composition of car and light truck fleet: 10% advanced high effcy. IC engine (3l/100km equiv.) 60% fuel cell (PEM) engines w/ hydrogen 10% fuel cell (PEM) engines w/ methanol 10% hybrid using electric traction and 2 l./100km IC gasoline engine 10% battery-powered electric vehicles.	Cars are hybrid (60%) or electric (40%), the latter being used mostly as a second car for urban use only.	Hypercars (light hybrid vehicles) will be used, consuming 1.3l/100km gasoline. Light, power-reduced hypermotorcycles consume <1l/100km. Also light-duty vehicles with fuel-cell technology and H_2 fuelled. Noise will be reduced by using encapsulated engines, improved exhaust systems, and low-noise tires.	Cars are small, efficient electric (80% of use) or light-weight hybrid fuelled by liquefied petroleum gas (20%)—safe but less comfortable than at present. Electric cars can be joined in trains and powered from rails.	30% of cars are “lightweight” gasoline vehicles, 20% use biofuels, and 50% are diesel vehicles.	
Heavy-duty road vehicles	Fuel cell (PEM) type engines: 75% using hydrogen and 25% using methanol.	Lower emissions for buses and trucks but emissions reduced too by ensuring higher load factors and better matching of vehicles to demand. Vans and buses are electric and hybrid.	Fuel cells will be used, using liquefied or compressed H_2, mechanical (flywheel) storage of energy, and regenerative braking. Trolley buses used for public transport. Noise will be reduced as above.	Vans and buses are electric where practicable, with trolleys where possible. Other buses are hybrid using LPG. Trucks are powered by H_2 fuel cells (80%) or hybrid.	Conventionally powered but more energy-efficient (annual improvement of 0.7%); 5% of the fleet use biofuels.	Vehicles are mostly powered by H_2 fuel cells.
Rail	Electrification of network. Maglev commuter rail (200 km/hr). Mix Maglev (450km/hr) and high speed rail (300 km./hr.) for inter-city transport. Increased double-stacking for train freight containers.	Some improvements through technology and better utilisation.	Improvements through use of better motors, advanced pollution control devices (catalysts and traps), and regenerative braking, resulting in a 40% reduction in fuel use and 90% and 95% reductions in NO_x and PM. Light-rail trains for public transport. Use of low-noise trains.	All electrified; light-weight with improved matching of vehicles to demand. Longer distance rail replaced in part by airships.	More high-speed trains, but without increased energy consumption.	All electrified, with numerous improvements including regenerative braking, better aerodynamics, and more efficient train management.
Water	Fuel cells with methanol.		More efficient diesel engines used (direct injection, turbocharging, etc.) with improved emissions control (particulate filters, catalysts, etc.)	Inland and ocean-going vessels will be powered by H_2 fuel cells.	All large ships will be equipped with SCR technology combined with oxidised catalytic converters. The sulphur content of bunker oil used will be reduced to about 0.4-0.5% by weight.	

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FEATURE	QWC	OSN	GER	NET	SWE	ALP
Aviation	50% aircraft using liquified hydrogen (regenerative production) w/ 95% reduc. in NO_x and 100% in direct CO_2 and VOCs, 50% turbo fan and turboprop aircraft, 10% higher fuel efficiency than in BAU.		Liquefied hydrogen used as fuel.	Long-distance aircraft will be powered by H_2 fuel cells. Rigid airships will be used for shorter journeys.	Improved combustion chambers resulting in reduced fuel consumption and reduced NO_x emissions.	
Electric power	95% from zero-emission sources (e.g. hydro and nuclear), remaining 5% from natural gas.		More than 90% is produced from domestic and imported renewable sources.	80% of production is from renewable fuels.	Not stated.	Electricity is sustainably produced.
Other	Increased intermodalism, better logistical organisation and improved load factors for freight.	Widespread use of information technology to improve vehicle efficiency and utilisation—enough to reduce CO_2 emissions by 45% in peak hours and by 35% in off-peak hours. Pricing remains similar to 1990 to avoid activity loss.	Fossil fuels comprise 37% of primary energy use; other fuels are renewable, including hydrogen. Design features reduce noise, especially from tires and road pavement, and by use of low-noise trains.	Starting point is that in 2030 crude oil will be being abandoned as a primary energy source for transportation.		Design features reduce noise impacts, especially from tires.

Table 22B.
EST1 scenarios: Ratios of unit emissions of nitrogen oxides, 2030/1990[1]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.00	*0.03*	0.02 *0.03*	0.02 *0.02*	0.00	0.07	
Surface public transit	0.00	*0.04*				0.30	
Aviation	*0.285*		*0.19*		*0.00*	*0.25*	
All personal travel		*0.03*					
Light-duty road freight	0.00.	0.05	0.00	0.00	0.01		
Heavy-duty road freight	0.00		0.00 *0.00*	0.00 *0.00*		0.30	0.02 *0.02*
Rail freight	*0.00*						*0.20*
Water-borne freight	0.00		*0.07*			*0.14*	
All freight transport	0.00						*0.09*

[1] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)

Table 23B. EST1 scenarios:
Ratios of unit emissions of volatile organic compounds, 2030/1990[2]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.00	*0.03*	0.00 *0.00*	0.00 *0.00*	0.00	0.08	
Surface public transit	0.00	*0.04*				0.27	
Aviation	*0.27*				*0.00*	*0.10*	
All personal travel		*0.03*					
Light-duty road freight	0.00	0.05	0.00	0.00	0.03		
Heavy-duty road freight	0.00		0.00 *0.00*	0.00 *0.00*		0.27	0.02 *0.02*
Rail freight	0.00						*0.36*
Water-borne freight	0.00		*0.36*			0.10	
All freight transport	0.00						*0.15*

[2] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)

Table 24B.
EST1 scenarios: Ratios of unit emissions of particulates,2030/1990[1]

Mode	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles			0.00 *0.00*	0.00 *0.00*	0.01		
Surface public transit							
Aviation					*0.00*		
All personal travel							
Light-duty road freight			0.00	0.00	0.11		
Heavy-duty road freight			0.00 *0.00*	0.00 *0.00*			0.00 *0.00*
Rail freight							*0.36*
Water-borne freight			*0.02*				
All freight transport							

[1] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)

Table 25B.
EST1 scenarios: Ratios of unit emissions of carbon dioxide,2030/1990[2]

Mode	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.08	*0.06*	0.14 *0.15*	0.19 *0.22*	0.07	0.53	
Surface public transit	0.10	*0.07*				0.80	
Aviation	*0.27*		*0.00*		*0.09*	*0.68*	
All personal travel		*0.06*					
Light-duty road freight	0.06	0.25	0.00	0.00	0.16		
Heavy-duty road freight	0.10		0.00 *0.00*	0.00 *0.00*		0.80	0.06 *0.06*
Rail freight	*0.08*						*0.20*
Water-borne freight	*0.01*		*0.45*			*0.80*	
All freight transport							*0.17*

[2] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)
* Bus only (expressed in grams per veh. km). Other ratios for Surface Public Transport are 0.23 for Rapid Transit (expressed in grams per passenger km.) and 0.05 for Passenger Rail (expressed in grams per passenger km.)

Table 26B. Features of EST2 scenarios: proposed changes in activity and other changes

FEATURE	QWC	OSN	GER	NET	SWE	ALP
Private automobiles	Much lower activity (31% of 1990 pkt, 18% of 1990 vkt) through fuel pricing, increased “gas-guzzler” taxes, parking management and vehicle licensing fees. Also greater public information campaigns to shift demand.	Much lower activity, through increases in the costs of car use (e.g., gasoline cost, parking cost, and road pricing) and ownership.	Drastically lower use: 10% of 1990 vkt in 2030 and 18% of pkt.	Personal automobiles are hardly used—only for special services. No mopeds or motorcycles.	The total amount of vkm as today, i.e., the kilometres travelled per capita will be lower than today.	
Other passenger transport	Great expansion of current public transportation modes, introduction of new forms of public transport (e.g. rider-responsive “smart shuttles”, car-sharing, station cars, etc.). High speed rail ridership 3 times as high as in EST1.	Large investments in infrastructure to facilitate use of public transport, especially rail, and non-motorised modes.	A slight shift to less harmful motorised transport modes (bearing in mind the strictness of the CO_2 criterion).	Rail predominates in the provision of local and regional public transport. Changes in logistical organisation to improve efficiency.	Increased use of train for long-distance travelling; only the longest journeys will be by air. The use of local and regional public transport will also increase (amounting to 30% of journeys in southern Sweden). For shorter trips, walking and bicycling will be much more common than today.	
Freight movement	Improved logistics and better inter-modal integration reduce total freight vkt by 20%, more emphasis on local production would decrease road tkm by 40% and air tkm by 90%.	Much reduced, beyond what can be achieved through load optimisation.	Lower use of road freight achieved in part through increasing share of locally produced products and reducing the volume of materials circulating per unit of GDP: 78% reduction of vkt and 75% reduction of tonne-kilometres moved. Large increase (160%) in rail freight, with only 80% increase in energy use (on account of better load factors). 95% increase in tonne-kilometres moved by inland shipping; 45% reduction in maritime shipping.	There is much less reliance on road vehicles; more on rail and, especially, on water-born modes.	A transfer of freight movement from trucks to rail and an increasing load factor will result in unchanged transport volumes (vkm) on the roads.	Reversion from “just-in-time” modes and other changes to ensure higher load factors, more combined transport, shorter trip lengths, etc., and overall fewer vehicle-kilometres travelled. Shift from road to rail (perhaps required entirely in some areas).

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FEATURE	QWC	OSN	GER	NET	SWE	ALP
Aviation	Passenger air travel reduced by 40% through pricing instruments.		Drastically lower energy use (resulting from fewer flights) down by 90% of 1990 values in 2030, but pkt down by only 80% on account of increased occupancy.	There is very little aviation—only for highly necessary trips. Long-distance travel is mostly replaced by telematics.	More efficient use of aircraft, e.g., increased occupancy and more than one hub for domestic flights. In southern Sweden most flights will be replaced by high-speed trains.	
Land use	Cluster development in nodes served by transit, less low-density single-use developments, greater higher density mixed-use devlpmts. Targets set for job/ worker ratios and population and employment density for urban areas.	Redesigned, higher-density communities with community "work-stations" allow much greater dependence on public transport and non-motorised modes.	Land use practices have been changed to provide for more densely populated, mixed-used settlements and less dispersed commercial activities.	Much denser settlements are achieved, allowing much more reliance on walking and bicycling, which are facilitated.	A more dense land-use pattern will provide for more use of public transport, and also shorter trips.	Relocation of industry to support EST2 features, particularly more use of rail and more local production.
Telecommunications	Telecommuting implemented on a wide-scale basis (e.g. replacement of half of work trips in Toronto by telecommuting). Teleconferencing replaces almost all air business travel. Assumes that telecommuting does not increase other categories of trips.	Enhanced use, in part to support community "work-stations."	Transfer of information substituted for transfer of physical products and for business travel (the latter through extensive video-conferencing).		Use of information technology will substitute for much commuting and travelling for business.	
Economic activity		The overall assumptions about economic growth cannot be sustained with of implementation of this scenario; there will be negative economic growth.	Potentials for decoupling economic development and freight transport activity have been developed.	The macro-economic projections for the BAU scenario cannot be sustained; overall economic growth may be of the same order, but different in nature. There is less consumption overall, and more local production. Food production and transport is given priority. Goods are built to last longer.	Not stated.	Much more local and regional production of goods.

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FEATURE	QWC	OSN	GER	NET	SWE	ALP
Other			The attractiveness of closer locations for vacation trips is increased, in part by improving the liveability of residential areas and the use of land for roads in other ways. Car occupancy increases from 1.24 to 2.20 within urban regions and from 1.5 to 2.5 elsewhere. Speed limited to 30 km/h in residential areas. Drastic restrictions on night-time truck traffic and aviation to avoid noise disturbance.			

Table 27B.
EST2 scenarios: Expected changes in movement/transport activity ratios 2030 to 1990*[1]

MODE	QWC	OSN	GER(i)	GER(o)	NET	SWE	ALP
Non-motorised	*4.85*	2.35	*2.00*		*2.66*		
Private automobiles	*0.30*	0.32	*0.19*	*0.17*	*0.08*	*1.00*	*0.27*
Surface public transit	*4.71*	2.67	*3.23*	*2.26*	*3.06*	*2.00*	*4.86*
Aviation	*0.45*		*0.20*		*0.01*	*2.03*	
All personal travel	*0.65*	1.07	*0.62*		*0.64*		*1.04*
Light-duty road freight	*0.20*	0.44 *0.63*	0.35	0.35			*0.31*
Heavy-duty road freight	*0.32*		*0.29*	*0.25*	0.34	*1.00*	*0.28*
Rail freight	*1.93*		*2.58*		*4.56*	*2.00*	*4.42*
Water-borne freight	*1.89*		*0.63*		*0.62*	*1.22*	*2.59*
All freight transport	*1.20*	0.44 *0.63*	*0.74*				*1.40*

* What is included in each of the transport categories for each study is explained in Table 35B, together with other relevant information.

[1] Note: Ratios are based on vehicle-kilometres (normal font) and passenger- or tonne-kilometres (italic font)

Table 28B. Features of EST3 scenarios: proposed changes in technology and activity

Feature	QWC	OSN	GER	NET	SWE	ALP
Private automobiles	Car fleet composed of: 25% High efficiency ICE 25% Fuel cell 25% Hybrid 25% Electric Decreases in car ownership and use, but not as significant as in EST2.	Decrease in car ownership and use, but not as drastic as in EST2.	Mostly hypercars with internal combustion engines (light vehicles without batteries) will be used, also more efficient motorcycles (all less expensive than proposed for EST1, but less efficient). Vkt decreases by 75% within urban areas and by 60% elsewhere. Noise will be reduced by using encapsulated engines, improved exhaust systems, and low-noise tires. Occupancy increases from 1.50 to 1.90 inside urban areas, and from 1.24 to 1.70 elsewhere.	Almost all cars are hybrid (some electric in urban areas). Reduction of 50% in use. Speeds reduced. De-NO_x catalysts used and vaporisation controls. More efficient mopeds and motorcycles are used.	Conventional with improved energy efficiency (5 litres/100 km). Over 20% of the energy used in the road sector is renewable (biofuels). Vehicle-kilometres-travelled increases by 20%; less in cities due to the introduction of an environmentally based road-pricing system. Very strict noise requirements on cars in cities.	
Other passenger transport	Greatly improved public transport, introduction of new public transport options as in EST2, high speed rail ridership levels twice that of EST1. Buses use methanol fuel cells, rapid transit is electrified, high speed rail is advanced electrified conventional rail or maglev.	Improvement of infrastructure for non-motorised transport. More parking near stations. Development of public transport; emphasis on light rail and other rail.	There is a shift to less harmful modes. Buses will be both natural gas (50%) and electric (trolley) powered, making use of flywheels. Noise reduced as above.	Focus on reducing long-distance travel, but as much public transport because of the shift from cars. Hybrid buses with diesel engines. Much more walking and bicycling.		
Heavy-duty road vehicles	Will use mostly methanol fuel cells. logistical and load optimisation occurs at same levels as in EST2. 10% less overall tkm than in 1990.	Logistical and mode optimisation in place. Large reduction in vehicle kilometres, but not to the extent of EST2.	Conventional but more efficient diesel engines used (-40% CO_2) with much better pollution control (SCR catalysts and PM traps). Noise reduced as above.	Logistical and mode optimisation in place. Large reductions in transport distances, but not to extent of EST2 scenario. Smaller vehicles are hybrid; larger vehicles use sustainably produced hydrogen.		Different strategies for the different countries but, in general, limits placed on road transport volume helped by some shift to rail (more in Switzerland). Much use of hydrogen as a truck fuel.

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Feature	QWC	OSN	GER	NET	SWE	ALP
Rail	Rail freight is electrified advanced conventional type.		450% increase in tonne-kilometres. More efficient, low-noise, electric trains used. Diesel trains are 40% more efficient and pollute less (-80% NO_x; -95% PM).	Only electric trains used.		Substantial increase in use of rail, including much use of the "piggy-back" system.
Shipping	Will use mostly methanol fuel cells.		More efficient, less polluting diesel vessels used, with improvements as for diesel trains. Inland shipping increases by 88%; marine shipping unchanged.	More efficient, less polluting vessels used. Half of vehicles use hydrogen as fuel. Better load factors in place.		
Aviation	Continues to use conventional aviation fuel at 10% greater efficiency. 20% less passenger travel.		Much improved aircraft using conventional fuels; 50% of total distance flown with additional 25%-more-efficient turboprop machines.	Rigid airships used for shorter distances. Little long-distance air travel.	The number of flights will be significantly reduced in order to achieve the criteria for noise. Take-off and landing rights are auctioned.	
Electric power	High reliance on hydro and nuclear as in BAU.		50% produced from renewable sources.	Electricity is produced with 80% efficiency with 40% of fuel being sustainable.	All large ships will be equipped with SCR technology combined with oxidised catalytic converters. The sulphur content of bunker oil will be reduced to about 0.4-0.5% by weight.	Optimised use of French nuclear power achieved by re-routing trains.
Land use	Less reliance on land use changes than in EST2 but still much use of re-development towards transit-oriented clusters and higher density mixed use neighbourhoods.	Change in urban form to reduce travel: increase density, mix uses. Develop community centres with "work-stations" for telecommuting.	Urban sprawl stopped. More densely populated and mixed-used settlements allow greater dependence on public transport and non-motorised modes.	Activities brought closer together.	Very strict regulations for new infrastructure.	Rail use facilitated by appropriate land use policies.
Telecommunications	Slightly less reductions of travel due to telecommuting as were assumed for EST2. Some business travel takes place by cars and airplanes.	Enhanced use, in part to support community "work-stations."	Less use than in EST2.			

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FEATURE	QWC	OSN	GER	NET	SWE	ALP
Economic activity		Promotion of regionalisation of production.	Economic activity and freight movement decoupled.	Shift to local production. Decrease in volumes of production of non-food items.		
Other	Freight activity is more localised but not as much as in EST2 -- 20% marginal reduction in road freight and 50% for air freight. Freight transport also benefits from increased logistical improvements at almost the same level as in EST2.	Freight movement generally received more attention for EST3 as it poses more difficulty for attainment of EST criteria.	Production, treatment, and storage of hydrogen is highly fuel consuming, expensive, and inefficient; therefore not used for EST3. Primary energy is used as directly as possible. Speed limited to 30 km/h in residential areas. Restrictions on night-time truck traffic and aviation to reduce noise disturbance.			

Table 29B.
EST3 scenarios: Expected changes in movement/transport activity ratios 2030 to 1990[1]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Non-motorised	*3.27*	1.31	*1.50*		*2.00*		
Private automobiles	*0.63*	0.70	*0.34*	*0.51*	*0.66*	*1.10*	*1.20*
Surface public transit	*4.10*	2.20	*3.91*	*3.73*	*1.3*	*1.44*	*3.36*
Aviation	*1.09*		*0.41*		0.84**	*1.50*	
All personal travel	*0.93*	1.12	*0.98*		*0.84*	*1.17*	*1.56*
Light-duty road freight	*0.74*	1.00 *1.15*	0.49	0.25			*0.86*
Heavy-duty road freight	*0.91*		*0.43*	*0.28*	*.67*	*1.24*	*0.93*
Rail freight	*1.87*		*4.48*		*9.64*	*1.56*	*3.25*
Water-borne freight	*1.82*		*1.00*		*1.28*	*1.27*	*1.54*
All freight transport	*1.43*	1.00 *1.15*	*1.18*		*1.34*	*1.34*	*1.54*

[1] Note: Ratios are based on vehicle-kilometres (normal font) and passenger- or tonne-kilometres (italic font)
** Dutch data for Aviation are expressed in total number of passengers

Absolute number of billion passenger/tonne kilometers EST 2030

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Non-motorised	4.05		79.8		25.6		
Private automobiles	112.24		79.2	241.5	91	99	256.6
Surface public transit	60.64		147	398.6	28.8	21.4	143.3
Aviation	24.1		41.1			11.1	
All personal travel	201		987.2		145.4	131.5	399.9
Light-duty road freight	.5						10.32
Heavy-duty road freight	75.92		21.8	41.7	23.9	36.1	63.18
Rail freight	126.85		468		29.6	31.3	93.4
Water-borne freight	68.25		105		45.8	33.0	2.2
All freight transport	272		636.5		99.3	100.4	169.1

Table 30B.
EST3 scenarios: Ratios of unit emissions of nitrogen oxides 2030/1990[2]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.00	*0.05*	0.02 *0.03*	0.02 *0.02*		0.03	
Surface public transit	0.00*	*0.13*				0.25	
Aviation	*4.87*		*0.30*			0.64	
All personal travel		*0.08*					
Light-duty road freight	0.00	0.10	0.02	0.01			
Heavy-duty road freight	0.00		0.12 *0.07*	0.13 *0.11*		0.25	0.06 *0.05*
Rail freight	*0.00*						*0.14*
Water-borne freight	*0.00*		*0.09*			0.11	
All freight transport		0.10					*0.09*

[2] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)
* Bus only (expressed in grams per veh. km). Other ratios for Surface Public Transport are 0.13 for Rapid Transit (expressed in grams per passenger km.) and 0.00 for Passenger Rail (expressed in grams per passenger km.)

Table 31B.
EST3 scenarios: Ratios of unit emissions of volatile organic compounds 2030/1990[1]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.00	*0.05*	0.00 *0.00*	0.00 *0.00*		0.06	
Surface public transit	0.00	*0.15*				0.16	
Aviation	*0.49*					0.02	
All personal travel		*0.09*					
Light-duty road freight	0.00	0.10	0.00	0.00			
Heavy-duty road freight	0.00		0.32 *0.05*	0.32 *0.14*		0.16	0.07 *0.07*
Rail freight	*0.00*						*0.33*
Water-borne freight	*0.00*		*0.45*			0.10	
All freight transport		0.10					*0.17*

[1] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)

Table 32B.
EST3 scenarios: Ratios of unit emissions of particulates2030/1990[2]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles			*0.00*	*0.00*		*0.15*	
Surface public transit							
Aviation							
All personal travel							
Light-duty road freight							
Heavy-duty road freight			0.01 *0.00*	0.05 *0.04*		*0.15*	0.02 *0.01*
Rail freight							*0.26*
Water-borne freight			*0.03*				
All freight transport							

[2] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)

Table 33B.
EST3 scenarios: Ratios of unit emissions of carbon dioxide 2030/1990[1]

MODE	QWC	OSN	GER(I)	GER(O)	NET	SWE	ALP
Private automobiles	0.19	*0.25*	0.23 *0.18*	0.32 *0.25*		0.41	
Surface public transit	0.40*	*0.40*				0.55	
Aviation	*0.49*		*0.51*			0.56	
All personal travel		*0.29*					
Light-duty road freight	0.16	0.45	0.22	0.28			
Heavy-duty road freight	0.40		0.57 *0.30*	0.58 *0.46*		0.55	0.18 *0.16*
Rail freight	*0.07*						*0.14*
Water-borne freight	*0.01*		*0.56*			0.88	
All freight transport		0.45					*0.15*

[1] Note: Ratios are based on grams per vehicle-kilometre (normal font) or grams per passenger-kilometre/tonne-kilometre (italic font)
* Bus only (expressed in grams per veh. km). Other ratios for Surface Public Transport are 0.15 for Rapid Transit (expressed in grams per passenger km.) and 0.04 for Passenger Rail (expressed in grams per passenger km.)

Table 34B.
Correspondence of transport categories used in tables and figures in this report, and sources of information

STUDY	TRANSPORT CATEGORIES AND SOURCES OF INFORMATION
OSN	**TRANSPORT CATEGORIES: Non-motorised:** Refers to the walk/cycle category in the study report. **Private automobiles:** Refers to the car and private car categories in the study report. **Surface public transit:** Includes the bus and rail/light rail categories in the study report. **All personal travel:** Estimated from information provided in the study report. **Light-duty road freight:** All information about freight transport in the study report is included in this category. **All freight transport:** In each case identical to the light-duty road freight category. **SOURCES:** For Figures 6 and Table 16B here see Tables 3.5 and 3.7 of the OSN study report. For Table 10 and Table 27B see Tables 5.3 and 5.5. For Figure 10 and Table 29B see Tables 6.3 and 6.6. For Table 17B to Table 20B, inclusive see Tables 3.2 and 3.3. For Table 22B to Table 25B, inclusive, see Tables 4.1 and 4.2. For Table 30B to Table 33B, inclusive, see Tables 6.1 and 6.2.
GER	**TRANSPORT CATEGORIES. Non-motorised:** Includes the walking and cycling categories in the study report. **Private automobiles:** Includes the passenger car, car (Otto), car (diesel), and car (electric) categories in the study report. **Surface public transit:** Includes appropriate information regarding scheduled and tourist buses (diesel and gas) for inside and outside urban areas, as well as light rail for inside urban areas and train for outside urban areas. **All personal travel:** Uses the provided information. **Light-duty road freight:** Includes the light-duty vehicle categories. **Heavy-duty road freight:** Includes the heavy-duty vehicle categories. **Rail freight:** Includes the freight transport, train categories. **Water-borne freight:** Includes the barge, IN vessel, and ocean ship categories. **All freight transport:** Uses the provided information. **SOURCES AND OTHER NOTES:** Information in the present report comes from the twelve detailed tables provided in the study report between Appendix B and the four charts found at the end of the report. For present purposes, these tables have been numbered from 1 to 12 in sequence. For Figure 6 and Table 16B here see Table 3 of the GER study report. For Table 10 and Table 27B see Table 6. For Figure 10 and Table 29B see Table 11. For Table 17B to Table 20B inclusive, see Tables 1, 2, and 3. For Table 22B to Table 25B, inclusive, see Tables 4, 5, and 6. For Table 30B to Table 33B, inclusive see Tables 8, 9, and 10.
NET	**TRANSPORT CATEGORIES: Non-motorised:** Includes the bicycles category in the study report. **Private automobiles:** Includes the cars category in the study report. **Surface public transit:** Includes the rail passengers, train, buses, bus-public transport, and bus-other in the study report. **Aviation:** Not included, because information given about passengers only. **All personal travel:** Not included, because cannot be estimated. **Light-duty road freight:** Includes vans in the study report. **Heavy-duty road freight:** Includes lorries and heavy lorries in the study report. **Rail freight:** Includes rail goods in the study report. **Water-borne freight:** Includes only the inland shipping category in the study report. **All freight transport:** Not included, because cannot be estimated. **SOURCES:** For Figure 6 and Table 16B here see Tables 4.3.1 and 4.3.3 of the NET study report. For Table 27B see Table 6.6.2. For Table 29B see Table 7.6.2 and an additional communication. For Table 17B to Table 20B, inclusive, see Tables 4.4.1 to 4.4.4. For Table 22B to Table 25B, inclusive, see Tables 5.6.1 and 5.6.2.
SWE	**TRANSPORT CATEGORIES: Non-motorised and private automobiles:** Information about what was included in these categories was not provided. **Surface public transit:** This included both bus and rail modes. **Aviation:** This includes both domestic and international flights. **All personal travel:** As provided by the Swedish Environmental Protection Agency (SEPA). **Light-duty and heavy-duty road freight:** All road freight is considered in the latter category. **Rail freight:** Because emissions from the production of electricity are not considered, emissions from Sweden's almost all-electric railways are negligible. **Water-borne freight:** The main changes here result from the anticipated replacement of two-stroke with four-stroke engines. **All freight transport:** As provided by SEPA. **SOURCES:** There is no special Swedish report concerning Phase 2, although there are four reports in English concerning the Swedish EST project. The information in the tables is based on these reports and on supplementary information provided by SEPA to the OECD Secretariat. No efficiency changes are assumed for the BAU scenario; therefore changes in passenger- and tonne-kilometres are equivalent to changes in vehicle-kilometres.
ALP	**TRANSPORT CATEGORIES: All personal travel:** This part of the Alpine study refers to freight only; thus there is no information about passenger travel. **Light-duty and heavy-duty road freight:** The Alpine study considers heavy-duty road freight only. Swap bodies in combined transport were not considered. **Rail freight:** Inconsistency is noted in the study report with respect to the treatment of efficiencies of and emissions from electric power plants in the three countries participating in this study. **Water-borne freight:** Not considered in the ALP study. **All freight transport:** Estimated from information provided. **SOURCES:** For Figure 6 and Table 16B here see Table 9 of the ALP study report. For Table 10 and Table 27B see Table 21. For Figure 10 and Table 29B see Table 23. For Table 17B to Table 20B, inclusive, see Table 9. For Table 22B to Table 25B, inclusive, see Table 18. For Table 30B to Table 33B, inclusive see Table 23.

APPENDIX C

IDENTIFICATION OF INSTRUMENTS FOR USE IN PHASE 3 OF THE EST PROJECT

This appendix contains two items: (i) a copy of the form to be used in the identification and assessment of instruments, and (ii) a list of potential instruments.

Assessment of instruments

Which *type* of feature is being attained?	Which instrument is being assessed?	Effect of the instrument on:[a]		Cost-effectiveness[a]	Impacts inside the transport system on:[b]			Impacts outside the transport system on:[b]			Macro-economic impacts:[b]		Links to other features and/or instruments[c]	What are the advantages and disadvantages of implementing the instrument?	What are the social, economic, and political contexts within which this instrument can be implemented?
		Activity	Unit impact		Vehicles	Fuels	Infrastructure	Land use	Social activity	Psychological factors	Employment	Other impacts			

[a] Assess on a five-point scale as follows: -- = very negative, - = negative, 0 = neutral, + = positive, ++ = very positive

[b] Assess on a three-point scale as follows: 0 = no impact, + = some impact, ++ = strong impact

[c] Indicate links in this way: A—instrument is linked to features/instruments involving activity reductions; I—instrument is linked to features/instruments involving reductions in impacts per pk/tk; A/I—instrument is linked to features/instruments involving both activity and impact reductions.

List of instruments that might be useful in the attainment of Environmentally Sustainable Transportation

HARDWARE MEASURES

- ultra-low emission and zero-emission vehicles that use renewable energy
- down-sizing of automobiles, and other techniques for achieving higher fuel efficiency
- optimising public transport vehicles: ultra-low floor trams (streetcars), low-noise rolling stock, high-comfort wagons
- trains and buses for two-way operation (light-rail trams usable with various electric systems; hybrid buses)
- ultra-low emission lorries (trucks) and zero-emission delivery vans
- recuperating energy use during deceleration.

TRANSPORT LOGISTICS AND PLANNING

- optimising public transport logistics with a well-co-ordinated network of all public transport means, walking, and cycling
- sophisticated allocation of roadway priority for public transport
- developing and promoting demand-oriented public transport systems; integrating taxi, dial-a-ride buses, and car-pooling for times of day and areas with low demand for transport
- provision of sophisticated, user-friendly passenger information systems
- traffic calming, lowering vehicle speeds, traffic and parking restraints, car-free zones and communities
- multi-modal combined transport techniques and logistics providing an environmentally sound transport chain, including medium-haul freight transport.

INFRASTRUCTURE

- improving and extending the railway network
- improving and extending other public transport networks
- providing separated tram tracks and bus lanes
- designing stations and junctions of public transport routes as attractive public places
- reducing the negative environmental impacts of roads
- redesigning public areas including streets to be friendly to pedestrians and cyclists
- installing elevators for pedestrians
- providing terminals and logistics centres for combined transport.

ECONOMIC AND FISCAL FRAMEWORK

- variabilisation of the costs of transport, so that they are paid where and when they are incurred
- internalising external costs according to the ‘polluter pays’ principle
- road and parking pricing
- economical incentives for using environmentally sound means of transport
- further development of the eco-point system (as applied to Alpine transit)
- development of fiscal instruments for making transport pay its full costs (e.g., fuel taxes, road pricing)
- taxes on the use of land to endure efficiency in its use and reduced demand for mobility.

SPATIAL PLANNING AND LAND USE

- urban and regional planning to reduce the demand for motorised transport by shortening transport distances, including the mixing of land uses; curbing urban sprawl and changing the land-use mix
- developing urban areas so that not owning a car is more advantageous than owning a car
- establishing and preserving rail links and sidings for industrial plants.

REGULATORY FRAMEWORK

- adaptation of land-use regulations to the development of public transport in accordance with the ‘shortest distance principle’
- establishment of standards and limits for speed, noise, emissions, and land use with respect to transport based on best available technologies and health standards
- giving priority to the attainment of EST in transport laws and guidelines (e.g., for traffic and parking regulations).

TRANSPORT DEMAND MANAGEMENT (TDM)

- TDM for enterprises and public offices to give incentives for the use of environmentally sound transport modes
- public transport incentives for employees
- incentives for using bicycles
- better use of vehicle capacity
- promoting car pooling and car sharing
- offering user benefits for environmentally sound mobility behaviour
- passenger information services
- paying people not to travel or move freight when advantageous from an environmental and cost perspective (i.e., application of the ‘negawatts’ concept to transport)
- logistic information systems for delivery and goods transport.

PUBLIC AWARENESS AND MARKETING

- marketing and image campaigning for walking, cycling, and using public transport
- popularising new lifestyle ideals compatible with EST through opinion leaders
- EST orientation of transport education (e.g., in schools, driving schools)
- visualisation of emissions and costs for drivers in vehicles
- negative portrayals of motorised transport.

APPENDIX D

LISTS OF FIGURES AND TABLES IN THE REPORT

FIGURES IN THE REPORT

TABLES IN THE REPORT

Notes

1 OECD, *Environmental Criteria for Sustainable Transport: Report on Phase 1 of the Project on Environmentally Sustainable Transport (EST)*. OECD/GD(96)136. OECD, Paris, 1996. Further discussion on the topic can be found in the other publication arising out of the EST project, which is OECD, *Compendium of Expert Papers: Studies Presented in the Context of the OECD Environment Directorate's Environmentally Sustainable Transport Project.* OECD, Paris, 1996.

2 In the elaboration of considerations that follows, sources of statements not documented here can usually be found in the report on Phase 1 of the EST project (see Footnote 1).

3 Cofala J, *et al*, "The Contribution of the Transport Sector to the Achievement of Critical Loads and Critical Levels in Europe: Report to the Ministry of Environment, Norway, November 1995" In *Compendium of Expert Papers: Studies Presented in the Context of the OECD Environment Directorate's EST Project.* See also *Calculation and Mapping of Critical Thresholds in Europe: Status Report 1995.* Co-ordination Centre for Effects, National Institute of Public Health and the Environment, Netherlands.

4 A challenge concerning ozone is that ambient levels appear to have *increased* in some countries in spite of impressive improvements in the ability of pollution control technology to reduce unit emissions of NO_x and VOCs. The relationship between ozone formation and NO_x levels in particular is complex: high NO_x levels can be associated with *low* levels of ozone production. This may happen because of scavenging of ozone during the production of NO_x from the nitric oxide created during combustion. The relation between ozone formation and levels of VOCs is also complex.

5 Small, K.A., Kazimi C., On the costs of air pollution from motor vehicles, *Journal of Transport Economics and Policy*, January 1995, pp. 7-32.

6 Known or suspected carcinogens include 1,3-butadiene, benzene, and polynuclear aromatic hydrocarbons (PAHs) associated with particulate matter and products of incomplete combustion. Motor vehicle exhaust is the source of 94 per cent of current emissions of 1,3-butadiene in the U.S., a compound that the U.S. Environmental Protection Agency considers to be, by a wide margin, the most dangerous (in terms of cancer risk) airborne toxin emitted by motor vehicles. This VOC is also believed to be genotoxic and possibly responsible for other adverse health effects including heart, lung, and blood disease.

7 See the source detailed in Footnote 5.

8 A difference between emissions of NO_x and VOCs is that NO_x emissions are more likely to result from the operation of heavy-duty (diesel) engines, whereas the emissions of VOCs are more likely to result from the operation of light-duty (gasoline) engines. Indeed, gasoline-fuelled vehicles account for about 90 per cent of the VOCs generated by road transport. Of the gasoline-vehicle portion of road-transport VOCs, 30-50 per cent arises from fuel evaporation during vehicle use or during refuelling and the remainder from tailpipe emissions of unburned fuel. VOCs from diesels are almost entirely composed of unburned fuel in tailpipe emissions.

9 Houghton JT et al. (eds.), *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge, U.K., 1996, pp. 3-4.

10 OECD, *Motor Vehicle Pollution: Reduction Strategies beyond 2010.* OECD, Paris, 1996.

11 See, for example, John B. Robinson et al. *Life in 2030: Exploring a Sustainable Future for Canada.* UBC Press, Vancouver, 1996.

12 The term *scenario* is used in the EST project as a synonym for “scene”—i.e., scenario construction involved the painting of scenes of what transportation might be like in 2030. *Scenario* is more often used to describe a possible unfolding of events, as in “Let’s imagine the scenario of unilateral action by the Netherlands with respect to vehicle emissions standards.” In this sense, scenario refers to the whole sequence of events that might transpire if there were unilateral action by the Netherlands. The backcasting literature is confusing as to which is the more appropriate use of *scenario*. John Robinson, who introduced the term *backcasting*, uses scenario in both ways. Chapter 5 of his latest book, detailed in Footnote 11, is entitled “Life in 2030: the sustainability scenario.” It includes such phrases as “an integrated scenario of a sustainable society in 2030 was produced.” Here *scenario* is being used in the way we have used it in the EST study—as a picture of a desirable future. But elsewhere in the book *scenario* is used for an unfolding of events. What is meant by *scenario* in the EST project corresponds closely to the term *image of the future* as used by Karl H Dreborg, Essence of backcasting, *Futures*, vol. 28(29), 1996, pp. 813-828.

13 The three-letter codes are those used in this report to designate the six studies. The German analysis often distinguishes between transport inside and outside urban areas, a distinction that is reflected here with the abbreviations GER(i) and GER(o).

14 The Swedish base years, milestone years, and scenario-construction years are these: for CO_2, 1990, 2020, and 2050; for NO_x, 1980, 2005, and 2020; for VOCs, 1988, 2005, and 2020. (*Towards and Environmentally Sustainable Transport System: Final Report from the Swedish EST-project.* Swedish Environmental Protection Agency, Stockholm, 1996.) The Swedish criteria are noted in Section 2.2

15 See the first source detailed in Footnote 1, pp. 56-59.

16 Current WHO air quality guidelines for NO_x and ozone are set out in Derek Elsom, *Smog Alert.* Earthscan Publications Ltd.: London, U.K., 1996, pp. 40-41. The 1996 tightening of the NO_x guideline is noted in this source. WHO guidelines are based on the lowest level known to produce adverse health effects, with a margin to protect sensitive persons. WHO sets no guideline for VOCs in the belief there is no safe limit; individual countries, e.g., Germany and the Netherlands, have set standards for individual VOCs (Elsom, *op cit.*, p. 58).

17 Elsom, *op cit.*, p. 55 (see Footnote 16).

18 OECD, *Advanced Air Quality Indicators: Final Report.* OECD Environment Directorate, 1997, p. 41.

19 Elsom, *op cit.*, p. 61 (see Footnote 16).

20 OECD, *op cit.*, p. 56 (see Footnote 18). Unusually, no margin of safety is published for the ozone criterion, meaning that even small exceedances are likely to result in adverse effects on the health of sensitive individuals (*op cit.*, p. 49). Central areas where traffic is heavy tend to have lower ozone levels for two reasons: (i) the photochemical reactions producing ozone are relatively slow and elevated concentration may therefore not occur until several hours after production of nitrogen dioxide in the atmosphere; (ii) the primary NO_x component of vehicle exhaust is nitric oxide (NO), which reacts in air to form nitrogen dioxide (NO_2) in part through depletion of ambient ozone (*op cit.*, p. 48; see also Footnote 4).

21 This paragraph is mostly taken from the paper by J Cofala *et al*. detailed in Footnote 3. See also: GLOBE/RIVM, GLOBE-Europe Organisation of the Members of the European Parliament/National

Institute of Public Health and Environmental Protection (RIVM), *The Environment in Europe: A Global Perspective*, RIVM, The Hague, Netherlands, 1992.

22 The Swedish NO_x-criteria reductions by mode for 2020 were: 85 per cent for road traffic, 90 per cent for rail traffic, 80 per cent for shipping, and -30 per cent (i.e., an increase) for air traffic.

23 See the discussion of VOCs in the paper by J Cofala *et al*., detailed in Footnote 3.

24 As in the European standards EURO1, EURO2 and EURO3, the U.S. EPA Tier 1 standard, and the California standards known as TLEV, LEV, and ULEV.

25 The Swedish VOCs-criteria reductions by mode for 2020 were: 90 per cent for road traffic, 50 per cent for air traffic; 0 per cent for rail traffic, and 50 per cent for shipping.

26 Houghton JT et al. (eds.), *Climate Change: The IPCC Scientific Assessment*. Cambridge University Press, Cambridge, U.K., 1990, p. xi.

27 See the source detailed in Footnote 9.

28 See, for example, Figure 2.6 on Page 85 of the volume detailed in Footnote 27, and also Figure 10.4 on Page 388 of Bruce JP et al. (eds.), *Climate Change 1995: Economic and Social Dimensions of Climate Change*. Cambridge University Press, Cambridge, U.K., 1996. Both figures indicate that reductions of more than 60 per cent from anticipated 2000 levels will be required to stabilise CO_2 emissions. Atmospheric levels of CO_2 in 2000 are expected to be some 10 per cent higher than those in 1990.

29 According to *OECD Environmental Data: Compendium 1995* (OECD, 1995), between 1980 and 1993 CO_2 emissions from mobile sources increased from 2.28 to 2.92 billion tonnes in OECD countries and from 1.17 to 1.49 in non-OECD countries, an annual rate of increase in each case of 1.9 per cent.

30 E von Weizäcker, AB Lovins, AH Lovins, *Factor Four: Doubling Wealth, Halving Resource Use—the New Report to the Club of Rome*. Earthscan, London, 1997.

31 International Factor 10 Club, *Statement to Government and Business Leaders*. Factor 10 Institute, Wuppertal, Germany, 1997.

32 Said (in the source cited in Footnote 31) to have been proposed jointly by the World Business Council for Sustainable Development and the United Nations Environment Program.

33 See p. 20 of the source detailed in Footnote 14.

34 See the specific parts of the IPCC report detailed in Footnote 28.

35 Michaelis, L et al, “Mitigation options in the transport sector.” In Watson RT et al. (eds.) *Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*. Cambridge University Press, Cambridge, U.K., 1996, pp. 679-712. This source notes the technical potential to reduce fossil fuel use per unit of transport activity by up to 80 per cent by 2025 if reductions in vehicle size and performance are accepted. It argues that a transition to zero greenhouse gas emission is “conceivable but would depend on eliminating emissions throughout the vehicle and fuel-supply chain.”

36 Tables with numbers ending in B are found in Appendix B, which begins on Page 64.

37 The report on Phase 1 of the EST project (see Footnote 1) includes the following, “In the long term, sustainability is more a global than a regional or local matter. If an environmental impact is beyond the carrying capacity of the planet then life as we know it is threatened. If it is beyond the carrying capacity of one area then that area may become uninhabitable but life as we know it can most likely continue elsewhere. (p. 12)”

38 In spite of the variety of modes and indicators examined by participants in Phase 2, possibly significant sources of environmental impacts of transportation were not addressed. One example is pleasure boat use, which may have been addressed only in the Swedish study. An estimate of its impacts in the United States concluded that pleasure boating consumes annually about one-fiftieth of the amount of fuel used for private motoring, but that each litre of fuel used in pleasure boating results in 70 times more emissions of volatile organic compounds into the atmosphere. Thus emissions of VOCs from pleasure boating exceed emissions for personal automobile use and are approximately equal to that from all road-vehicle use. Pleasure boating has a vastly greater adverse impact on water courses than road transport. (Andre Mele, *Polluting for Pleasure.* W.W. Norton & Co.: New York, 1993.)

39 It is reasonable to question whether massive use of sustainably produced electricity, even using presently available technology, might not in itself require a degrees of technological innovation that would put such use properly in the EST1 or EST3 scenarios.

40 Transport activity can be expressed in vehicle-kilometres or passenger/tonne-kilometres. Vehicle-kilometres are more relevant for environmental impacts. This is because the amount of damage done is usually more a matter of the extent to which vehicles move than of how many people are carried or how much freight is moved. From other perspectives the important indices are person-kilometres or tonne-kilometres moved. The initial analysis in this section is so rough as to be insensitive to which kind of index of transport activity is use. The subsequent, more sophisticated analysis respects the distinctions by factoring in values for vehicle occupancy (movement of people) and vehicle loading (movement of freight). Occupancy is the ratio of passenger-kilometres to vehicle-kilometres and thus provides the link between the two. Loading is likewise the ratio of tonne-kilometres and vehicles-kilometres.

41 The contributions to the BAU scenarios as represented in Table 12 were estimated respectively from Figures 5a and 5b, and Figure 6, and checked against the estimates of overall impact in Figure 7. The contributions to the EST1, EST2, and EST3 scenarios were estimated respectively from Figure 8, Figures 9a and 9b, and Figure 10 and Figures 11a and 11b.

42 A key consideration in the present estimation of impact of technology is that *all* improvements in fuel intensity are included. Thus, improvements from the simple downsizing of vehicles as well as those arising from the use of more effective technology have been counted together. The separate estimation of the contribution of downsizing would require data beyond what was made available by the teams. In the meantime, given that some downsizing is likely, the present method will *overestimate* the contribution of technology.

43 The BAU and EST3 scenarios of only five of the six study teams are represented. At the time of preparation of this report, the Norwegian team had not provided sufficient information for the analysis to be conducted with respect to its scenarios

44 See the paper prepared for the EST project by Karst Guers, Bert van Wee, and Farideh Ramjerdi entitled *Backcasting and long-term transport scenarios* (National Institute of Public Health and the Environment, Bilthoven, Netherlands, and Institute of Transportation Economics, Oslo, Norway. March 1997).