Energy efficiency and specific CO₂ emissions

The energy efficiency of passenger car transport has improved slightly during the past two decades, and as a result so has its average specific CO₂ emissions. The voluntary agreement with the car industry to reduce CO₂ emissions from new cars is making progress towards its target, although continued efforts are still needed. These technological improvements in energy efficiency will however not be sufficient to stabilise or reduce overall CO₂ emissions of road transport.

Even though the energy efficiency of rail has remained stable in recent decades, it remains the most energy-efficient mode of passenger transport. Despite improvements during the 1980s, aviation continues to be the least efficient mode.

No improvement in efficiency can be observed for freight transport (trucking and rail). Trucks consume significantly more energy per tonne-km than rail or ship transport.

Figure 1: Energy efficiency of total car fleet for selected countries and EU

Figure 2: Energy efficiency of trucks for selected countries

Source: ODYSEE database

Objective
- Reduce energy use per transport unit (passenger-km or tonne-km).
- Reduce CO₂ emissions per transport unit

Definition
- Energy efficiency of passenger and freight transport, i.e. energy consumption per unit of transport activity (MJ/passenger-km and MJ/tonne-km), and by mode
- Specific fuel consumption of new cars and of the total car fleet, i.e. fuel use per km (litre/100 km)
- Specific CO₂ emissions of passenger and freight transport (emissions per passenger-km and tonne-km)

The average energy efficiency of passenger and freight transport is determined by the fleet composition (number and type of vehicles, see #Vehicle fleet and ownership), vehicle...
utilisation (occupancy rates and load factors, see #Load factors and #Occupancy rates) and driving characteristics (speeds, distances).

**Policy and targets**

**Common Transport Policy's action programme** (European Commission, 1998b)

The Common Transport Policy's action programme highlights the need to 'reduce the dependence of economic growth on increases in transport activity and any such increases on energy consumption' and calls for the development of 'less environmentally damaging energy alternatives'.

**Communication on transport and CO₂** (European Commission, 1998a)

In this context, the Commission forwarded a Communication on transport and CO₂, which identified a series of promising policies and measures to reduce CO₂ emissions, such as improved logistics, a strategy to reduce CO₂ emissions from passenger cars (see below); revitalisation of railways, promotion of public transport, short-sea shipping and intermodal transport; stepwise introduction of fair and efficient pricing in all modes of transport.

**Community's strategy to reduce CO₂ emissions from passenger cars** (European Commission, 1995a)

The Community's strategy to reduce CO₂ emissions from passenger cars and improve fuel economy was endorsed by the Council in 1996. It aims at achieving an average CO₂ emission for new passenger cars of 120 g CO₂/km by 2005, and 2010 at the latest. The strategy is based on three pillars:

1. Commitments of the automobile industry on fuel economy improvements (see voluntary agreement with the car manufacturing industry);
2. Fuel-economy labelling of cars (see car labelling Directive);
3. The promotion of car efficiency by fiscal measures.

**Voluntary agreement with car manufacturing industry** (European Commission, 2000f; European Commission, 2000g)

The Commission established voluntary agreements regarding CO₂ emission reduction from new passenger cars with the European (ACEA), the Japanese (JAMA) and Korean (KAMA) Automobile Manufacturers' Associations. All three agreements contain the same quantified CO₂ emission objective for the average new passenger car sold in the European Union, i.e. 140 g CO₂/km (to be achieved by 2009 by JAMA and KAMA and by 2008 by ACEA). In order to be able to verify whether the commitments are effective, intermediate targets have been set for 2003/2004. See ‘Findings’ for a full assessment.

**Car labelling Directive**

The purpose of the Directive 1999/94/EC¹ of 13 December 1999 is to ensure that the information relating to the fuel economy and the CO₂ emissions of new passenger cars offered for sale or lease in the Community is made available to consumers. The consumer information system is to be set up by:

1. Labelling of fuel consumption and CO₂ emissions;
2. Production of a fuel consumption and CO₂ emission guide;
3. Displaying posters in car showrooms;
4. Inclusion of fuel consumption and CO₂ emission data in advertising, brochures, etc.

**Action Plan to Improve Energy Efficiency in the**

The Commission Communication on energy efficiency set out a strategy for achieving a 1% per annum improvement in energy efficiency by the year 2010 over and above what would otherwise have been achieved.

¹ Official Journal L 012, 18/01/2000 p. 16 - 23
Energy efficiency and specific CO₂ emissions

European Community (European Commission, 2000e) In its subsequent Action plan, the Commission estimates that the potential for energy efficiency improvement is more than 18 % of the present energy consumption in the EU. The action plan proposes, among other measures, to enhance the integration of energy efficiency considerations into other non-energy policy and programme areas (like the transport sector) and measures for re-focussing and reinforcing existing successful Community energy-efficiency measures.

For the transport sector, measures to enhance the integration of energy-efficiency into non-energy policy programme areas include incentives for optimal occupancy of vehicles, promotion of new and alternative infrastructure and subsequently modal shifting and modal integration, management alternatives to air transport, completion of the internal market in rail transport and changing behaviour regarding mobility. With respect to re-focussing and reinforcing successful current energy efficiency policies and measures, the Action Plan emphasises the need to fully implement and monitor the voluntary agreements with the car manufacturing industry, and to provide additional incentives to accelerate the rate of compliance, through further action on vehicle fuel economy and improved pricing.

The short-term target is 5 to 10 % energy savings in order to achieve aggregate reductions in CO₂ emissions.

Community Strategy on Climate Change (European Commission, 2000d) In its Communication on EU policies and measures to reduce greenhouse gas emissions, the European Community proposes several common and co-ordinated policies and measures on climate change with respect to energy consumption of the transport sector, the following of which have been endorsed by the Environment Council on 10 October 2000:

- Reduction of CO₂ emissions from light utility vehicles;
- Reduction of GHG emissions from air conditioning in vehicles;
- Limitation of the increase of GHG emissions from air transport;
- Limitation/reduction of CO₂ emissions from road transport by promoting the use of rail freight and passenger transport, as well as intermodal and combined transport.

Auto-Oil Programme (European Commission, 2000b) The Auto-Oil programme aims to improve, amongst other things, the energy and emission efficiency of road transport. The review of the Auto Oil II programme is currently under discussion.

Urban transport The Citizens’ Network (European Commission, 1995b) aims at boosting the shares of public transport and rail, which are more energy efficient. Targets with respect to energy saving are probably included as new items in the Green Paper on Sustainable Urban transport expected in March 2001.

RTD programmes The THERMIE Programme (European Commission, 1994) of the Commission aimed to promote more efficient energy technology. The programme, now closed, had a budget of about 700 million ECU. The THERMIE Programme now forms part of the specific programme on research, technological development and demonstration on energy, environment and sustainable development for 1998 to 2002 (European Commission, 1999b). Priorities in this programme are given to an integrated approach to improving energy efficiency in transport, among others.
The SAVE programme was adopted by the Council in 1996 for a five year period (1996-2000). It now forms part of the Energy Framework Programme for 1998-2002 (European Commission, 1999c). It has several priorities for the transport sector. These include measures to increase the use of energy-efficient transport in European cities for both passengers and freight, including the optimal occupancy of vehicles (both public and private), promotion of new and alternative infrastructure, management alternatives to air transport and changing behaviour. For 2000-2002, emphasis will be placed on information dissemination and reducing the use of private cars, encouraging collective transport modes and seriously considering how to reduce the need for transport.

Findings
Energy efficiency and CO₂ emission from passenger cars

The energy efficiency of all passenger car transport has improved slightly in recent decades (see Figure 1). Consequently, CO₂ emissions from passenger cars have fallen (see Figure 2). There are significant differences between countries, for example:

- In Austria, energy efficiency of passenger cars improved by 13 % between 1980 and 1999, while CO₂ emissions of passenger cars fell by 18 %;
- In Denmark, energy efficiency of the passenger car fleet improved by 10 % between 1980 and 1999 while CO₂ emissions fell by 26 %.

The specific CO₂ emissions of passenger cars decreased more than energy efficiency, mainly due to improvements in fuel quality (Figure 3).

Figure 3: CO₂ emissions of total car fleet per passenger-km for selected countries and EU

Source: ODYSEE database
In its first annual report on the effectiveness of the Community’s strategy to reduce CO₂ emissions from passenger cars (European Commission, 2000c), results from the voluntary agreements with the car manufacturing industries have been evaluated. The main findings for the reporting period (1995-99) are:

- ACEA achieved an average reduction rate of CO₂ emissions from new passenger cars of 1.5 %, JAMA 1.15 % and KAMA 0.4 % per year (on average the reduction rate must be 2 % per year in the whole monitoring period in order to meet the 2008/9 target);
- The achieved reductions are mainly a result of technological developments (introduction of High Speed Direct Injection Diesel);
- ACEA and JAMA introduced passenger cars emitting less than 120 g CO₂/km;
- ACEA and JAMA are showing good progress towards the intermediate targets (i.e. 165-175 g CO₂/km by 2003/2004);
- KAMA has to increase efforts significantly;
- Based on the evaluation reports, the Commission has reason to believe that all associations will meet their commitments. However, to meet the final objective (120 g CO₂/km), the Community should continue its work in developing and implementing the two other pillars of its strategy to reduce CO₂ emissions from passenger cars, i.e. the car labelling Directive and fiscal measures.

**Figure 4: Achievements of the car manufacturing industries regarding CO₂ emissions from new passenger cars, 1995-1999**

Source: European Commission, 2000c
Specific fuel consumption: test values versus real values

Research has shown discrepancies between ‘on road’ fuel consumption and emission rates (i.e. real driving circumstances) and test emission values, resulting from poor driving behaviour, worsening traffic conditions and other problems, not generally taken into account in policy making. This emphasises the need for regular maintenance and inspection programmes, improvement of traffic management and changes in driving behaviour (see Box 1).

Figure 5 shows how test values for the specific fuel consumption of new cars have decreased over the years, mainly due to a significant decrease in the ratio of new-car fuel efficiency to weight (IEA, 1997). Figure 6 shows the specific fuel consumption for the total car fleet. Fuel efficiency of the total fleet decreased more than that of new cars (15 % for the total fleet, 6 % for new cars). Fuel quality improvement is probably the main cause of this difference.

Figure 5: Specific fuel consumption of new cars

![Figure 5: Specific fuel consumption of new cars](source)

Figure 6: Specific fuel consumption of total fleet

![Figure 6: Specific fuel consumption of total fleet](source)

Source: ODYSSEE database

Energy efficiency of rail, buses and coaches

Data from the ODYSSEE database shows that the energy efficiency of rail passenger transport has not changed much in recent decades. However, in some countries (United Kingdom, France and Denmark) the energy efficiency of rail passenger transport decreased markedly: by 50 % in the United Kingdom, 12 % in France and 10 % in Denmark between 1980 and 1999.

Figure 7: Energy efficiency in rail passenger transport

![Figure 7: Energy efficiency in rail passenger transport](source)

Source: ODYSSEE database

Based on ForeMove data, the energy efficiency of buses and coaches has remained stable in recent decades.

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CO₂ emissions of rail, buses and coaches increased by 6% between 1980 and 1998, corresponding with data from the Lawrence Berkeley Laboratory. However, a clear change in trend can be seen after 1994-1995. Data on CO₂ emissions of rail are not available.

Figure 8: Modelled CO₂ emissions per passenger-km of buses and coaches (EU-15), 1980-1998

Source: ETC/AE, 2000; Eurostat, 2001

Energy efficiency of air transport improved by around 17% since the 1980s, mainly due to technological improvements and increasing occupancy rates, but has not changed since (European Commission, 2000c). Air passenger travel remains the least energy-efficient mode.

Freight transport energy efficiency

The changes in energy efficiency of road freight (Figure 2) have different causes. The energy efficiency of trucks of a given size has improved in every country, with the increased penetration of diesels and general technical improvements in diesel or petrol trucks. But the ratio of fuel used to freight hauled has not fallen in all countries, and varies considerably between countries. With production dominated by large, international firms, the differences are not due to differences in the energy efficiency of trucks, but arise mainly from differences in fleet mix (between large, medium, and light trucks), traffic, and above all in loading and utilisation (Schipper, et. al., 1995) (see also #Load factors).

The usage of trucks is also increasingly governed by the need for just-in-time deliveries, the rising value (as opposed to tonnage) of freight, and the importance of costs other than fuel cost.

- Energy efficiency in rail freight transport has increased over the past years in the EU. However, some countries show decreasing energy efficiency for rail freight transport (see Figure 9);
- Maritime freight transport is increasingly energy efficient. Energy efficiency in freight transport by ship increased by 15% between 1980 and 1995 (Lawrence Berkeley Laboratory).
Energy efficiency and specific CO₂ emissions

Figure 9: Energy efficiency of rail freight transport for selected countries

Source: ODYSSEE database

Projections

Energy efficiency of passenger transport is expected to improve for all modes during the next decade.

- CO₂ emissions from passenger cars are expected to fall by around 8 % between 2000 and 2010, due mainly to the voluntary agreements with the European (ACEA), the Japanese (JAMA) and Korean (KAMA) Automobile Manufacturers’ Associations, if they are properly implemented.

- CO₂ emissions per passenger-km for buses are expected to fall by around 6 % (ETC/AE, 2000). However, the reductions depend strongly on the occupancy rate, which is expected to increase from 2000 onwards (see #Occupancy rates). If the expected improvement in occupancy rate is not achieved, CO₂ emissions per passenger-km might increase dramatically.

The energy efficiency of freight transport is also expected to improve however at a slower pace than that of passenger transport.

- Trucks are expected to become more energy efficient in the next decade. The expected CO₂ emission reduction between 2000 and 2010 is around 2 % (ETC/AE, 2000).

- The energy efficiency of aviation is expected to improve by between 15 and 24 % in 2010, compared with 1995 (European Commission, 1999a) as a result of improved aircraft and engine design and improvements in aircraft operations through better air traffic management. However, these reduction potentials are based on fuel consumption predictions and not on expected CO₂ emission per passenger-km. Forecasts of to CO₂ emission per passenger-km in aviation suggest a reduction of around 20 % between 2000 and 2010.
Comparing modes

- In passenger transport, aviation is the least energy-efficient and by far the fastest growing mode. This emphasises the importance of improvements in air traffic management and engine and aircraft design, along with other operational improvements and economic incentives.

- Rail, buses and coaches are the least polluting modes and have the potential of being even more energy efficient with increased occupancy rates.

Trucks are by far the least energy-efficient mode of freight transport (air freight transport is probably less energy-efficient, but no data exists) Rail and shipping are much more energy efficient, emphasising the importance of the Community’s strategy to promote shipping and intermodal freight transport.

Box 1: The New Driving Force

Improved driving behaviour, supported by technical devices, is an important way of saving fuel and thus improving energy efficiency. The Dutch former programme ‘Buy Eco-nice, Drive Eco-wise’ from 1992 aimed to encourage customers to buy more environmentally-friendly vehicles and drive in a more environmentally-friendly way. The successes of this programme are currently being continued in the ‘New Driving Force’ programme.

The ‘New Driving Force’ programme is being carried out by Novem (the Dutch Organisation for Energy and the Environment) on behalf of the Ministry of Transport. The programme aims to change the attitudes and actions of various target groups, by encouraging them to purchase and use cars, delivery vans, lorries and buses in a more energy-efficient and environmentally-friendly way. In communication and marketing, ‘New Driving Force’ is presented as the new driving style for the 21st century, the driving style that best fits new engine technology. The problem is that most drivers practise an obsolete style of driving, of which they are not aware. Another problem is that learner drivers are still taught an obsolete driving style. Instructors teach them the same elements that they were taught some decades ago, based on obsolete engine technology.

In February 2000 about 15 organisations signed a covenant to cooperate in the network - the ‘New Driving Force’ and to play an active role in carrying out the programme. These organisations ranged from touring clubs to the Dutch Consumer Association. The ‘New Driving Force’ is much more than a campaign and consists of four basic elements, addressing:

- Purchasing behaviour;
- Tyre pressure and maintenance;
- Driver training;
- Use of fuel saving in-car devices.

The last two elements are the most interesting with respect to driving behaviour. With the right training in driving style, drivers can save an average of 5-10 % of fuel, with some drivers saving more than 20 %. Some of the key elements in driving style are:

- Start the engine without touching the accelerator;
- Change as soon as possible to the highest gear possible;
- Use the highest gear possible while driving at a constant speed;
- Let your car roll for as long as possible in the highest gear possible when decreasing speed.
The new driving style is being implemented by training driving instructors and truck drivers. The potential CO$_2$ emission reduction for Dutch passenger cars and trucks is around 68 kilotonne per annum on average from 2000 to 2010.

In 1999 and 2000 a demonstration project was carried out with different types of eco-meters in cars, like the eco-revmeter, which has a coloured plate showing when to change gear and whether the driver is driving efficiently. A large scale test in delivery vans with speed and revlimiters showed that the fuel savings were of such magnitude (6 %, even without additional driving training) that the company involved earned back its investments within one year. The average annual CO$_2$ emission reduction potential, if Dutch passenger cars and delivery vans are equipped with in-car fuel saving devices, is estimated to be around 243 kilotonne on average per annum.

Changing driving style and using in-car devices together have an estimated CO$_2$ emission reduction potential of around 1 % in 2010, which is significant compared to the 6 % target by 2010 for the Netherlands.

Source: Novem

Box 2: ODYSSEE

Fifteen national agencies, implementers of energy efficiency and environmental policies, have set up a common database on comparative energy efficiency and CO$_2$ indicators, called ‘ODYSSEE’ and managed by Enerdata. The project started in 1992 under an initiative of ADEME and benefited from a combined financial support from the SAVE programme of the European Commission, ADEME, and national sources of funding. The objective is to set up a permanent technical structure among participating countries which permits the review, on a continuing basis, of yearly progress in sectoral energy efficiency and CO$_2$ emissions at the national and EU level.

The network that provides data for energy efficiency indicators for this project consists of statistical offices, energy agencies or energy consultants; all Member States (plus Norway) are represented. The energy efficiency indicators database (ODYSSEE) contains more than 250 indicators. Around 30 % of the basic data required for these indicators are obtained from Eurostat.

In 2000, Eurostat, in consultation with the Commission services and ADEME, selected a number of priority indicators, which are a sub-set of the ODYSSEE database indicators. Eurostat is currently conducting a quality control and improvement of the dataset, including extension to those countries that are not represented in the SAVE project by an official energy statistics correspondent (European Statistical System). This work aims to enable Eurostat to use these data officially and produce a report to the Council with the priority indicators.

Source: ODYSSEE database; Eurostat, 2000

Future work

- Harmonised EU data on energy and fuel efficiency for various transport modes and vehicles is not currently available. Data from the ODYSSEE database, combined with data from ForeMove (ETC/AE, 2000) has been used instead.

- The ODYSSEE database provides comprehensive data on energy efficiency for all modes of transport. A data quality control and harmonisation process is currently being conducted by Eurostat (see Box 2). This should soon result in an official dataset to be disseminated by Eurostat.
• The results achieved within TRENDS on road vehicles (CO₂ emissions) should be extended to aviation, rail and shipping. Eventually, real energy efficiency figures (MJ per transport unit) should also be included into TRENDS.

• An indicator on primary energy use per unit would provide a better basis for comparing modes, mainly because it would take account of the energy used for the production of electricity and fuels, and for the production and disposal of vehicles. This would, however, require extensive methodological development and data collection.

Meta data

Technical information

Data sources:
- Specific modelled CO₂ emissions are from ForeMove (ETC/AE, 2000);
- Energy efficiency data from the ODYSEE database (ADEME/SAVE project on energy efficiency indicators);
- Passenger-km data and tonne-km data from Eurostat Statistical Compendium (Eurostat, 2001);

Description of data:
- The data on energy efficiency is not available for all modes at the EU level. Therefore, this data has been extended with modelled CO₂ emission data from ForeMove (ETC/AE, 2000).
- The emission of CO₂ per passenger-km or tonne-km is calculated by dividing total tonne of CO₂ emitted by the corresponding passenger-km or tonne-km.
- The data on energy efficiency for cars, trucks, buses and coaches, ships and rail are from ODYSSEE.

File: Energy efficiency and specific CO2 emissions.xls

Original measure units:
Tonnes for emissions, passenger-km and tonne-km for transport units, MJ for energy efficiency.

Original purpose:
Unknown

Geographical coverage:
EU-15 (Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden and the United Kingdom).

Temporal coverage:

Methodology and frequency of data collection:
Unknown

Methodology of data manipulation:
Total tonnes divided by total passenger-km or tonne-km for the corresponding mode. Light- and heavy-duty vehicles are summed.

Qualitative information

Strength and weakness (at data level):
-

Reliability, accuracy, robustness, uncertainty (at data level):
-

Further work required (for data level and indicator level):
-
References


http://www.europa.eu.int/comm/environment/co2/co2_home.htm


ODYSEE database: ADEME/SAVE project on energy efficiency indicators.
http://www.ademe.fr


References not referred to in text:


http://europa.eu.int/comm/environment/climat/eccp.htm and
