

Energy Consumption Trends in the Danish Transport Sector

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1. Introduction

The Danish Energy Agency publishes a yearly report about the development in energy efficiency in each sector (including transport). The yearly report is part of an EU – SAVE project, which the EU-Commission has initiated for monitoring the development in energy efficiency in each EU country. The results in this paper are based on the Danish contribution to the EU-SAVE project and a presentation and paper made for an EU-SAVE workshop in december 2000 in Brussels¹.

This paper contains the latest trends in energy consumption in the Danish transport sector. The paper includes the following parts:

- 1) Total Energy Consumption in Transport
- 2) Energy Efficiency in Passenger Transport
- 3) Energy Efficiency in Freight Transport
- 4) Factors behind the Development in Energy Consumption

The first part gives a description of the overall trends in energy consumption in the transport sector as a whole. In section 2 and 3 the analysis is separated into passenger transport and freight transport to see if there is a difference in the development. The last section investigates the factors or driving forces behind the development in energy consumption in passenger and freight transport. A decomposition of the overall energy consumption shows which factors that have had major influence on the development in energy consumption (activity level, energy efficiency or mode-structure).

2. Energy Consumption in the Transport Sector

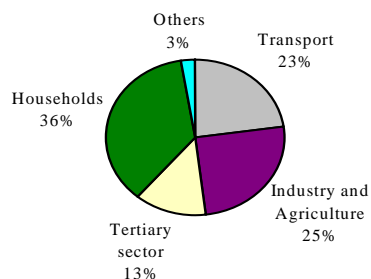
Energy consumption by sector

Figure 1 shows the final energy consumption in Denmark by sectors, and it appears that the share of energy consumption in transport has increased from a share of 23 % in 1975 to 31 % in 1999. In the same period the share of energy consumption in households has decreased. The rest of the analysis in this paper will focus on these 31 % of the final energy consumption in Denmark.

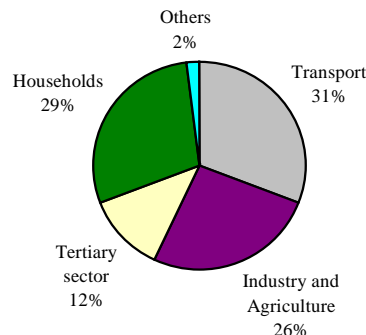
¹ The two sources are: 1) *Energy Efficiency in Denmark - An Analysis Based on the ODYSSEE Data Base from the SAVE project "Cross country Comparison on Energy Efficiency Indicators, Phase 6"*, december 2000. Can be downloaded from www.ens.dk. 2) *Energy Consumption Trends in the Danish Transport Sector*, december 2000, paper prepared for presentation on EU-SAVE workshop in Brussels the 18+19'th of dec. 2000.

Figure 1

Final Energy Consumption 1975 -
by Sector



Final Energy Consumption 1999 -
by Sector



Notes: Energy consumption is adjusted for climatic changes

Source: Danish Energy Agency, "Energy Statistics 99".

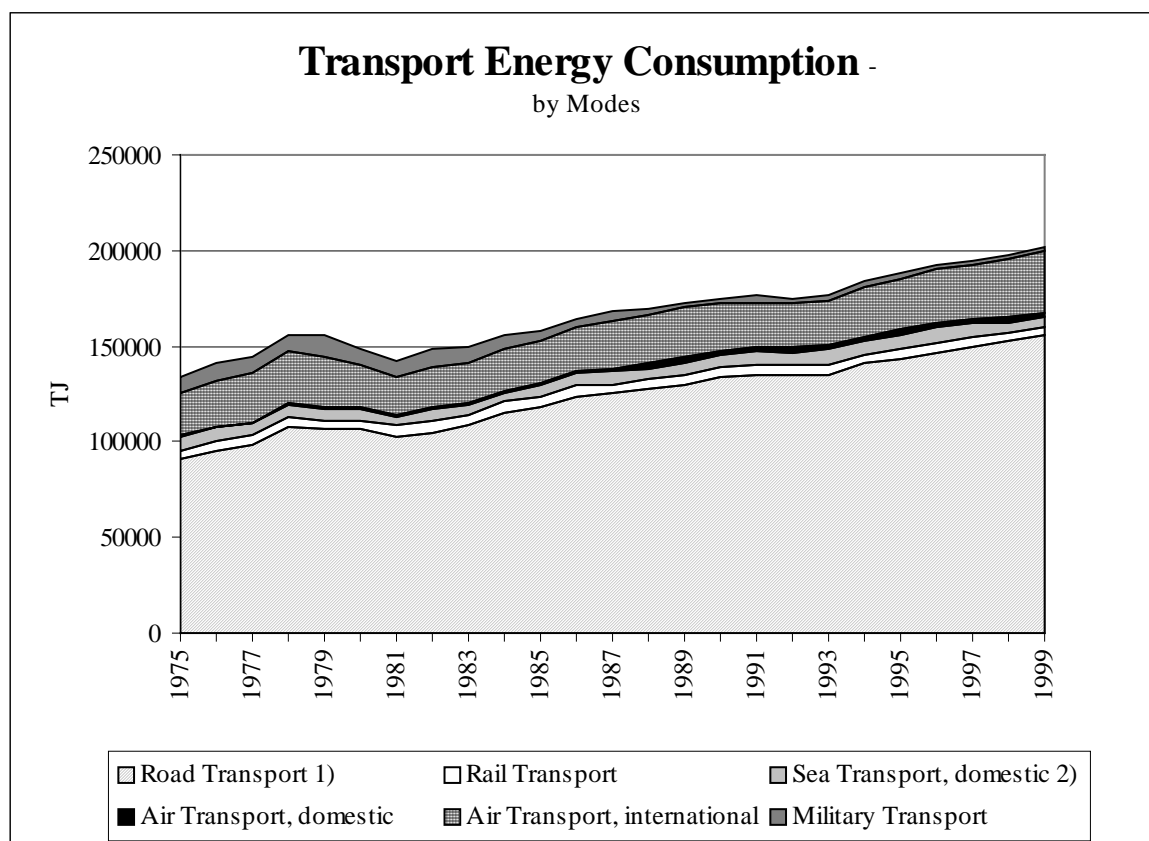
Energy consumption in transport – by modes

Figure 2 shows energy consumption in the transport sector divided by transport modes. From 1975-99 energy consumption in the transport sector has increased with 51 %, and in 1999 it accounted for approximately 200.000 TJ. The two main energy uses are road transport and international air transport accounting for respectively 77 % and 16 % of the energy consumption in 1999. There has been a significant increase in the amount of energy used to road transport and international air transport since 1993. It might be difficult to see in the figure, but from 1993-1999 energy consumption for international air transport has grown twice as much as energy for road transport. Energy consumption for international air transport increased on average 5,5 % per year, whereas energy consumption for road transport only increased 2,4 % per year.

Denmark - and other countries- should be aware of this fast growing international air transport, especially since recent research about climate effects shows that CO₂ emitted by aeroplanes in the sky has 3 times more climate effect than the equivalent amount CO₂ emitted at ground level (road transport)². Taking this into account international air transport might become a dominant contributor to the climate effect.

² Based on "Comparison of Greenhouse Gas Estimates from Aviation and other Forms of Transport in 1997", Danish Environmental Protection Agency, 1999 and "Aviation and the Global Atmosphere", IPCC, 1999.

Figure 2



Source: Danish Energy Agency, "Energy Statistics 99".

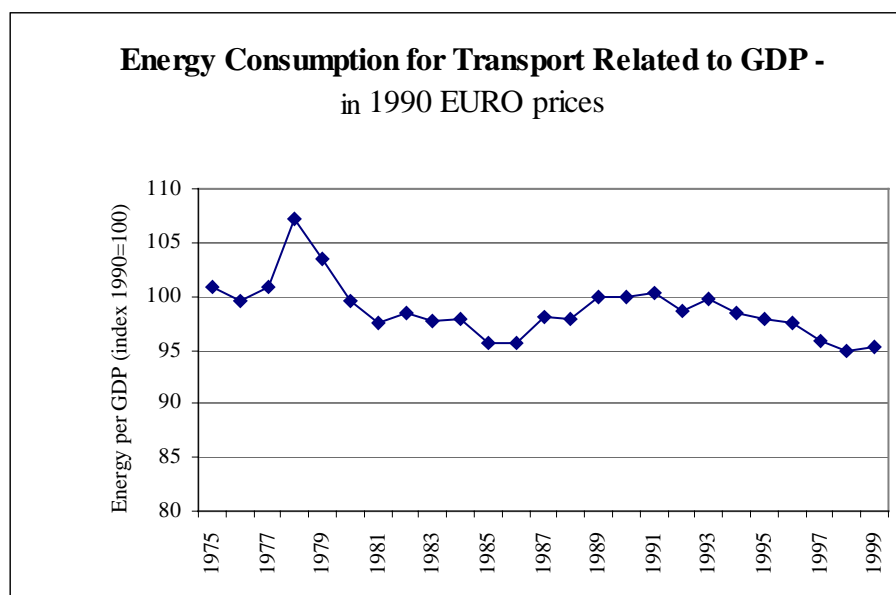
Notes: 1) Road Transport includes cars, light duty vehicles, trucks, busses, taxis, motorcycles and mopeds.
2) Do not include international Bunkring.

Overall transport energy intensity

Figure 3 shows that the overall energy intensity – measured as energy consumption in the transport sector per total GDP - declined 5 % during the period 1975-1999, which means that the amount of transport needed to produce one unit of GDP has declined 5 % since 1975. The change in energy intensity might be due to several factors. Both the change in GDP and the change in energy consumption in the transport sector could have an effect on this indicator³. The significant increase from 1977 to 1978 is due to a high increase in energy consumption for transport in 1978, see also figure 2. Possible explanations of the change in energy consumption will be analysed in section 5.

³ The change in GDP in the period has not been analysed, but such a change might also have an effect on the indicator. For example if there has been a structural change in GDP in the way that low transport intensive sectors has increased more than high transport intensive sectors.

Figure 3



Source: Odyssee database 2000.

3. Energy Efficiency in Passenger Transport

Unit Consumption by modes

The energy consumption in passenger transport depends on the need of people to be transported. The amount of energy needed to fulfil the demand of passenger transport depends on three factors:

- The number of passengers making a trip
- The actual number of kilometres each passenger needs to be transported
- Transport mode (car, bus etc.)

The total demand for passenger transport can be computed by adding up every passenger's transport – measured as each passenger's total kilometres of transportation in a given year⁴. However, there is often a lack of such detailed data, and as a substitute is used an estimate of the passenger demand by multiplying the number of kilometres driven by each mode (bus, car etc.) with the average number of passengers in that type of vehicle.

Regardless of the method of calculation it is the total number of driven/sailed/flied passenger-kilometres that indicates the activity level. The question is “How much energy is used for transporting each passenger each of his/hers kilometres?”. This is shown in Figure 4.

The overall energy consumption for passenger transport – measured as MJ per passenger-kilometre – has decreased 6 % from 1980 to 1999 (shown by the thick black line). This means that an average kilometre of passenger transport is carried out with less energy – there has been an improvement in the

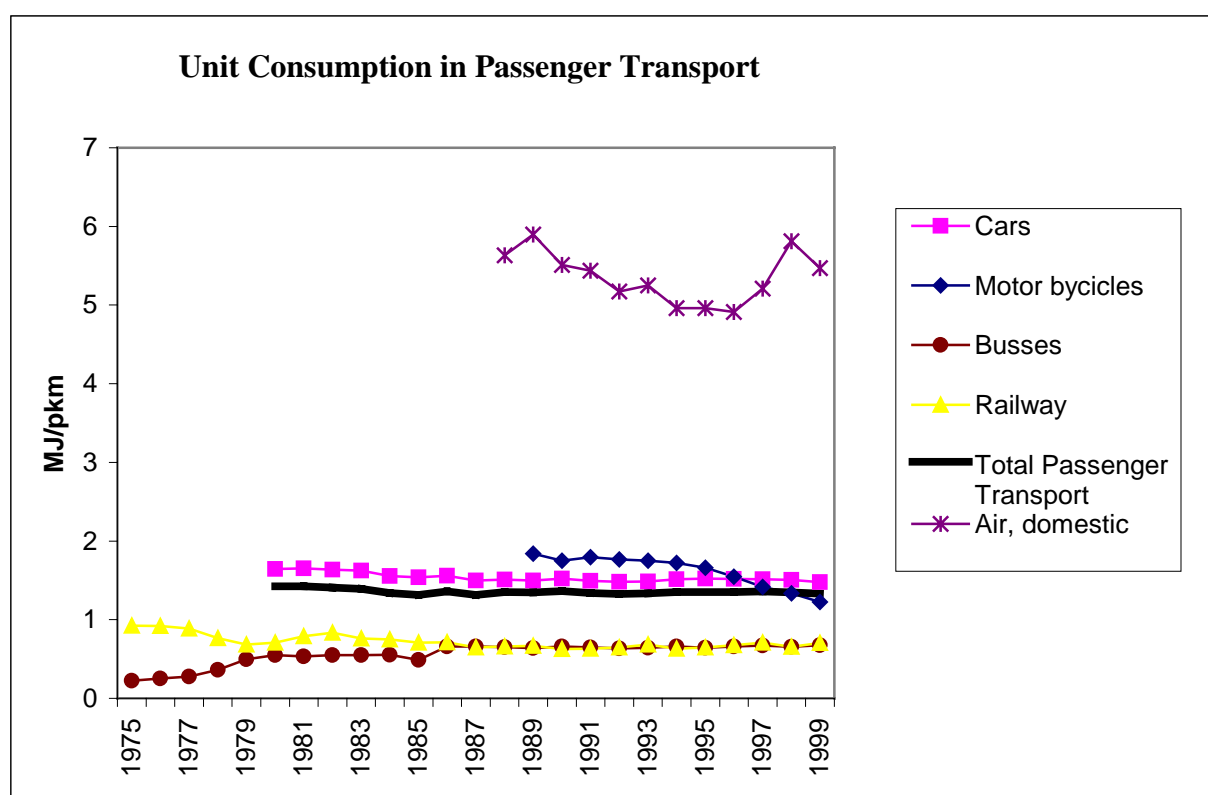
⁴ Referred to as total passenger-kilometres

overall energy efficiency. It is also shown in Figure 4 that the energy efficiency varies substantially across transport modes. Passenger transport by aeroplanes uses 3-4 times more energy per passenger-kilometre than other modes, whereas public transport (train and bus) has much lower energy consumption than both cars and aeroplanes. The variation across transport modes can be explained by two factors:

1. The variation in technical efficiency of the different vehicles (litre per 100 km)
2. The variation in utilisation factor of the modes.

The improvement in overall energy efficiency could either be caused by increased share of collective modes, higher utilisation factors, or more energy efficient modes. Some of these things are analysed by decomposing the energy consumption in section 5.

Figure 4



Source: Odyssee database 2000.

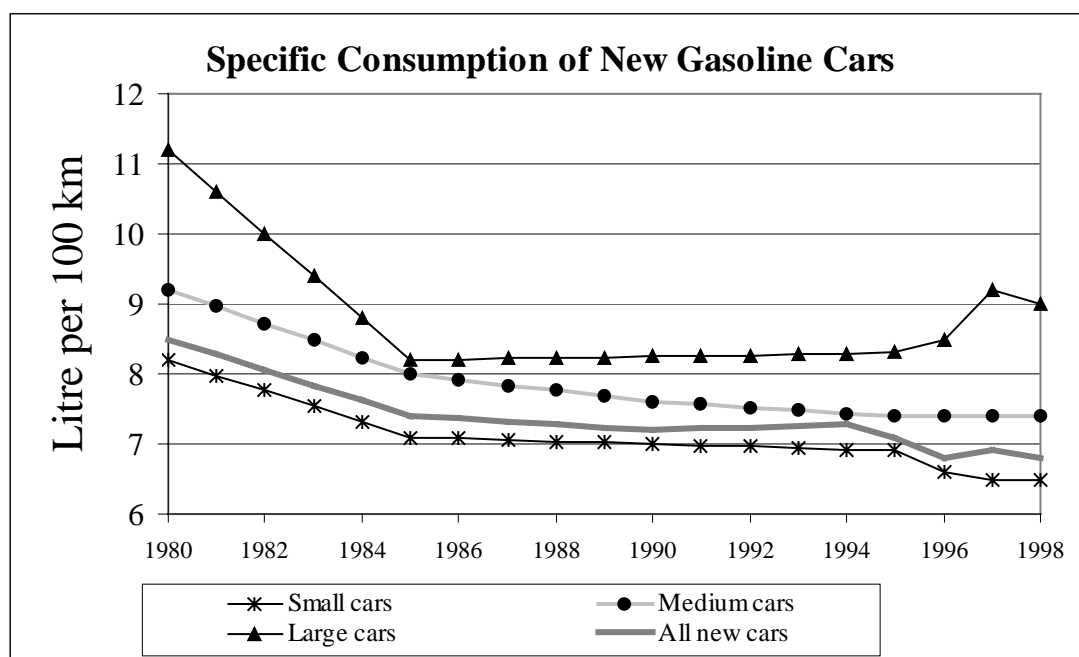
Notes: Total Passenger Transport (the thick black line) is total energy consumption by cars, busses, aeroplanes and railway divided by total passenger-kilometres by cars, busses, aeroplanes and railway.

The increase in energy consumption per passenger kilometre of domestic aeroplanes in 1998 can be explained by the opening of the Great Belt Bridge, which made several passengers switch from aeroplane to car or train. This has lowered the utilisation factor of the domestic aeroplanes. But the efficiency is slowly improving again in 1999 since air companies have begun to adapt the number of aeroplanes to the new demand.

Specific Consumption of Cars

As shown in Figure 5 the average specific consumption of new gasoline cars has not changed much over the period. Looking at the average of new gasoline cars (the thick grey line) there are 3 different trends during the period, starting with an technical efficiency improvement from 1980-85, then a long period of no change from 1985-95 and finally some technical improvement has happened again in the latest years. However it can be concluded that in the last 15 years (1985-98) the specific consumption of new gasoline cars has only decreased on average 0,6 % per year. The same development is seen for the small and medium gasoline cars, whereas the new large cars' energy consumption has increased. However, the share of large gasoline cars is only 2 % and therefore this increase does not influence the overall average of new cars.

Figure 5



Source: Kaj Jørgensen, Danish Research Institute RISØ, 1998, "Personbilers energiforbrug" – udarbejdet for Energimiljørådet.

Figure 6 shows the specific consumption of all new cars. The data is from another source and includes diesel cars as well, but it only includes the latest trends from 1997 and onwards. It is obvious from Figure 6, that the reduction in energy consumption of new cars has been much higher the last 4 years than during the period 1985-96. The energy consumption of all new cars has been reduced by 8 % from 1997-2000 and the improvement is mainly due to more diesel cars which have had a 19 % reduction in energy consumption during the period, whereas the reduction of energy consumption of gasoline cars has been 5 %.

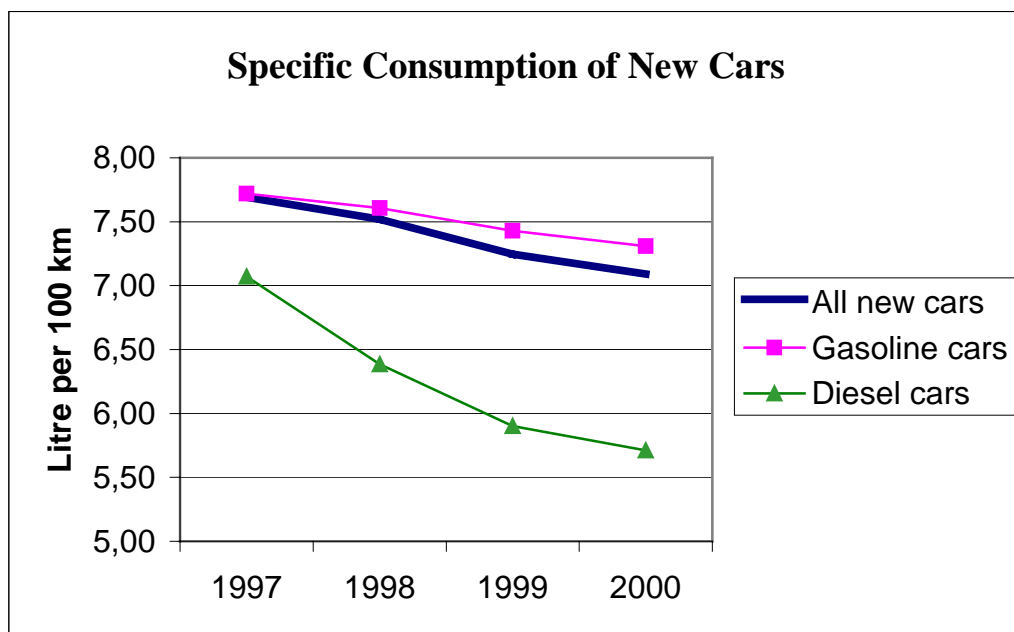
In Denmark there has been a significant increase in the share of diesel cars in per cent of the total sale of new cars and the share is now approximately 12 %⁵. If this tendency continues and at the same time

⁵ Based on the sale of new cars the first half year of 2000 (Statistics Denmark, Statistiske Efterretninger, Transport, 2000:41).

the high reductions in energy consumption of diesel cars continues we can expect to have further improvements in the technical energy efficiency in Denmark.

Next year there will be a consistent time series of specific consumption of all new cars in Denmark since the Danish Energy Agency have just started an analysis to make the historic data (before 1997) consistent with the recent data.

Figure 6



Source: Statistics Denmark. "Energy Efficiency for new passenger cars from 1997-2000".

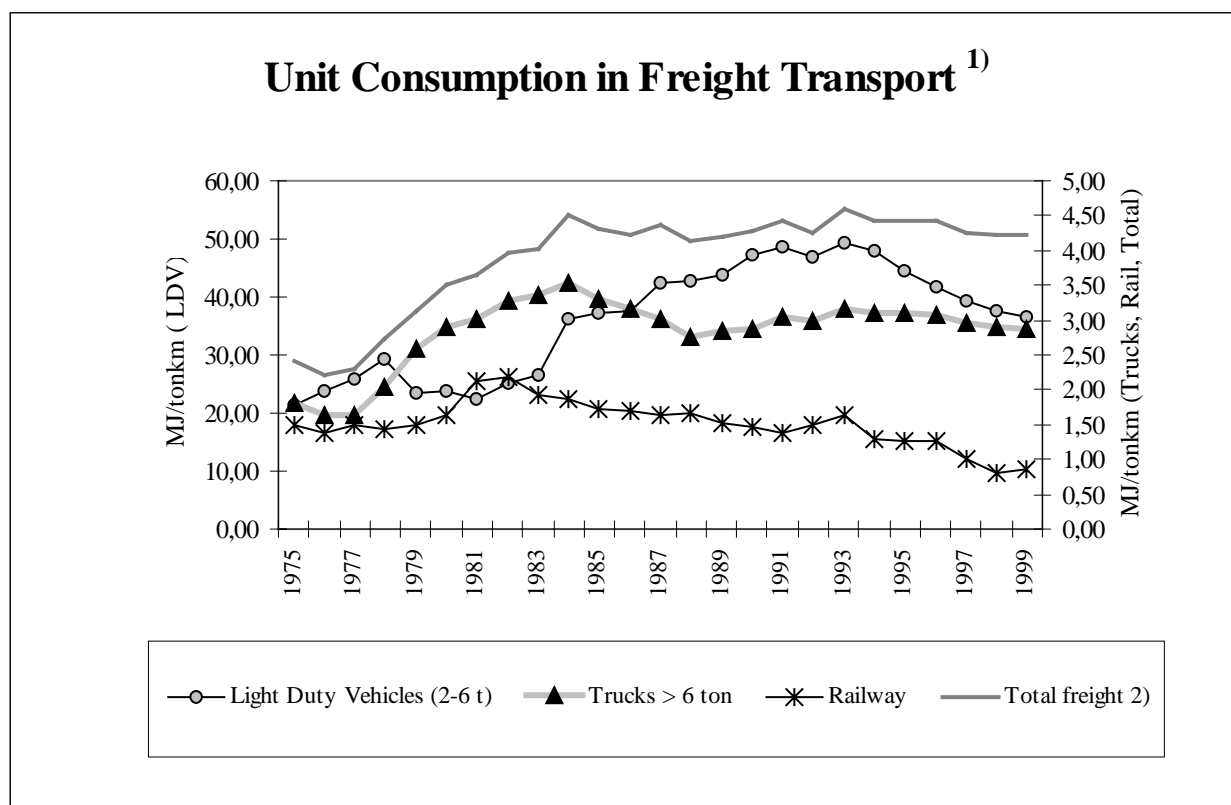
4. Energy Efficiency in Freight Transport

Unit Consumption by modes

As seen in Figure 7 the average energy consumption for freight transport – measured as MJ per ton-kilometre – has increased strongly from 1975 to 1984, after which it has remained rather steady (the thick grey line). This means that nowadays each ton-kilometre of freight transport is carried out using more energy than in the late 70's and the early 80's. The main factor behind the decline of the overall energy efficiency of freight transport between the mid-70's and the mid-80's was the reduced energy efficiency of trucks > 6 tonnes since they account for a high share of total energy used for freight transport (approximately 59 %).

It is also seen from Figure 7 that the unit consumption varies substantially across modes. Freight transport by light duty vehicles (See the left Y-axis in Figure 7) uses much more energy compared to the other modes – actually it uses 10 times more energy per ton-kilometre.

Figure 7



Source:

Odyssee database 2000.

Notes:

1) Unit consumption of Light Duty Vehicles should be read at the left Y-axis and the unit consumption of trucks, railway and total freight should be read at the right Y-axis.

2) Total Freight Transport (the thick grey line) includes trucks, LDV and railway.

The development in overall unit consumption and its variation across modes can be explained by two things:

1. The variation in technical efficiency of the different freight modes (litre per 100 km)
2. The variation in utilisation factor of the modes

The increase in energy consumption of trucks from the mid 70's to mid 80's can be explained by lower utilisation factors as a consequence of the payload being virtually constant despite a shift towards heavier vehicles within each category of trucks⁶. It is unclear from the statistics why the energy efficiency of trucks improved during a 5-year period in the mid-80's. However the improvement of energy efficiency of trucks in the early 90's might be explained by the Danish governments decision - in 1992 - to stop reimbursing energy- and CO₂ taxes for trucks. This means an increase in real diesel prices, which probably made the freight companies more aware of energy prices, utilisation factors and energy efficient transport.

⁶ Lee Schipper et al: "Energy Use in Denmark: An International Perspective". Lawrence Berkeley Laboratory, Berkeley, California, 1992; Road Directory of Denmark: "Tal om vejtrafik." (Report No. 156, in Danish). Copenhagen, 1998.

The very high unit consumption of light duty vehicles can be explained by very low utilisation factors since some of these modes are often used to transport very few tonnes⁷. Statistics shows that the average payload of light duty vehicles is around 100 kilo⁸.

Another explanation is that a substantial number of light duty vehicles are used for passenger transport and mixed uses, which means that they are used to produce passenger kilometres. According to a study carried out by Statistics Denmark⁹, only about 25 % of traffic with these vehicles are for freight purposes, 25 % is for passenger transport and the remainder 50 % is mileage for mixed uses¹⁰. Half of the 25 % freight traffic with light duty vehicles and small trucks (2-6 tonnes) is low weight services such as distribution of letters and parcels. However in Denmark there is no information about the number of passenger kilometres made by light duty vehicles in the category 2-6 tonnes. This mixed use influences the indicator for light duty vehicles and it might be better not to include it in the analysis. However this problem can not alone explain the factor 10 difference and the fact is that light duty vehicles are less energy efficient for freight transport than other modes. Therefore it is important to exclude them from trucks when calculating freight transport indicators.

The improvement of the energy efficiency of freight trains from 1980 onwards can to a large degree be explained by a reduction in the number of short freight-trains (notably small package transport) and a general effort to increase the number of wagons per train.

5. Factors behind the Development in Energy Consumption

In trying to understand and explain the development in energy consumption it can be useful to decompose the overall energy consumption by overall activity, mode-structure and overall energy efficiency as follows:

Activity:	Passenger kilometres and ton-kilometres
Mode-Structure:	Share of passenger-kilometres travelled by each transport mode (passenger-kilometres with car, bus, train) and share of ton-kilometres travelled by each mode.
Overall Energy efficiency:	Energy consumption per passenger-kilometre for each mode and energy consumption per ton-kilometre for each mode.

The decomposition analysis consists of calculating 3 hypothetical development scenarios of the development in energy consumption. The first scenario shows how energy consumption would have developed if only the activity level is allowed to vary over the period while energy efficiency and modal split is held constant. The result of this scenario shows whether the activity level has had an influence

⁷ For example some of the light duty vehicles are only used to transport tools for workmen.

⁸ Statistics Denmark, 2000, "Transport 2000".

⁹ "Varebilers og små lastbilers årskørsel 1997" (in Danish). Danmarks Statistik, Statistiske Efterretninger Samfærdsel og Turisme 1998:47.

¹⁰ Traffic is defined as vehicle-kilometres.

on the development in actual energy consumption. The second scenario shows how energy consumption would have developed if only the mode-structure is allowed to vary, and the result shows whether the change in mode-structure has had an influence on the development in actual energy consumption. In the third scenario only the overall energy efficiency varies and this will show whether this factor has had any influence on actual energy consumption.

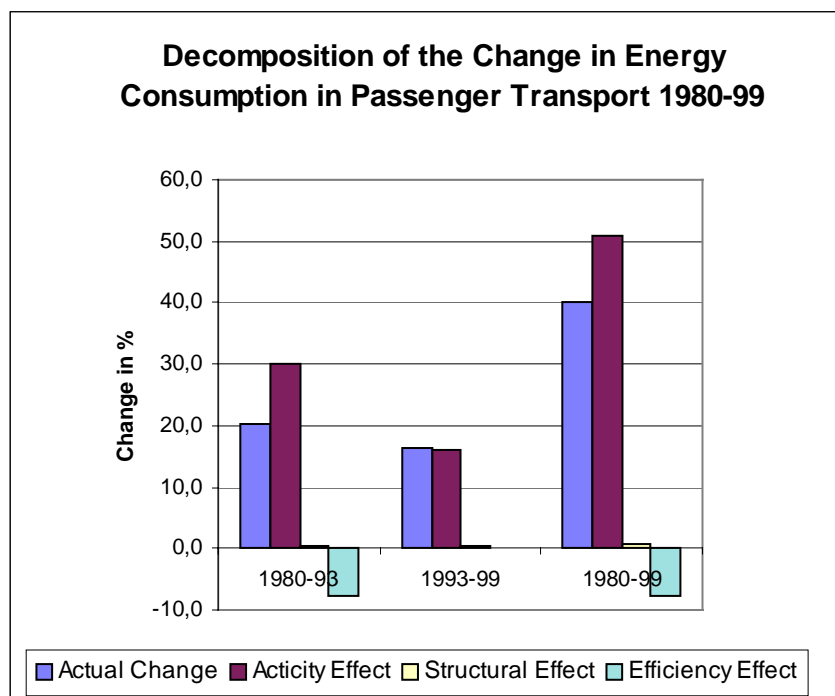
The decomposition analysis is based on the Divisia method which is the method used in the Odyssee project (see the Odyssee methodology paper).

Decomposition for passenger transport

Figure 8 shows the result of the decomposition analysis for passenger transport. The 4 columns to the right show the results for the whole period 1980-99, and it is seen that the actual energy consumption for passenger transport has increased approximately 40 % in this period. The other curves show possible explanations of the development in energy consumption.

It is seen from Figure 8 that energy consumption would have increased even more – by + 50 % - if only the activity level had changed over the period while modal split and energy efficiency were at a constant 1980- level. However the last column of the figure shows that energy consumption would have decreased if only the energy efficiency had changed over the period while at the same time activity level and modal-structure stayed constant at 1980 level. There has been no effect from changes in modal structure.

Figure 8



Source: Odyssee database 2000.

Notes: The analysis includes energy consumption of cars, busses and rail.

It can be concluded that the development in transport demand (passenger km) has had a dominating influence on energy consumption. However the improvement in overall energy efficiency has had some reducing effect on total energy consumption.

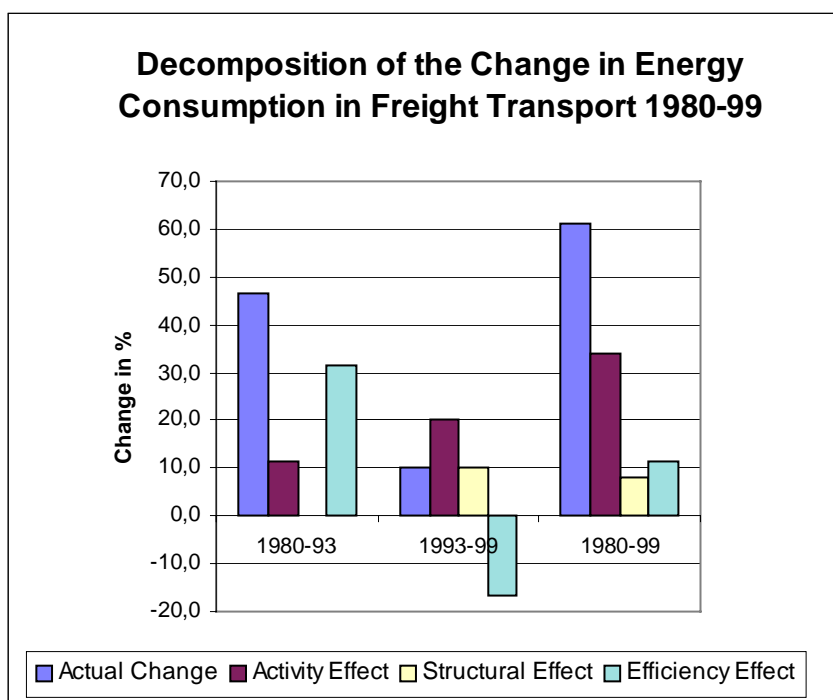
The same conclusions are true for the two sub-periods in Figure 8, however the efficiency effect is only obtained in the first period 1980-93.

Decomposition for freight transport

Figure 9 shows the result of the decomposition analysis for freight transport in the period 1980-99. When looking at the total period it is seen that actual energy consumption for freight transport has increased 60 % in this period. The other columns of the graph show possible explanations of the development in energy consumption.

The analysis provides a different picture than for the passenger transport. In freight transport all 3 factors have made the energy consumption increase. The activity effect is not as dominating as in passenger transport, but it is still an important factor in explaining energy consumption. However in freight transport another important explanation of the increase in energy consumption is the overall increase in energy consumption per ton kilometre (see also section 4). One further difference from passenger transport is the effect from the change in modal-split (the increasing share of LDV) which has made the energy consumption increase.

Figure 9



Source: Odyssee database 2000.

Notes: The analysis includes energy consumption of trucks, light duty vehicles and railway.

It is also interesting to look at the two sub-periods since it shows quite different results. In the first period from 1980-93 there was a negative effect from the development in overall energy efficiency and

in the second period after 1993 there has been a positive energy efficiency effect, since the overall energy efficiency started to improve during this period.

There can be several explanations of the improvement in energy efficiency (energy per ton-kilometre) from 1993-99:

- One explanation is the higher real taxation on diesel fuels for trucks and LDV. In 1992 the government stopped reimbursing energy- and CO₂ taxes for trucks, which made the freight companies more aware of energy prices, utilisation factor and energy efficient transport.
- Another explanation might be the high activity level in freight transport since 1993. In periods with high activity levels it is easier to use the existing vehicle fleet more efficiently¹¹.
- Also the type of goods being transported can be an explanation since higher value goods may induce the freight companies to pay less attention to utilisation factors (load factors).

For further explanations see section 4 about energy efficiency in freight transport.

¹¹ More load in each vehicle means less energy consumption per tonkm.