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Energy Savings in the Transport Sector

ENERGY SAVINGS IN THE TRANSPORT SECTOR

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This is the twenty-fifth publication in a Technical Report Series which aims to meet the needs of a wide range of government officials, industry managers, and environmental protection associations, by providing information on the issues and methods of environmental management relevant to various industrial sectors.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD

The transport of both people and goods is an essential human activity and has a critical input to social development, national and global economies. However the environmental costs of this energy-intensive sector are also critical and far-reaching: the transport sector now accounts for more than half of world oil consumption. It generates 20 per cent of anthropogenic greenhouse gas emissions and has significant impacts on land use, on surrounding eco-systems, on waste generation, noise and air pollution.

While all modes of transport have environmental impacts, by far the most important is road transport which carries 70 per cent of all goods and people. Considerable progress has been made in the past 25 years in curbing emissions from motor vehicles and improving fuel efficiency. But this progress has been outstripped by the rapid and continuing growth of the sector. By the year 2015, it is predicted that the world's roads will be filled with more than one billion motor vehicles. Greater numbers of cars in urban centres has led to traffic congestion with consequent waste of fuel, higher emissions and concentrations of harmful air pollutants at levels which frequently exceed public health guidelines and standards.

Clearly, much greater progress is needed to bridge the gap between increasing transport demands and the goal of sustainable development. This challenge can though be met and at acceptable costs – through technical measures along with planning, policy and management options.

This report examines transport systems and focuses particularly on road transport. It seeks to provide decision-makers in governments at national and local levels, as well as managers of transport systems, with key elements of the information they need to design or improve energy-efficient transportation systems.

Part I of the report provides general information on trends in the transportation sector and highlights the preponderant and growing role of road transport in countries throughout the world. It demonstrates the need for the rational long-term management of transport and presents some of the policy and management tools available.

Any transport policy will have far-reaching social and economic impacts and must be adapted to the specific circumstances of a given country – from its geography and demography through to its institutions and financial means. This report presents practical case studies to illustrate the energy savings that have been achieved through different programmes in developed as well as developing countries.

Part II concentrates on the road transport sector and details some of the basic technical steps that can and should be implemented in all countries, by national decision-makers and corporate managers as well as the private motorist. Various technical measures are explored – from town planning and traffic control systems, to vehicle design, through to maintenance and individual driving skills.

It is clear that while technological progress can go a long way towards achieving greater energy efficiency, the general public and corporate users have a considerable role to play through their driving behaviour as well as through their choice of means of transport. Government decision-makers must assure that the public is offered a real and rational choice and, through planning and infrastructure, encourage greater public and commercial use of cleaner, alternative transport systems.

Agenda 21, adopted in 1992 at the United Nations Conference on Environment and Development – the "Earth Summit" – calls on governments to review existing transportation systems and to undertake more effective design and management of traffic and transport. UNEP hopes that this report will encourage all those concerned by transport development to effectively implement Agenda 21 and that they find in these pages some of the information they need to act.

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GLOSSARY

toe = ton of oil equivalent, the energetic unit used in this report.
1 toe = 41.868 10^9 joule.

goe = gram of oil equivalent.
1 goe = 41.868 10^3 joule.

pkm = passenger . km
(1 passenger transported 1 kilometre).

tkm = ton . km
(1 ton transported 1 kilometre).

Energetic intensity

The ratio: $$\frac{\text{Energy Consumption}}{\text{Gross National Product}}$$

Unit energy consumption In the transport sector, the ratio:

For passengers: $$\frac{\text{Energy Consumption}}{\text{Number of Passengers Transported x Distance}}$$

For goods: $$\frac{\text{Energy Consumption}}{\text{Weight Transported x Distance}}$$

PART I

POLICY AND MANAGEMENT TOOLS

1. THE NEED FOR EFFICIENT MANAGEMENT

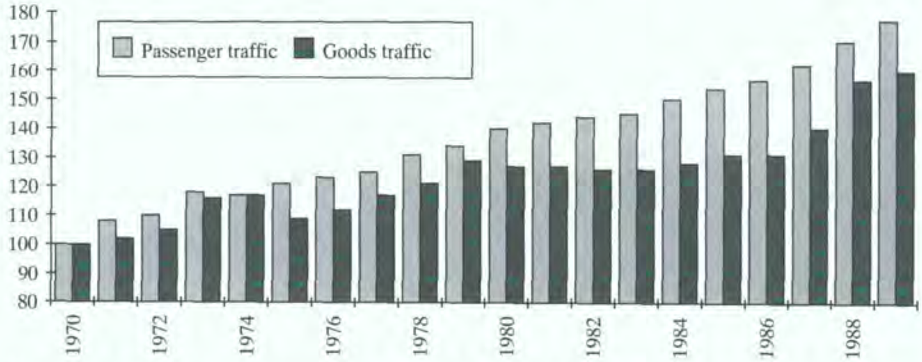
Transport, the life-line of all other industry sectors, is vital to the economies of all countries, whether industrialized or developing. Its often major political implications can sometimes lead to the continuation of practices which are not necessarily consistent with rational economics and energy control, but which respond to more immediate concerns regarding society, national unity or industrial development.

1.1 Growing Demand for Mobility

There is a growing demand for mobility in most countries which can be accounted for by:

- population growth;
- rising living standards, which tend to bring about an increase in the frequency and length of personal travel and in the volume of goods transported;
- increased urbanization and in particular the expansion of big cities, which creates a need for urban transport;
- increased accessibility to transport, also observed in low-income countries where, for example, a rural exodus leads to constant to-and-fro movements between cities and villages; and
- evolutions in industrial practices which increase demand for goods transport (flexible stocks, express deliveries, etc.).

Figure 1: Evolution of traffic levels in Europe



Passengers: based on 17 countries – Goods : based on 16 countries

Source: CEMT (Conférence Européenne des Ministres des Transports).

1.2 The Predominant Role of Road Transport

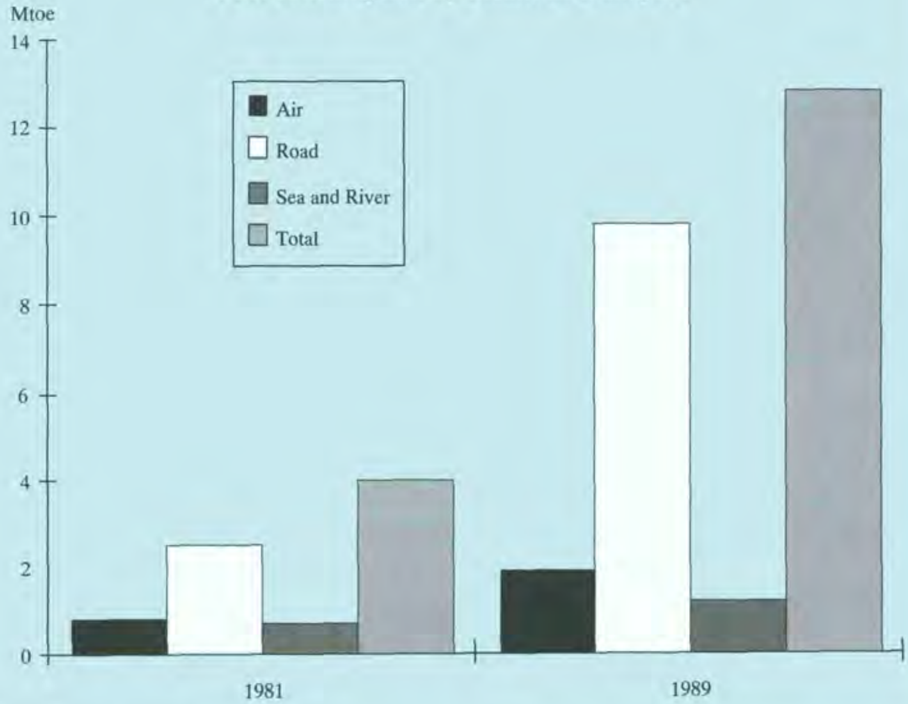
The demand for mobility, including all types of transport and transport systems, is therefore generally on the increase. But, as shown in Appendix 1, this increase chiefly concerns road travel, a phenomenon widespread throughout the world in all developed as well as developing countries. An interesting case study carried out in South Korea provides a helpful and detailed illustration of this trend.

Growth in road transport: the case of South Korea

Within the South Korean transport sector, the share of road transport in total energy consumption has significantly increased over recent years. At the beginning of the 1980s, road transport accounted for 60 per cent of total energy consumption. Since then, the car and motorcycle fleet has increased six-fold, an average annual growth rate of more than 22 per cent. Between 1986 and 1989, this growth more than doubled, increasing by more than 30 per cent a year. While in 1980 there were only 250,000 cars and 200,000 motorcycles, the fleet increased respectively to 1.6 and 1.2 million in 1989. This exceptional development can largely be explained by the rapid expansion of the automobile sector since 1984.

The relative and growing importance of road transport as well as the growth in numbers of cars is clear when it is compared to rail transport of goods and passengers.

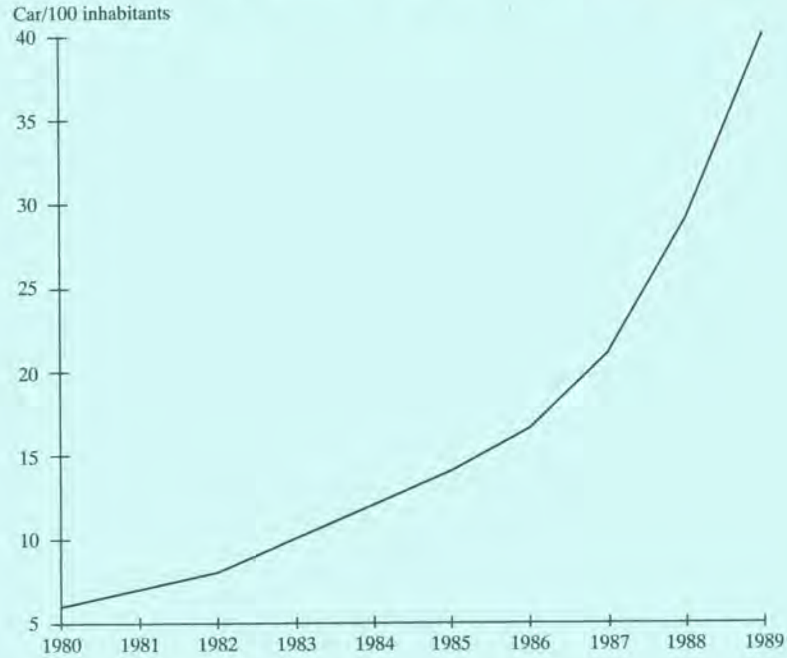
Fuel consumption by means of transport



Source: ENERDATA

There is a general and growing tendency for people to equate the private car with freedom. In South Korea, as elsewhere, the sudden increase of automobile transport corresponds to an increased public desire to own a private car.

Growth in numbers of cars per inhabitant



Source: ENERDATA

To this growth in private cars must be added an increased fleet of trucks and buses whose numbers multiplied four-fold between 1980 and 1989 (an average of 17 per cent growth per year).

In terms of passengers per kilometre travelled, the share of rail transport has declined over the last 20 years in favour of more flexible and rapid bus transport. While rail transport stood at 33 per cent in 1970, it decreased to 23.5 per cent in 1980 and 18.5 per cent in 1987. At the same time, bus transport has increased its share from 66 per cent in 1980 to 87 per cent in 1987.

For goods transport, the trend of declining rail transport is similar and even more marked. While it accounted for 60 per cent of traffic in 1970, this share fell to 39 per cent in 1980 and to 25 per cent in 1987.

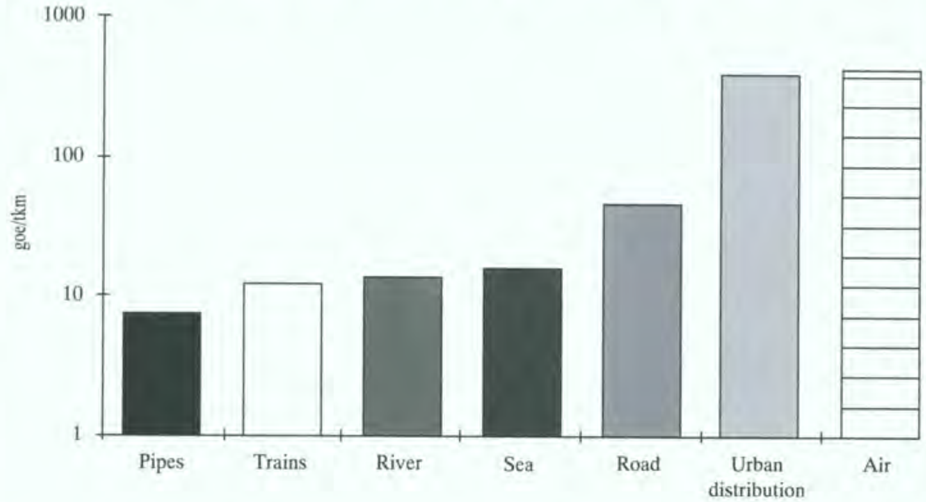
For ten years, total railway traffic (goods and passengers) has been slowly increasing, by 2 to 3 per cent annually. Total traffic growth has however favoured roads. The case of South Korea illustrates a well known phenomenon characteristic of the evolution of transport systems throughout industrialized countries.

1.3 The Energy Efficiency of Different Means of Transport

From the point of view of petroleum product consumption, this relative and rapid growth in road transport means that we are meeting increased transport demand by what could be considered the most unfavourable means. In addition to the relative growth of road transport, it is also important to consider its relative level of energy intensity as compared to other modes of transport.

As shown by the following figures, the highest energy consumption is most often found in the most commonly used systems for both passenger (cars) and goods transport (trucks). It is therefore clear that road transport must be given a high priority within the framework of an energy saving policy.

Figure 2: Unit of energy consumption by mode of freight transport



Source: INRETS (Institut National de Recherche sur l'Environnement, les Transports et la Sécurité)

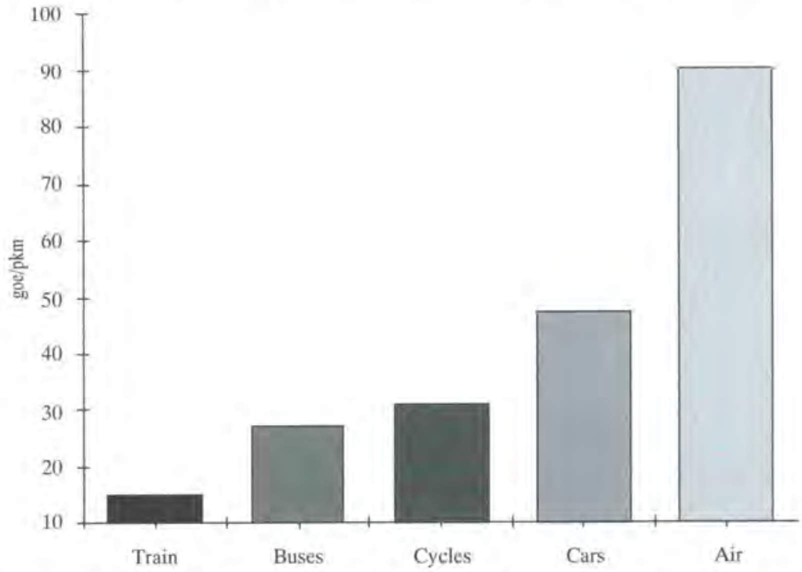
It should be noted that these figures represent absolute values with no operational interest: they are provided to give a comparative view of the share of different modes of transport and are the result of theoretical calculations and measurements in laboratory conditions, based on the most recent vehicle models in common use in developed countries.

This concept may best be illustrated in terms of energy consumption for passenger transport on a global basis (see Figure 3). Were an average car, built during the last five years, loaded with five passengers and driven in nominal conditions, compared to a loaded bus driven in similar conditions, energy per person transported would be 50 per cent less using the bus. It must be borne in mind that this figure would change were we to compare the bus to a car carrying only one passenger (the driver), a common scenario.

The figures must therefore be used carefully, taking into account the local conditions of the country concerned (geographic and demographic, as well as the age of vehicles, reliability and quality of roads and materials, specific behaviour patterns of the population, etc.).

As the following section demonstrates, trends in the transport sector have enormous energy implications in terms of fuel consumption at country level.

Figure 3: Unit of energy consumption by mode of passenger transport



Source: INRETS (Institut National de Recherche sur l'Environnement, les Transports et la Sécurité)

1.4 Energy Implications

Energy demand in the transport sector has quite the same characteristics throughout the world. In this it differs from other industry sectors or from the residential and service sectors.

From the point of view of energy consumption, four aspects of the transport sector merit detailed analysis:

- Energy demand in the transport sector is supplied almost exclusively by petroleum products.
- The transport sector accounts for more than half of world oil consumption.
- There is a constant increase in energy consumption in the transport sector.
- At present, there is low potential for the use of substitute fuels.

1.4.1 High consumption of petroleum products

As shown in Table 1, except where electric-powered transport systems can be used[1] (electrified railway networks, underground railways, tramways and trolley-buses), petroleum is the sole energy source in the transport sector. **In all countries, the transport sector is over 95 per cent dependent on hydrocarbons.** This is especially the case in developing countries which have even less electrified transport than industrialized countries.

1. In any case, electricity is often produced with hydrocarbon fuel.

Table 1: Consumption of different fuels in the French transport sector

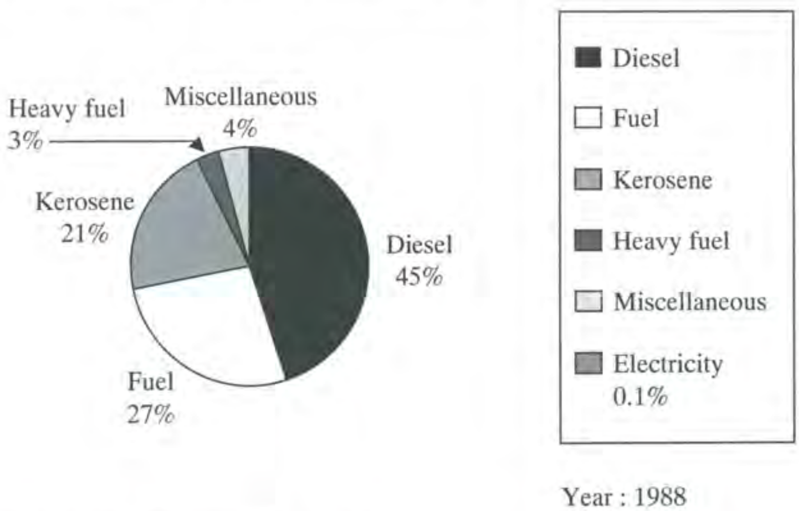
Product	Mtoe 1973	1985	1990
Kerosene	1.9	2.7	4.0
Usual fuels for cars	16.5	19.2	19.1
Diesel	6.6	10.6	17.5
Heavy fuel	4.6	2.0	2.1
Domestic fuel and LPG	1.4	1.0	0.8
Total petroleum	31.0	35.4	43.5
Electricity	1.4	1.7	1.8
Total	32.4	37.1	45.3
Total - All Sectors	152.4	158.6	179.8
Total Petroleum Products All Sectors	90.5	65.0	73.6

Source: CPDP (Comité Professionel du Pétrole)

It should moreover be noted that this demand is chiefly for light petroleum products (ordinary and premium-grade petrol, diesel or light fuel oil), with heavier products acceptable for maritime transport only. This partly explains the disequilibrium in worldwide refining which increasingly focuses on the production of highly refined cuts, with the heavy cuts as an inevitable residue. **The transport sector can thus be characterized as a 'petroleum monoculture'.**

These statistics, which are similar for all industrialized countries, also show that energy consumption in the transport sector is dominated by the road transport sub-sector, responsible for 80 per cent of total energy consumption. The same also holds true for developing or newly industrialized countries such as Côte d'Ivoire, South Korea or Thailand (see Figure 4).

Figure 4: Consumption of different fuels in the Thai transport sector



Source: Ministry of Transport (Thailand)

In most African countries, the transport sector is responsible for more than 70 per cent of petroleum product consumption. In Cameroon, the ratio was 71.02 per cent in 1988. In that year, the country consumed 558,900 tons of oil products as shown in the following breakdown.

Table 2: Oil product consumption in Cameroon (in 1988)

Transport mode	Consumption (metric tons)	Per cent
Road	436,600	78.0
Air	57,950	10.4
Sea	51,210	9.2
Rail	13,140	2.4

Source: Final Report Energetic Plan of Cameroon, December 1990

1.4.2 Transport accounts for over half of world oil consumption

The figures clearly demonstrate that while the transport sector represents only 30 to 35 per cent of total energy consumption, it accounts for 45 to 55 per cent of total hydrocarbon consumption. This is the case in both industrialized countries (such as European countries) as well as in newly industrialized or developing countries.

Table 3: Worldwide fuel consumption by road and air transport – Per cent of petroleum product demand by region

	1980		1985		1989	
	Mtoe	%	Moe	%	Mtoe	%
World	989	42	1,069	47	1,226	50
OECD	694	47	732	53	848	57
Asia	93	28	117	33	145	37
Latin America	77	46	79	47	92	49
Africa	27	49	34	50	30	48
Other	98		106		111	

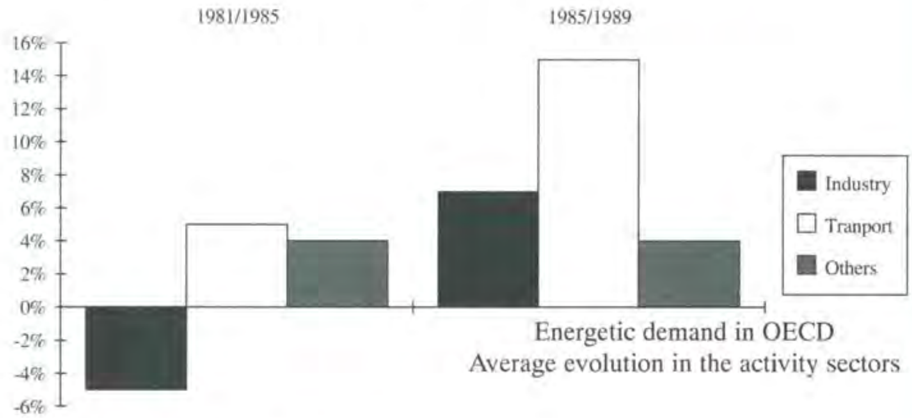
Source: ENERDATA

1.4.3 Trend towards increased energy consumption

There is a strong trend in the transport sector towards a constant increase in energy consumption. This obviously exacerbates the effect of the factors already discussed. The transport sector, unlike industrial and tertiary sectors, structurally generates increased energy consumption. The following figures and tables provide examples of the mean annual growth rate in energy consumption in the transport sector for various countries over the period of 1980 to 1990, and by sector.

During the period 1981 to 1985, following the second energy crisis, while energy consumption decreased in the industrial sector, it continued to increase in the transport sector which realized the highest growth rates. This trend was confirmed during the period 1985 to 1989, clearly establishing transport as the most important sectoral consumer.

Figure 5: Trends in average energy demand in OECD countries



Source: International Energy Agency

Table 4: Ten highest national growth rates in transport sector energy consumption (1985 to 1989)

		Per cent/year
1	Philippines	35.7
2	Burkina Faso	22.1
3	Iran	21.8
4	South Korea	15.2
5	Thailand	14.0
6	Pakistan	11.4
7	Ethiopia	10.9
8	Taiwan	10.9
9	Hungary	10.5
10	India	9.7
	World	3.4
	OECD	3.6

Source: ENERDATA

This trend to increased energy consumption in the transport sector is due to numerous factors. Among others, they include:

- Population increases with a consequent growth in travel frequency and transport volumes.
- Rising standards of living (on average) which tend to increase travel frequency and distances. A corollary to this is an increase in the level of household car ownership and a trend to more powerful cars.
- The predominant role of road transport which has the lowest intrinsic energy efficiency.
- Bad quality of roads in many developing countries which contributes to increased energy consumption.

- Constant urbanization which further degrades the conditions of urban transport.
- In most cases, poor organization of goods transport networks with, very often, empty trucks returning to their point of departure.
- Poor understanding and knowledge on the part of the car user regarding his own energy consumption.

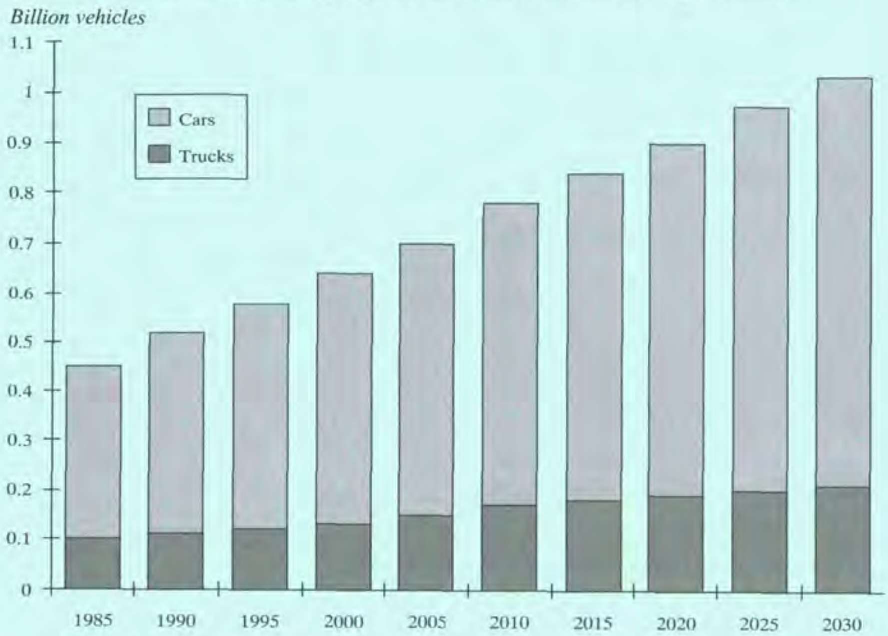
In Europe, this trend, although attenuated by energy control policies carried out since 1974 in a few countries, is clear. While total petroleum consumption is decreasing in absolute value, as is the consumption of fuel oils generally (heavy and domestic fuels), consumption of motoring fuel has continued to increase. The statistics available for 1990 show no slowdown in the trend, but indicate rather quite the opposite. This may be seen as the result of the inadequate policies followed through in industrialized countries.

Past and future trends in transport

The worldwide car fleet has grown from 50 million vehicles in 1950 to more than 400 million in 1993. A car fleet of more than one billion in the year 2030 has been forecast using two methods, one a straight linear regression, the second a regression of per capita trends multiplied by population trends. Though overall transport has increased dramatically since 1950, the share of mass transit has stagnated or, as in the case of buses, has fallen rapidly.

Car ownership is heavily skewed throughout the world. Sixteen per cent of the world's population – in North America, Europe, Japan and Oceania – produce 88 per cent and own 81 per cent of all automobiles. The USA alone produces 25 per cent and owns 35 per cent of the world's cars, and has a level of car ownership more than double that of Japan, Spain and Denmark. As markets saturate in North America and Western Europe, car manufacturers are eyeing markets in developing countries where car ownership is extremely low: 1000 times less in China than the USA, and 250 times less in India.

Worldwide vehicle projections (based on linear regressions)



Source: Michael P. Walsh

1.4.4 Low potential for substitute fuels

In these circumstances, none of the petroleum substitutes so far envisaged would meet the scale of the problem. The option of electrical systems (if electricity production is mostly based on hydraulic or nuclear production) is hindered in developing countries by the need to finance the requisite infrastructure.

The use of oxygenic fuels, such as methanol, ethanol or other more complex molecules produced from biomass or coal, pose problems of procurement for many developing countries. The problems are different than those posed by hydrocarbons procurement, and are no easier to resolve. These fuels can be produced from several sources: various agricultural products, wood, or coal. To do so, a country must first have these available resources, a transformation station must be installed and, thirdly, the cost of the enterprise, at least in the long term, must be competitive with the cost of importing fuels. Few countries are ready to make such a technical and economic gamble. Brazil's ethanol scheme (produced from sugar cane) appears difficult to transfer. The true economic impact of this experience, as regards both the actual costs of the products obtained and the indirect effects, such as speculation on farming lands or the disappearance of food crops to the benefit of sugar cane, must be examined in far greater detail. In the medium term, it does not look as if oxygenic fuel from biomass, regardless of its source, can compete with petroleum-based fuels.

While methanol produced from natural gas is competitive, it can only be substituted in a very marginal manner (mixed with petrol up to a proportion of 10 per cent) or in specially adapted cars.

Finally, the introduction of substitute fuels, such as alcohols or plant-based fuels, poses the problem of the technological adaptation of the vehicle fleet. This will certainly not be easy in developing countries which are until now for the most part dependent on imports for their supply of vehicles.

The use of electricity for passenger cars is another idea which has been explored for many years, but with little success so far. The limiting factor is the capacity of electric batteries. In spite of recent progress with lead-acid and nickel-cadmium alkaline batteries, they still do not provide adequate vehicle autonomy (about one hundred kilometres). They require excessively long recharging times (eight to ten hours), unless the electric network allows for the implementation of short recharging systems. All of these factors make such vehicles unsatisfactory to operate, except in specific urban conditions. Furthermore, it must be noted that electricity is produced in power plants which more often than not consume fossil fuels, the source of considerable polluting emissions.

Table 5: State-of-the-art electric batteries

Type	State of Development	Wh/kg
Lead - Sulphuric acid	Available	40
Ni-Fe (Nickel - Iron)	Abandoned	—
Ni-Cd Potassic solution	Available but still in development to lower price	65
Ni-Mh (Nickel – Metallic hydrocarbons) Potassic solution	Research and development	80
Li(C)-OM2	Research and development	140
Li-Al + S_2Fe	Research and development	150
Na-S	In development	180

There are other ideas which could be considered, both to completely eliminate the use of hydrocarbons in certain transport sectors, as well as to diversify their forms of use. For example, in recent years the use of gas generators in the field of road transport has undergone extensive testing in France. A great deal of research and development have gone into wood-fueled systems to improve their practical performance in a large firm, the Calberson Company. However, no satisfactory solution seems to have been found to the technical and economic problems encountered. These include: loss of payload capacity due to the space required by the system and the fuel supply; tricky control problems; gas purification difficulties which soon result in system fouling and degraded performance; etc. Were this system to be developed in future, it would in fact be more suited to river navigation, where it is easier to employ the technical facilities required for gas purification.

The use of liquefied petroleum gas (LPG) by vehicles is not really a substitution. It is a confirmed technique, economical for a country with butane and propane gas resources (recovery of gas in oil-fields, for example). It is especially appropriate for use in the industrial sector.

Finally, for countries with gas resources (domestic or imported), the compressed-gas solution is technically and economically viable for vehicle fleets especially in urban environments. Pilot projects, which have shown encouraging first results, are under way in many developing countries.

Naturally, other technical possibilities remain to be studied which may have industrial applications in the future (for example, hydrogen as a fuel) but in the medium term (fifteen years), they will probably not have a significant impact on transport sector energy consumption.

2. MANAGING ENERGY IN THE TRANSPORT SECTOR: GENERAL ORGANIZATION

2.1 Establishing a Decision-Making Institution

Since, as we have seen, the transport sector is now and will remain the largest energy consuming sector throughout the world, almost completely dependent on petroleum products supply and consequently responsible for a large part of total atmospheric pollution (see Appendix 3), energy savings in this sector is essential.

Decisions about trips and choice of transport mode have a major impact on the level of infrastructure use. This is especially true in urban areas where public traffic space is reduced and subject to congestion.

Traffic and congestion (measured by average speed) have an important effect on consumption and pollution balances (see Appendix 3). However, as has been shown throughout the world, additional road building generates increased transport demand.

It is possible though to achieve significant results in reducing energy consumption in this sector. Taking into account the experiences described, and the observations and ideas presented in Appendix 3, it is recommended that developing or newly industrialized countries build an action strategy along two lines:

- **A long-term strategy** on the basis of rational organization of transport and within the framework of a multimodal approach. The objective of such a strategy will be to transfer road transport to other modes of transport (to railway in the case of goods and to collective transport in the case of passengers). This type of organization is essential in the design and establishment of an energy saving policy based on control of unitary consumption. In this way, optimum use can be achieved for every mode of transport and each mode will be able to provide the best service with minimum fuel consumption.
- **A short-term strategy** including specific actions to reduce energy consumption of the different transport modes used in a country and, especially, of road transport. While a long-term strategy will have the greatest global effects, it is also more difficult to implement. Good short-term measures can however show concrete and effective results in the first stages of an energy strategy and are for this reason developed in more detail in Part II.

In order to clearly define an energy saving policy and to properly organize the actions to be undertaken, a specific, coordinating structure must be put in place. A specific study is necessary to establish and define the objectives of such a coordinating institution. The relationship between the coordinating structure and the various government departments, and its real means, must be clarified as a prerequisite. This will depend on the political, financial and legal situation of any given country. To analyse these aspects and propose a suitable solution, an external adviser may be of some help, on condition that the adviser can develop comprehensive concepts and not simply copy old ideas that have already failed in Europe and the United States.

2.2 Identifying Data

To organize transport on a national level and to give each transport mode its optimum position, a minimum of information on the true condition of the transport system is necessary. This is all the more important as the persons involved in transport are generally numerous and the system complex. Furthermore, in many countries, few people and managers fully understand the transport system and its energy implications. Some of them are only familiar with specific aspects of the problem and do not have a comprehensive view of the situation.

So, firstly, appropriately detailed data should be gathered concerning the consumption of the various transport systems, including information on how they function. These data may also be collected through the preparation of a nationwide transport plan. While not necessarily designed for energy purposes, such a plan provides the opportunity for gathering a certain amount of information on the sector. It should also be the occasion for introducing statistics on fuel economy into the compilation of data and analysis of the system operation. All data collected should however be stored and treated in a transport and energy database, as explained below.

2.3 Creating a Transport and Energy Database

The majority of developing countries encounter difficulties in properly appraising the operation of their transport systems due to a lack of appropriate information. The information exists but is sparse, making it difficult to design, implement and follow through any fuel-economy measures. **The creation of a transport and energy database is therefore a prerequisite for the implementation of an effective policy.**

The structure of this database must be clearly defined regarding the general lines of variables and indicators so that it will be possible in the future to carry out comparative studies, considering different time periods and for different countries.

Apart from general information on the transport system, there should also be information on flows and fares, the actual consumption of different transport modes and different types of vehicles or means of transport. Wherever possible, input should be included on passenger trends vis-à-vis fare changes in public transport and on car driver trends vis-à-vis changes in fuel prices. Information related to the travel behaviour of the population is also of great interest. It must however be borne in mind that some of this data (such as elasticities) are often difficult to collect or to calculate and, in developing countries, may be subject to rapid change.

The material and human resources needed to create and run such a database can be very modest, considering that a lot of data, in general, already exists in varied forms, within government bodies, local administrations and transport companies. The problem is to identify the information available, to complete it when necessary and to put it into usable form.

To achieve this objective, the active participation of the authorities and companies holding the information must be sought and, to this end, it is desirable that they be involved in the creation of the database from the outset, defining in common its purposes and contents and seeing the advantages which they themselves can draw from it.

Any missing information should be gathered through enquiries. It is a good idea to incorporate questions regarding the reduction of fuel consumption at this stage in the development of a transport plan, thus reducing the need to undertake extensive future enquiries.

2.3.1 Processing data

Data will generally be processed on micro-computers using conventional, inexpensive programmes which present results in the form of graphs and tables.

Particular attention should be given to the dissemination of results to concerned parties and to their layout. It may often be useful to include commentaries which will facilitate understanding and use. The following provides an example of how to create a database of the suggested type for a developing country.

Creating a transport and energy database:
The case of the Thailand National Energy Administration

Starting situation

- *Very incomplete information on the transport sector which accounts for 30 per cent of national energy consumption.*
- *Willingness to take action to control energy consumption in this sector.*

Action

1. *Detailed definition of information to be gathered (according to the ministries concerned).*
2. *Inventory of existing information within authorities and companies concerned.*
3. *Selection of complementary information to be collected.*
4. *Selection of type of presentation.*
5. *Collection of needed information through enquiries.*
6. *Progressive input of data on micro-computers, following personnel training.*
7. *Regular publication and distribution of results*

Personnel involved

- *Two statistician-economists*

Time involved

- *One year*

To complete this database, it may also sometimes be helpful to develop specific analysis tools allowing the description of different evolution scenarios. Such tools already exist: the MEDEE[1] method, for example, is a modelisation method which can evaluate energy demand. 'MEDEE-South', applicable to developing countries, is based on this method.

1. Modelization models such as MEDEE, designed to provide a working framework for forecasting energy consumption according to different scenarios, are also available in the United States.

2.4 Regulatory, Financial and Fiscal Considerations

Within this framework, great attention must be paid to other important considerations such as:

- **Institutional and legal aspects:** specific regulations and laws, regulatory measures such as definition of standardized vehicle consumption, speed limits, or organization of technical checks.
- **Financial aspects:** definition of the means available for developing new activities.
- **Fiscal measures:** in this field particularly many ideas can be studied depending on the political situation of the country, including specific taxes for high-powered vehicles, taxes on fuels, and tax exemptions to encourage fuel savings in transport companies.
- **Price measures:** setting prices relative to fuels, fixing fares for public transport, and road pricing (as in Singapore).
- **Awareness-raising and training schemes** for the general public and within companies, etc.

It is clearly not possible, in the context of this general presentation of energy consumption in the transport sector, to discuss all of the different possibilities in the regulatory, financial and fiscal fields. Moreover, all measures considered must be studied taking into account the specific parameters of the country in question: social and political aspects, the industrial situation, etc. For example, the fiscal issue is very important but is very closely linked to the juridical structure and legal culture of each country. Furthermore, fiscal measures taken in the transport sector may have secondary effects in other sectors depending on each specific country situation. Indeed, certain measures must in some cases be discussed on an international basis.

With these considerations in mind, it could be useful to carry out studies of what has already been done in other countries and what results have been achieved. To carry out such studies, the help of an external adviser may be required.

3. ORGANIZATION OF AN ENERGY-EFFICIENCY POLICY

3.1 Promoting Rational Transport Use

3.1.1 Promoting economic modes of transport at national level

The unit energy consumption of the various modes of transporting people and goods varies to a large degree (see Appendix 1). Developing a mode of transport generally implies the creation of infrastructures which are designed to last for a very long time. This means that decisions regarding different modes of transport will impact fuel consumption for many years. It is therefore necessary to **rationally determine the priority given to railway transport versus road transport, to public transport versus individual transport,** etc. Very clearly, a number of parameters come into play when an individual selects a mode of transport, and the energy parameter is one of them. But, this is relevant only if people are given a real choice and if the adequate infrastructure is in place.

A certain number of developing countries, having made extensive analyses within the context of 'transport plans', were, when faced with energy considerations, forced to give renewed and increasing importance to long-forsaken railways or to particularly economical river transport. Switching from road transport to river or rail presupposes, of course, efforts in terms of quality of service and fare incentives. It is an economic absurdity that existing railways are largely under-used due to a lack of financial, commercial and technical management when road transport, on the same routes, is developing very quickly with undisputedly higher fuel consumption costs.

In the same way, creating specific infrastructures for goods transport, which would allow the use of railway traffic instead of road transport, should be encouraged. Many techniques have been developed to facilitate the loading and unloading of trains or even to transport trucks on special carriages when the problem of the start and finish of trips cannot be solved by train. In addition, manufacturers have to create regional and decentralized production structures to reduce the basic demand for transport.

More generally, the problem is knowing what priority to give to individual car transport as opposed to collective transport. Some countries have enforced very restrictive policies with regard to private cars (very high purchase taxes and annual road taxes, as well as fuel taxes, etc.) with the aim of saving energy and limiting pollution and congestion by controlling fleet growth.

Situations vary, of course, depending on the economic development of a country and its ability to provide alternative means of transport. It follows that this question should be debated at government level to direct the actions to be taken.

While leaving a maximum number of initiatives to the private or semi-public sector, the State can play an essential orientation role through its choices of investment, taxes on vehicles, its policy regarding energy prices, its regulations, etc. **Rational transport includes a number of complementary and coherent actions.**

3.1.2 Promoting collective transport or alternative systems

The promotion of collective transport or alternative systems applies chiefly to newly industrialized countries. In developing countries, the main problem lies in the availability of such transport. Nevertheless, the development and use of collective and alternative transport systems should be encouraged and, in urban areas, consideration should be given to policies which reserve the roadway for collective transport. Many experiments have been carried out in this field in developing and newly industrialized countries. The example of Curitiba, Brazil, described below, should be studied in greater depth in order to transfer the results to other countries.

The type of policy carried out in Curitiba, Brazil, stands in marked opposition to the tendency to reorganize the urban landscape to provide ever more space for the development and use of the private passenger car, a tendency which is generally uneconomic, from both the energy and, ultimately, social point of view.

Urban transport planning in Curitiba, Brazil

The city of Curitiba, capital of the state of Parana in the south of Brazil, saw a five-fold increase in population between 1955 and 1980 and reached 1.6 million inhabitants in 1990. The increase was due to the economic growth of Parana and immigration from poorer regions.

The tramway, which dated from 1887, was replaced in 1954 by a number of automobile transport systems. In 1955, the mayor drew up a public transport programme and, in 1964, requested a group of town-planning architects to carry out a study. One of these architects was the future mayor, Jaime Lerner. The study led to the implementation in 1971 of a plan which is still in place today. It replaced a concentric configuration by linear extensions.

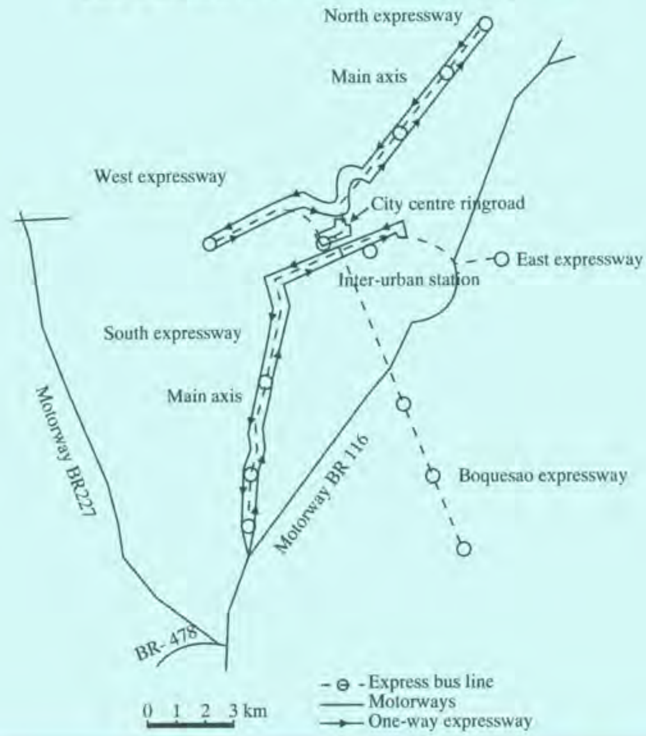
Curitiba's urban policy is based on transport systems. Bus lines are graded. Each of the city's five main axes are designed with a central corridor for high-capacity express buses and two expressways for cars. Tubular bus stations, located at 400 metre intervals, include various facilities: lifts for wheel chairs, lighting, ticket offices and letter boxes are designed for rapid boarding and disembarkation within one minute at peak hours. New bi-articulated buses make up to ten circuits on one-way road and pavement systems. Other bus lines provide feeder, inter-district and suburban lines. Transport planning is entirely coordinated with space planning and ground occupancy rates which decrease with distance from the bus routes.

The positive effect of the coordination of land-use, road systems and public transport systems can be seen in the popularity of the public system: though the number of private cars in Curitiba is high – about 330 per thousand inhabitants – the system carried 540,000 persons every day in 1991.

In 1992 to 1993, given the passenger load carried by the buses and the inability to fund a light underground system, the city authorities decided to purchase bi-articulated buses with capacity for 270 passengers, and to organize 'direct lines' with very few stops (covering two to three kilometres). This met with great success: 20 per cent of present passengers previously travelled by car.

The measures adopted by Curitiba also proved that the city could avoid major and inflexible investments and that an efficient public transport policy could be applied without penalizing car owners.

The Curitiba inter-urban transport system



Of course, it should be made clear that the use of collective transport facilities does not necessarily require a supply structure similar to that prevalent in, for example, European countries. **It is quite feasible to adopt intermediate forms of transport which correspond to local concerns:** collective taxis (which are already in widespread use), car pooling to increase the rate of vehicle occupancy, corporate provision of a large-capacity vehicle to transport employees, etc.

Where collective transport is not feasible, the use of alternative systems – such as cycles or even, where necessary, walking – should be facilitated. However, energy efficiency considerations should not make one forget that some of these systems (two-stroke motorcycles, for example) are often major air and noise polluters, as has been shown in Bangkok, Taipei, Manilla, etc.

From the public's point of view, it is always preferable for a driver, insofar as possible and especially in the case of low vehicle occupancy (driver only), to consider the use of another system:

- Walking, the most economical of all means of transport, and which can replace the motor car for many short trips.
- The bicycle, with its obvious advantages (operating flexibility, speed for short trips) but which requires, in large urban areas, the building of a specific network.
- Motorcycles (light motorcycles and motor-powered bicycles), which have absolute low fuel consumption (average fuel consumption is between two and four litres per 100 kilometres) and are very useful for relatively short trips.

However, such solutions have only localized use and meet only specific needs (e.g., short trips): they are in no way a basis for a transport or energy policy, even though a few countries (China, The Netherlands) do seem to follow this trend.

More broadly then, it is the general organization of transport, and especially passenger transport, that should be dealt with through the acquisition, where financial resources permit, of the most attractive transport infrastructure and through developing supply to match demand in terms both of quantity and quality.

Depending on the case and in order to allow everyone a real choice of transport system, the coordinated development of various transport systems in towns should be promoted. The purpose is not to prevent the use of the car but to encourage switching to other more economical systems whenever possible. Accordingly, urban development should be undertaken to facilitate pedestrian traffic (pedestrian streets, footbridges, etc.), cycles (cycle tracks) and buses (reserved lanes).

3.1.3 Traffic control and collective transport facilities in urban areas

In the 1990s, in OECD countries, **about one third of energy consumption in the transport sector is due to urban transport for passenger travel (of which 10 per cent for public transport) and for urban distribution of goods.**

The rational organization of urban transport therefore has major energy implications, which largely justify the adoption of specific measures to reduce related fuel consumption.

Experience in OECD countries in this field shows that the adoption of traffic control techniques (regulation and synchronization of traffic lights) and, to a lesser extent, operating-aid systems for collective transport facilities can indeed lead to substantial fuel consumption savings in urban environments. These techniques are detailed in Part II, Chapter 1.

3.1.4 Priority for public transport in urban settings

Public transport in towns and cities is generally more fuel-economic than private cars and obviously takes up less space on the roads. It should therefore be systematically developed in an economic way in order to reduce the use of the private car.

If public transport is to win more customers, in the majority of developing countries, capacity must be increased and the quality of services improved. This includes:

- better service to suburban areas;
- increased service frequency;
- improved passenger comfort;
- attractive fares compared to other means of transport;
- enhanced bus speed by the use of reserved bus lanes.

Several major towns in developing or newly industrialized countries have in these ways succeeded in considerably improving their urban public transport and gaining new passengers (as shown above in the example of Curitiba). Certain towns offer bus services with variable comfort and speed for different fares (air-conditioned buses in Bangkok, for example) and have thus won new customers who previously used a private car.

Policy decisions must be made: either to favour the private car by investing considerable sums in more and more costly urban roadways (ringroads, flyovers, urban highways, etc.) which leads to extensive fuel consumption, or to resolutely develop public transport services, at considerably less cost, and on the understanding that the car will always maintain its role as a complement to public transport. Analysis must be carried out in each individual case in order to determine the optimal combination of transport modes.

To implement these policies, **town twinning between developing and developed countries can be very useful for the practical transfer of acquired experience,** with prices adapted to local contexts.

3.2 Controlling Unit Consumption Levels

As we have seen, the first step is to organize the transport system so that less consuming modes of transport are used as often as possible. Once this has been clearly understood and different incentives determined, it is then necessary to consider the different methods suitable to reduce the energy consumption of each mode of transport, taking into account both the nature and the technical characteristics of the vehicles used and the users' behaviour.

3.2.1 General policy

There are many simple lines of action to achieve this:

- Promotion of awareness and information for concerned users and personnel;
- Rational selection of vehicles;
- User education;
- Maintenance;
- Improved equipment.

Table 6 illustrates the scale of fuel savings that can be achieved through these actions.

Table 6: Lines of action to achieve fuel savings

Actions	Percentage of Fuel Savings
Driver training	5 to 15
Fuel accounting	2 to 6
Vehicle improvement	2 to 5
Improvement in productivity	3 to 10
Servicing and maintenance	2 to 6

Note: Percentages are given for actions taken in isolation and should not be simply added up.
Source: ADEME (Agence de l'Environnement et de la Maîtrise de l'Énergie)

The reader is referred to Part II, Chapters 2 to 5 for further details concerning the different technical aspects of these issues.

It must also be noted that, most frequently in the case of freight transport or passenger transport companies, an 'energy manager' should be appointed to ensure implementation. Such a manager will be responsible for organizing and setting up the different phases of an energy saving programme, ensuring that they are carried out, analysing results and adapting the programme as the company progresses (see 3.2.4. hereafter).

3.2.2 Improving the efficiency of a country's vehicle fleet

Consideration should be given to all measures liable to speed up fleet renewal with new vehicles which consume less fuel and are better equipped to facilitate economical driving. Concerning this point, continuing efforts should be made to promote public awareness of the criteria for vehicle selection and priority should naturally be given to those vehicles which favourably influence fuel consumption: less power, small engine capacity, lightweight, and improved drag coefficient (see also Part II, Chapter 3).

3.2.3 Technical centres for vehicle inspection

Variations in the performance of different vehicles are due, as we have seen, to their general state of maintenance, and the condition of ignition and carburetion or fuel injection systems. One vehicle in two consumes 10 per cent more fuel than it normally should, due chiefly to incorrect adjustment of the ignition and carburetion systems.

This excess consumption amounts to a veritable tax on car use which too many drivers levy on themselves, through a lack of knowledge and awareness. A satisfactory solution is the establishment of specialized technical centres to perform the requisite checks on equipment and make the necessary repairs, with an assurance of reliability. Such technical centres must be equipped with the appropriate electronic test and diagnostic equipment, with highly skilled personnel and standardized services in terms of both cost and quality. Part II, Chapter 4 provides a list of recommended interventions to be carried out in these inspection centres.

3.2.4 The energy audit at corporate level

Experience shows that companies in the transport sector can seldom themselves determine an optimum energy saving programme. Faced with matters of everyday operation, market prospection and personnel management, the company has only a piecemeal view of the problems related to fuel consumption control. A good solution is to take outside advice from a qualified consultant with knowledge of the transport world, experience in methods of reducing fuel consumption and competence in the field of equipment proposed by vehicle manufacturers.

A five-point energy audit should be carried out:

1. *Analysis of the company's energy situation*
   This stage involves collecting all available energy data concerning the entire vehicle fleet as well the parameters related to each individual vehicle. This analysis is performed on the basis of information available from the company's

accounting department and by researching additional data, including direct consumption metering by means of meters installed on test vehicles, random inspections performed on fuel tanks, investigation of energy procurement invoices, etc.

All of this data is examined in relation to mileage travelled, tonnage transported, and climatic and road conditions.

2. ***Analysis of the company's management methods***
   The purpose of this step is to assess everyday operating and administrative conditions both in general and, more particularly, those aspects relating to: energy management, energy accounting and metering methods, organization of vehicle routes and turnaround, and the method of prospecting. Freight is naturally one of the aspects analysed at this stage which is a fundamental part of the recommendation process.

3. ***Analysis of the company's technical and human resources***
   This step requires the diagnosis of the technical condition and quality of the equipment available to the company, as well as the level of staff training at all ranks of the corporate ladder, irrespective of the position held. On the equipment level, the analysis focuses in particular on the vehicles (condition, age, suitability for the type of task performed) and the technical conditions of their maintenance (garage, nature of equipment and methods, etc.). On the human resources level, special attention is paid to the driver's ability to apply economical driving rules.

4. ***Analysis of various methods for improvement***
   In this step of the energy audit, it is necessary to make an exhaustive identification of all measures which could be taken at company level, in its technical equipment or its personnel. Such measures may include the setting up of management facilities, equipment with metering or maintenance facilities, vehicle replacement or improvement using suitable apparatus (such as detectors, driving-aid systems, etc.), or defining further training programmes.

5. ***Definition of a coherent overall plan***
   A coherent overall plan of action, adapted to the company's financial resources, should cover all measures which can significantly reduce the company's fuel consumption, at a reasonable cost.

   The advantage of such a plan is its comprehensive nature, providing synergy between the various measures adopted and a gearing effect when the results of various measures converge. In general, such a plan of action is fully coherent only when it is planned over several years, as shown by the example described in Figure 6. It should also be noted that a supervisor should generally be appointed to implement the plan, an 'energy man' responsible for supervising and implementing the various stages of the programme, monitoring their execution, analysing the results and adapting the programme as the company develops. If such a supervisor is not available within the company, an outside contractor, paid on the basis of the results achieved, can also be a good solution.

3.2.5 Implementing an action plan

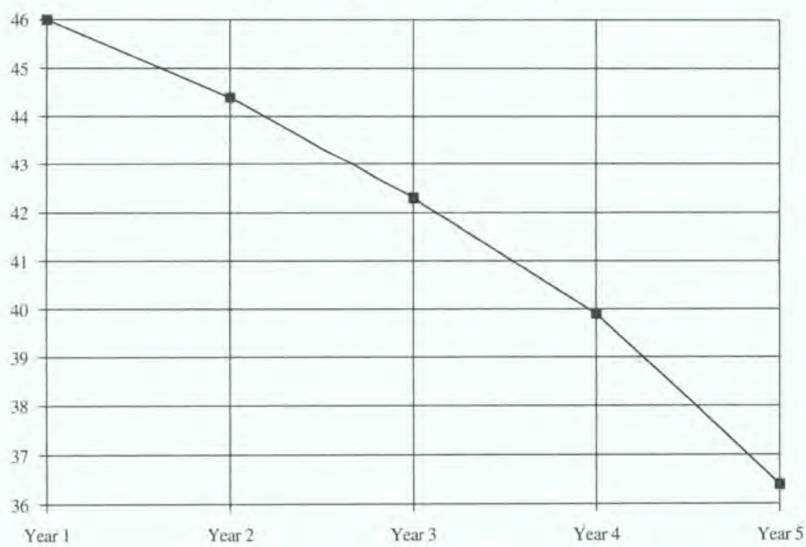
Apart from the need to appoint an energy supervisor to implement, coordinate and monitor the plan of action resulting from the energy audit, all managerial staff must take part, both for their own instruction as well as to assure that the operatives are not left alone to handle the inevitable changes involved in the plan of action.

Figure 6: Energy savings in a freight transport fleet[1] (Total company truck fleet: 277 trucks)

Investments launched after the audit	Number
1. Energy accounting and management	
• badge pumps	3
• consumption counters	196
• chronotachygraphs	277
2. Improvement of vehicles	
• deflectors	196
• driving aids	14
3. Improvement of maintenance	
• oil analysis	20
• injection controllers	2
4. Improvement of productivity	
• thin wall vans	35
5. Training	
• energy manager	1
• drivers	350
• mechanics	32
• managers	90
6. Vehicles	
• replacement in 3 years of old vehicles by modern ones	196

Results: Savings achieved - 1,206 toe, i.e. 18 per cent of initial consumption

Average consumption per vehicle
(in litres per 100 kilometres)



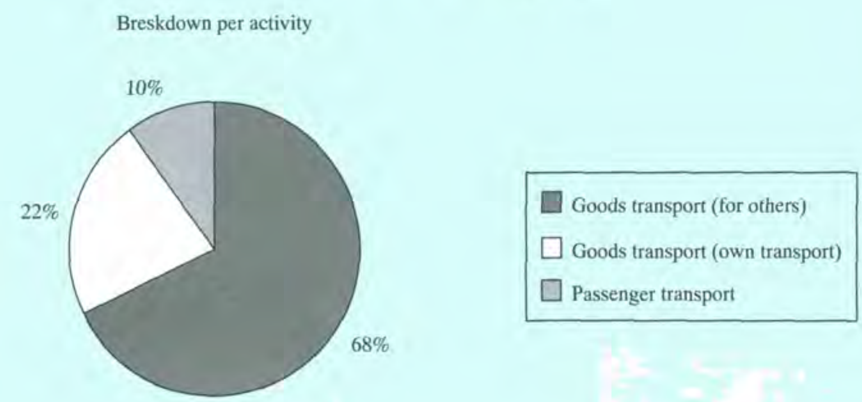
1. *This is real example from a European company still in operation. The programme was carried out between 1981 and 1986.*

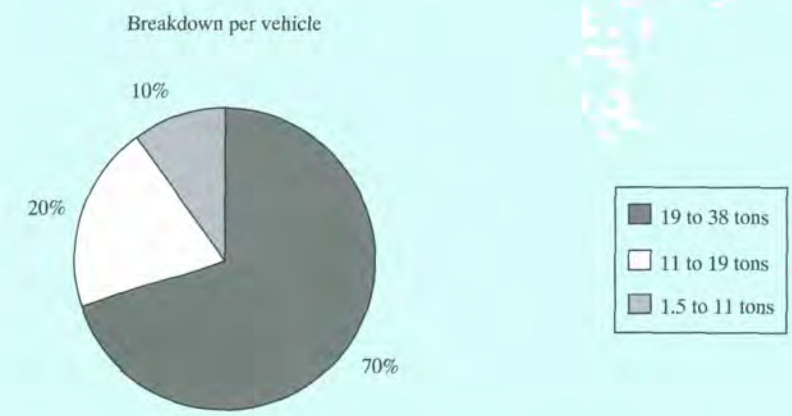
An energy audit policy in France

In France, the concept of energy expertise for road transport fleets was developed in 1982 and extensive experience has now been acquired in this area. Over 700 audits have been performed, covering nearly all the major transport companies in France and half the country's industrial vehicle fleet. These audits have led to the implementation of over 400 programmes of action which, according to the most recent assessment by ADEME (French Agency for Energy Control and Environmental Protection), have resulted in average savings of approximately 18 per cent. The investment made by the companies concerned has been paid off in less than three years.

At the same time, this policy has made it possible to train a body of experts specialized in energy-related matters in the transport sector. Their expertise has already been made available to various other countries (South Korea, Jordan, Niger, Argentina, etc.) through energy audits on these countries' transport fleets.

Results of the audit policy





Results of 400 energy saving programmes

Energy savings achieved during the first year (average):	*9%*
Energy savings achieved at the end of the programme:	*16%*
Payback time:	*2.5 years*

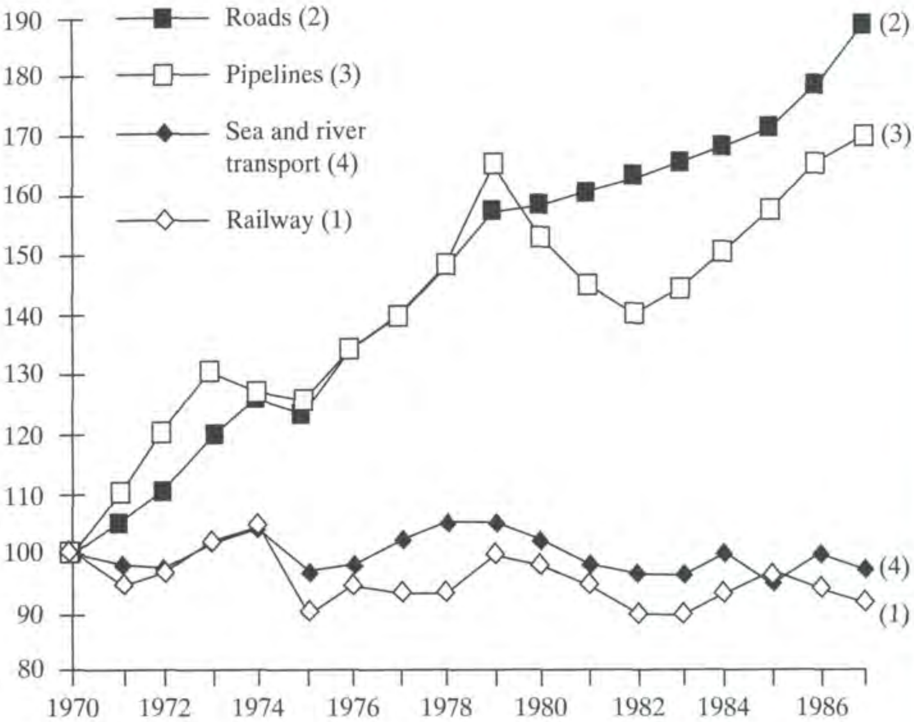
It should be noted that the choice of an energy supervisor is very important as this person must be aware of all of the company's internal problems and the state of mind of its employees, as well as of technical aspects; and he must keep abreast of these questions over a long period of time.

In addition, the expert's recommendations concerning organization, technical upgrading of equipment, and staff training, while they may pose no major problems in industrialized countries, could face particular difficulties in developing countries, due partly to habit and specific behavioural patterns, and partly to difficulties in procuring energy-saving equipment, the availability of specialized training instructors, or of satisfactory after-sales service by the suppliers.

Accordingly, **to enable companies to cut their energy costs, it may prove necessary to launch a national policy to create a favourable economic and technical environment.** In this case, it is highly desirable to appoint a central organization responsible for the design and application of such an overall policy and which could, for example, find concrete applications in specific technical schools.

APPENDIX 1
TRENDS IN EUROPEAN GOODS AND PASSENGER TRAFFIC

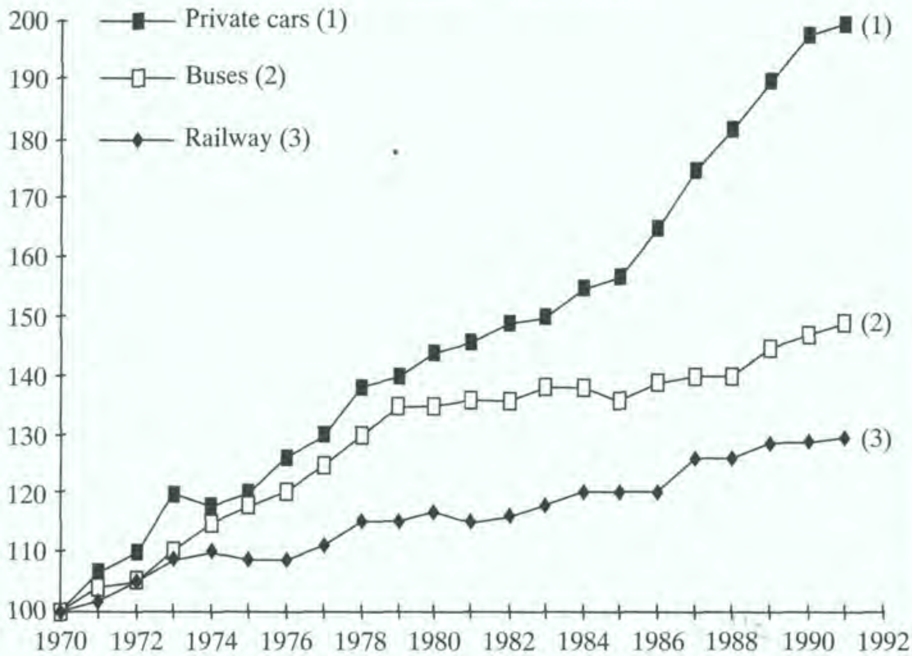
Trends in European goods traffic
1970 = 100 (ton-kilometres)



1. All 18 CEMT countries
2. 15 countries: Germany, Austria, Belgium, Denmark, Spain, Finland, France, Italy, Luxembourg, Norway, Netherlands, United Kingdom, Sweden, Switzerland, Turkey
3. 11 countries: Germany, Austria, Belgium, Spain, France, Italy, Netherlands, Norway, United Kingdom, Switzerland, Turkey
4. 10 countries: Germany, Austria, Belgium, Finland, France, Italy, Luxembourg, Netherlands, United Kingdom, Switzerland

Source: CEMT (Conférence Européenne des Ministres des Transports)

Trends in European passenger traffic
1970 = 100 (passenger-kilometres)



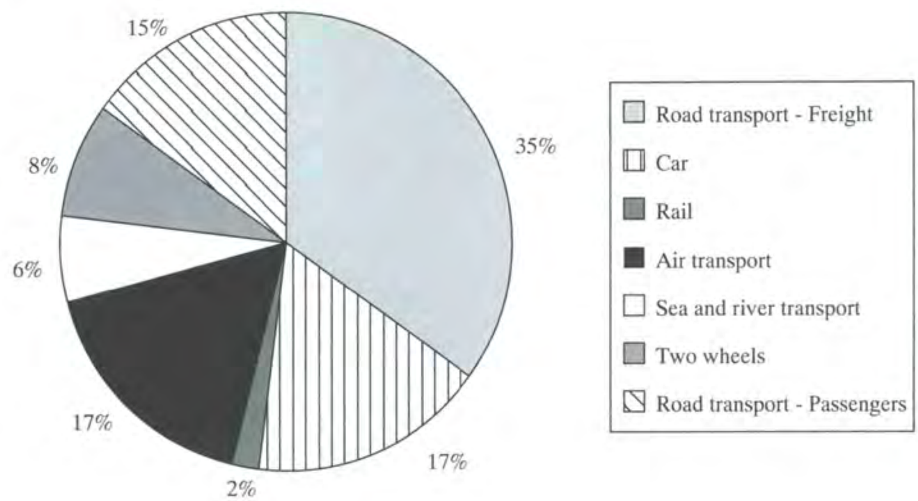
1. *14 countries: Germany, Austria, Belgium, Denmark, Spain, Finland, France, Italy, Norway, Netherlands, Poland, United Kingdom, Sweden, Switzerland*
2. *15 countries: Germany, Austria, Belgium, Denmark, Spain, Finland, France, Greece, Italy, Norway, Netherlands, Poland, United Kingdom, Sweden, Switzerland*
3. *All 18 CEMT countries*

Source: CEMT (Conférence Européenne des Ministres des Transports)

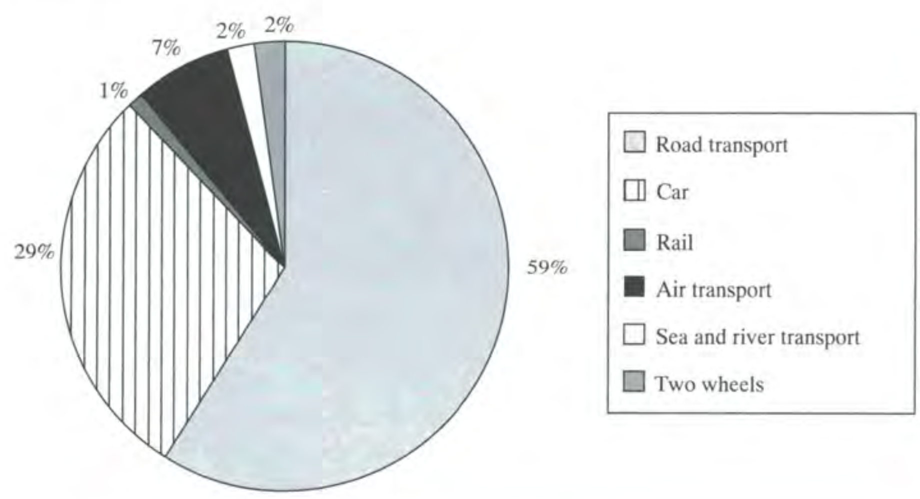
APPENDIX 2

ENERGY CONSUMPTION BY MODE OF TRANSPORT IN THAILAND AND CÔTE D'IVOIRE

THAILAND
Year: 1989



CÔTE D'IVOIRE
Year: 1988



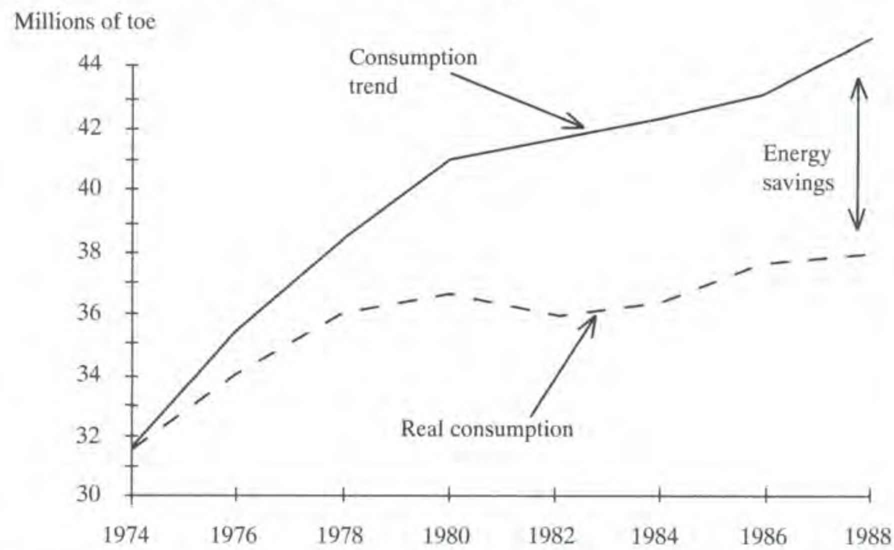
The predominance in market share of road transport compared with other transport systems, and the trend to private car use whenever a country's development conditions permit, are characteristic features of this sector worldwide.

APPENDIX 3
EXAMPLES OF ENERGY SAVINGS IN THE TRANSPORT SECTOR

1. Savings Are Possible

An analysis of the factors determining energy demand in the transport sector may reasonably lead one to question the real chances of controlling and reducing consumption in this sector. But the means for action exist, their effectiveness has been tested. For example, in a developed country such as France, in 1990 savings of close to 7 million toe were achieved compared with projected consumption based on trends as they appeared before 1974.

Figure 7: Reduced fuel consumption in France



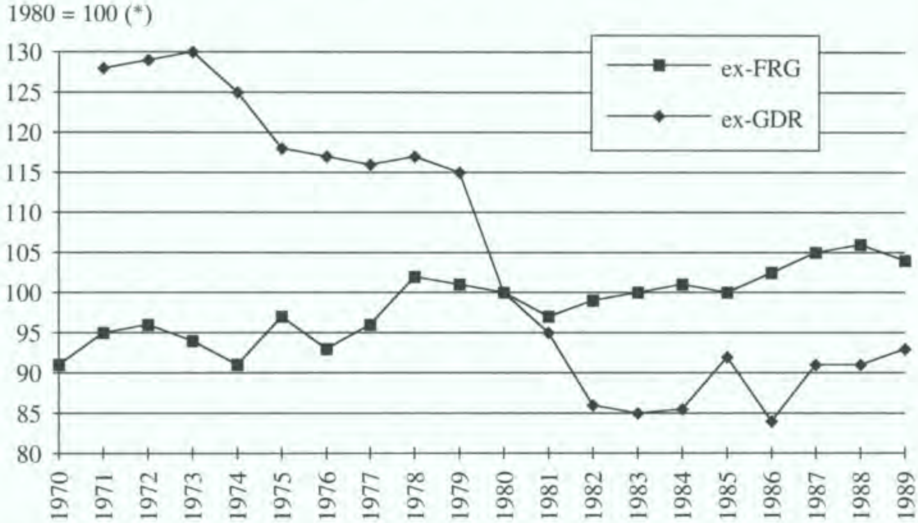
Source: ADEME

Another way to measure energy savings performance in the transport sector is to calculate the ratio of transport intensity to the gross domestic product (GDP). Figures 7 and 8 show the difference in trends between the former East and West Germany.

2. Effective Policy Based on Appropriate Priorities

The different facts and figures outlined in the previous chapters show that energy savings in the transport sector is much more complex than, for example, in industry or even in the household.

Figure 8: Transport intensity compared to GDP in Germany



$$* \text{ Energetic transport intensity} = \frac{\text{Final consumption in the transport sector}}{\text{Gross domestic product (constant price)}}$$

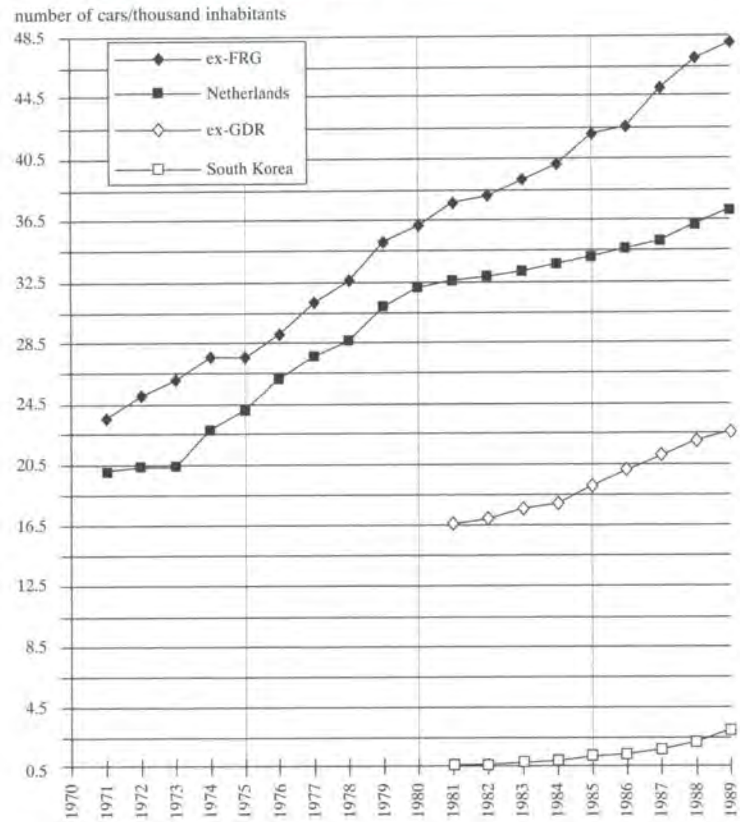
Source: ENERDATA

All of the policies undertaken in industrialized countries to reduce energy consumption in the transport sector have concentrated, in their first phase, on the control of unit consumption levels. Efforts in this area have achieved undeniably substantial results. As we shall see in the following chapter, many other measures may be undertaken with similarly positive results.

But it is necessary to bear in mind that an energy saving policy in this sector cannot be based on technological improvements alone as they cannot compensate for growing demand. The real progress achieved over the last ten years in European countries and the United States concerning, for example, consumption levels of cars did not prevent an increase in the absolute value of transport sector energy consumption. This is due to several factors:

- The annual mileage of cars did not decrease. It is, on the contrary, once again on the increase in newly industrialized or developing countries. This is also the case in some European countries such as The Netherlands. This trend shows the limits of the results that can be achieved through improved car or truck energy efficiency.
- As shown in the trends charted below, there has been a parallel increase in the number of cars.
- It should also be noted that, over the past ten years, fuel consumption improvements have been less attractive to both car makers and buyers. Energy consumption levels have again been on the increase due to a new consumer demand for:
  - more powerful cars which means more energy consuming cars;
  - new accessories which reduce efficiency (catalytic chambers) or consume energy (air conditioning, radios, etc.);
- Increased priority given to safety which increases vehicle weight.

Figure 9: Trends in size of car fleets



Source: ENERDATA

- Short trips generally made in towns also have an important impact as the vehicle is driven, from the point of view of energy consumption, in the worst conditions of utilization.

Table 7: Effect of traffic and congestion: private cars

	V km/h	CO g/km	HC g/km	NO_x g/km	CO_2 g/km	Fuel Cons. g/km	Traffic Type
Petrol car	5	72	8.5	1.7	425.5	182	slow urban
	25	0.25	3	2	174	65	fluid urban
	40	20	2.3	2.2	148	54.5	slow road
	70	16.4	1.6	2.7	140	51.5	fluid road
	100	15	1.3	3.1	151	56	motorway
	120	14	1.1	3.4	162	60	motorway
Gasoil car	5	2.6	0.8	2.1	485	156	slow urban
	25	0.9	0.2	0.6	200	63	fluid urban
	40	0.7	0.15	0.5	171	54	slow road
	70	0.6	0.1	0.5	159	52	fluid road
	100	0.6	0.1	0.55	164	56	motorway
	120	0.6	0.06	0.6	172	60	motorway

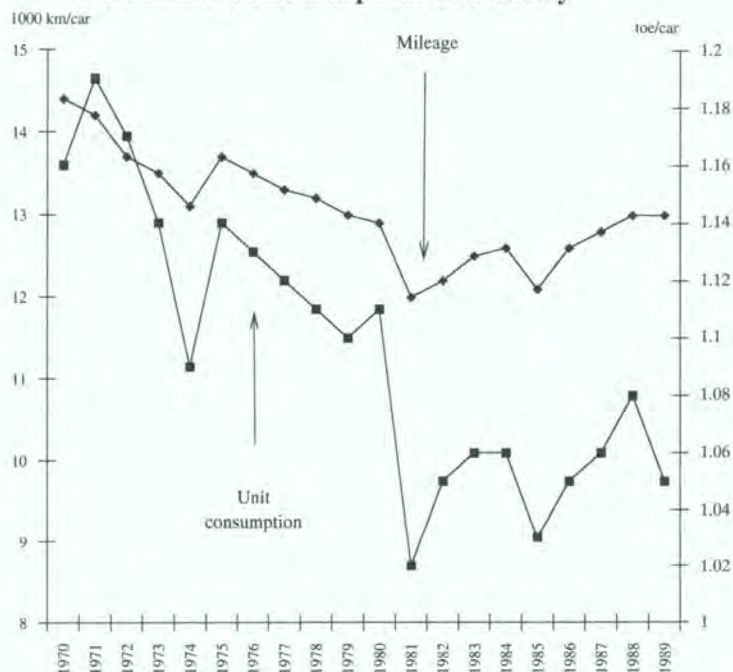
Source: INRETS (Institut National de Recherche sur l'Environnement, les Transports et la Sécurité)

Table 8: Effect of traffic and congestion: trucks

	CO g/km	HC g/km	NO_x g/km	Particulates g/km	Fuel Cons. g/km	Traffic Type
Petrol	70	7.0	4.5	0	225	urban
> 3.5 t	55	5.5	7.5	0	100	road
	50	3.5	7.5	0	165	motorway
Gasoil	6.0	2.6	11.8	0.9	218	urban
3.5-15 t	2.9	0.8	14.4	0.9	210	road
	2.9	0.8	14.4	0.9	210	motorway
Gasoil	7.3	5.8	18.2	1.6	369	urban
>15 t	3.7	3.0	24.1	1.6	377	road
	3.1	2.4	19.8	1.3	310	motorway
Gasoil	6.6	5.3	16.5	1.4	335	urban
Buses	2.8	2.2	18.2	1.2	285	road
	2.1	1.7	13.9	1.9	218	motorway

Source: Eggleton

Figure 10: Unit consumption and mileage of cars in the former Federal Republic of Germany



Average annual car mileage decreased regularly from 1970 to 1985, from 14,000 to 12,000 km/year (about 15 per cent), as the public faced two energy crises in 1973 and 1981 and consequent high fuel prices. Since 1985, prices have been reduced and average mileage is again on the increase in all developed countries.

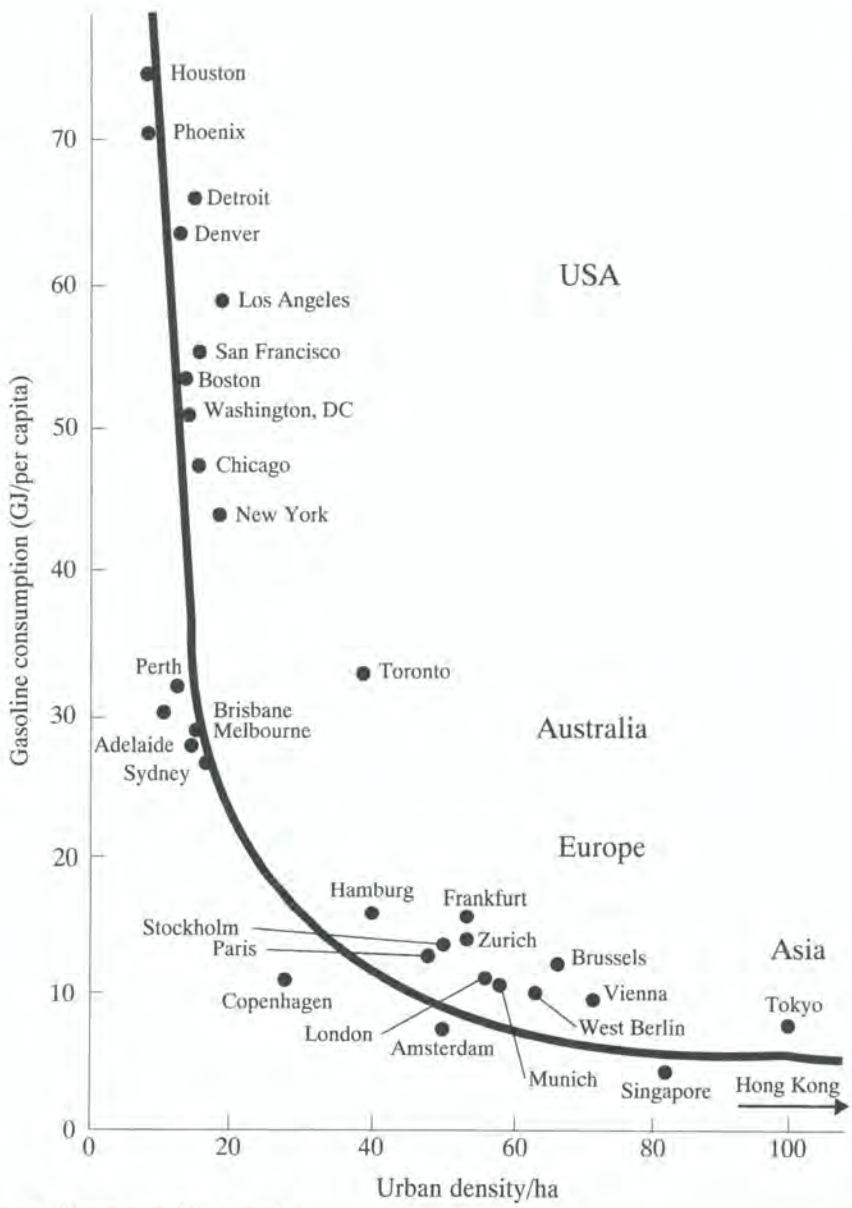
Average unit consumption per car also decreased but, until 1985, not as rapidly as mileage. Since that time, unit consumption per car has roughly stabilized as a result of two opposite trends: technical improvements in new vehicles on one hand, and an increase in the number of more powerful vehicles on the other. In 1970, only 30 per cent of cars had cylinders of more than 1,500 cm^3; in 1990, this had risen to 63 per cent.

Source: ENERDATA

• Local town planning decisions have an important impact on the level of transport supply, especially on the length of home-to-office journeys (work areas different from residential areas), on travel for shopping (proximity of residential sites to shopping centres) as well as on the need for mobility: green areas in residential areas may, for example, reduce the number of leisure trips. Town planning decisions also affect opportunities for attractive public transport and thus have a large impact on the long-term effects on fuel consumption.

The following graph underlines the fundamental importance of different types of town planning. Energy expenditure per inhabitant can fluctuate from 1 to 4 and 1 to 7 between European and American towns. In European towns, it can fluctuate from 1 to 2.

Figure 11: The impact of town planning on fuel consumption



Source: Newman and Kenworthy

Most of the observations made regarding individual transport by car are also applicable to freight transport by truck. In the latter case, the trend is even stronger, as throughout the world the development of this transport mode has led to an increasing fleet of trucks. In European countries and the United States, the role played by the rail sector for the transport of goods is declining in very large proportions. In developing countries, a similar though even greater problem exists since, in many cases, rail infrastructure does not exist.

These observations provide some guidelines for possible approaches to policies for reducing energy consumption. **Road transport,** the largest consumer of petroleum products, can be clearly seen as the **essential target** of any energy savings programme, and has two main components:

- individual passenger cars, and
- freight transport.

As has been pointed out, technological improvements cannot alone solve the problem. This is especially the case in developing countries which are dependent on vehicle imports and where new technologies cannot spread very rapidly.

Therefore, for both passenger and goods transport, the implementation of **an energy saving policy is inseparable from general measures to reduce transport needs,** to optimize and organize transport, including clear decisions in favour of a given system: individual transport versus collective transport, rail transport of goods versus road transport, etc.

PART II

TECHNICAL MEASURES

1. TRAFFIC CONTROL AND OPERATING-AID SYSTEMS

1.1 Traffic Control

The primary reasons for setting up traffic lights in an urban network are not related to energy, but correspond rather to a concern for safety (dangerous crossroads) and fluid traffic.

On the other hand, the siting and, where applicable, the synchronization of the various lights in a network have significant energy implications. The importance of these implications depends on the control system adopted.

Traffic control by means of traffic lights at crossroads make it possible, for a given route, to achieve more fluid traffic flow; it can enable more regular speed and reduce travel time, the number of vehicle stoppages at crossroads, and total idling time, all of which contribute to vehicle energy consumption in towns.

The effects of traffic control on energy consumption have been determined with scientific accuracy through research and experimentation. There are two types of traffic control technique:

- micro-control, and
- coordinated traffic-light control.

Micro-control is a technique applied to an isolated crossroad which adapts to the density of demand from vehicles appearing on each of the two axes of the crossroads.

Detection loops (cables buried in the roadway) located upstream of the crossroads on each of the axes detect the number of vehicles arriving at the crossroads on each axis. These detection loops send the information back to the crossroads control cabinet (or controller) to which they are directly connected. The control cabinet then gives the order for the lights to go to green on the axis on which demand is greatest, and to red on the other.

Coordinated control of traffic lights applies to a route and subjects all the lights on the axis in question to the same overall control logic. In other words, it will synchronize them.

This strategy of traffic light coordination, known as the 'Green Wave', means that a driver travelling at the recommended stabilized speed will encounter green lights throughout the zone in question. This involves coordinating all the lights on a given axis by staggering them in time for a given cycle duration.

It is feasible (and desirable) to combine these techniques into a centralized control system. In this way, the various controlled crossroads are connected to **a central control station which allows the techniques to operate with greater flexibility and efficiency.** The central station allows information to be collected in the field in real time, analysed and processed, so as to deal rapidly with any incidents.

To achieve this, the station incorporates a traffic control computer, a control desk and, where applicable, a mimic panel displaying the traffic flows on the controlled routes.

In short, a control system can be used:

- at peak hours, by allowing the same traffic to flow over a smaller area, thereby contributing to improved sharing of the roadway in favour of more economical transport systems;
- at off-peak hours, by increasing the energy efficiency of travel, again through appropriate distribution of the roadway.

1.2 Operating-Aid Systems for Collective Transport Facilities

These are more or less complex systems designed to improve traffic flow conditions for public urban buses. Their operation is based on real-time processing of precise knowledge concerning bus location during a trip. This information is used:

- to alter the operation of traffic lights located on the bus routes to give them priority while disturbing the general traffic flow as little as possible;
- to trigger bus departures from the terminus taking into account actual traffic conditions. Certain operating-aid systems, which include a permanent record of bus occupancy rates (e.g., by means of steps which meter the number of passengers mounting and descending), can also take into account variations in transport demand;
- to detect incidents on the route and rapidly trigger appropriate corrective measures;
- to inform users of actual timetables (time of bus passage at bus stops).

Off-line processing of the recorded data also provides accurate statistics which are essential for optimizing operating schedules, adapting supply to demand, etc.

Existing systems employ a variety of technical facilities.

- For example, vehicle location is determined either by sophisticated wheel revolution counters or by the vehicle passing near markers (magnetic loops, markers, radio points).
- Some systems are highly centralized, transmitting information to a central traffic control computer which controls the traffic lights at crossroads. Other systems operate in a more decentralized manner, with crossroad priorities being triggered locally (via direct microwave radio link or magnetic loop, etc.).

Such operating-aid systems are at present operational in many European cities. Some have been operational for more than ten years and thus provide sufficient hindsight to judge their effectiveness. Various evaluation studies recently carried out show similar results:

- Direct fuel savings due to the reduction in the quantity and length of stoppages at traffic lights are relatively modest, between 2 and 5 per cent depending on the initial characteristics of the lines.
- On the other hand, the installation of an operating-aid system produces a big improvement (about 10 per cent) in commercial bus speed and regularity. This means reduced waiting time at the terminus. The chief results of this are:
  - improved quality of public transport service (speed, reduced waiting time at stations, regularity, user information), which makes them more attractive;

- lower operating costs, due to improved use of drivers and equipment, which enables, in particular, increased supply at peak hours, using the same resources.

A more attractive service, increased supply and lower costs lead to an increase in customers for public transport, partly at the expense of the private car. The fuel savings resulting from these indirect effects, which are clearly very variable, are nevertheless of an order of magnitude similar to the direct savings made by the installation of an operating-aid system.

2. IDENTIFYING SOURCES OF ENERGY LOSS

The major share of energy in the overall operating costs of transport systems is too often ignored or underestimated. As seen in Table 7, the proportion of energy costs is far greater than is generally the case in the industrial sector.

In the sector of road transport for goods, in most countries where this activity is widespread, energy costs represent nearly the same proportion as personnel costs. The statistics for OECD countries are as follows:

Table 9: Goods transport by road – expenditures in OECD countries

Nature of costs	Expenditure item	Percentage of total costs
Variable costs	Energy	22.4
	Tyres	3.1
	Maintenance	8.4
	Personnel	27.2
Fixed costs	Insurance	4.0
	Tax and duties	1.3
	Depreciation	17.5
	Financial costs	2.0
	Structural costs	14.1

Source: ADEME

The first step, then, is to promote awareness among the various economic players concerned and to encourage thinking on the management level about energy costs and their impact.

2.1 Private Motorists

The relationship of the private motorist with his motor car is sometimes of a passionate nature. It is especially difficult to promote the necessary awareness as it is frequently countered by the influence of other economic interests, particularly of the car makers and distributors. Nevertheless, in addition to priority for collective transport facilities where they exist, rational car use should be recommended. Given the comparative costs of individual and collective transport systems, there is still plenty of room for manoeuvre in this area. Awareness of this sharp cost differential, and especially of the annual fuel budget, should be further developed.

The individual user can control fuel costs by regularly keeping a log, noting the various times when fuel is bought and the mileage covered. This practice makes it possible to clearly identify the cost per extra kilometre and to avoid short, repetitive trips, which inordinately increase consumption. It also makes it possible to compare equivalent periods of time, to detect any anomalies and to guide any decision as to maintenance or mechanical overhaul.

2.2 Corporate Users

The same question is posed, but in very different terms, for those companies which are (or are due to be) equipped with accounting facilities allowing them to control their consumption. Only such knowledge makes it possible to take stock of the situation and especially, through routine comparisons, detect any anomalies and unjustified excess consumption. It also leads to troubleshooting and the definition of required remedies.

2.2.1 Monitoring consumption

Monitoring consumption, vehicle by vehicle, is therefore the first stage in the process of corporate energy control.

For strict control, various methods can be used, involving the setting up of an energy accounting system, with the following objectives:

- gaining clear knowledge of consumption;
- promoting awareness among decision-makers of the costs involved;
- motivating employees;
- improving corporate competitiveness and profitability;
- determining the impact and usefulness of energy saving measures and equipment.

2.2.2 Equipment for simplified monitoring

Various types of equipment are now available to achieve strict yet convenient monitoring. Depending on the characteristics and activities of the company, some types of equipment may be more suitable than others.

The fuel consumption meter, fitted on each vehicle with a flow sensor and an electronic control box, enables consumption to be determined not only in absolute value but also in relation to the distances travelled and depending on the various routes taken. In this way, anomalies due to the vehicle or its operation can be detected and corrected rapidly. Some models also provide the driver with *instantaneous consumption information,* a very valuable guide for more energy efficient driving.

As an essential supplement, the *four- or five-pen control plotter* allows continuous recording of consumption and engine speed, or of periods during which a predetermined speed is exceeded. In this way, the efficiency of professional drivers can be monitored.

Finally, there are fuel distribution systems of the *'badge pump'* type which give precise data concerning the quantity of fuel distributed within the firm to each vehicle, each day. These figures can then be compared with the mileage travelled to establish consumption averages and vehicle comparisons. Naturally, for easier processing of this data in suitably large firms, it is preferable to choose equipment which provide data in a form compatible with computerized processing.

2.2.3 Computerization for improved control

Different fleet management systems are at present available on the market. Their flexibility and high data processing capability assure the efficient processing of all the data monitored during vehicle operation.

3. SELECTING THE APPROPRIATE VEHICLE

Astonishing technical progress has been made in recent years, in both car design (lightweight or special materials, improved engine efficiency, computer-assisted design) and equipment (electronic ignition, fuel injection, turbo-diesel, etc.). This progress explains the energy performance achieved by present day vehicles. The most economical models already incorporate the latest technological breakthroughs, such as electronic control of certain engine functions, optimized aerodynamic streamlining, driving aids, etc.

Such research has major implications at a time when consumption of motoring fuels represents close to 25 per cent of total petroleum product consumption. However, successful research is of little value if the users themselves do not participate by purchasing fuel-efficient models.

3.1 Selecting the Appropriate Passenger Car

In the catalogue of conventional fuel consumption levels of passenger cars on sale in France, published by ADEME (French Agency for Energy Control and Environmental Protection), stars are now printed to indicate the most fuel-efficient cars in a given category. Between two cars of identical size and similar power, neither of which seems in theory 'better' than the other, there can be major differences in the level of fuel consumption.

The important technological progress in car manufacturing is logically leading to reduced fuel consumption, without affecting the general levels of safety, comfort or passenger space. This progress can be measured on three main levels:

- **Engine:** Progress in engines includes new, more efficient combustion chambers, which accept poorer mixtures supplied by increasingly sophisticated systems (carburetor or injection system), the widespread introduction of electronic ignition (which ensures virtually life-long stability of the initial setting), the introduction of electronic units providing coordinated control of the various ignition-carburetion parameters, sometimes in 'self-adapting' mode, elimination of friction at all levels, etc.
- **Weight reduction:** This applies to engines (widespread introduction of lightweight alloy or cast-iron engine blocks with ultra-thin walls), but especially to the engine cell. Computer-assisted design makes it possible to place matter where it is really needed, resulting in cars which are increasingly light but (contrary to a widely held belief) just as resistant, especially to impacts. Weight reduction is also achieved by the use of plastics and composite materials, now standard for major body components as well as for essential parts (such as suspension components). Finally, new materials are coming into use, such as magnesium and fibres, which give ultra-high performance. Other new materials, such as aramides and carbon fibre, are however still expensive.
- **Aerodynamics:** Major work is being undertaken to reduce 'air resistance'. By means of very 'tight' front panels (the big secret of aerodynamics), fluid and cuneiform lines (very high rear) and optimum continuity (very close fitting

bodywork panels, flush window panes), and Cd (drag resistance) values which ranged between 0.40 and 0.45 a few years ago and are now in the range of between 0.28 and 0.36. This means improved performance and fuel efficiency.

Proper selection of a car must take into account all parameters which determine its cost-efficiency ratio:

- **Length:** will provide a general idea of passenger space (important for the user);
- **Weight:** will provide, in conjunction with real power, the well known weight-power ratio to give an idea of the compromise made on the performance level;
- **Engine capacity:** since a more powerful car clearly leads to more energy consumption, engine capacity is helpful in selecting the appropriate power;
- **Type of fuel used:** the price difference between ordinary and premium-grade petrol should not be underestimated in calculating cost per kilometre;
- **Real engine power:** this translates efficiency relative to engine capacity;
- **Type of transmission** (mechanical or automatic transmission and number of gears): transmission type must be related to the end reduction ratio (1000 rpm engine speed on the longest ratio), which is taken into account in calculating the fiscal rating, and gives precisely the rate of over – or under – reduction;
- **Aerodynamic characteristics of the frontal area** (a function of passenger space dimensions): multiplied by coefficient Cd, translates bodywork finesse.
- **Choice of tyres and of good pressure.**

Finally, it should be pointed out that a decision-aid utility exists for private users or for public decision-makers responsible for managing vehicle fleets, which takes into account the consumption parameter (conventional consumption levels). Conventional consumption is measured precisely and in reproducible manner over three cycles close to car use conditions on road, on motorway and in urban areas:[1]

- Consumption at a stabilized speed of 90 km/h (or at the vehicle's maximum speed if it is less than 130 km/h);
- Consumption at a speed of 120 km/h (only if the vehicle's maximum speed is greater than 130 km/h);
- Consumption during an urban type test, called the 'Europe' cycle, performed on a dynamometer bench at an average speed of 19 km/h.

These values are measured by an approved laboratory, but they are not representative of all the vehicle's operating configurations. There may be differences between conventional values and the values of actual use due to numerous factors (driving style, vehicle running-in, state of maintenance, external conditions) which cause constant changes in the vehicle's running condition, and hence its fuel consumption. Nevertheless, by adapting the factors under his control (correct driving, regular car maintenance), each driver can greatly improve consumption and even, in some cases, attain these conventional values.

1. This is a conventional system used only in Europe which aims at allowing comparisons between cars; it does not produce reliable data concerning consumption in real use.

3.2 Selecting the Appropriate Commercial Vehicle

In the commercial vehicle sector, the right choice is equally essential. Selecting the industrial vehicle best adapted to a company's constraints (operating and management constraints, etc.) is often a difficult decision to make given the great diversity of vehicle types available on the market.

Choice is largely determined by **the type of transport** for which the vehicle is destined:

Type of load:
- heavy, light
- cumbersome
- miscellaneous
- animal

Type of routes:
- town
- mountainous
- road, motorway

Type of operation:
- urban distribution
- regional, international
- regular line
- 'strong' timetable constraint (translating into a high ratio between average and maximum speed)
- need for versatility or not.

Choice also depends on **a company's general policy:**

Renewal policy:
- uniformity of brands and profiles
- lifetime
- cost of new vehicles compared to old or second-hand ones

Maintenance policy:
- sub-contracted
- in-house workshop

Monitoring of cost per kilometre.

Finally, extensive allowance should also be made for recent developments and for the technological progress in fuel consumption levels in all ranges of utility vehicles over recent years.

To facilitate selection of the most suitable vehicle, one should first answer the following questions.

3.2.1 What profile?

The answer obviously depends on the type of transport the vehicle will be required to perform, but also on the company's policy of equipment standardization. The decision-making study should take into account:

- Mean consumption per useful ton, per kilometre or per useful cubic metre, obviously depending on:
  - vehicle payload or useful volume;

- types of load or volume to be transported;
- the vehicle's specific consumption features;
- the trips to be made.

- Influence on consumption of possible unladen return trips (influence of dead weight).

3.2.2 What cab?

The parameters which may be taken into account are as follows:

- Aerodynamic coefficient: The shape of the cab directly influences the vehicle's air penetration. Rounded shapes should therefore be chosen, with as few sharp angles as possible. However, it should be remembered that the Cd can be improved by means of a deflector mounted as original or aftermarket equipment.
- Comfort: There is no doubt that comfort, especially sound insulation, represents an added advantage for a vehicle travelling long distances: it reduces fatigue and hence the risk of accident, and directly improves driving quality.

3.2.3 What wheelbase?

A simple rule should be complied with if possible: for equal volume, a long wheelbase with a low body, offering a small surface to the wind, is preferable to a short wheelbase with a high body. However, if a minimal ground area is desired (vehicles for urban distribution), a short wheelbase should be selected, with a higher useful loading clearance; a cab deflector may be mounted for fast delivery trips.

The choice of a wheelbase must though be determined in line with regulations concerning axle loading. The choice will obviously depend on the types of load and, especially, the weight the vehicle will have to withstand.

The wheelbase selected will frequently determine the number of axles. Here again, a simple rule should be followed: select a minimum of driven axles, except if the vehicle has to function in conditions of poor traction (quarries, worksites, loose soil, etc.). The greater the number of axles, the higher the vehicle purchase price, the higher the maintenance costs and the higher the fuel consumption.

3.2.4 What type of body?

Here again, the answer depends on the planned use of the vehicle. However, a few general recommendations can be given:

- Whenever possible, the body should not project beyond the cab (in width or in height). Preferably choose smooth walls and rounded angles.
- Do not use sheetmetal side walls with vertical corrugations which create more wind resistance.
- Streamline the hoods or canopies as much as possible (move the van forward over the roof of the cab).

- When a tarpaulin-covered body must be used, make sure the tarpaulin offers the least possible wind resistance.
  - When choosing the tarpaulin, preference should be given to a 'lined' or 'plasticized' tarpaulin, smooth in both cases.
  - Stretch the tarpaulin tightly and close the rear part properly to avoid any floating or flapping.
  - Never travel with the vehicle half-covered or with the rear partly open.
  - On a bare platform, if the cargo must be covered with a tarpaulin, fasten the tarpaulin so that it cannot swell in the wind.
- To optimize the useful loading volume and the payload by reducing the unladen weight, consider reducing the body weight (body with smooth, thin walls).
- Major weight variations can occur on similar bodies. For example, long wheelbases and major overhangs can increase body weight.

3.2.5 What engine power?

A good power rating, adapted to the vehicle's operation, must be selected:

- 6 to 7 hp/ton is generally sufficient on flat or relatively flat ground.
- 8 to 10 hp/ton is sometimes preferred for the extra zip it gives to the vehicle. Extra engine power can also improve dependability and safety provided the vehicle is driven correctly.

However, lower power levels are often adequate and can offer a good performance/fuel-consumption compromise in, for example, the following cases:

- when the vehicle is almost always unladen on the return trip,
- when the loads transported are of low density,
- when only motorways or open highways are travelled on.

By complying with certain driving rules (speed, engine speed, gear ratio), average commercial speed can be improved without affecting fuel consumption too much. The company must therefore make its own evaluation regarding time gained in operation compared with increased operating costs.

3.2.6 What drive line?

The choice of an appropriate drive line must take into account the conditions of vehicle travel (on motorway, in the mountains, average cruising speed) with respect to the economical driving range defined for the vehicle.

There are three main factors involved in defining the most appropriate drive line:

- choice of the number of transmission ratios and their staging;
- choice of axle torque;
- choice of tyres.

These three choices are obviously interdependent:

- The choice of axle torque must take into account the defined economical operating conditions and the corresponding cruising speed. A 'long' axle with a speed limiter is suitable for motorway travel, whereas a 'short' axle is used exclusively in mountain travel. A 'medium' axle of 100 km/h can be a good compromise since, at 80 km/h, the engine is operating in an economical range.

- The number of transmission ratios chosen will depend on the type of axle selected.
- Finally, the choice of tyres, which likewise depends on axle torque, may influence vehicle productivity. It is therefore important to select the optimum tyre size: an overlarge tyre increases road running resistance, resulting in excessive consumption.

  Wherever possible, 'single' tyres are preferable to 'twin tyres', especially on the second and third trailers of trailer vehicles. Apart from the energy savings (estimated by manufacturers at between 2.5 and 6 per cent compared with a 'tandem' axle), a weight saving of approximately 150 kilograms can be achieved, allowing a corresponding increase in the payload.

4. PREVENTIVE MAINTENANCE AND RECOMMENDED CHECKS

The mechanical components of a vehicle wear out and become misadjusted. Their operating condition must therefore be monitored regularly to prevent any failures or defects. The best way of limiting driving risks and minimizing the vehicle's operating costs is:

- to reduce the risk of breakdowns;
- to extend the vehicle's lifetime;
- to cut fuel expenses through optimization of the vehicle's energy efficiency.

4.1 Recommendations for Cars

There are two levels of maintenance practice which can improve the final energy balance:

- operations on mechanical components;
- preparing the vehicle for the road.

4.1.1 Operations on mechanical components

In addition to complying with carmakers' recommendations concerning the frequency of conventional operations (oil changes, setting of rocker arms, changing spark plugs, etc.), it is particularly recommended that the condition of the ignition and carburetion systems be checked as they are frequently the source of disorders as well as **up to 10 per cent excess fuel consumption.**

The gaseous mixture of air and petrol that fuels the car is formed in the carburetion stage. This mixture must be perfectly proportioned and homogeneous. The essential aspects of carburetion should therefore be checked at least once a year, including at least:

- the cleanliness of the air filter;
- component tightness;
- the richness of the mixture;
- idling speed;
- emission levels (CO/CO_2 check).

The ignition system ignites the gaseous mixture in the cylinders. The operating condition of its special electrical system (spark plugs, coil, igniter, battery) should also be checked at least once a year and include at least:

- measurement of compression;
- measurement of battery and coil voltages;
- check on spark advance;

- measurement of camshaft angle, check on condition of contact breakers;
- check on high-voltage circuits and spark-plugs.

The cost of these operations can be amortized within a year, given the fuel savings that can be expected.

4.1.2 Preparing the vehicle for the road

Before taking to the road, it is customary to perform routine checks which can be carried out by the motorist himself. These checks aim at eliminating any unnecessary resistance to the vehicle's movement and include, in particular:

- A pressure test on cold tyres to be performed approximately every two months. Tyres underinflated by 300 grams increase rolling resistance by 10 per cent, severely compromise safety and result in a 2 to 3 per cent increase in fuel consumption. In fact, the pressure recommended by the carmaker can be increased by 200 grams without any risk.
- The luggage rack or unused luggage rails should be removed when not in use. In the case of a caravan, the air deflector should be removed when the caravan is not being drawn. Unnecessarily maintaining the luggage rack or rails costs an average of one extra litre per 100 kilometres at 120 km/h.
- Rational loading of the vehicle. Unnecessary loads should not be kept in the boot and, in particular, cumbersome loads on the roof luggage rack should be avoided.

4.2 Recommendations for the Road Transport Sector

Any fuel economy measures will be wasted if they are applied to a vehicle which is poorly adjusted and poorly maintained. The first fuel economy measure is in fact to run a properly adjusted car. In addition to the above checks, then, routine maintenance and adjustments must be performed before any increase in fuel savings can be achieved.

Routine everyday maintenance has a direct influence on consumption. For example, the oil level must always be at the top gauge level but never exceed it as this can cause oil slopping, thereby reducing power by up to 15 hp for a 300 hp engine. If the oil level is too low, it could cause faster oil circulation, adversely affecting cooling and soon leading to over-consumption and risks of connecting-rod melting. Monitoring of belts and electrical circuits, like the monitoring of optimum tyre pressure, avoids many problems including premature wearing of parts and excess consumption of up to 8 per cent.

Weekly maintenance inspections should be performed, with special emphasis on:

- cleaning the radiator and checking on fan engagement, if the fan can be disengaged by the clutch;
- checking the supercharger setting for supercharged vehicles;
- a pit check to detect anomalies, prevent incidents, and detect any leakage of vehicle fluids;
- checking axle alignment.

At monthly check-ups, where in particular oil and filter changes are performed, systematic inspection should be carried out on essential components, with especial checking for potential leaks.

If a company does not perform checks by analysis of the engine oil, it should at least require that the used oil be drained into a clean tank and finely filtered. In this way, it is possible to detect any metallic particles or scale which can sometimes be swept along by the drained oil.

If, as in many transport companies, the engine oil is systematically monitored, there is the advantage of rapid detection of any incipient wear, malfunctioning, or mechanical incident (without having to disassemble the engine).

Various systems exist for quickly checking the injection system and are known as injection or diesel testers. The use of such devices enables consumption savings of approximately 1 to 4 per cent. Other mechanical and electrical checks on the engine, transmission system, steering (detection of any leaks), clogging of air and diesel filters also have a definite impact on vehicle fuel consumption.

Finally, preventive maintenance involves correcting a component, part or equipment item before a fault occurs. Although it is hard to put a figure on this, significant consumption savings are achieved by preventive operations. Properly scheduled preventive maintenance can, in particular, prevent untimely immobilization of rolling stock with all the adverse consequences that involves.

Carmakers and component suppliers increasingly indicate 'projected life' before wear for the most common components. In this way, depending on traffic and duty conditions, interventions can be 'predicted' and wearing parts can be replaced. A good example of this is the engine spark plugs (worn spark plugs can result in 10 per cent over-consumption). Other examples include the water-pump, alternator belts, etc.

Some carmakers propose maintenance contracts with preventive operations, calculated at a fixed cost per kilometre. As a general rule, it is estimated that such a contract can produce annual savings of between 2 and 4 per cent.

4.3 Vehicle Inspection

The first step in maintaining vehicle fuel consumption at a normal level is to comply with the carmaker's maintenance recommendations. However, the energy efficiency of the engine should also be diagnosed regularly by a professional to precisely determine any anomalies responsible for excess fuel consumption. As a general rule, any intervention on the engine ignition and carburetion systems should be preceded by a diagnosis performed by trained and skilled personnel using special equipment. Engine diagnosis and the resulting interventions should be performed at least once a year, or every 12,000 kilometres.

4.3.1 Recommended interventions

The engine diagnosis may lead to three types of recommendations: minimal adjustment of the ignition system, complete adjustment of ignition, carburetion adjustment, or complete tuning.

- **Minimal adjustment of the ignition system (less than one hour)**

  For vehicles equipped with electronic ignition or having low mileage and which have received regular maintenance, the following operations should be performed:
  - dismounting and inspection of spark plugs;
  - adjustment of camshaft angle;
  - idling adjustment;
  - CO-CO_2 emission check by gas analyser.

- **Complete adjustment of ignition (less than two hours)**

  The following work should be performed on the ignition system:
  - compression ratio by compression meter;
  - dismounting of spark plugs;
  - inspection of wire harnessing and coil;
  - disassembly and bench testing of the igniter, with a check on the contact breaker and capacitor;
  - check on spark advance curves (static and dynamic);
  - camshaft angle adjustment;
  - idling adjustment;
  - CO-CO_2 emission check by gas analyser.

- **Carburetion adjustment (less than two hours)**

  The correct proportioning and homogeneity of the air-petrol mixture depends on this adjustment which includes:
  - check on nozzles, fuel inlet valve, float valve and tank level and their settings in accordance with the carmaker's standards;
  - clean or change air filter, depending on its condition;
  - check circuit tightness;
  - check choke and accelerator cable;
  - idling adjustment and CO-CO_2 emission check by gas analyser.

- **Complete tuning (less than half a day)**

  Following the engine diagnosis, complete tuning involves operations recommended for ignition and carburetion adjustment, and then a road test.

5. RULES FOR ENERGY-EFFICIENT DRIVING

In general, fuel consumption varies sharply between different drivers and different trips. Personal driving style and driver behaviour (and, more generally, the driver's temperament) have a major effect on a vehicle's fuel consumption balance. A lack of driving flexibility can cancel out any efforts to save energy.

5.1 Principles of Energy-Efficient Driving

An effective way to limit petrol consumption is to adapt one's driving style to the engine requirements and traffic conditions. This enables fuel consumption savings of up to 30 per cent while maintaining the objectives of minimum travel time and driving pleasure. A less aggressive driving style improves driving flexibility and comfort.

A driver should therefore look at all times for ways of optimizing the engine's energy efficiency. To this end, the following principles should be borne in mind.

a) Placing in motion a mass as big as a car, which weighs approximately one ton, and bringing it up to a speed of 90 km/h, takes a considerable amount of energy.

   To fully exploit the momentum of a vehicle, **the accelerator and brakes should not be operated unnecessarily,** a fact taught in driving schools. Sharp acceleration leads to unnecessary enrichment of the fuel mixture, causing over-consumption; sudden braking rapidly neutralizes the built-up momentum. Economical driving implies a steady, regular speed.

   When starting, it is better to accelerate gradually to achieve the desired speed. To avoid sudden speed changes when driving, **traffic should be anticipated:** for example, slow down when approaching an obstacle or a corner in order to brake as little as possible.

b) By changing gear, a satisfactory engine speed (2,500 to 3,000 rpm) can be maintained irrespective of the vehicle's speed.

   It is important to **use the highest possible gears** as long as the vehicle will accept them. Third or fourth gear can be engaged far sooner than is generally thought (at 45 or 50 km/h on the flat for fourth gear).

c) **Petrol consumption increases with speed.** Driving at an average speed of 130 km/h consumes 25 per cent more than at a speed of 110 km/h, and gains only a relatively small reduction in travel time.

d) When starting, **there is no need to warm up the engine by idling.** By immediately setting the car in motion, the engine is quickly brought up to the required temperature, and the choke can then be pushed back in. This reduces excess consumption due to cold starts, which is of the order of 50 per cent in the first few kilometres.

Such economical driving, and in particular the reflex of anticipation, produces not only direct savings in fuel consumption, but also spin-off gains in reduced wear of the most heavily loaded components (brakes and tyres). At the same time, the objective of fuel savings can be reconciled with safety.

The driver should also know how to optimize vehicle use in town. Town trips are frequent, repetitive and always short. In developed countries, statistics show that one in every two urban car trips is for a distance of less than 2 kilometres. These trips involve cold starts, which are unfavourable for engine energy efficiency since the engine only reaches its optimum operating temperature after five kilometres. During the first kilometre, the fuel consumption of an average model is 30 litres per 100 kilometres; in the second kilometre, it is still only 15 litres per 100 kilometres.

In addition, the conditions of town traffic result in excess petrol consumption due to:

- Frequent vehicle stopping. In towns, including cities in developing countries, it has been observed that stoppages represent one quarter of car travel time. And, it is during the engine speed build-up phase that fuel consumption is highest.
- A stop-and-start driving style due to obstacles in the smooth flow of traffic (traffic lights, crossroads, pedestrian crossings, etc.). This driving style, marked by sharp accelerations and braking, leads to petrol wastage, either due to unnecessary enrichment of the fuel mixture (sudden accelerations) or through loss of built-up momentum (sudden braking).

The conclusion is clearly that, as far as possible, the best way to save energy is to reduce the use of the private car.

5.2 Road Transport and the Commercial Driver

For drivers in the commercial road transport sector, consumption control first requires a study of the log and then driving a reference circuit to calibrate the driver's fuel consumption. Moreover, when running the vehicle, the carmaker's recommendations should be scrupulously complied with during the first kilometres travelled. Remember that a 'knocked-out' vehicle is a source of excessive consumption throughout the vehicle's lifetime.

Subsequently, economical driving involves compliance with the statutory speed limits. The driver should avoid sudden accelerations and decelerations and never push the engine to its utmost limits. Engine speed should be kept in the economical range (generally indicated by the revolution counter) even on the intermediate gear ratios. While double declutching should be avoided when the gearbox is synchronized, engine braking should be used insofar as possible for slowing down.

Finally, economical driving can be promoted by on-board electronic systems. On the basis of data acquired by sensors and based on vehicle characteristics stored in its memory, a computer can instantly deliver consumption information, thus encouraging the user to shift up or down a gear, thereby reducing consumption.

Urban or suburban areas with high population densities are likewise a cause of increased consumption. In this respect, a simple rule is as follows: one stoppage equals approximately one additional litre of diesel oil consumed. Hence, any action undertaken in the field of energy saving should include driver monitoring to ensure optimum use of a vehicle and to obtain a rapid return on the investments made.

5.2.1 Training programmes

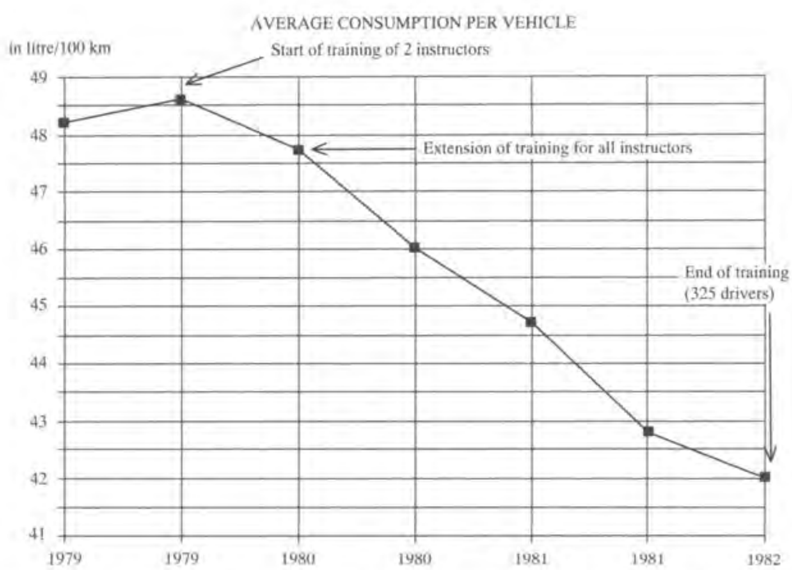
Specialized organizations can provide training courses in economical driving for foremen and, of course, for drivers. These economical driving programmes include technical training, essential to update knowledge of fuel consumption questions, as well as refresher training concerning the operation of the main components, torque values, engine speed ranges, checking, maintenance, inspection, etc.

Programmes also include a large practical section with the support of an experienced instructor. In most European countries, there are many organizations or companies dealing with transport problems which can provide assistance in the preparation of special energy conservation training programmes adapted to the conditions of developing countries.

However competent the instructor though, going 'back to school' may be poorly accepted by some drivers. This problem must be dealt with by the company manager by introducing his company to the concept of energy control prior to the training courses and by taking a special interest during – and especially after – the courses. There is nothing to prevent him taking part in such courses himself to make his staff even more aware of the new confidence placed in them and their new responsibilities. These responsibilities will also imply action when a driver is taking over a new vehicle with which he must very quickly become acquainted

Obviously, such measures must be followed by regular checks within the company. This implies that the company will have a suitable system of information feedback and also that the executives and foremen will be well aware of and thoroughly trained in the various aspects of the campaign to reduce fuel consumption. The training proposed, in the form of inter-company courses or within the company itself, represents an investment which will be very quickly and well paid off, given the stakes involved and depending on the effectiveness of the instruction.

Figure 12: Fuel consumption chart of a medium-sized urban transport fleet



In this example, concerning a city which at the time had a fleet of 95 buses and 325 drivers, a training plan for all the drivers made it possible to achieve a 13.5 per cent savings compared with the initial consumption figure.

The plan started with preliminary instruction for two drivers who were assigned responsibility for gradually training the other drivers in a programme spread over 30 months.

Naturally, the problem faced after the training session is how to maintain the results achieved. Experience shows that this can accomplished only through strict monitoring within the company and the appointment of an energy manager.

CONCLUSION: WHAT ENERGY FUTURE FOR THE TRANSPORT SECTOR?

Energy Trends in the Transport Sector

As seen in Part I, transport's share of fuel consumption is constantly rising: in 1989, this sector accounted for 43 per cent of world fuel product consumption compared to 36 per cent ten years ago. And transport in OECD countries accounts for half of world fuel product consumption.

The annual growth rate of fuel consumption is alarming, not only in OECD and developed countries, but also in developing countries which are densely populated and will be developing their equipment. In 1988 to 1989, the annual growth rate in Japan was 7 per cent, in Great Britain 4.3 per cent, in France 3.7 per cent, in Brazil 4.9 per cent, and in India 11.4 per cent.

The energetic intensity of transport varies greatly. But many countries, including both developing and developed, are not very efficient. This increases the importance of technology transfer and better organization: when the energetic intensity of transport reaches a worldwide average of 61.9 (toe/10^6 US $), it is 80.4 in OECD countries, 112.6 in the United States and 183.3 in the United Arab Emirates.

Table 10: Countries with the highest energetic intensities in transport (in 1989)

	toe/10^6 US $
Lebanon	185.0
United Arab Emirates	183.3
Iraq	174.3
Lybia	162.2
Luxembourg	155.2
Jordan	117.2
United States	112.6
Argentina	103.2
Australia	102.5
OECD	80.4
World	61.9

This criterion of energetic intensity in transport provides a measurement of the efficiency of the transport system within the framework of general economic activity. It is important that the energy consumption of activities be reduced without reducing the activities themselves. This can be achieved by reducing unnecessary motorized travel and encouraging non-motorized activities.

Source: ENERDATA

The highest growth rates in transport energy consumption are registered in countries with high development. In South East Asia, for example, this phenomenon is particularly important: between 1985 and 1989, the Philippines saw a 35.7 per cent increase, South Korea 15.2 per cent and Thailand 14 per cent.

What Energy Future Are We Preparing?

The following provides a brief worldwide scenario for the near future:

- The equipment rate for private cars, in 2060, will reach a ceiling of 50 cars per 100 inhabitants in Northern countries and 20 or 30 cars per 100 inhabitants in Southern countries. (In the United States, the rate is already greater than 50 cars per 100 inhabitants and could be the same in Europe in 2020.)
- Mobility is estimated to reach a ceiling of 13,000 km/year in the poorest countries, 15,000 km/year in Europe and 17,000 km/year in the United States. These values have already been exceeded in several countries, especially those which are geographically extensive, such as the United States, Argentina, India, etc.
- The fuel consumption of cars will particularly be reduced compared with current standards: worldwide consumption is estimated to fall from 9.5 litres/100km in Europe and 12 to 13 litres/100km in other countries to between 5.5 and 6 litres/100km (real consumption). This estimate is based on a level of technical progress in car prototypes of 3 litres/100km in conventional consumption and on reasonably priced worldwide distribution.

This scenario can be further illustrated by a few figures:

- **In 2060, transport will consume 2 billion toe compared with 0.6 billion in 1985, and;**
- **will generate 1.6 billion tons of carbon emissions compared to the current 0.6 billion.**

Such a development is clearly unacceptable.

It should be remembered that the transport sector is already the sector responsible for most pollutant emissions, as indicated by the figures below established for European Economic Community countries:

Table 11: Transport sector share of pollutant emissions in European Community countries (1992)

Pollutant	Per cent of emissions due to the transport sector
CO	75
HC	75
NO_x	74
SO_2	22
Pb	80

Source: CITEPA (Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique)

This raises fundamental questions concerning the rail and river transport share versus road, concerning collective transport, traffic restrictions in commercial centres, urban tolls, speed control and limitation, control of goods and passenger traffic, etc. Technological progress must continue. Choices of infrastructure and space development will be a determining factor if we are to avoid ever more road space which leads to ever more cars. Growth control through effective environmental integration is particularly important in the transport sector.

The transport sector plays a key role in a country's economy by allowing organization of the territory and linking up producer and consumer activities. This latter function is vital as, even in the event of a serious crisis, the transport of goods and passengers cannot be halted: it is a well known fact that transport stoppages may induce political destabilization.

Establishing a policy of rational energy consumption in the transport sector must therefore be a priority in every country and especially in developing countries.

This can be achieved in different ways – through basic improvements in technology but also, and primarily, by rationalizing transport systems with the aim of increasing the sector's energy efficiency. Such organization must allow for as much mobility as necessary but in an improved way, with reduced energy consumption and reduced impact on the environment.

The Need for a Complete Sectoral Policy

Energy consumption in the transport sector represents a major challenge as much because of its volume in developing countries as its rate of growth, its hydrocarbon use and its polluting emissions.

An energy savings policy in the transport sector is therefore an absolute must for every country. Developed countries have a particular and important role to play as they must set the example and be the source of technological and organizational schemes transferrable to developing countries.

Various examples prove that considerable savings are possible everywhere. Based on present trends, setting a target today of a 25 per cent decrease in consumption within the next ten years, while obviously an ambitious challenge, does not seem unrealistic in many cases if the means are quickly provided.

To meet this challenge, the preceding sections have proposed a certain number of measures aimed at reducing unitary consumption and at improved transport organization. However, in view of the extent of the challenge, incomplete measures are unlikely to help reach such a target. **An overall sectoral policy for controlling transport fuel consumption must be implemented.**

This policy must first be carefully prepared. It is generally desirable that a small specialized team be set up and equipped with the neccesary facilities to define the major thrust of the policy and play an organizing role. One of the features of the transport sector is the number of parties who must be involved in preparing and implementing an effective sectoral policy. This team must therefore see that the different authorities and local organizations take the necessary steps it suggests and ensure that action is coherent.

A rational energy saving policy in the transport sector also constitutes the basis for a complementary energy substitution policy, helpful in order to reduce or even eliminate hydrocarbon consumption when the required technical and economic breakthroughs have been made.

A national policy appears both possible and highly desirable: the technical means, the methods and the experience exist and are available; concrete results show that significant savings can be achieved at a cost acceptable in terms of conventional economic criteria.

What is needed is the determination to do it.

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ABOUT UNEP INDUSTRY AND ENVIRONMENT

It is now widely accepted that sustainable development and a sound environment go hand-in-hand. UNEP recognized this as early as 1975 when it established its Industry and Environment centre (IE), located in Paris. UNEP IE functions as a catalyst to bring industry, government and non-governmental organizations together to work towards environmentally sound forms of industrial development. UNEP IE seeks to:

- define and encourage the incorporation of environmental criteria in industrial development;
- help formulate policies, strategies and management tools for sustainable industrial development and build the capacity for their implementation;
- promote preventive environmental protection through cleaner, safer production as well as other pro-active approaches; and
- stimulate the exchange of information on environmentally sound technologies and forms of industrial development.

To promote the transfer of information and the sharing of knowledge and experience, UNEP IE has developed three complementary tools: a *Technical Report Series;* the quarterly *Industry and Environment* review; and a *Query-Reponse Service.*

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PERSONAL NOTES

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