Energy and mass transportation

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EDRC 1994

Executive summary

The South African Energy Policy Research and Training Project (EPRET), of which this paper is a part, aims to develop policy options for widening access to basic energy services for the urban and rural poor. Although transport is not strictly an energy service it is an essential service to the majority of poor people, and a major component of transport provision cost is energy use.

Apartheid government policies in South Africa have produced urban areas unlike any other nation. Largely through the group areas act, cities have not been allowed to evolve in the accepted usual way. Most cities in the world have complex spatial patterns of poor and affluent residential, commercial and industrial areas. There is no simple model that can be used to describe all cities, but some patterns can be observed. High-density working-class residential areas are found close to the city centre and adjacent to employment areas, such as industrial centres. The more affluent live in residential areas further from the business centres in densities that reduce with distance from these centres.

The result is that the poorer people live close to their place of work, minimising their transport needs and the percentage of their income that must be spent on transport, whilst the more affluent, who can afford to commute, travel greater distances.

In South Africa, legislation until the 1980s forced the black working class to live in outlying areas and travel vast distances to work, using considerable proportions of their income, while the largely white middle classes live in low-density residential areas close to the workplace. The density of housing in cities is thus extremely low. To further exacerbate the inequalities, transport policies have centred around the private car. Vast road infrastructures have been built for the car-owning minority, a process eased by the low density of land use within the city, and little invested in public transport.

The majority of the urban poor rely on minibus taxis and buses to travel to work. There has been little or no investment in urban rail systems since the rise of the private car. The public transport that operates is uncoordinated and inefficient, with passenger surveys highlighting concerns over safety, overcrowding and high costs.

Any policies that profess to be aimed at improving the lives of the poor cannot ignore the injustices that exist as a result of past planning and transport policies.

In addressing the needs of the poor, there clearly needs to be an emphasis on public transport provision rather than private. Planning considerations are also an integral part of this debate; however, although touched on, to provide the fuller picture, detailed planning proposals are not within the remit of this paper. The introduction of new planning philosophies and the removal of racial barriers to home ownership will only allow the fundamental situation to change slowly. In the short term, strategies to provide appropriate and affordable mass transportation systems must be designed, including light rail systems, and coordinated bus and minibus networks.

Investment in road infrastructure in the past has been considerable. Although there are areas of traffic congestion within South African towns and cities, it is argued that providing considerable investment in public transport systems is the only way of providing efficient transport for the majority, and the provision of efficient services will ultimately reduce the present reliance on private vehicles and congestion problems. A shift of investment from road provision to an integrated public transport system would involve a radical change of policy. There will be many new

ideas implemented in the new democratic South Africa. If the needs of the poor are to be addressed, these significant changes in transport investment must be introduced.

There are many arguments for the promotion of public transport that have been well developed in Europe over the last twenty years. This paper uses these arguments to show that the provision of equitable access to goods and services for the majority of urban people, in an environmentally sustainable manner, can only be achieved through the provision of an integrated public transport system.

The primary argument used is that of energy efficiency. An attempt is made to calculate an energy balance for transport in South Africa. The various energy efficiencies of transport modes are investigated, in all areas of the transport sector from vehicle manufacture and maintenance to infrastructure provision and mobility efficiency. Through this examination, it is argued that an integrated public transport system should replace private road transport as the primary means of providing access to goods and services. It is argued that such a system must not only integrate all modes of transport, but be integrated with local and national, urban and rural planning policies.

Chapter 1 places the paper in context, both within the EPRET series and with respect to the rural and urban poor. It also outlines the limitations imposed by the present distribution of people, goods, services and areas of employment within South African cities.

Chapter 2 highlights the differences between urban and rural areas. It shows that although mobility needs are significantly different, the needs of the majority can best be addressed in both areas by appropriate public transport systems. A system that is appropriate in a dense urban area, such as light rail, will not be as viable as a more flexible system in rural areas, but continued investment in private transport infrastructure will never address the needs of the urban or rural poor.

Chapters 3, 4 and 5 draw an energy use picture of each sector of the transport energy economy. Mobility energy is dealt with in Chapter 3. The efficiencies of different modes are discussed and figures for the consumption of largely petroleum resources included. It is shown that the private car and airliners are the least efficient users of mobility energy even at high occupancy levels. Walking, cycling, electric light rail, and all bus modes are the most efficient modes. The majority of energy is used in the road sector.

Transport infrastructure is discussed in Chapter 4, firstly the provision and then maintenance. Figures for road and rail services are included with road provision using 480% more energy than rail infrastructure per annum. This difference is due to the much larger length of road that is built. Although road construction is more energy intensive than rail, it uses only 60% more energy per kilometre. Road maintenance uses over four times as much energy per kilometre than rail, with much of this cost associated with bituminous surfacing. The greater length of existing road over rail, results in approximately twenty-two times as much energy being used in road maintenance annually.

The energy used in the production and maintenance of transport vehicles is analysed in Chapter 5. Again, considerably more energy is expended on road vehicles than rail, due to the greater numbers. Similar quantities of energy were consumed by the road vehicle population for both manufacture and maintenance per year.

Chapter 6 addresses the environmental implications of energy use in transport. Local global and national implications are discussed with respect to marine, air, rail and road modes. The chapter concentrates on the pollution emissions from the burning of fossil fuels that provide almost all the energy used in the transport sector.

The degradation caused by this pollution is at the forefront of international debates on the environment. If future policies are directed towards sustainability, then pollution abatement issues are of vital importance and must be understood in the South African context.

In conclusion, Chapter 7 includes an energy balance for South Africa, Table 1 below.

	Road	*Rail*	*Total*	*%*
1. Vehicle Operation	100 450.5700	7 418.9800	107 869.5500	91.4
2. Vehicle manufacture	4 657.5706	N/A	4 657.5706	3.9
3. Vehicle maintenance	4 636.8046	871.6599	5 508.4645	4.6
4.Infrastructure provision	102.0301	26.5672	128.5973	0.1
TOTAL	109 846.9800	8317.2071	118 164.1800	100

TABLE1 Total average annual energy use resulting from demand for South African transport [GWh]

The transport sector contributes significantly, approximately 34%, to the country's energy use, with road vehicle operation forming the largest component. Transport users' perceptions are discussed and seen to be the key component in the successful implementation of any future policy proposals. Finally, policy recommendations are made, accompanied by the objectives they hope to meet.

The resultant proposals provide for access to services rather than mobility for its own sake. In terms of energy efficiency and ease of travel for the majority, efficient public rail and bus networks are a vital part of the restructuring of South Africa. Considerable efficiency gains can be made reducing the rate of fossil fuel use and the levels of pollution emissions.

This research is an essential informant of viable and sustainable transport policies for South Africa.

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CHAPTER ONE

Introduction

The Energy Policy Research and Training Project (EPRET), of which this paper is a part, aims to develop policy options for widening access to basic energy services for the urban and rural poor. Although transport is not strictly an energy service it is an essential service to the majority of poor people, and a major component of transport provision cost is energy use.

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Any policies that profess to be aimed at improving the lives of the poor, cannot ignore the injustices that exist as a result of past planning and transport policies. In addressing the needs of the poor, there clearly needs to be an emphasis on *public* transport provision rather than private. Planning considerations are also an integral part of this debate; detailed planning proposals, however, although touched on to provide the fuller picture, are not within the remit of this paper. The introduction of new planning philosophies and the removal of racial barriers to home-ownership will only allow the situation to change slowly and fundamentally in the long term. In the short term, strategies to provide appropriate and affordable mass transportation systems must be designed, including light rail systems, and coordinated bus and minibus networks.

In South Africa, as in any other country, energy and the supply of energy is of major importance. Virtually every sector of the economy – industrial, commercial and domestic – all need energy for their day-to-day operation and long-term survival. Unfortunately, energy is not an infinite resource. As South Africa's economy develops and its population grows, the rate at which these finite resources are

consumed will steadily increase. It is therefore important that we know where these scarce energy resources are being expended, in order to ensure that we are utilising them in the most effective way, enabling the society and economy to develop and prosper in a sustainable manner.

In this paper the issue of energy use by the transport sector is addressed. Although this sector is a diverse one with three types of transport – by air, sea and land – the emphasis of this research is aimed mainly at the largest energy user, land transport. It is also important that energy use by the transport sector is scrutinised, for it is one of the fastest-growing energy consuming sectors, but not recognised as such. Hence there is a severe lack of information available, both in South Africa and, to a lesser extent, world-wide.

The debate surrounding the energy consumed for transportation is of major importance, due to fast-dwindling reserves of oil, and the environmental problems associated with road transport in particular. The political and economic ramifications of these two issues are massive. For instance, in 1973 the world was thrown into crisis by the OPEC oil embargo. The crisis was relatively easily resolved in that oil was soon available, but the threat was recognised that a few oil-producing countries could undermine the world's major economies with ease. The crisis highlighted the uneven distribution of oil resources and the fact that limited global reserves are not going to last more than about 50 years at present consumption rates: they are a scarce resource without a long-term future. The environmental problems related to oil consumption are of equal, if not of more, importance. Burning fossil fuels is the major contributor to local pollution, global-warming and acidic rain. This could result in the raising of sea levels, climatic change, unreliable food supplies, desertification and a host of associated problems, all with enormous potential political and social implications. Although the environmental problems referred to relate to all fossil fuels, transport is a major consumer of oil, one of the most scarce fossil fuels; as such, it is a major player in both the scarcity and environmental scenarios.

Transport uses energy in a number of sectors, the most prominent being in the actual movement of vehicles. This sector is well documented. However, transport also uses energy in a number of other sectors including the provision of a transport infrastructure, the building and maintenance of vehicles, and demand for raw materials. It is important that the energy use of these sectors is also analysed, in order to gain a more realistic view of the true size of transport energy use.

1.1 Scope of the paper

As the aim of this paper is to produce a transport energy policy that makes efficient use of energy, a section will be included which looks at the issue of planning – in particular, land use planning for transport. This is an important issue with regard to energy uses in transport, as the way our cities are built determines, in most cases, the demand for transport. This issue is of exceptional importance in South Africa, due to the legacy of apartheid in determining the urban structures, via the Group Areas Act. As Naude states (1992):

> For a long time now, South Africa has pursued a set of spatial development strategies, which can loosely be termed an urbanisation/ decentralisation (u/d) policy.... [T]he decentralisation aspect of the regional policy has been used to provide an economic rationale for the political policy of locating blacks in homelands remote from existing metropoles and, because this political policy contravenes rational economic principles, it is not surprising to find that efforts to provide these homelands with an industrial base have not worked.

This policy of not allowing natural communities to develop around centres of work, essential services or ease of transport, has led to an extremely inefficient use of transport resources. There is also a corresponding negative impact on people's socio-economic situation, with the poorest of the society obliged to travel vast distances in order to make a living, while the affluent live relatively close to their places of work.

Transport has been used to further the apartheid ideal of a racially divided society, but in this pape, it will be shown that it can also be used to integrate the divided society in urban areas by acting as the connections of the city. Of course, transport cannot do this on its own, but as part of a planning policy which aims to densify the population in urban areas of cities, it can act as the means by which South African cities can become vibrant and desirable places in which to live.

The present structure of South African cities is not amenable to good transport, private or public. The result is an extremely inefficient use of resources, which has a negative impact on the economy and general welfare of society. The policies advanced here aim at reversing the present situation, to ensure that energy is more efficiently used by transport. That, in turn, should lead to a better and more harmonious city structure as well as a more equitable South Africa for all its peoples.

CHAPTER TWO

Transport planning

2.1 Urban transport planning

Much of the time of planners of transport and towns, both worldwide and in South Africa, has been taken up in accommodating the motor-car into our urban areas. This fact, more than any other, has changed the fabric of our cities: how we live in them and how their inhabitants relate to each other. The motor-car has been seen to give people individual freedom of movement, and the belief has grown that it is each individual's right to have this mobility. The motor-car and the 'freedom' it offers had become a status symbol. Cars demote wealth and status in work, with the size of company cars mirroring the company's chain of command, and expensive cars reflecting the affluence of a company.

The motor-car seems to have become an extension of people's egos, with motor-car advertisements successfully playing on this to reaffirm the relationship and the importance of cars. The result of this fascination with the car is that, for the past forty years, urban areas have been designed around accommodating the car, in the belief that only the car offers freedom of personal mobility. Car ownership levels in a country are seen as an indication of that country's wealth, and therefore car ownership and use has been seen as a desirable goal for societies.

Planners themselves have promoted this belief in the car and, more importantly, mobility, in the belief that greater motorised mobility would lead to greater access to goods and services, and so improve people's ability to fulfil their needs. The result of this belief has been planning policies that promoted and allowed for urban sprawl. This in turn has meant that vast distances are travelled by urban dwellers in order to fulfil their basic needs. In South Africa this scenario has been exacerbated by apartheid, in that racial segregation has ensured even greater urban sprawl, by forcing the poorest to live without cars on the outer fringes, while the rich, car-owning minority of whites live closer to the city centres. Further, in order to not demean whites by using the then adequate public transport, a mass of roads has been built in order to ensure that motor-care use and ownership became a necessity of the urban culture.

Today, planning ideology in car-dominated societies no longer holds firm to this belief that mobility offered by the car is a panacea for urban transport problems. It is slowly being realised, as European and American cities become choked by the motor-car, that greater mobility does not mean greater access to goods and services, for either the car-owner/user or, even more, the non car-owner/user. (Although planners are now changing their views, government, with its vested interests in the car industry, and vice versa, is still not willing to change, opting instead to build more roads to ease congestion, only resulting in more congestion.) In planning for the car, access to goods and services has diminished, not only for the non-car-user, but also for the car-user. In the UK, people who own and use cars travel further and, although driving speeds may be faster, take longer and use far more energy to fulfil the same functions that were previously done on foot or by public transport. The result of the planning ideal is that we waste scarce energy resources and urban land space on roads which divide our communities and destroy the social fabric of our cities. This, in turn, results in dysfunctional cities, where the aim of many residents is to live outside the city and commute considerable distances to work, so perpetuating the urban sprawl cycle. Urban sprawl is not conducive to a public transport system that needs areas to be fairly densely populated for the system to work efficiently.

It should be clear from the above that mobility and access are at odds with each other when it comes to planning around the motor-car. Too much mobility has resulted in restricted access to goods and services as well as inequity of opportunity for urban dwellers. In fact, it is impossible to have a goal of equal opportunity for all urban peoples while motor-car mobility remains the city planners' goal. Both planners and government are at fault with regard to how our cities have developed, and in many cases bad developments could have been avoided if proper public consultation had been practised. Many costly mistakes have been made by planners working in the interests of the minority, rather than taking proper cognisance of all the people's needs and wants. This last point is mentioned because it often comes as a surprise to planners, when making transport decisions, that many urban dwellers often do not want more roads, or roads widened to supposedly reduce congestion (more congestion is the result), or so much dependence on the car. They would often rather have a good public transport system which would better serve their needs. In South Africa at least 69% of people of car-driving age either do not own cars or cannot drive[1].

South Africa stands at a crossroads in its history giving an opportunity to rectify the present transport problems, as well as planning to ensure that a similar situation cannot arise with such ease. So what should be done?

The planning system, like the country as a whole, should be democratised. This means that any planned developments must be put before the public, whose views must be accepted by planners and acted upon. No development, no matter how brilliantly far-sighted it may seem, should be allowed to go ahead without the consent of the people affected and the public as a whole. Plans which claim to be of 'strategic' importance to the country must also be questioned by the public, and opponents should receive funding from the state in order to contest such plans. 'Strategic' plans have a history of being strategically useful to a minority and costly to the majority.

Urban sprawl needs to be halted, and a policy of urban population densification should be implemented. Greater urban population densities along public transport routes and mixed-use activity streets will allow for a good, fast and efficient public transport system.

The basic aim of transport planners and city planners should be to develop the cities in such a way that transport needs can be fulfilled on foot, a policy that access to goods and services is based on walking distances.

Roads should become transport corridors and, as such, used to connect and integrate city areas rather than dividing them. This is not that difficult to achieve if roads are made multi-functional, by dividing the road in such a way that pedestrians, cyclists, public transport (tram, bus and taxi), as well as cars, can utilise these areas in safety. The opportunity for small business development and market stalls along these corridors would integrate these corridors further, pulling the city together rather than dividing it as in the present situation.

Private car transport should be restricted in the interests of public transport, a coordinated public transport system should replace the present car-oriented goal of transport and city plans. Planners and government must be made to realise that the unrestricted growth of car-use in urban areas is neither sustainable nor desirable. The car-uses road space and scarce oil resources inefficiently, it creates urban sprawl and severely pollutes the local and global environment.

To conclude this section it must be emphasised that the present transport policy aim of providing mobility, rather than access, is no longer acceptable. Transport planners and government should aim to design and implement planning policies which are in the interests of all South Africans. The transport planning goal should be one that aims at achieving maximum access to goods and services in urban areas

1. Approximately 5 120 467 driver's licences are held in South Africa; therefore, out of a population of 26 288 390 (1991 Census), of which about 16 467 839 are of driving age, the percentage of the population qualified to drive road vehicles is 31%.

by foot, bicycle and public transport. The car should no longer be accepted as the prime transport mode.

The proper future development of South African urban areas and the transport means to integrate these urban areas must be a subject of great interest and responsibility for any South African government, particularly as it has been forecast that, by 2010, 86% of the total population of sixty million[2] people will be urbanised. In the light of this prediction, in transport planning terms, there can be no doubt that the motor-car and road transport in general, would not be an efficient means of providing mobility to such a large urban population. A much more efficient transport system is required. It is the belief of this research that only a coordinated, well-funded, government-supported, public transport system could meet the future urban dwellers needs. Such an integrated transport policy would coordinate all transport modes: car, taxi, bus, rail, tram, bicycle and walking, with the aim of maximising access to goods and services and minimising congestion and pollution.

Due to the scope of this paper, this topic is only touched upon, with some of the main transport planning issues and possible remedies being highlighted. The urban transport planning issue is a complex and demanding one in that politics and ideology are very much part of the process.[1]

2.2 Rural transport planning

The issue of mobility and accessibility is also important in rural transport planning. Accessibility to goods and services for the rural population is important. Mobility for rural dwellers is not important as these people would happily reduce travel if they still had the benefits of, and access to, to a wide range of facilities. Travel for travel's sake is not a prized commodity; it is seen by most people as a waste of time. It would, then, seem more appropriate to reduce the travelling distances for rural dwellers to these needed facilities.

In order to achieve this aim of maximum accessibility for the rural population, different facilities for health, education, shopping, entertainment and sport need to be considered. An approach of this sort should be beneficial to the rural areas, as it would establish balanced rural communities, representing all sectors of society. The main tenet of this approach is one of the decentralisation of facilities as opposed to the present centralisation approach. This, in turn, means that the car and road modes of transport (such as the bicycle and walking, even horse riding) become more important, Naude (1992: 4) suggests that two institutional developments currently under way could accelerate counter-urbanisation in the future:

- Firstly, it is generally believed that urban development has been subsidised in Southern Africa, largely through expenditure on city infrastructure, and that the new Regional Services Council system will serve to neutralise this trend, thus raising costs in urban areas.
- Secondly, the effect of the intention to phase out cross-subsidisation, so that transport tariffs will become more cost-related, will be to encourage industry to locate close to raw material supplies rather than the major markets in the metropoles.

These influences may be important in building economies outside the metropoles, but the primary decentralisation approach would hinge on the ability to make goods and services accessible to non-motorised transport modes. At first glance, this may seem to be economically prohibitive, but the true costs of the centralised system have not yet been compared with the costs of a decentralised approach.

1. A recommended text for further information on the urban and transport planning problems faced by South Africa, and how South Africa can overcome these problems, is 'South African cities: A manifesto for change', (Dewar & Uytenbogaardt 1991).

In costing the competing approaches, issues such as travel, time costs and saving to the provider of the service need to be taken into account. More importantly, however, the cost of the use of resources such as energy for travel and infrastructure provision needs to be taken into account, and if environmental costs of motorised transport are also included, the benefits of centralisation over decentralisation are unlikely to be clear-cut. In this approach, transport provision is seen in a directive role. Such an approach would lead to rural areas achieving a high degree of self-sufficiency and therefore sustainability.

To achieve this goal of decentralisation of the majority of facilities for the rural population would be extremely slow, if indeed possible. The situation at present is that transport, and mainly private road transport, does play a directive role in rural life in South Africa. This is due to the low rural population density prohibiting the growth of a practical urban-type public transport system. However, as the South African population increases, and present small rural towns become larger and more urbanised, the scope for linking these larger towns by rail rather than upgrading the present roads becomes more attractive. In such a scenario, transport centres could be set up along the rail 'trunk' services, with buses and minibus taxis (depending on demand) feeding these transport centres. Such a programme would allow for the growth of a decentralised system of facilities as mooted at the beginning of this section. The larger part of such a system is already in place, but it remains primarily a road transport system. In extending the rail infrastructure to become a much larger part of the rural transport system, it would be possible to integrate all modes of transport, vastly improving the efficiency of energy use.

To summarise this section it is important to emphasis that an increase in the provision and use of rail transport in South Africa is desirable. South Africa is well suited for rail transport, with the majority of the population living in low-lying plateau areas. The rail services should then be used to carry both goods and people over the longer distances or 'trunk' journeys, while road transport and other modes of transport act as a feeder service. Such a system would allow for an efficient use of scarce energy resources, as well as allowing for the growth of a decentralisation of necessary facilities along main transport routes at transport centres. This, in turn, would allow for greater access to these goods and services for the rural population, while at the same time reducing the present rural population's need for great mobility. A transport system of this nature would allow for a much greater degree of equality for the rural population, as the inability to drive or own a motor-car would not be a barrier to opportunity.

CHAPTER THREE

Energy in transport mobility

In South Africa, it is estimated that the transport sector uses 28% of the total nett energy consumed (Synman 1992: 3), although this figure varies between 26.4% and 30%, depending on the source used (Pirie 1991: 3). In comparison with other countries world wide, a figure of 28% appears reasonable. In most industrialised countries, transport accounts for approximately 30% of total nett energy consumption, although there is some variation from country to country (Silverleaf & Turgel 1991: 10). In the United Kingdom, this figure is about 30% (Potter & Hughes 1990: 6). In the European Community (EC) (Silverleaf & Turgel) 1991: 10) and OECD countries (Synman 1992: 3) transport again accounts for approximately 30% of nett energy consumption.

3.1 Modal split between transport sectors

Of this 28% of South African total nett energy consumption, 58% is generated from petroleum, 34% from diesel, 5% from electricity and 3% from coal (Freeman & Burger 1978: 51).

By far the largest user of energy in the transport sector is land transport, followed by air and then maritime transport. In 1976 the situation was of a similar nature, with the transport sector consuming 30% of South Africa's energy. Of this, petroleum products made up 80%, which in turn represented 66% of the country's total petrol consumption (Silverleaf & Turgel 1991: 10). The modal share of this petroleum consumption was as follows:

Mode	*Percentage*
Road transport (all)	85.3
Air transport	7.9
Rail transport	6.3
Maritime transport (not international)	0.5
TOTAL	100.0

TABLE 3.1 Relative petroleum consumption by transport mode
Source: Freeman & Burger 1978: 51

It is clear from the above table that land transport (in particular road transport) takes by far the largest share of energy in mobility terms (energy used to move vehicles). Although the table is dated in that it refers to the situation in 1976, the position is comparable to the present. Restrictions on energy consumption are gradually being lifted, but at the time of writing certain data was still restricted. The DMEA quote figures for the consumption of liquid petroleum consumption up to 1992:

- petrol consumption in 1992 was 8 985 megalitres, a 60% rise since 1976; whereas
- diesel consumption at 4 875 megalitres corresponds to only a 6%increase since 1976.

Although the specific figures to show that the modal share of consumption is similar in 1992 are not available, the transport modal energy split in OECD countries provides a useful comparison and suggests that the 1976 split is likely to have remained similar. However, the far greater increase in petrol consumption over

diesel, suggests that private car use has increased significantly more than diesel-using modes such as rail, marine, buses and heavy trucks. Thus if the modal split has changed it is likely to be even more skewed towards road transport.

Mode	*Percentage*
Road transport	82
Air transport	13
Rail transport	3
Inland waterways	2

TABLE 3.2 Energy consumption in OECD countries by transport mode
Source: Silverleaf & Turgel 1991: 10

It is clear from the above two tables that in both South Africa and OECD countries, road transport takes a lion's share of the total energy consumed by transport in mobility terms, which is generally the terms of reference in which energy and transport are linked.

Road transport is the greatest user of energy, in the form of petroleum and diesel, simply because of the vast number of vehicles and the huge road infrastructure that facilitates their use. In South Africa, there were 4 901 212 road vehicles registered in 1990, of which 3 403 605 were motor cars, 196 243 mini-buses, 28 107 buses and 1 273 257 commercial vehicles; in addition, there there were a further 298 941 motor cycles and 105 571 tractors registered (CSS 1991: 1).

3.2 Efficiency of mobility energy use

Road transport is dominated by the motor car, or private transport. In terms of vehicle fuel efficiency this is not a good situation, as, out of all the land transport modes, motor cars are the least fuel efficient. In fact, only air transport is less energy efficient than the motor car, especially when it is utilised at low occupancy levels. The average occupancy levels for South African cars during peak hours is approximately 1.25 persons per car (Mann 1990: 1), which is similar to EC car occupancy levels of 1.4 persons per car (Zeevenhooven 1990: 8).

In Table 3.3 an EC analysis of modal energy use in the transport sector (see Appendix I for comparative South African study), it is clear that at 25% occupancy levels, most transport modes are energy inefficient. However, it is the motor car, which is constantly used at this occupancy level, which can be seen as the most energy inefficient, even though it is better in terms of MJ per passenger km than air transport and in some cases, high-speed trains. Both air and high-speed rail transport could not operate on a commercial basis at 25% occupancy levels for a sustained period of time, but the private car has, for many years. It is also important to note that only a car of less than 1.4 litres engine capacity is more fuel efficient than high-speed rail transport at equal occupancy levels, while medium and large cars are always less energy efficient than such trains. The least energy efficient mode of transport remains air transport.

The South African figures given in Appendix 1 are largely similar to the EC figures. However, some differences are worth highlighting. Private car efficiencies are directly comparable, as similar types of car are used. The figures for Kombi taxi's of 0.45 MJ/pass-km at 50% occupancy and 0.39 MJ/pass-km at 100% (for a 16 seater), show it to be a far more efficient mode of transport than the car, but marginally less efficient than suburban rail, or bus transport, at similar occupancy levels. South African intercity rail energy efficiencies compare favourably with those of the EC; 0.24 MJ/pass-km at 91% capacity compared to 0.29 MJ/pass-km at 100% capacity. Suburban rail is less efficient than its EC counterpart; 0.39 MJ/pass-

km at 76% occupancy compared to 0.35 MJ/pass-km at 75% occupancy. However, it can be seen that all forms of rail travel in South Africa are highly energy efficient if occupancy levels are high.

It is also worth noting that all the average (ie, not high-speed) public transport land modes are significantly more energy efficient than the private car alternative. A future transport policy could make far more efficient use of the existing rail and road networks, at minimum cost, primarily by introducing highly efficient buses and express cars (trams), in preference to private cars.

Table 3.3 gives the energy efficiency of the various land passenger transport modes as well as air passenger transport:

Mode	*Seat capacity/unit*	*Occupancy rate*			
		25%	*50%*	*75%*	*100%*
1. Gasoline car					
<1.4 (Engine capacity in litres)	4	2.61	1.31	0.87	0.62
1.4 - 2.0	4	2.98	1.49	0.99	0.75
>2.0	4	4.65	2.33	1.55	1.16
2. Diesel car					
<1.4	4	2.26	1.13	0.75	0.57
1.4 - 2.0	4	2.76	1.38	0.92	0.69
>2.0	4	3.65	1.83	1.22	0.91
3. Railways					
Intercity	563	1.14	0.57	0.38	0.29
Super sprinter	147	1.31	0.66	0.44	0.33
Suburban electrical line	300	1.05	0.59	0.35	0.26
High-speed train 300 km type					
Brussels to Paris	375	2.86	1.43	0.96	0.72
London to Paris	700	2.50	1.25	0.83	0.62
4. Bus/car					
Double-decker	100	0.70	0.35	0.23	0.17
Bus	48	1.17	0.58	0.39	0.29
Minibus	20	1.17	0.58	0.39	0.17
Express car	46	0.95	0.50	0.33	0.25
5. Air					
Boeing 727	167	5.78	2.89	1.94	1.45
6. 'Soft' transport					
Cycling	1				0.06
Walking	1				0.16

TABLE 3.3 Specific energy consumption for different passenger transport modes at different occupancy rates
(MJ primary energy/passenger km)
Source: CEC 1992: Tables 1 and 2

3.3 Oil imports and synfuel production

A tremendous amount of energy is being consumed by an energy inefficient mode of transport, the motor car, and at an increasingly high cost to the South African economy. South Africa is not an oil-producing nation, and imports all its oil, with a large impact on the balance of trade and the economy. In an attempt to ensure oil supplies during the oil embargo, imposed as part of the international anti-apartheid sanctions, two plants were built to produce synthetic oil from indigenous resources. The SASOL and MOSSGAS plants produce oil from coal and natural gas respectively. Both processes are recognised as expensive and not cost effective. It is estimated that the MOSSGAS plant alone has absorbed R10.7 billion of investment that is highly unlikely to be recovered (McGregor 1993). The synthetic oil is subsidised by the government to allow it to compete with imported oil, and it supplies 40% of South Africa's refined oil needs (McGregor 1993).

Car ownership and use in South Africa is skewed disproportionately in favour of the white population. Approximately 80% of black commuter trips are made by public transport, while at least 60% of white commuter trips are made by car (World Bank 1991: 14). When the figures for oil importation are shown, it becomes clear that considerable sums of money are being spent in the interests of the minority of South Africans. Table 3.4 gives the cost of oil imports as a percentage of total imports from 1973 to 1977. Data after 1977 was severely restricted until 1993 under the Petroleum Act of 1977, introduced in the face of the international oil embargo. By early 1994 all petroleum product data should once more be available.

Year	*Percentage*
1973	4.6
1974	9.7
1975	11.6
1976	14.5
1977	15.0

TABLE 3.4 Oil imports as a percentage of total imports (monetary value)
Source: Freeman & Burger 1978: 56

3.4 Mobility energy consumption figures

In order to calculate an energy balance for South Africa's transport sector, figures for mobility energy consumption must be included. It has been stated in section 3.1 that in 1976 84% of transport energy was derived from petrol and diesel. Table 3.2 shows that road and air transport use 95% of OECD mobility energy. Both these modes rely on oil to provide this energy. Thus this paper will assume that a minimum of 90% of mobility energy is derived from petrol and diesel.

Figures for petrol and diesel consumption are shown in Table 3.5. These values will be used to calculate the figures used in the final energy balance in the absence of more comprehensive data. Although the figures may not be precise, they are sufficient to fulfil the papers objective of providing an overall energy balance, and allow a comparison of energy use between vehicle operation, manufacture and maintenance.

User	Petrol (Megalitres)	Diesel (Megalitres)	Total (Megalitres)
ROAD			
Service stations	8 326.815	621.181	8 947.966
Local authority	82.334	95.530	177.864
Buses	9.190	297.702	306.901
Municipal buses	0.311	18.359	18.670
Road hauliers	31.921	721.788	753.709
Transnet	26.780	302.329	329.109
MARINE			
Fishing	0.914	83.538	84.452
MIXED			
State	219.415	177.928	397.343
TOTAL	8.697.689	2 318.355	11 016.044

TABLE 3.5 Consumption of petrol and diesel for transport mobility in 1992
Source: DMEA: 1993

The total of 11 016 megalitres accounts for approximately 80% of the total combined petrol and diesel consumption for 1992 of 13 860 megalitres. The remaining 20% is consumed by the farming and industrial sectors and sold through general dealers for a variety of end-uses (DMEA 1993).

To include the figures for petrol and diesel consumption into the final energy balance, they must be converted into annual energy usage units of GWh per annum.

One barrel of typical crude oil has the potential to provide 1 700 kWh of power. Petrol and diesel make up over 60% of the barrel, and fall into the light and middle distillate groups respectively (McGregor 1993: 7). The conversion factor used for the barrel as a whole can thus reasonably be applied to the use of petrol and diesel for traction purposes. If one barrel of crude contains 159 litres, then one litre is equivalent to 10.69 kWh. Multiplying this value by the total (from Table 3.5) of 11016.044 million litres gives an annual energy use figure of 117 761.51 GWh. This figure appears somewhat large, and should be treated as an order of magnitude estimate at best. It will be included in the overall energy balance in Chapter 7.

In terms of order-of-magnitude estimates it is useful to split this energy-use figure into road and rail components. Table 3.1 shows that 85.3% of petroleum products are used for road transport and 6.3% by rail. Table 3.6 summarises the data.

Road	Rail	Total
100 450.57	7 418.98	107 869.55

TABLE 3.6 Estimate of annual mobility energy use based on 1992 figures (GWh)

3.5 Towards a more efficient future

In the light of both the energy efficiency for various vehicles and the cost of oil imports and synthetic production, it is clear that South Africa should be placing more emphasis on more energy-efficient forms of transport. Such emphasis would result in a far more energy- and finance-efficient system than presently exists. This in turn would be in line with current political and social aims of redressing the huge wealth imbalances which exist in South African society.

In order to improve transport energy efficiency significantly there needs to be a

switch from low-occupancy private car-use to more efficient road and rail alternatives. The use of more fuel-efficient, smaller-engined, cars is often advocated as a route to improved energy efficiency. Although, as Table 3.3 indicates, efficiencies can be high when the car is full, this is rarely the case. At 25% capacity no car is an efficient user of energy or road space.

However, in order to change the energy use of cars, one is first faced with the generally held view that cars allow greater mobility and shorter travel times than any other form of transport, as well as providing privacy and ease of travel. The latter two points may well be true for many travellers, but the view that greater mobility is achieved and shorter travel times result can certainly be challenged. There are many societies which have held this belief and have reached very high levels of car ownership and, more importantly, car usage. The UK provides a good example of a country that has failed to challenge the dominance of the private car, resulting in a situation that South Africa will face sometime in the future, if present priorities are not changed.

In the UK car ownership and use has risen dramatically. Yet, although personal mobility has increased for car users, journey length and time has increased, resulting in increased energy consumption. There are now some 22 million motor vehicles, using 33 000 km of road in the UK. However, although the number of journeys made per week has remained static, at 18, both time and distance travelled have increased by 10% and 33% respectively to fulfil the same needs (Potter & Hughes 1990: 6). Increased mobility, rather than facilitating quicker and shorter journeys has had entirely the opposite effect. The result is an increase in energy consumption and reduced access to services, that is further worsened as the continued increase in traffic densities leads to congestion of roads and disrupts bus services.

Energy used in transport mobility has clearly not been an important consideration when providing transport facilities in the past, with far more energy consumed than is necessary, adding to the problems of both resource depletion and pollution. An integrated transport system that did not rely so heavily on road transport could avoid the resource inefficiencies that have been highlighted. The important issue of mobility energy use and planning has been addressed in the planning section of this paper.

3.6 Summary

The motor car is not energy efficient when compared to other competing modes of transport. Light rail, buses, cycling and walking are by far the most efficient users of mobility energy. When combined they also provide better access to goods and services for the vast majority of people.

In the new South Africa, in which wealth imbalances need to be addressed to achieve a more egalitarian society, continuing to support the motor car at great economic cost is in the interests of only a few, primarily the white privileged minority. It is argued that it is not in the interests of South Africa to further entrench societies dependence on the motor car as the primary means of transport, nor is it possible to provide this mobility to the majority of people. A move to more energy efficient modes of transport, a greater emphasis on public, as opposed to private, would better serve both the social and economic goals of a new South Africa.

CHAPTER FOUR

Energy use in transport infrastructure

Traditionally, energy analysis of transport systems has only addressed the energy that is consumed during transportation – the mobility side of energy use, not the energy used in the provision and maintenance of the vehicles and associated infrastructure. This analysis is now being challenged by new techniques that attempt to include all the other energy using stages into the analysis. Each sector, or component, of transport has an energy cost. This, and the following chapter, will attempt to quantify this additional energy consumption and include it in the total energy use of the transport sector.

A transport mode is dependant on its infrastructure, as it determines the mode's ability to deliver transport services. All transport modes are constrained by their infrastructure and, in most cases, infrastructure constraints also determine the amount of interaction possible between modes. The infrastructure provision for each mode usually gives a clear indication of a country's transport goals.

4.1 Infrastructure provision

In South Africa the infrastructure provision is clearly aimed at promoting road transport. In a country ideally suited to rail transport, in that there are vast distances between major urban areas, the past and present transport policies of the South African government have been road-based. These policies have produced a substantial, and rapidly expanding, road network at a huge economic and energy cost, and a far smaller rail system that has received little infrastructure investment.

In South Africa, the World Bank Mission claims there are some 305 000 km of road, of which about 100 000 km are tarred, while there are about 34 000 km of single rail track (World Bank 1991: 19). However, in the light of more recent statistics, compiled under a new classification system by the TSRI (SATS 1990: 72), the following table gives a more accurate picture of the national and provincial road network in South Africa.

Year	*Road classification and amount in km*				
	Dual-carriage freeway	*Conventional dual-carriage*	*Single-carriage paved*	*Gravel & earth roads*	*Total all roads*
1981	1 331	188	48 152	136 083	185 754
1982	1 483	234	47 064	135 947	184 708
1983	1 614	264	47 384[1]	134 592	183 854[1]
1984	1 686	272	48 002	134 296	184 256
1985	666	302	48 744	133 106	183 818
1986	718	312	48 717	130 874	182 621
1987	1 781	390	50 333	130 484	182 988
1988	1 740	403	49 208	128 777	180 128
1989	752	357	50 238	128 794	181 141
1990	893	419	53 071	130 368	185 751

Note

1. Numbers differ by 228 from Department of Transport figure for the same year.

TABLE 4.1 Summary of national and provincial road networks in kilometres at 31 March for each year
Source: SATS 1990

Table 4.1 shows that there are only 55 383 km of tarred road in South Africa, just over half the World Bank mission figure of 100 000. This discrepancy can be partially explained by the omission of urban roads from Table 4.1. Table 4.2 uses the old administrative classification system, adding a further 34 000 km of urban tarred roads to the network, bringing the figure up to approximately 90 000 km of tarred/paved roads in South Africa, and the total road length to approximately 250 000 km.

In view of this differing information, this analysis will also use the older administrative classification system. (The analysis remains the same, but due to data inaccuracies, it was thought that this system should be used until more reliable data is available.) Table 4.2 shows the breakdown of roads by administrative responsibility.

Road authority	*Length of paved road*	*Length of unpaved road*	*Total length*
National	6 100		6 100
Provincial	47 500	116 000	163 500
TBVC	3 000	16 500	19 100
Self-governing territories	1 000	16 800	17 800
Urban areas	34 000	9 000	43 000
TOTAL	91 600	157 900	249 500

TABLE 4.2 Road network in South Africa in km (old classification)
Source: Department of Transport (World Bank: 19)

The above figure of 249 500 km of road, when compared to the 34 000 km (SATS 1990: 72) of rail track, gives a ratio of road to rail infrastructure length of approximately 7:1. The World Bank Mission figure of 305 000 km of road compared to rail of 34 000 km results in a ratio of 9:1, while the TSRI report results in a ratio of 5.5:1 (however, when the extra 43 000 km of urban road is added to this figure, resulting in a total of 229 000 km of road the ratio of road to rail is 6.7:1). The average ratio of road to rail length is thus approximately 7:1. By EC and OECD standards, this is quite a favourable ratio for rail. In the EC the ratio is 20:1 in favour of road. This comparison suggests that South Africa has a more balanced network than is found in the EC, potentially allowing an integrated transport network to be more easily developed. It is worth noting that, although th EC is still maintaining a strong road building scheme in the poorer EC countries, in the most developed EC countries the emphasis is now on providing a more comprehensive rail infrastructure. This is as a result of the realisation that the unfettered growth of road transport is no longer desirable, nor possible. As the EC 'Group Transport 2000 Plus' states:

> [T]he sum of the negative factors seems to cancel out the extra wealth, efficiency, comfort and ease which should result from the rise in [road] traffic volume. The situation now is that these negative factors have become a very real threat to the single market and worse – to the very essence of the EC. Quite simply, they pose a direct threat to the main objectives of the Community. (Royal Institute of Chartered Surveyors 1991: 14)

South Africa is now in a position to redress the imbalance between road and rail without incurring the massive costs of financing road schemes that are doomed to create more congestion rather than relieving congestion problems. Parts of the EC and the USA have begun to realise that further road building is not the most efficient method of addressing transport needs. Rather, they are turning to rail and public transport as the means of ensuring an efficient transport system for the future, for all users of the system.

The rail network in South Africa is in a much more favourable position than in the EC in terms of the ratio to road. The following table gives the size of the network

from March 1982 to March 1989.

	Year ending 31 March						
	1982/3	*1983/4*	*1984/5*	*1985/6*	*1986/7*	*1987/8*	*1988/9*[1]
Route distance	23 644	23 270	23 821	23 740	23 607	23 507	21 244
Track distance	36 214	36 499	36 809	36 875	36 735	36 449	34 090
Double-track distance	5 901	6 142	6 327	6 528	6 817	6 958	6 920

Note
1. Namibia excluded as from 1988/9

TABLE 4.3 Length of railway line in South Africa (kilometres)
Source: SATS 1990: 72)

Chapter 3 showed that a switch to rail and public road transport would use energy for mobility more efficiently and provide better access to goods and services for the majority of people. In terms of infrastructure construction and maintenance it is also more energy efficient to build railway lines than highways. Table 4.4 indicates that 61% more energy is required to build a kilometre of tarred road than a kilometre of railway line.

It has been calculated that rail is able to carry 70 000 passengers per track per hour, while road transport would need thirteen times as much space to achieve the same volume of passenger traffic (Roberts et al 1991: 6) (or about thirteen lanes of traffic); this is known as the infrastructure 'use value'. In any terms, not least in those of energy consumption for infrastructure provision, this can only be viewed as a most costly means of providing transport. Table 4.4 shows that the provision of a two-lane road (one lane in each direction), requires more energy than a single-rail track. If the 'use value'[1] of the two infrastructures is also considered, the energy needed for road construction would then need to be multiplied by 6.5 for it to achieve the same use value as a single-rail track (by 6.5 and not 13 because the data refers to the energy needed to build a road with a single lane in each direction, two lanes in total).

Infrastructure type	*kWh per km*
Infrastructureconstruction	
Road	90 000
Rail	56 000

TABLE 4.4 Energy use in road and rail infrastructure provision 1988
Source: Howard 1990: 15

Infrastructure construction in Table 4.4 refers simply to the building of the actual road or railway line. In reality infrastructure costs include far more than just road or rail building, such as the provision of, for example, garages, terminals and stations.

In order to obtain a meaningful comparison of the energy used to construct each system, the 'use value', or the system's carrying capacity, must be taken into account. Using the figures from Roberts et al (1991), the 90 000 kWh per kilometre energy cost of road construction must be multiplied by 6.5, resulting in a figure of 585 000 kWh per kilometre. Therefore, in order to construct both infrastructures to achieve equal capacities, rail uses only 9.5% of the energy needed to build a road of equal capacity. However, in order to achieve an energy balance for transport in South Africa, it is important that an energy figure is calculated for the total length of road and railway line built each year.

1. 'Use-value' refers to the maximum volume of traffic a pathway is able to accomodate without congestion: its 'capacity'.

Bitumen accounts for approximately 55% of the energy needed to construct a tarred road, with the remaining 45% split between the energy used in the production of other raw materials and the use of vehicles to build the road. This distinction is important when calculations are done for the energy consumption in the construction of gravel roads.

The following two tables show the increase in road and rail respectively, and the energy consumption involved in constructing these new roads and railway lines. The increases in the network sizes are based on Tables 4.1 and 4.3.

Infrastructure type	*kWh per km*	*SA total kWh/annum*
Infrastructure construction		
Road	90 000	71 244 000[1]
Rail	56 000	12 219 200
TOTAL		83 463 200

Note
1. Excludes urban roads.

TABLE 4.5 Estimate of the average energy consumption for road and rail infrastructure provision in South Africa 1983-1988

Table 4.5 shows that almost six times as much energy is expended annually on road infrastructure provision as on rail. This can be seen as an inefficient method of providing transport infrastructure when the capacity constraints of road, compared to rail, are taken into account. An annual energy consumption figure for road and rail infrastructure provision has now been calculated, albeit an estimation. These figures will be important contributors when calculating the energy consumption cost of the land transport sector.

4.2 Infrastructure maintenance

All infrastructures need regular maintenance to insure their efficient utilisation. This maintenance has an energy consumption component which, in the case of road maintenance, is actually higher per kilometre than construction. Table 4.6 provides energy consumption data for maintenance of the road and rail networks.

Infrastructure type	*kWh per km*	*Lifespan (years)*
Infrastructure maintenance		
Road	97 000	40
Rail	21 100	50

TABLE 4.6 Energy use in road and rail infrastructure over track lifespan
Source: Zeevenhoven 1990: 13

The main reason for the energy intensiveness of road maintenance is the renewal of the bituminous surfacing, which forms some 67% of the total maintenance energy consumption, and some 70.5% of the total energy consumption in raw material production. The remaining energy is consumed in the production of other raw materials and the use of vehicles and machinery to carry out the work. These distinctions are important when calculating the energy consumption of maintaining gravel roads.

Using the figure of 249 500 km of total road length in South Africa from Table 4.2, and assuming a 40-year lifespan of a road, the average energy consumption for maintenance purpose per annum would be 307 861 850 kWh. For rail, using the

total track distance of 34 090 km, and assuming a 50-year lifespan, the average energy consumption for maintenance purposes per annum is approximately 14 348 000 kWh. Table 4.7 shows this more clearly.

Infrastructure type	*kWh/annum*
Road	307 861 850
Rail	14 348 000
TOTAL	322 209 850

TABLE 4.7 Annual South African energy consumption for infrastructure maintenance purposes

As in Table 4.4, the above estimates include only the energy consumption needed to maintain the actual road and rail track, and not the associated structures such as petrol stations and rail termini.

The ratio of annual energy consumption for infrastructure maintenance of road to rail is 21:1. When compared to the ratio of the length of road and rail in the country of 7:1, it is clear that the road infrastructure requires considerably more energy to maintain it than the rail system.

4.3 Summary

This chapter has shown that any transport infrastructure has a high energy cost, both for provision and maintenance. The figures calculated are estimates only, and should be treated as such, due to the lack of detailed reliable data and previous research in this field in South Africa.

However, the figures do highlight the vast energy cost associated with road building and maintenance, compared to rail, even though it is unable to deliver a similar level of service. Put another way, a far greater carrying capacity could be achieved if the current annual road energy expenditure was transfered to rail provision and maintenance.

In terms of the energy costs of infrastructure, the present accepted policy of promoting road transport as the primary mode, by providing it with the bulk of energy infrastructure investment, should be re-evaluated if South Africa is to move to a more energy efficient transport system.

CHAPTER FIVE

Energy use in vehicle provision and maintenance

5.1 Vehicle provision

In South Africa there is a large vehicle manufacturing industry. Traditionally, the energy balance of this industry has been allocated to the manufacturing sector. However, in order to get a true picture of the transport sector, this paper challenges this view, and argues that the energy consumption involved should be a part of the transport energy balance. In order to satisfy transport needs, vehicle provision is essential. Infrastructure such as roads, railway lines, ports and airports, along with fuel produced to power each mode of transport are all useless without the vehicle to exploit them. All are provided to satisfy the demand for transport services. It therefore follows that the energy consumption involved in procuring these vehicles should be allocated to the transport energy balance account.

In South Africa 340 094 road vehicles of all categories are produced on average each year, according to the NAAMSA (1992) statistics for vehicle sales in 1988, 1989 and 1991. Production figures differ from the number of vehicles registered in South Africa because, although the vast majority stay in South Africa, vehicles are also sold to other African states and the 'independent homelands'. The fact that these vehicles are sold outside South Africa is not of great importance, for the purpose of this analysis; the important issue is that these vehicles are produced in South Africa and, therefore, the energy consumption in their production has an influence in a South African energy transport balance. It is impossible to produce absolute figures on energy consumption in vehicle manufacture, but figures are useful in estimating vehicle production energy consumption.

Energy consumption estimates for vehicle manufacture calculated by Zeevenhoven (1990: 14), are given in Table 5.1.

Energy for manufacturer	*Car (Light vehicle) 1 340 kg + driver*		*Truck (Medium vehicle) 9.5 ton*		*Truck (Heavy vehicle) 23 ton*	
	EL	*FE*	*EL*	*FE*	*EL*	*FE*
Raw materials	2.0	9.7	5.9	32.0	11.4	67.1
Manufacture	2.2	0.2	7.9	7.9	14.8	15.2
TOTAL	4.2	11.9	13.6	39.9	26.2	82.3

EL: Generated energy *FL: Fossil energy*

TABLE 5.1 Energy used in the production of vehicles for passenger and freight transport (1000 kWh)
Source: Zeevenhooven 1990

The lack of data in this area means that any figures produced from this table can be considered as estimates only. A further problem related to the energy used in manufacture is that not all road vehicles fall into the above three categories. As Table 5.1 shows, there are considerable differences in energy use between categories; so it becomes important to define each category precisely, in order to overcome this difficulty. This paper assumes that vehicles which weigh up to 5 000 kilograms fall into the car, or light vehicle, category, vehicles from 5 001 kilograms to 12 500 kilograms fall into the 9.5 ton, medium vehicle, category, while vehicles above the 12 500 kilograms fall into the 23 ton, heavy vehicle, category.

Table 5.2 shows the vehicle sales in South Africa by weight classification for the years 1988, 1989, and 1991.

Weight (kg)	Year (January to December)				
	1988	1989	1991	3 yr total	Average
Category: Light vehicle					
Car	230 447	221 273	197 736	649 456	216 485
Car -2 251	38 243	32 285	29 113	102 641	34 213
2 251-5 000	75 845	81 995	71 292	229 132	76 377
TOTAL	344 535	335 553	298 141	981 229	327 075
Category: Medium vehicle					
5 001-7 500	5 611	4 280	4 127	14 018	4 672
7 501-10 000	943	925	801	2 669	889
10 001-12 500	1 924	1 698	1 354	4 976	1 658
TOTAL	8 478	6 903	6 282	21 663	7 219
Category: Heavy vehicle					
12 501-15 000	3 170	3 244	1 767	8 181	2 727
15 001-17 500	613	609	366	1 588	529
Over 20 000	2 926	3 188	1 519	7 633	2 544
TOTAL	6 709	6 798	3 652	17 402	5 800

TABLE 5.2 Vehicle sales in South Africa by weight classification for the years 1988, 1989, 1991
Source: NAAMSA (1992)

In order to calculate an energy balance for the road vehicle manufacturing industry, the production energy figures from Table 5.1 for each category are multiplied by the total average number of vehicles produced over the three years (Table 5.2). Table 5.1 has divided the energy used in the manufacturing process into two distinct areas. Firstly the use of energy in the place of production, basically electricity, (EL), and, secondly, the total energy used, which includes the generation of the energy-using fossil fuels, (FE).

The EL calculations result in a figure of 1 623.8534 GWh for the South African road vehicle manufacturing industry, whilst the FE calculation results in a figure of 4 657.5706 GWh. The FE estimate appears more realistic when compared to a survey done on behalf of Eskom, which concluded that the South African motor vehicle production industry consumed some 4 700 GWh per annum (ESKOM Motor vehicle production energy use report).

Having produced an estimate for the total energy used in the production of road vehicles in South Africa, the energy used for maintenance must be addressed. The manufacture of railway engines and rolling stock has not been addressed in this section because they are not built in South Africa. The maintenance of rolling stock is undertaken within the country and is covered in section 5.2. The energy consumption figures for the maintenance of all these modes of transport produced by Zeevenhoven have been used. Although not produced within a South African context, the figures are felt to be suitable, and can be used with some confidence where there is no indigenous information available.

5.2 Energy use in the maintenance of land transport vehicles

Maintenance of transport vehicles carries a cost, in both monetary and energy terms. Unlike the manufacture of these vehicles, which is a one-off capital cost, maintenance continues throughout a vehicle's life. An example of this is the taxi industry in South African in 1986, where expenditure on vehicle maintenance equalled approximately 22% of the total value of the South African taxi fleet (Census of transport services 1986: 197). At this rate of expenditure, the maintenance bill for the taxi sector would have exceeded the initial cost of the taxi vehicle fleet within five years. Although this cannot be considered an absolute figure for all vehicles, it serves as a broad benchmark for most commercial transport concerns. The maintenance cost for private cars is, on average, likely to be considerably less than the figure quoted for the taxi fleet, because they are used far less – how much less is not known.

The interest of this paper is to determine the maintenance energy cost for transport vehicles and, although statistics are not available for the South African scenario, European figures produced by Zeevenhooven are contained in Table 5.3.

1 000 kWh	*Car: 1 340 kg + driver*		*Truck: 9.5 ton (Medium vehicle)*		*Truck: 23 ton (Heavy vehicle)*	
	EL	*FE*	*EL*	*FE*	*EL*	*FE*
Maintenance						
Spare parts	1.2	3.4	3.1	9.2	6.0	19.0
Tyres	0.2	3.0	0.9	16.2	2.6	44.5
Lubricants	–	1.4	–	4.0	–	21.0
TOTAL ENERGY	1.4	7.8	4.0	29.4	8.6	84.5

TABLE 5.3 Energy consumed in the maintenance of vehicles for passenger and freight transport
Source: Zeevenhooven, 1990

The above energy values for maintenance of vehicles are the approximate total energy consumption in supplying a vehicle's maintenance needs over its lifetime, which, in the case of cars or light and medium vehicles, is taken to be 200 000 km. Heavy vehicles are assumed to have a life of 480 000 km. In order to calculate an annual energy balance, it is assumed that the average life of a vehicle in South Africa is approximately ten years (the maintenance figures are, therefore, divided by ten to get an average yearly figure). Ten years is, according to the statistics available, a close enough approximation for the purposes of this study (CSS 1991: 5). The maintenance energy consumption figures for each of the categories of vehicle size, are contained in Table 5.4.

Light vehicles	EL	140 kWh per annum
	FE	780 kWh per annum
Medium vehicles	EL	400 kWh per annum
	FE	2 940 kWh per annum
Heavy vehicles	EL	860 kWh per annum
	FE	8 450 kWh per annum

TABLE 5.4 Vehicle maintenance energy consumption per vehicle

This paper will use the FE estimates, as they more accurately reflect the total energy that is used, the primary energy, and, as was seen in the vehicle manufacturing section, the FE estimate appeared more realistic when compared with other data.

It is now possible to estimate, using the above three broad categories of vehicle, the average energy consumption for road vehicle maintenance for 1990, using the Central Statistical Services data for the number of vehicles registered for each category at 30 June 1990:

- Light vehicles: 4 576 754 x 7 80 kWh = 3 569 868 100 kWh
- Medium vehicles: 105 512 x 29 40 kWh = 310 205 280 kWh
- Heavy vehicles: 89 554 x 84 50 kWh = 756 731 300 kWh
- Total road transport maintenance energy consumption per annum: = 4 636 804 680 kWh

It is now possible to estimate the energy consumption for the manufacture and maintenance of road transport modes by adding the two primary energy (FE) estimates together.

- Total energy balance = 10 179.4697 GWh per annum.

It is worth noting that the assumed maintenance energy consumption of South African road vehicle transport is almost as great as the total manufacturing industry of road transport vehicles. Only 21 GWh separates the two estimates, so it is only a matter of time before road vehicle maintenance energy consumption overtakes road vehicle manufacturing energy consumption, assuming the vehicle population rises as expected (4.5 million cars by the year 2000). It should also be stressed that the above calculations result is only an estimated energy consumption for this sector. This estimate is a very conservative one, and as such it should be realised that the actual energy consumption figure for manufacture and maintenance of road transport vehicles is likely to be greater than this estimate.[1]

Maintenance is undertaken on railway vehicles in South Africa, and the comparison to road transport maintenance energy consumption is useful, and important for calculating the transport energy balance. The following table gives both the manufacture and maintenance energy consumption figures, but at this stage it is the maintenance figures which are important.

1 000 kWh	*Rail engine + 32 twin-axle freight cars*		*Rail engine + 5 passenger cars*	
	EL	*FE*	*EL*	*FE*
Energy for manufacture				
Raw materials	825	3 097	549	1 785
Manufacture	281	757	251	546
SUB-TOTAL	1 106	3 854	800	2 331
Maintenance				
Spare parts	1 278	3 234	1 552	4 107
Tyres	–	–	–	–
Lubricants	–	–	5 250	–
SUB-TOTAL	1 278	3 944	6 802	5 150
TOTAL	2 384	7 798	7 602	7 481

TABLE 5.5 Energy consumed in the production and maintenance of vehicles for freight and passenger transport
Source: Zeevenhooven 1990: 14

The life of a freight engine is estimated at 7 000 000 km, while the twin-axle wagon's life is 600 000 km. The passenger train engine life is also estimated at 7 000 000 km, with the passenger wagons at 5 250 000 km. This paper assumes that this mileage

1. Lack of data, and the time constraints of this paper, preclude a more accurate appraisal of this transport sector, but it should become a major area of transport research, as it would seem to be an area where energy saving could be achieved.

lifespan would be achieved over 20 years.

South African Railway transport fleet statistics, showing the average annual stock from 1981 to 1989, are included in Table 5.6. Steam locomotives are excluded.

Electric locomotives	2 230
Diesel Locomotives	1 605
Coaching vehicles	10 070
Goods stock (excluding cranes)	176 442

TABLE 5.6 South African rail transport fleet average annual figures (1981-89) (excluding steam locomotives)
Source: South African Transport Services (1990)

Table 5.6 shows that there are enough freight and passenger wagons to fulfil Zeevenhooven's criteria, in Table 5.5, of 32 goods wagons and five passenger coaches per train. It is assumed that both diesel and electric engines are used for passenger and freight transport – half for freight and half for passenger transport. The resultant maintenance energy consumption estimates are contained in Table 5.7.

1 917 train engines + 32 2 axle cars per engine	EL: 122 496 300 kWh per annum
	FE: 370 032 400 kWh per annum
1 917 train engines + 5 passenger cars per engine	EL: 651 971 700 kWh per annum
	FE: 493 627 500 kWh per annum

TABLE 5.7 Rail maintenance energy consumption estimates

Using the primary energy consumption (FE) estimates, a total figure of 871.6599 GWh is estimated as the annual maintenance energy consumption for the South African passenger and freight railway vehicle fleet. Again, it must be stressed that this is a broad estimate, and can only be considered as such; it is believed to be a conservative estimate as the true maintenance energy consumption is probably in excess of this.

It is now possible to compare the manufacture and maintenance energy consumption of road and rail transport. Table 5.8 outlines the figures.

Road transport uses approximately 4 600 GWh in the manufacture and in the maintenance of vehicles. There are no figures for rail manufacture, because no railway engines are built in South Africa. Rail uses only 871 GWh of energy annually to maintain its fleet, approximately one fifth of the road maintenance energy. Overall the figures clearly show that the manufacturing and maintenance of land transport vehicles is a large energy consuming sector. Within the road sector, it is clear that the vast majority of energy is consumed by light vehicles, of which most are private cars.

To obtain a clearer comparison between road and rail, it is useful to break the figures down to the energy used per vehicle over each kilometre travelled. Table 5.9 shows the total energy used for manufacture and maintenance for road and rail vehicles in these terms. The calculations are based on the data used in this chapter and have assumed occupancy levels of 40%.

	Consumption per vehicle / annum (kwh)	Total per annum (gwh)
Manufacture		
Road		
Light vehicles	11 900	3 892.1925
Medium vehicles	39 900	288.0381
Heavy vehicles	82 300	477.34
TOTAL ROAD: 4 657.5706		
Rail		
Train engine + 32 2-axle cars	3 854 000	n/a
Train engine + 5 passenger cars	2 331 000	n/a
TOTAL RAIL: N/A		
Maintenance		
Road		
Light vehicles	780	3 569.86810
Medium vehicles	2 940	310.20528
Heavy vehicles	8 450	756.73130
TOTAL ROAD: 4 636.80468		
Rail		
Train engine + 32 2-axle cars	197 200	378.03240
Train engine + 5 passenger cars	275 500	493.62750
TOTAL RAIL: 871.65990		
Total South African rail and road energy consumption for transport manufacturing and maintenance per annum		10 166.03518

TABLE 5.8 Estimated energy consumption for the manufacture and maintenance of road and rail transport vehicles in South Africa

Light vehicle	*Medium vehicle*	*Heavy vehicle*	*Engine train + 32 2-axle cars*	*Engine train + 5 passenger cars*
96	315	104	35	46

TABLE 5.9 Energy expended per kilometre of travel per vehicle at 40% occupancy, average vehicle life, and total maintenance and manufacture energy consumption (kWh/km/vehicle)
Source: Zeevenhooven 1990: 14

A passenger train is shown to be approximately twice as efficient, in these terms, as a private car, and a freight train three times more efficient than a heavy goods lorry. The figure for medium vehicles suggests that they use considerably more energy than any of the other modes – this figure appears high and should be treated with caution. The figures given are averages, and there will be occasions – for instance when a car is full and a train nearly empty – when the situation may be reversed. However, overall it is clear that rail transport uses manufacture and maintenance energy more efficiently than road transport.

CHAPTER SIX

The environmental implications of energy use in transport

The issue of the environmental cost of energy used in transport is a relatively new one, but it is a pertinent topic, as energy use has a considerable impact on the environment, both locally and globally. In order to understand the environmental effects of transport, one cannot look at South Africa in isolation. Transport, like pollution, transcends international boundaries, and this topic should be approached on a national as well as an international scale.

The environmental impact of transport energy use will be considered here in this light. Where possible, South African statistics will be used; however, in many areas in this field, the environmental data is not yet available. Hence, much of the information used in this chapter will have been taken from other parts of the world. The use of such data is felt to be justified, and can provide a better understanding, in areas where no indigenous information exists. The use of external data can also provide a useful alternative approach to a problem. In this instance a great deal of data is available in the EC, a region where car saturation has reached enormous proportions. The EC can be treated as a possible future scenario for South Africa if transport policies fail to address the growing reliance on the private car.

Three main modes of transport exist: maritime, air and land. Each of these modes impacts on the environment in different ways, but the impacts of their energy use emissions are largely common.

6.1 Marine and air transport

In terms of mobility energy, maritime transport is the least environmentally damaging of all the transport modes. Huge quantities of cargo can be carried with the minimum of propulsion energy, keeping the energy expenditure per tonne-kilometre, and the corresponding emissions, well below other modes of transport. In these terms, the only other transport mode that can achieve a better energy use per tonne-kilometre is gravity-propelled pipeline transport. Passenger transport by sea is also efficient, but accounts for a tiny proportion of total passenger transport.

The major impact in environmental terms of maritime transport is due to accidents, oil spillages and deliberate dumping. Nuclear-powered vessels pose the greatest danger through accidents, although the effects of this type of accident are not yet fully comprehended. There are few examples of nuclear vessels sinking, but where it has happened (the Soviet Union's submarine losses being one example) whole food chains in these areas are feared to be contaminated by nuclear radiation. However, although nuclear accidents are potentially catastrophic, they are as yet not seen as the greatest transport threat to the maritime environment.

The main cause of environment degradation resulting from maritime transport is from the carriage of oil, the major energy source of all transport modes. The impact of an oil slick from a damaged or sinking oil tanker is well known. The toll on the environment of such an accident is however not fully understood, but the Exon Valdiz disaster is an example where costs have been estimated. The cost to fisheries, water, wildlife and land affected, is estimated to be in the region of $2.5 to $5 billion (CEC 1992: 33). This is a high price to pay for a relatively small spillage of oil, only some 35 000 tons or 10.8 million gallons. Although this spillage attracted considerable publicity and public outcry, the greatest source of maritime oil pollution is not

high-profile accidents, but the deliberate dumping that occurs throughout the world every day. It is estimated that annually 1.84 million tons of oil is dumped into the sea, but only 0.41 million tons is a result of accidents. The remaining 1.43 million tons is the result of routine dumping of unwanted material and the cleaning of tanks before taking on new cargo.

It is also worth noting that oil waste/run-off from the continents adds a further 1.7 million tons a year into the sea. 1.4 million tons from urban and industrial origins (more oil from road vehicle oil changes and exhaust emissions enters the sea than from any other source) and 0.3 million tons from atmospheric pollution, again largely the result of cars. The total oil input into the sea is thus 3.5 million tons per annum, of which only 12% is from accidental spillages, while 41% is routinely dumped at sea and another 41% comes from urban and industrial run-off (Greenpeace 1991: 38).

These figures show that, although maritime transport is responsible for a major part of the environmental damage of the sea, industrial and land transport pollution run-off also play a major role. The motor car in particular is a major contributor. It is the greatest consumer of the oil transported by sea, emits pollutants when burning petroleum products for mobility and contributes to waste oil through maintenance. In order to reduce the environmental damage of maritime transport, therefore, the demand for oil products for transport in general needs to be reduced. This in turn means that on both a South African and worldwide scale, oil-based energy in transport needs to be far more efficiently used.

Air transport is far more damaging in environmental terms than maritime transport, with the polluting emissions from jet engines the primary cause. Air transport is the most inefficient of all transport modes in terms of energy used per passenger/tonne-kilometre. Although air transport is not the major energy user of the transport modes, it is still a major contributor: in the EC it uses approximately 11-13% of the total transport energy budget, in terms of propulsion/mobility energy use (Silverleaf & Turgel 1991: 10). In South Africa, air transport propulsion energy use is approximately 8% of total propulsion energy used (see Chapter 3).

The main problem with all research done in this field is the lack of data. This is especially relevant in air transport, where the military plays a key role. The military in any country are very rarely willing to divulge information, but in such a strategic and high technology area as air transport secrecy is paramount. The resultant lack of military information renders any energy research done on air transport incomplete. Thus although researchers know the effects of certain emissions of aircraft, they do not know the actual extent, and therefore the true effects, on the environment of emissions.

Nitrogen oxides (Nox) are seen as one of the most problematic pollutants that aircraft emit. They are more destructive than those released at ground level, because aircraft release most of their gases at high altitudes, destroying ozone much more quickly as a result. This is one of the main reasons why air transport poses such a great danger to our environment. Ozone depletion is believed to increase the rate of global warming, and researchers in this field claim that air transport is responsible for at least 2% of global warming – although it has been suggested that the figure could be as high as 43% (Barrett 1991: 7). For this reason, air transport is seen as a great danger to the environment.

6.2 Land transport

The bulk of concern over the environmental impact of transport lies with land transport. The remainder of this chapter will address the environmental impacts of road and rail transport. Both modes have similar impacts on the environment – only

the scale of the impacts differ. The environmental impacts of energy use in both modes will be examined firstly in terms of energy use, and secondly with respect to their emissions.

6.2.1 Energy use of land transport

In environmental terms, energy use does not mean fuel alone, but rather the energy used from the mining of the raw materials, the vehicle manufacture, the building and maintenance of the road infrastructure to the end product of actually moving the goods.

There is no doubt that the world will face an energy crisis at the present rate of consumption, with global vehicle numbers set to double by 2015 (Greenpeace 1991: 6). All transport modes use non-renewable sources of energy. From extraction to the final use of these fossil fuels, resources are used unsustainably at the expense of ecology and the environment. Other than air transport, road is the greatest user of energy in that it needs more energy per tonne (or passenger)-km than any other mode. (Chapter 3 gives an indication of the different rates at which each mode uses energy for mobility.) The rapid depletion of non-renewable resources is not a new issue. In the past alternative fuels have superseded traditional ones as knowledge has grown – for instance, the replacement of wood and coal with oil and gas in most developed regions of the world. However, the research into carbon dioxide-free alternatives to the combustion engine has been limited. The use of hydrogen has been proposed, but such technologies are far from being a commercially viable alternative to petroleum. (Incidentally, the production of hydrogen requires considerable energy which, in the present climate, is likely to be fossil-fuel produced, so negating any benefits of hydrogen.)

Alternative energy sources may yet take a long time to reach the market, but the problem of energy pollution degradation is here, and not getting any better. The true environmental costs of the extraction, transportation and final use of these non-renewable forms of energy are extremely difficult to quantify, but, at present unsustainable consumption rates, the true costs are undoubtedly enormous. Events such as the recent Gulf war, a conflict over access to oil resources, give some idea of the real cost of our reliance on oil.

However, as has been shown in Chapters 4 and 5, considerable energy is also consumed in the provision of infrastructure and in the production of all types of transport vehicles. Table 6.1 gives estimates of the energy needed to produce and maintain transport vehicles and infrastructure.

	Road	*Rail*	*Total*
1. Vehicle operation	100 450.5700	7 418.98	107 69.5500
2. Vehicle manufacture	4 657.5706	N/A	4 657.5706
3. Vehicle maintenance	4 636.8046	871.6599	5 508.4645
4. Infrastructure prov.	102.0301	26.5672	128.5973
TOTAL	109 846.9800	8 317.2071	118 164.18

TABLE 6.1 Total average annual energy use by the South African transport sector (GWh) (excluding vehicle operation)

The energy used to produce and maintain a car or truck is less than that used to construct and maintain a train or ship. However, over the lifetime of the vehicle road transport is far less efficient in terms of energy used per passenger or tonne-kilometre than rail or marine transport. Table 6.1 shows that over ten times as much energy is used in the road sector than rail, the vast majority of this road consumption going on vehicle manufacture and maintenance.

It has been shown in Chapter 3 that energy use for the movement of vehicles is

greatest for road transport. In this context it is worth noting that rail can, and does at present, use electric power from the central grid, which is produced almost entirely from coal. The technology exists and is financially viable, to replace this fossil-fuel generation with ambient energy sources, a trend that is likely to be followed in the future, allowing electric rail services to be even more energy efficient through the reduction of the real costs of pollution externalities. The use of electricity for personal road transport is far from viable at present, largely due to poor battery technology, and there is no tradition of electric tram systems in South Africa.

Much criticism in the field of energy usage is levelled at rail transport as a user of fossil-fuel generated electricity, which remains one of the major sources of carbon dioxide pollution. As has been stated there is considerable scope for replacing this generation capacity with renewable technologies.

At present, direct transport accounts for 30% of total energy consumption in industrialised countries. Worldwide, with approximately 550 million road vehicles, the energy and environmental cost of transport is considerable (Greenpeace 1991: 6). This statistic becomes positively frightening when it is forecast that world vehicle stocks are to double within the next 25 years (Hughes & Potter 1989: 4). Even with technological advances in more efficient engines, with a reduction (perhaps up to 30% by 2015) in fuel consumption, the growth in vehicle population is sure to outstrip these innovations.

Thus it can be seen that present and future predictions for transport energy use show an unsustainable consumption of fossil fuels. Coal for electricity production can be replaced, but petrol and diesel have no presently viable substitutes. In terms of resource use, an emphasis on facilities that rely on electricity are more desirable than those reliant on oil. All transport modes currently rely on finite fossil fuel energy supplies and produce harmful pollutants. In order to reduce the rate of resource depletion and pollution levels, the most energy efficient mode is favoured, which for land transport is rail.

6.2.2 Land transport emissions

Environmental researchers are particularly worried about land transport emissions, as a major constituent is carbon dioxide (CO_2) the main contributor to global warming via the enhanced greenhouse effect. The greenhouse effect can be defined as: 'the retention of heat by the earth and atmosphere owing to CO_2 in the air being transparent to incoming short wave radiation, but opaque to the longer wave radiation back from the earth. It is called the greenhouse effect because glass in a greenhouse acts in a similar heat retentive way' (Howard 1990: 13). Chlorofluorocarbons (CFCs) produce the same result, only their effects are approximately 1 000 times stronger per molecule.

The fear is that gases being added to the atmosphere at a hitherto unprecedented rate will result in a rapid warming of the planet. Research suggests that climatic change will result in changes especially in rainfall patterns leading to desertification, crop failure and flooding, the raising of sea levels resulting in coastal flooding, changes in vegetation, plant growth rates and potential food shortages. The worst scenarios predict global upheaval and considerable hardship, others only social adjustment for the majority, with a few marginalised people suffering. Whatever the result, continued pollution pushes the planet further into the unknown.

Although there are moves afoot in the EC to legislate on catalytic converters[1] and tighten vehicle emission standards, to reduce CO_2 emissions, even with such measures vehicle population growth rates will result in a real increase in pollution emission levels. In order to halt or reverse the greenhouse effect, we need to reduce CO_2 emissions, not increase them. While most other sources of CO_2 emissions are reducing their output, as shown in Table 6.2, transport, largely due to growth in

1. There is some controversy in environmental circles over the benefits of catalytic converters, in that the push for 'green' (lead-free) petrol is aimed more at accomodating converters than at cleaning up the motor car's environmental damage. This is particularly relevant with regard to benzine, the additive that replaces lead in petrol, as the WHO considers benzine carcinogenic and claims there is no safe level of human consumption.

road vehicle numbers, continues to increase emissions.

Source	1978	1983	1988	Change 78-88 (%)
Domestic	23	23	24	4.4
Power stations	58	52	52	-10.3
Refineries	5	5	5	0.0
Other industry	50	38	37	-26.0
Transport	23	24	31	34.8
Other	12	10	9	-25.0
TOTAL	171	152	158	-7.6

TABLE 6.2 Sources of CO_2 in the UK: 1978-88 (million tons)
Source: Howard: 36

Table 6.2 shows how transport is becoming a major cause of environmental concern, as the larger of only two sectors that increased carbon dioxide emissions between 1978 and 1988. All other sectors, except for a small rise in domestic output, reduced their emissions. What is really alarming is that the total production of CO_2 in the UK was reduced by 7.6% over this period, while transport increased its CO_2 production by nearly 35%. The major reason for this growth is due to the increase of road transport, with the private car as the major offender.

The following chemicals are the main pollutants released from transport energy use of the combustion engine. The known effects of these emissions are also included:

- Carbon Dioxide (CO_2): Approximately 35% of all CO_2 emissions are a result of transport emissions. This pollutant is seen as a major cause of the greenhouse effect, and there is inter-state consensus in Europe that the production of this gas must be curtailed.
- Carbon Monoxide (CO): Approximately 90% of the total amount of CO emissions are released by the transport industry (OECD). The known health effects of this pollutant are that CO exacerbates cardiovascular disease and increases the risk of respiratory disease. As CO oxidises to CO_2 relatively quickly, CO is a big contributor to the greenhouse effect.
- Nitrogen Oxides (NOx): 47% of NOx emissions are from motor vehicles (OECD): inhalation results in bronchitis, asthma/emphysema. NOx is also responsible for destroying ozone at high levels and is therefore implicated in global warming and ozone hole creation. At lower levels it helps create ozone which is harmful and it contributes to acid rain.
- Sulphur Dioxide (SO_2): Particulate intake results in respiratory diseases, and is claimed to be carcinogenic. In conjunction with NOx and HCs causes acid rain.
- Hydrocarbons (HC): Up to 50% of total output is from motor vehicles and, when joined with SO_2 and NOx, causes acid rain.
- NOx, HCs and SO_2 combined cause acid rain and have dangerous health side effects. Acid rain is responsible for the killing of forests and lakes and damages the exterior of buildings.
- Lead is toxic and easily retained by the body in red blood cells, affecting the nervous system and blood. It can also impair children's mental development .
- Benzine, an additive to lead-free petrol (euphemistically called 'green petrol' by the road lobby), is claimed to be carcinogenic, and the World Health Organisation allows no safe level.

The pollutants listed are released into the atmosphere, affecting the environment in many ways. Some will sink to the ground, contaminating the soil and ground water, eventually entering the food chain, with associated hazards to all life including human. Others remain in the atmosphere contributing to the depletion of atmospheric ozone and the enhanced greenhouse effect. The environmental issue is an important issue that governments ignore at their peril. The contribution to environmental degradation from transport has been shown to be considerable. The energy sources, and the efficiency of energy use, must become a serious policy issue in the interests of improving our environment in the present and, more importantly, sustaining it for future generations.

6.3 Summary

There are numerous environmental issues relating to transport, but in terms of the energy use by transport, the two effects scrutinised in this chapter remain the most prominent.

One important additional impact is that of infrastructural land use. Roads compete, often successfully, for land in urban and rural areas. It is worth pointing out that if all the roads in the EC were laid side by side, it would cover an area as large as Belgium. In South Africa the greater availability of space can be used as an argument for building greater capacity roads, not only using more land, but consuming more energy in their construction and stimulating greater road vehicle use. The energy issue is pertinent in infrastructure provision in that vast amounts of energy are used in producing and maintaining this infrastructure. A good infrastructure also ensures that the emissions and negative environmental impacts of transport are spread throughout the country.

Accidents are also a transport and environmental issue. Every year, over a quarter of a million people die worldwide as a result of road accidents. In South Africa approximately 10 000 people are killed each year as a result of road accidents (World Bank: 20), considerably more than in the UK, where between 4 000 and 5 000 deaths per year (Potter and Hughes 1990: 9) occur with a larger car population. (The death toll for British rail over the last ten years is equal to the death toll on British roads for one week .)

Congestion on roads is also becoming an environmental issue, in that energy is being wasted while vehicles idle in traffic jams. British industry claims that the cost of congestion is in the region of £15 billion per year – £350 billion in the EC (Royal Institute of Chartered Surveyors: 14), and this estimate does not include any environmental costing. Building more roads to deal with the congestion results only in increased congestion as the suppressed demand for road space expands to fill the new road. In order to tackle congestion, we need to utilise all modes of transport to their maximum efficiency; only then will there be a real possibility of transport becoming congestion-free.

Clearly, transport's impact on the environment does carry a cost, how much and how to go about calculating this cost is still a matter for much debate, both economic and ideological. However, that there is a need for reducing transport's impact on the environment should no longer be an issue. The most effective way of achieving this would be to reduce transport's energy consumption. The private car is the single greatest, and most inefficient, user of energy and thus must bear the brunt of this energy reduction. The only effective method of substantially reducing this use is to reduce the reliance on private cars.

This should not mean that we reduce the amount we *need* to travel, only that alternatives to road transport and the motor car should be encouraged and supported by government.

South Africa stands in a unique situation in its history. It is a time when government has the opportunity to act for the benefit of the majority, for the benefit of the environment and to set the ground rules for developing a sustainable future. Transport provision is vital to all these ideals and must thus be made available to all in the most efficient way possible. The most sensible way of doing this, both economically, politically and environmentally would seem to be a massive economic investment in energy efficient public transport. Such an investment would be far more profitable in the long run than the continued support of road transport, which is detrimental to everyone's well being, and in the interests of only the wealthy minority in the short term. The goal of universal individual mobility via the motor car remains impossible, and should no longer be dreamt of.

CHAPTER SEVEN

Conclusion and policy recommendations for an energy efficient transport policy

7.1 Conclusion

The transport sector is a considerable energy user in most countries, and South Africa is no exception. The conventional view taken by most developed countries, when calculating energy balances, is that transport contributes about 30% of total energy consumption. This paper has challenged this traditional view, and attempted to show that the real transport energy consumption figure is higher. The discrepancy has been shown to lie within the definition of the sector. To gain a realistic figure, the transport sector as a whole has been considered, not simply the energy used directly in moving goods and people. This more holistic view of the transport sector indicates a 34% share of total energy consumption.

	Road	*Rail*	*Total*	*%*
1. Vehicle Operation	100 450.5700	7 418.9800	107 869.5500	91.4
2. Vehicle manufacture	4 657.5706	N/A	4 657.5706	3.9
3. Vehicle maintenance	4 636.8046	871.6599	5 508.4645	4.6
4.Infrastructure provision	102.0301	26.5672	128.5973	0.1
TOTAL	109 846.9800	8317.2071	118 164.1800	100

TABLE 7.1 Total average annual energy use resulting from demand for South African transport [GWh]

Table 7.1 summarises the energy balance for South Africa's road and rail networks. The figures indicate that vehicle operation accounts for over 90% of the total and infrastructure provision only 0.1%.

The vast majority of energy consumption is used within the road sector, with the private car taking the largest share. This is due to the fact that in South Africa, as in Europe and the USA, the private car has developed as the primary means of transport. The inefficiency of road transport, and particularly car transport, has not, in the past, been considered important. The inability of our urban conurbations to accommodate such reliance on the motor car has been slow to reach the planners' agenda, but it is now recognised throughout the world that cities congested with cars do not serve anyone's interests.

Road transport is also responsible for a large part of global warming and local environmental degradation, which is becoming a serious concern of governments. In this paper, the discussion on the environmental damage caused, directly and indirectly, by the motor car and road transport was restricted to only that caused by energy use. As considerable as these effects are, they only constitute the tip of the iceberg of environmental damage resulting from road transport.

This paper argues that South Africa, and the planet as a whole, can no longer afford the motor car and road transport to be the main land transport mode, in economic, political and environmental terms. This is not to say that we should suddenly get rid of all road transport and private cars. That may be the best solution in environmental terms, but is clearly not a viable option. The aim of this paper has been to show, in energy consumption terms, that to rely solely on private road transport as the main transport mode is courting disaster for South Africa's transport system,

its people and economy.

It is simply not possible for a transport system to operate efficiently if government policy upholds the ideal that each citizen should own and use a car for their basic travel needs. In energy terms it would be impossible to supply the quantity of fuel required, especially in a non oil-producing country such as South Africa. In economic terms, the country would not be able to afford the large supplies of energy this would demand. It would also be foolhardy for any government to remain convinced that road transport has the ability to fulfil the country's transport needs in anything but the very short term, in the light of the dwindling oil resources, that cannot be expected to last more than about 50 years at current rates of consumption.

The transport system of a country should not be planned around the promotion of maximum mobility, but rather around achieving maximum access to goods and services, as well as opportunity for all its people. Such an aim is both laudable and possible if one does not rely solely on one mode of transport. The way to achieve this goal is to utilise all modes of transport, to their maximum efficiency.

The advocation of rail services as the most efficient form of future transport has many associated problems. Many have been discussed in previous chapters, but not least is the public perception of rail as unreliable, inflexible and dangerous. Section 7.1.1 deals with passenger perceptions; however, a major tool that must be employed to encourage rail use is that of infrastructural improvement.

To achieve efficient rail systems, mixed land uses of high density should be developed along existing rail lines and close to stations. Stations should also be upgraded and integrated with other land uses along with the a general upgrading and improved image of rolling stock and service infrastructure. Where densification of housing around stations is not possible, access to stations should be improved or new stations built. Rail transport must link with other modes to provide a travel 'package' that attracts passengers.

7.1.1 Transport users' perceptions – addressing people's demands

This paper has addressed the technical efficiencies of the transport systems in South Africa with respect to energy consumption and to a lesser extent, access to goods and services. Any future planning policy must also be aware of the public's attitude to proposed changes. Systems that may appear efficient on paper will not be tenable if they are not accepted by the people they are built to serve.

However change will always be unpopular with the minority who enjoy the 'freedom' of the existing car culture. A commuter who is used to travelling by car will often prefer to continue to do so even when congestion has increased journey times beyond that of other modes. South Africa has developed without a tradition of public transport use amongst the white population. Car ownership is perceived as a statement of wealth and highly desirable, even in congested cities. To be free from the constraints of public transport is important for many people not simply for reasons of increased mobility.

For instance, the National Passenger Panel report of 1992 produced by the Transportation Research and Consultancy Group found, through survey work, that the main reason for respondent dissatisfaction with train services was fear of crime – not level of service. Dissatisfaction with bus services was split between the race groups used in the survey. Infrequency and punctuality of service, level of crowding and cost were all important. Minibus taxis were felt to be too crowded, cost was high and accident rates unacceptable. The report also demonstrates that the white population is generally satisfied with public transport services, whilst other groups are not. This is due wholly to the fact that the majority of the white population has access to cars, and considerable road infrastructure on which to use them, and would not use public transport even if it were provided, while other groups relying

on buses, taxis and trains are aware of the inadequacies of the system. These attitudes are understandable, as services have been built to accommodate car mobility that has only been available to the minority. To begin to change these deeply held beliefs, investment in public transport must come first. It is no use attempting to persuade people to leave their cars at home and take the train if their journey times will increase and security diminish.

The building of a public transport-positive culture will be difficult, and can only be achieved as part of overall planning policy. Existing public transport users need to be lured away from energy inefficient taxis and onto vastly improved train and bus services, against their perception of the taxi's superior flexibility and security. Car users will only be lured on to buses and trains by great improvements in service, comfort, safety and security.

Europe, where many cities have great public transport traditions, is having considerable problems reducing the reliance on the car in the face of powerful opposition from the car industry lobby. South Africa must struggle against the lack of public transport tradition, but it also has a considerable potential advantage. In the rapidly changing political environment of the new South Africa, all policies must be aimed at redressing the imbalances of apartheid. Policies will need to address the needs of the black majority, as such, investment in planning that provides integrated public transport for the majority, rather than personal transport for the minority, is in line with these goals. Assuming the political will is strong and the mandate sufficient, the considerable influence of the oil and car industry lobbies can be minimised. The improved efficiency of such systems would benefit the country as a whole facilitating better use of all natural resources and access to goods and services for all its peoples.

Table 7.2 illustrates the differences in transport use between segregated groups in society – the legacy of apartheid.

Main mode	*Percentage of respondents*				
	Whites	*Coloureds*	*Asians*	*Blacks*	*Average*
Train	5.4	36.8	4.0	25.6	18.0
Bus	2.1	11.1	26.7	13.1	13.3
Taxi	1.1	7.2	10.8	42.6	15.4
Car driver	78.4	17.0	25.6	4.4	31.4
Car passenger	7.6	14.6	19.9	4.4	11.6
Walk	2.7	8.1	6.8	9.1	6.7
Other	2.7	5.2	6.2	0.8	3.7
TOTAL	100.0	100.0	100.0	100.0	100.0
Sample size	1 284	650	500	1 204	1 683

TABLE 7.2 Transport use by commuters in South Africa, 1992
Source: Transportation Research and Consultancy Group (1992: 5-14).

A clear split between black and white is shown with respect to car and public transport use. The average figures confirm the overall reliance on the car, with 43% of commuters travelling as drivers or passengers in cars. It is interesting to note that there are almost three times as many car drivers as passengers, indicating that on average one-third of cars have one passenger and two-thirds no passengers at all. Thus not only is there reliance on the car, but it is used in the most inefficient manner.

7.1.2 Summary

This paper has shown that the energy efficiency of the various transport modes is an important factor in any transport policy. The result has been two-fold, in that it is now clear that transport is a major energy consumer in South Africa, and secondly, that this consumption is wasteful, in that alternative modes can supply an efficient transport system that consumes far less energy.

In addition, these alternative transport modes to the car would serve as a good, viable transport foundation in both the short and long terms, especially if the majority of transport services can be run off the central electricity grid. This last point is especially relevant in view of the forecast population growth and the degree of urbanisation that is likely to take place. Only a good public transport system which utilises all modes of transport could possibly cater for the huge demand this will place on the transport system.

In South Africa, where wealth imbalances are huge, with the majority of the population unable to afford private transport, the provision of a cheap and efficient public transport system must be high on any political agenda. Such a transport system is possible, but only if it is a system which integrates all modes of transport with future planning policy and utilises them to their maximum energy efficiency.

It is hoped that this research on transport energy consumption will be useful in determining how to go about achieving an energy efficient and useful transport policy for South Africa that will supply all transport needs well into the next century.

The fact that transport energy consumption is so large, and inefficiently used by inappropriate modes, should also make energy researchers and administrators aware that massive energy savings can be made by opting for an energy-efficient transport policy. This is especially relevant in view of South Africa's balance of payments, as the vast majority of transport energy has to be imported in the form of oil at great cost. An energy-efficient transport policy would therefore provide economic savings for the country, which in turn should aid the South African economy to better the lives of its people.

7.2 Policy proposals

Table 7.3 outlines the basic policy proposal recommendations, along with the broad objectives of each policy. The list is not intended to be exhaustive, but to provide a basis for further discussion. It is hoped to provide an input to the transport planning sector that has not been addressed in sufficient detail in the past.

Policy	Objective
1) Encourage the use and provision of public transport. Coordinating bus, train, taxi, cycle and walking modes to maximum efficiency	• To improve energy efficiency in all areas of transport: mobility, vehicle and infrastructure construction and maintenance. • To achieve maximum access to goods and services, rather than mobility for its own sake. • Reduce congestion.
2) Discourage private car use, and actively plan for a reduction in numbers, rather than assuming new roads will be needed to accommodate further growth.	• Increased equity of transport access for all people. • Reduce congestion. • Reduce pollution. • Improve energy efficiency in all sectors of the transport economy.
3) Actively promote rail transport above other modes. Invest in new infrastructure and rolling stock, improve the overall image, and improve accessibility and flexibility. Invest in electric trains and encourage the future use of renewable energy sources to generate the electricity.	• To build a rail commuting culture that perceives the advantages of rail, and uses it as a preference to other modes. • The use of electric trains to reduce reliance on the internal combustion engine. • Reduce pollution levels associated with road transport use. • Reduce dependence on oil.
4) Coordinate land use planning and transport planning to reduce the need for travel.	• Increased densities and mixed land use development along public transport routes -especially rail lines. • Public transport interchanges should be the foci of development. • All planning should address the needs of cyclists and pedestrians explicitly. • To provide a safe environment in which to use public transport, and to walk to and from destinations without feeling the need for the security of the private car.
5) Improve energy efficiency within transport systems. Always strive for further improvements.	• Reduce reliance on non-renewable fossil fuel resources, especially oil. • Minimise harmful pollution emissions. • Minimise local and global environmental destruction. • Reduce financial cost to South Africa of direct energy use and associated externalities.

TABLE 7.3 Policy recommendations and their associated objectives

Appendix

Road transport

Small car:	Mass	<900 kg	(Tare)
	Engine capacity	<1600 cc	
Medium car:	Mass	900 – 1125 kg	(Tare)
	Engine capacity	1600 – 2300 cc	
Large car:	Mass	>1125 kg	(Tare)
	Engine capacity	>2300 cc	

TABLE A.1 Categorisation of passenger cars

Vehicle	*l/pass-km (RANGE)*	*MJ/pass-km (RANGE)*
Small car	0.075 – 0.017	2.62 – 0.60
Medium car	0.090 – 0.020	3.15 – 0.70
Large car	0.106 – 0.023	3.71 – 0.81
Combi taxi	0.118 – 0.014	4.13 – 0.49

NOTE: RANGE refers to occupancy levels of vehicle, in the case of cars, 1 – 5 occupants, while for combi taxi the maximum occupancy is 10 persons (including the driver).

TABLE A.2 Relative energy efficiencies of private passenger vehicles operating under normal urban conditions in South Africa
Source: Stanway 1992: 23

The new 16-seater Combi taxi was also compared with the 10-seater at 50 and 100% capacity and the result were as follows:

- 10-seater: 50% occupancy: 0.85 MJ: 100% occupancy: 0.42MJ pass-km
- 16-seater: 50% occupancy: 0.45 MJ: 100% occupancy: 0.39MJ pass-km

Mode	*Urban conditions fuel (1/100 km)*	*Rural conditions fuel (1/100 km)*	*National conditions fuel (1/100 km)*
Cars	11.00	9.30	10.45
LDVs	12.30	11.05	11.55
LGVs	36.00	31.77	33.46
HGVs	71.60	67.72	68.30
Buses	48.90	44.92	47.71

TABLE A.3 Fuel consumption under various operating conditions
Source: Stanway 1992: 27

Vehicle	*No. of pax*	*km/h*	*ml/km*	*ml/pax at 100% occupancy*
6 metre bus	23	56	132	5.7
12 metre bus (front engine)	80	50	349	4.4
12 metre bus (rear engine)	80	50	348	5.0
Double-decker bus	110	47	412	3.7
Bus train	184	46	453	2.5

Note: Larger buses operate at maximum fuel efficiency at lower speeds than other buses, when fully occupied.

TABLE A.4 Travel speed for minimum fuel consumption and efficiency for different classes of bus
Source: Stanway 1992: 27, 31

Rail

Mainline services: These are inter-city services (3 services studied).
Trans-Natal: Electric; 21 bogies; tare weight: 1 017 tons; pax capacity: 589
Pretoria – Pietersburg: Diesel; 15 bogies; tare weight 750 tons; pax capacity: 761
Johannesburg-Durban: Electric; 17 bogies; tare weight: 825 tons; pax capacity 1 437
Utilisation levels worked out over 1981/82 fiscal year.

Train	*Trans-Natal*		*Pretoria-Piet'burg*		*Jhb-Durban*	
Capacity (max)	589 pax		761 pax		1 437 pax	
Utilisation level (U/L)	*U/L*	*Mj/pax-km*	*U/L*	*Mj/pax-km*	*U/L*	*Mj/pax-km*
Average	74%	0.79	76%	0.50	85%	0.26
Minimum	67%	0.87	65%	0.65	79%	0.29
Maximum	80%	0.73	82%	0.43	91%	0.24

TABLE A.5 Energy efficiencies for three main line trains at observed utilisation levels (% of capacity) & MJ/pax/km
Source: Stanway 1992: 34

Suburban trains

Capacity: 2 220 pax in 12 coaches; tare weight 438.3 ton						
Class	*Peak*		*Off-peak*		*Average*	
	U/L (%)	*MJ/pax-km*	*U/L (%)*	*MJ/pax-km*	*U/L (%)*	*MJ/pax-km*
1st	70.6	0.41	10.4	1.80	16.4	1.55
3rd	78.0	0.38	22.3	1.24	30.3	0.90
Total	76.0	0.39	16.3	1.55	27.0	1.30

TABLE A.6 Energy efficiency for a suburban passenger train at different utilisation levels (% of capacity) and (MJ/pax-km)
Source: Stanway 1992: 37

Note: The above Table includes in the calculation the amount of energy needed for the empty return trip.

The above example shows us that in this study, the train only becomes energy-efficient with over 800 pax per trip, at over 40% capacity, below this capacity level trains are not energy-efficient in comparison to other modes. p 37

A more recent study in 1990, based on the 5M and 6M suburban pax trains, gives the following results:

	Utilisation level (% of capacity)		
	100%	78%	22.3%
%M set			
Passengers	3 850	3 003	859
Electricity used (Kwh/km)	49.34	45.89	37.4
Secondary energy (MJ/pax-km)	0.046	0.054	0.156
Primary energy (MJ/pax-km)	0.006	0.073	0.2
6M set			
Passengers	4 172	3 254	930
Electricity used (Kwh/km)	21.49	19.81	15.54
Secondary energy (MJ/pax-km)	0.0018	0.022	0.06
Primary energy (MJ/pax-km)	0.006	0.073	0.2

TABLE A.7 The 5M and 6M suburban pax trains
Source: Stanway 1992: 39

References

Barrett, M 1991. Aircraft pollution: environmental impacts and future solutions. WWF Research Paper, Geneva: WWF.

Central Statistical Services (CSS) 1986. *Census of transport and allied services*, Report No 71-01-01 (1986). Pretoria: Government Printer.

— *1991. Registered vehicles as at 30 June 1990.* Report No 71-11-01. Pretoria Government Printer.

Clark, P & Naude A 1986. *Bus subsidization in South Africa: An overview of central government systems and policies up to 1986.* National Institute for Transport and Road Research, CSIR, South Africa, Technical Report RT/38.

Commission of the European Communities (CEC) 1992. *Green Paper on the impact of transport on the environment: A community strategy for sustainable development*, COM (92) 46 Final, Brussels.

Department of Mineral and Energy Affairs (DMEA) 1993. Private communication.

Dewar, D & Uyttenbogaard R S 1991. South African cities: a manifesto for change. Unpublished paper, Urban Problems Research Unit, University of Cape Town.

Freeman, P N W 1978. *The cost of road traffic congestion in the Republic of South Africa.* National Institute for Transport and Road Research, CSIR.

Freeman P N W, & Burger, C J 1978. *Principles of energy conversion.* Department of Planning and the Environment. Pretoria: Government Printer.

Granger S. *Road and rail construction – Benefits to conservation.* Cape Town: Ninham Shand.

—. *Integrated environmental management in road planning: a pioneering project.* Cape Town: Ninham Shand.

Greenpeace, 1991. *The environmental impact of the car.* Amsterdam: Greenpeace International.

Howard, D 1990. *Energy, transport and the environment.* Transnet, Claverts.

Hughes, P & Potter, S 1989. *Routes to stable prosperity, energy and the environment.* London: Open University.

Kennedy, T L 1986. *Calculation of railway unit costs in South Africa.* National Institute for Transport and Road Research, Technical Report, RT/44.

Mann, P 1992. *Public transport study for Cape Town metropolitan area*, Reports Nos T1/90; T3/90; T4/90 T11/92 (draft); T12/92 (draft); T13/92, Liebenberg & Stander, 1992.

Metropolitan Transport Planning Branch 1986. Projections of the population of Cape Town: Land Use/Transport Study Area 1980-2000. City Engineers Department, Cape Town.

National Association of Automobile Manufacturers of South Africa (NAAMSA) 1992. *Retail Sales Statistics.*

Naude, C M 1992. *Transport energy implications of urbanisation and decentralisation.* DMEA. Pretoria: Government Printer.

Pirie, G S 1991. ...And when the pumps run dry? Transport systems. Unpublished paper, Annual Transport Convention, Session 1 C, 1991, CSIR Conference Centre, Pretoria.

Potter, S & Hughes, P 1990. *Vital travel statistics, on behalf of Transport 2000.* London: Open University.

Roberts, J, Cleary, J, Hamilton, K & Hanna, J 1992. *Travel sickness: the need for a sustainable transport policy for Britain*. London: Lawrence and Wishart.

Royal Institute of Chartered Surveyors 1991. Shaping Britain for the 21st century: Land use and planning strategy. Discussion paper.

Silverleaf, A & Turgel, J 1991. *Environmental assessment methods in transport*. INTRA.

Snyman C 1992. Status and future of alternative transport energy. Draft copy of internal Eskom paper.

South African Transport Services (SATS) 1991. Annual Report 1989

Stanway, R A 1992. *Relative energy efficiency of transport modes: Development of energy efficiency indices*. DMEA. Pretoria: Government Printer.

Sweet, R J 1988. *Car ownership demand study*. National Institute for Transport and Road Research, CSIR, Technical Report RT/112,.

Transportation Research and Consultancy Group 1992. National Passenger Panel Report.

Van Zyl N J W, Wilmot, C J, van der Reis, A P & Burger, H T 1992. *Guidelines on promoting energy efficient transport*. DMEA.

World Bank 1991. *South Africa: Urban sector reconnaissance*. Washington: World Bank.

Zeevenhooven N C H E 1990. The energy consumption of various transport systems. Paper presented to ITF Symposium on Railways, Environment and Transport Quality.

PROJECT DESCRIPTION

A major two year research project was launched by the Energy for Development Research Centre in April 1992. It aims to investigate policy options for widening access to basic energy services for the urban and rural poor in South Africa. Research papers are being produced in the following areas:

Background papers
Research outline
Integrated energy planning: a methodology for policy analysis and research
Development context for energy planning in South Africa
Background on South African energy system

Energy demand analysis
Energy demand in underdeveloped urban and rural areas

Rural areas
Energy for rural development: an introduction and overview
Energy and small-scale agriculture
Rural household energy supply options
Afforestation and woodland management
Remote area power generation options

Urban areas
Household energy supply in formal and informal urban settlements
Energy and informal sector production

Ancillary sector
Energy and mass transportation*

Key supply sector
Electricity distribution sector*

Cross-sectorial studies
Energy efficiency and conservation*
Energy and environment*
Southern Africa linkages*
Investment requirements and financing mechanisms*
Pricing policy*
Institutional analysis*

Policy options
A concluding document will draw together key policy conclusions
** The scope of these studies is restricted to energy issues concerning the urban and rural poor.*

EDRC

The Energy for Development Research Centre is located at the University of Cape Town. Its objectives are to study energy related problems of developing areas in Southern Africa, and possible ways to address them.

EDRC seeks to achieve its objectives by:

- undertaking research projects;
- running a specialist postgraduate programme to support research projects and to train personnel to contribute to this field;
- transferring relevant information to user groups by offering consulting services and running workshops, and through publishing books, journal papers, reports, leaflets and design and user manuals.

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PAPER Nº 13

Energy and mass transportation

Geoffrey Boerne and Richard Hatfield

SOUTH AFRICAN ENERGY POLICY RESEARCH AND TRAINING PROJECT

widening access to basic energy services for the urban and rural poor

ENERGY FOR DEVELOPMENT RESEARCH CENTRE
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