# UTILISATION OF NATURAL GAS AS A PUBLIC TRANSPORT FUEL IN SOUTH AFRICA

Submitted in partial fulfilment of the requirements for the degree of Master of Philosophy (Energy and Development Studies)



**ENERGY AND DEVELOPMENT RESEARCH CENTRE**
**FACULTY OF ENGINEERING AND THE BUILT ENVIROMENT**

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# DECLARATION

I, RODNEY MBULELO XHALI submit this dissertation to the University of Cape Town in partial fulfilment of the requirement for the degree of the Master of Philosophy. I declare that, unless otherwise acknowledged, this is my original work and that it has not been submitted in this or any similar form for a degree at any other university.

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## ABSTRACT

The aim of this study is to investigate the feasibility of utilizing natural gas as a fuel in the public transport sector in South Africa. The study examines the feasibility of utilizing natural gas from the environmental, economic and technical perspectives.

The study asserts that with adequate policies and cooperation of different stakeholders this option can be considered by the government for both energy diversity and security.

Information from this report may help to make some suggestions for future policies regarding air quality control and transport fuel diversity. It will also widen the market for the rapidly growing natural gas industry in Southern Africa.

## DEDICATION

**To my mother – my greatest inspiration**

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Many thanks to my family, who kept the home fires burning.

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AMI | American Methanol Institute |
| ANC | African National Congress |
| BCP | Black Community Programmes |
| BPC | Black Peoples Convention |
| CBD | Central Business District |
| CCGT | Combined Cycle Gas Technology |
| CDM | Clean Development Mechanism |
| DOT | Department of Transport |
| E&HVT | Electric and Hybrid Vehicle Technology |
| EV | Electric Vehicle |
| GDP | Gross Domestic Product |
| Gg | Giga grams |
| GHG | Greenhouse Gases |
| GJ | Giga joules |
| ICE | Internal Combustion Engine |
| IPCC | Inter-governmental Panel on Climate Change |
| JESA | Journal of Energy in Southern Africa |
| LEAP | Long-range Energy Alternative Planning |
| LEV | Low Emission Vehicle |
| LNG | Liquefied Natural Gas |
| MT | Metric Tonnes |
| MTBE | Methyl Tertiary Butyl Ether |
| MW | Mega Watts |
| NASA | National Aeronautics and Space Administration |
| NMVOC | Non-methane Volatile Organic Compound |
| OEM | Original Equipment Manufactured |
| PAC | Pan Africanist Congress |
| PM2.5 | Particulate Matter of less than 2.5 microns |
| SACP | South African Communist Party |

| | |
|---|---|
| SADC | Southern African Development Community |
| SAPP | Southern African Power Pool |
| SASO | South African Students Organisation |
| SORSA | Seed Oil Refinery of South Africa |
| ULSD | Ultra-Low Sulphur Diesel |
| UNEP | United Nations Energy Programme |
| WEC | World Energy Council |
| ZEV | Zero Emission Vehicles |

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# CHAPTER 1:

# 1. INTRODUCTION

South Africa's transport fuel needs depend to a large extent on fossil fuels in the form of petrol and diesel . All crude oil used to produce these transport fuels is imported, therefore, any disruptions in the supply of crude oil or the production of the required transport fuels would lead to serious problems, including the country's transport system coming to a standstill. Goods that need to be ferried to different locations would not be done and people would be unable to get to places of work. Due to the present situation in which a large number of transport trips are closely tied to economic activities, the entire economy would be adversely affected. Therefore, total dependence on imported crude oil for South Africa's transport sector makes the country vulnerable to the security of oil imports, which are also likely to be affected by potential political and economic disruptions. There is a need to diversify the transport fuel base by introducing alternatives.

Air quality management is also a serious problem in South African cities. A recent study done in Cape Town, known as the "Brown Haze" study, clearly shows that emissions from diesel and petrol contribute 42% and 25% respectively to visibility apportionment in that city (Wicking-Baird et al, 1997).



Finding alternative transport fuels could help address such pollution problems, and could also present an additional benefit in the mitigation of greenhouse gas (GHG) emissions that accrue from carbon intensive traditional transport fuels such as diesel and petrol.

## 1.1.Transportation and the Gross Domestic Product (GDP)

In developing countries, transport demand is likely to increase faster than the Gross Domestic Product (GDP), because of the movements of the population from rural to urban areas, and also of the increasing movement of goods within and between countries. Also, based on the informality of the economy, not all transport movements are accounted for in the GDP evaluation. In South Africa the urban population is increasing rapidly, more than the national growth rate, and car ownership is growing at an unprecedented pace. At the same time, urban settlements are developing erratically without the necessary adequate public transport infrastructure. This gives rise to a high degree of congestion and pollution as well as long and costly commuting times between home and work (WEC, 1998). Without mobility and adequate development of the necessary infrastructure there is a risk that the quality of life might suffer, and that will affect growth in the economy which will adversely affect poverty reduction efforts.

## 1.2. Transportation and Roads

The road system is very important to the overall economy, although road construction and maintenance accounts for only 1% of the country's GDP. Poor road conditions, especially in rural areas can lead to high fuel bills, restrict economic activities, increase vehicle maintenance costs and limit commuting activities, giving rise to adverse economic factors. Poor road conditions also result in loss of productive time and increased fuel use. This leads to huge delays because congestion is worse during peak times. Also, it can be a major contributor to the current high rate of accidents in urban areas in the country.

A former United States of America official commented that: "It is not wealth which makes good roads possible, but good roads which make wealth possible". Road transport is central to development. Without physical access to jobs, health, education and other amenities the quality of life generally suffers. Without physical access to resources and markets, growth stagnates and poverty reduction cannot be sustained (DOT, 1996).

## 1.3 Transport, Income and Mobility

Throughout history transportation has been, and will continue to be the pivot of economic and social development, especially for developing countries. History has shown that income and mobility have always complemented each other, though mobility has a tendency of increasing faster than income, especially in the economies of developing countries because of development needs and transport conditions. Given that mobility increases with income, this implies that individual use of transport increases faster and tends to move to more efficient modes of transport.

Generally, in South Africa, as in most developing countries, public transport is important and crucial for fostering development, and it requires some form of state intervention in order to ensure service provision and affordability to a wider community, including the disadvantaged. On the other hand more private participation in the public transport system can be useful to stimulate competition and increase efficiency, affordability and reliability of service.

can be useful to stimulate competition and increase efficiency, affordability and reliability of service.

## 1.4 Transport and the Imbalances of Past History

Historically, the transport system of South Africa has been geared towards the satisfaction of the privileged sector of the population, mostly whites who own cars. The other group of people, mostly black, and which forms by far the majority of the population, depends on an underdeveloped and inefficient public transport system. In South Africa, as in other African countries there is a high concentration of roads in cities. These roads serve to link only the main cities thus ignoring the surrounding rural areas. This pattern of growth is mainly due to the colonial past of these countries. Increased transport demands, mostly road transport and very high population growth rates, especially in urban areas are causing problems with serious (economic) implications for the development of the whole sub-Saharan region (Davidson, 1993).

The public transport system in South Africa is orientated around the strong 'apartheid imprint' of the country. It was developed around the idea of providing transport services for the black labourers living on the outskirts and rural areas to work in urban areas. On the whole, the public transport system is ineffective. It restricts labour mobility, impinges on worker productivity and also impedes social integration.

## 1.5. The Transport System and Land Use Patterns

Most cities in the world generally have special separate areas for the poor, middle and affluent people for their residences and how they relate to the central business district. Although there is no simple model that can be used to describe the patterns of all cities, this model is relatively common. The general trend has been for high-density working class residential areas to be found very close to the city centre, adjacent to employment places. The more affluent tend to live in areas further away from the business centre in lower densities that reduce with the distance from the business area. The resultant pattern is caused by the fact that the more affluent can afford to commute, while the poorer live closer to their places of work, minimising their transport costs, and so use a lesser percentage of their income on satisfying their transport needs (Boerne and Hatfield, 1994).

The structure of cities in South Africa is different from countries that have not gone through a similar history of apartheid. The Group Areas Act of the apartheid government did not allow cities to evolve as they did in many other countries, but their growth was channelled in a manner dictated by the legislation that existed then. As a result, transport needs are different from the transport organisation in the country.

In South Africa, the poor working class, mostly black people, was forced to live in far outlying areas away from their places of work, which are normally in the city centre or the homes of the white population. Because they make up the poorer section of the community, they are unable to purchase private transport and their mobility is restricted to public transportation. Hence, rail, bus or "minibus taxi" (a ten or twelve seater passenger vehicle, basically made for the larger family) is their only way of travelling to work or gaining access to economic, health, educational and social services. Also, because of the long distances they have to travel, transport costs make up a substantial portion of their incomes. In this respect they are often heavily dependent on some form of transport subsidies provided by the government to make transport fares more affordable.

## 1.6 Transport Infrastructure and Use

Fast growing urban populations are characteristic of every developing country, and this is not different in the case of South Africa. Growing urban populations in South Africa also result from the repeal of discriminatory legislation and the reduction of jobs in rural areas. This puts increasing pressure on the urban infrastructure. Measures may be needed to ensure the efficient functioning of cities. One of those measures will have to be the promotion and improvement of public transportation.

In South Africa the existing infrastructure is not utilised to its maximum capacity, e.g. the use of railways. There is a general lack of co-ordination between transport modes, poor scheduling and very little, if any partnerships between private and public sectors for infrastructure and other provisions.

Almost 80% of commuters in South Africa make use of some form of public transport. Of these more than 50% are transported by minibus taxi, while the remainder are divided between bus and rail. Most workers use taxis because these are the most accessible, and the fastest, but the most unpopular in terms of cost as well as safety (Moving SA, 1999).

It is imperative that a high premium be placed on the introduction of, not only alternative low emission fuels for public transport in South African cities, but also both adequate infrastructure development and intense land use planning.

## 1.7. Transportation and the Environment

Generally, the transport sector has significant effects on the environment. In particular, it is the main source of urban air pollution as shown by the brown haze over cities like Pretoria and Cape Town. Road transport is the dominant source of emissions that contribute to urban air pollution. Motorised transport contributes to global warming through carbon dioxide emissions and precursors of tropospheric ozone. Several of the pollutants emitted by the transport sector, especially by motor vehicles, have damaging effects on the health of the population.

The South African transport sector, as in all other countries in the world, has relied almost entirely on petroleum products for virtually all of its transport energy needs. However, there are some problems associated with this dependence, such as the social and environmental costs of using these fuels. These problems increase as the population grows and more people use public transport. The public transport of the country is private-car orientated and this leads to high pollutant emissions. There is therefore a need for a low emissions alternative in this sector, taking into consideration the fact that most of the 40 million blacks in the country use public transportation for mobility.

The impact of road transportation on the environment can be seen from the role of buses and taxis. Emissions from buses and taxis in South Africa come both from intra-city and inter-city travel.

All fossil-fuel burning vehicles emit sulphur dioxide ($SO_2$), carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), carbon monoxide (CO), suspended particulate matter (SPM) and volatile organic compounds (VOCs) which can be carcinogenic. At this stage the proportion of pollution that can be attributed to public transport in South Africa is difficult to measure but the overall road transport figures show that $CO_2$ gives out 9,68% greenhouse gas emissions, CO gives out 12,89% VOCs give out 91,41% and $NO_x$ emits 0,06% (JESA, 2000).

Table 1 shows transport-related environmental problems nationally, regionally and globally.

**Table 1.** **TRANSPORT-RELATED ENVIROMENTAL PROBLEMS**

| SCOPE | EVIROMENTAL ISSUE | IMPACTS |
|---|---|---|
| GLOBAL | Global Warming (GHG Emissions) | Impacts on:<br>Ecosystems<br>Hydrology and Water<br>Food and Fibre Production<br>Coastal systems<br>Human Health |
| REGIONAL | Air Pollution (Emissions of $NO_x$, etc) | May affect nearby nations |
| | Marine Pollution(Emissions of $NO_x$, $SO_x$, etc) | Run-off to water resource |
| NATIONAL | Air Pollution (Emissions of CO, HCs $NO_x$, $SO_2$, SPM, etc) | Health Impacts |
| | Water Pollution | Surface and groundwater run-off |
| | Land Disturbance | Land destruction and Waste disposal |
| | Solid Waste | Waste disposal from vehicles and machinery |
| | Noise and Vibrations | Acoustic pollution and vibration effects |
| | Accidents | Injury and death from damage to property transporting waste |
| | Socio-cultural | Social and cultural disturbance |

Source: Davidson, 1998

The use of alternative fuels such as natural gas and electricity in public road transport would cut these figures down considerably. Natural gas produces about two-thirds of the $CO_2$ of a petrol engine. Electricity produces no emissions at all from the tail-pipe. Liquid fuels account for 92% of energy used for transport. The total local demand for liquid fuels in 1999 was 16778 MT (Fast Facts, 2000). South Africa needs to look more seriously into the question of using alternative cleaner burning fuels for its transport sector.

## 1.8. Transport Fuels

The issue of transportation can be discussed under three broad categories, namely, transport fuels, transport vehicles and transport infrastructure. This paper will, however, only deal fully with transport fuels.

The exploitation of indigenous resources for transportation can contribute enormously to the growth of a country's economy. This also relieves pressure on the balance of payments. For this reason it is crucial for countries to promote research and technological development in order to stimulate the optimal development of its indigenous natural resources. Improving the technological efficiency of transport systems offers significant technological and energy benefits. This can lead to a longer life span and lesser use of fuel for the same transport activity.

There is generally an increase in transport energy use on a global level (WEC, 1998). Such a rate of growth in transport energy demand has serious implications for the environment, and possibly for global climate change. Given that transport mobility is essential to economic and social development, the challenge for policy makers is to find solutions to curb the negative effects of transport use, without reducing its positive contributions.

The use of alternative fuels in the South African transport sector would need some adjustments in energy and transport policy. The government would have to enter into agreements and partnerships with the private sector and would have to commit itself to rolling out the necessary infrastructure.

## 1.9. The structure of this report

This dissertation consists of seven chapters, which are structured as follows:

Chapter 1 introduces the transport system from a South African perspective and outlines the main tasks undertaken in developing this report.

Chapter 2 looks at the use of alternative fuels for the South African transport sector. This chapter will also examine global trends in this regard.

Chapter 3 focuses on the South African road passenger transport situation, looking at, and analysing emerging trends.

Chapter 4 takes a closer view at indicators of what the future holds for natural gas as an alternative fuel for the public road transport sector, in South African cities. This chapter also examines transport causes of air pollution and greenhouse gases.

Chapter 5 discusses the feasibility of natural gas-use in South Africa's public transport.

Chapter 6 looks at policy issues regarding the implementation of natural gas in South Africa's transport sector, as well as recommendations.

Concluding remarks and future work that still needs to be done in this respect are presented in the final chapter, Chapter 7.

# CHAPTER 2

# ALTERNATIVE FUELS

## 2.1.Introduction

Current literature was surveyed and critically analysed to provide the state of existing knowledge on alternative fuels as there is worldwide concern for environmental and economic reasons. In general, findings show that several alternative fuels have been tried in the transport sector in different countries in the world, with varying degrees of successes and failure. The ensuing discussions will summarise some of the different options that were identified from the literature.

## 2.2. Different Alternative Fuels

As previously stated, several options have been tried. The ones being reviewed here, because of their relative success, are as follows:

- **Ethanol** can be produced from any biological feedstock that contains appreciable amounts of sugar or materials that can be converted into sugar or starch. Sugar cane, found abundantly in most African countries and in Kwazulu-Natal in South Africa is an example of such a feedstock that contains starch or cellulose, which can be converted to ethanol.

- **Bio-diesel** is a clear-burning diesel replacement fuel made from natural and renewable sources such as new and used vegetable oils and animal fats. Just like petroleum diesel, bio-diesel can be used in combustion-ignition engines.

- **Methanol** is an alcohol-based fuel. The ability to produce methanol from non-petroleum feedstock such as coal or biomass is of significance for the reduction of South Africa's petroleum imports. In the near future neat methanol may be used. Methanol is also currently made into ether, called methyl tertiary butyl ether, which is blended with petrol to enhance octane and create oxygenated petrol.

- **Natural gas** can be used as a transport fuel in the form in which it is extracted, but since it will not be used in that particular location, it normally has to undergo some processing before the gas is distributed to where it should be used.

- **Electricity** as transport power is being considered in several countries, but its importance is based on the fuel used for its production since different sources have different impacts. In the case of South Africa, coal is used to provide nearly all its electricity, including the little used in the transport sector.

- **Hydrogen** is the most abundant gas in the universe and can be manufactured from a wide range of feedstock such as water, coal, oil, natural gas, and biomass and solar.

- **Fuel cells** are now being considered and can use feedstocks that are available in South Africa e.g. natural gas, biomass, and petrol. This is a technology that will be used increasingly in the future by the transport sector.

### 2.2.1. Ethanol

Ethanol is a renewable fuel made from agricultural feedstocks. It lowers harmful carbon monoxide (CO) emissions by 30% and reduces carbon dioxide ($CO_2$) emissions by 27%. The use of clean burning ethanol also reduces the amount of noxious fumes and volatile organic compounds (VOCs) that petrol emits into the air (www.iowacorn.org). Ethanol has penetrated the transportation market as a fuel in selected countries especially Brazil and Zimbabwe. Amongst other benefits is that it is a renewable resource, and reduces air pollution. Ethanol blends of up to 20% normally referred to as gasohol can be used in present available engines as flexible fuels without modifications because gasohol vehicles use similar technologies to that of petrol vehicles.

Ethanol made from wood biomass could reduce greenhouse gases drastically since young plants absorb more carbon dioxide as they grow, and the conversion process requires little energy. Apart from carbon dioxide, ethanol vehicles are thought to produce fewer emissions than petrol vehicles when equipped with similar emission-control devices (www.afdc.nrel.org). Because ethanol is less volatile than many other fuels it is less likely to seep into the air, where it could be ignited. Ethanol is also not as toxic on the skin as petrol and methanol.

Ethanol has to be guarded against gas line freeze as it absorbs moisture that gets into the tank during cold weather and this can lead to problems. It is also a proven octane enhancer and a replacement for lead and other toxic compounds in petrol. A 10% ethanol blend is warranted for use by all motorcar manufactures in the United States of America. The 10% blending boosts the octane rating by three points (http://www.iowacorn.org).

### 2.2.2. Bio diesel

Bio diesel used in a conventional engine can reduce emissions of unburned hydrocarbons substantially. The best results are seen with the use of pure biodiesel than with blends. The bio-diesel industry can use any fat or oil feedstock, including recycled cooking oil. Most bio-diesels degrade rapidly if spilled on soil, decomposing in a matter of weeks. These would appear to be good fuel candidates for application in areas where the environment is ecologically sensitive.

Many vegetable oils can be used without any engine or vehicle specifications, but usually with serious consequences due to high acidity. The distribution, storage and refuelling infrastructure for boidiesels should not be very different from that of ordinary diesel fuel, as was reported by Poulton (1994).

If the USA government's alternative incentives were comparable to those provided for fuels like ethanol, biodiesel sales could easily reach two billion barrels per year. At this level of market penetration, boiaiesel would probably be used in bus fleets and heavy-duty trucks (www.afdc.nrel.gov). Low-sulphur diesel has been introduced in many European countries and also in the United States for bus fleets. South Africa seems to be following the trend as it aims to introduce a bill to this effect before the end of the year. Emissions of sulphur oxides are the result of oxidation of the available sulphur in a fuel. Sulphur oxides are a health hazard and are important contributors to acid rain.

The production of bio diesel in the country is another strategy that might help South Africa decrease its dependence on imported crude oil. This also has other environmental spin-offs as bio diesel is 100% pure and when burnt does not give off any sulphurous contaminants of greenhouse gases.

Technically bio diesel is a vegetable oil methyl ester. It is formed by removing the triglyceride molecule from vegetable in the form of glycerine. Once the glycerine is removed, the remaining molecules are to a diesel engine, similar to petroleum based diesel fuel. Bio diesel is made up of almost 10% oxygen, making it a naturally oxygenated fuel which is 100% vegetable oil-based containing no petroleum diesel. The by-product is oilcake, which can be used in animal feed production.

The local production of bio diesel is on the cards and the managing director of Seed Oil Refinery South Africa (SORSA) says the refinery would produce 60 000 tons of diesel fuel a year, and create about 4000 jobs (Cape Times, 27/08/01).

Mossgas, the state-owned natural gas-to-liquids producer in the Southern Cape has also produced an environmentally friendly transport diesel product to add to its range of motor fuels, called eco-diesel. The firm has produced more than 70 million barrels of petrol, diesel and paraffin for the South African market. The diesel has very low sulphur and is suitable to meet international emission quality requirements. Emission tests carried out on the product show up to 20% less nitrogen oxide and up to 45% less particulate matter in the exhaust. Carbon monoxide and hydrocarbons are also appreciably reduced (Engineering News, 2001).

### 2.2.3.Methanol

Methanol is an alcohol-based fuel. The least expensive source of methanol requires natural gas feedstocks. Methanol improves engine life and vehicle performance by providing about 5 to 20% more power per unit volume than petrol. From an emissions-reduction point of view, methanol is especially attractive for substitution in diesel engines. Methanol diesel typically emits half the NOx of their diesel counterparts, have virtually no particulate matter, and emit about the same levels of CO and hydrocarbons (Gordon, 1991).

One advantage that methanol has over some other alternative fuels is that it is a liquid at normal room temperature, allowing it to be stored in conventional fuel tanks. It can be used in any conventional car petrol engine or in any diesel engine, which is spark ignited or has ignition assistance (www.afdc.nrel.gov). The main disadvantage with methanol is that it is corrosive and highly toxic and also has a lower energy density than petrol, leading to a smaller vehicle range. Methanol is completely soluble in water and could therefore cause serious contamination in water supplies in the event of a spill. Moreover, it is very expensive.

## 2.2.4. Electric Vehicles

As early as the 1960s, Detroit automobile makers sponsored a number of research and development (R&D) programmes into electric vehicles (EVs) and this led to the development of several models. In 1966, General Motors unveiled a "Convair" conversion powered by batteries of the silver-zinc type. Another automobile company, MCR, in California introduced six 40-foot battery-powered buses. These buses carried more than 1 200 people daily (Mackenzie, 1994).

In South Africa, Eskom, the national electric utility, has shown some interest in electric vehicles as exhibited by their joint venture with the Midrand Town Council and the Department of Minerals and Energy in 1996. Two electric shuttle buses were used to transport people working in the Kyalami office park. About 18 000 passengers used this service. The running costs for the 7990km travelled averaged at only 1.3 US cents per km and 3.4 cents per trip (E & HVT: 97). Nissan S.A are also interested and support EVs in South Africa, and in collaboration with Eskom delivered an electric game-viewing vehicle that was exhibited at the Kruger National Park. Amongst other objectives, Eskom seeks to commercialise electric vehicles to the point where they are regarded in the same way as ICE vehicles through programmes which will lead to high use.



In many cities of the world, including Cape Town, the exhaust gases produced by internal combustion engines are regarded as the single most significant contributor to atmospheric pollution.

Some studies have suggested that by the time carbon fuel use exceeds the rate at which new oil reserves are discovered, a substitute for oil will have been found. It is probably difficult to agree or disagree with this assertion. Trends show that oil use will continue for some decades to come, e.g. for hybrids, fuel cells, hypercars, etc. On the other hand, since other alternative fuels are unable to power zero emission vehicles, electric vehicles are likely to remain the only ones that emit no poisonous gases at the point of use, with the exception of hydrogen (Ogden, 1995). The argument that pollution from power stations is as bad as that from vehicles is not very convincing, especially when it is generally agreed that it is easier to control emissions from a relatively few stationery chimneys than from thousands upon thousands of mobile pipes.

Pressure may be applied on South Africa to comply with global standards as far as air pollution and greenhouse gas emissions are concerned. That pressure will compel the country to make some radical shifts in policy, especially its energy and environmental policies. It would be advisable for South Africa to anticipate such pressures and make the necessary adjustment to its policies. The possible introduction of low emission vehicles would be a start because this measure will cut down pollution levels and GHG emissions. A possible way of phasing in lower emission vehicles (LEVs) would be to introduce them in public transport and fleet operations. At the moment South Africa's entire transport sector is driven by petroleum derivatives that are produced from imported oil. If electric vehicles are used and the electricity is derived from renewable sources, then little or no adverse emission will be emitted.

South Africa lies on the sub-tropical high pressure belt with a constant high pressure cell in the interior that ensures sunshine throughout the winter months. This abundant sunlight could be utilised with the appropriate technologies to power a vehicle throughout the length of day. Steeply declining costs and rising efficiencies coupled with the fact that they emit little or no carbon dioxide will make solar energy renewable technologies play a rapidly growing role in the near future.

The proposed combined cycle gas turbine power station for Cape Town would enable more than 1500MW of electric power through the grid. The Athlone coal fired power station currently produces around 180MW of electricity for the unicity. With the utilization of the CCGT technology the city would have more than enough power to run electric vehicles for its public transportation system. In its efforts to improve air quality the city should look more into technologies that use electric drive propulsions such as batteries and hybrid combinations of electric motors and small internal combustion engines. The technologies are very clean and energy efficient. Hybrid-electric technologies reduce energy consumption by up to 50%, and electric vehicles produce no tail pipe emissions at all. Using natural gas for electric power for EVs through the grid would produce very little emissions at the source.

### 2.2.5. Hydrogen

Hydrogen is currently known as one of the cleanest fuels since it generates little or no carbon dioxide or any other adverse emission during combustion. It is said that hydrogen was used as a fuel as far back as the 1920s. For about three decades little attention was given to it, until about thirty years ago when this topic was revisited as intense searches were made for alternative fuels. Currently, vigorous efforts have been centred in Germany and in Japan

(Poulton, 1994). The United States of America is the leading country working on the storage and safe handling as well as transportation of hydrogen. In Germany, Daimler-Benz has also used hydrogen in their vehicles.

The New Energy Systems and Conversion Conference in Yokohama, Japan discussed the modelling of hydrogen penetration into the transport energy market. From 1970 researchers at the Musashi Institute of Technology in Tokyo studied and developed several hydrogen-fuelled automobiles, aiming at lightweight, compactness and high power output (The Clean Fuels Report, 1993).

In the USA Ogden (1989) looked at the prospects of using renewable hydrogen as a transport fuel. They identified two methods:

i. Solar electrolyte hydrogen systems in which a source of renewable electricity from either hydro, wind or solar is connected to an electrolyser splitting water into hydrogen and oxygen.

ii. Biomass gasification systems in which biomass feedstocks like wood chips and agricultural residues are gasified at high temperatures. The gasifier output can then be reformed and shifted to produce a mixture of hydrogen and carbon dioxide

Hydrogen can either be used to power vehicles by use of fuel cells or it can be stored in hybrid form although the latter system is still too massive and heavy.

### 2.2.6.Fuel Cells

Although a fuel cell is not a fuel, it is important that it be mentioned here. A fuel cell converts chemical energy directly to electrical energy. The basic concept of the fuel cell originated during the 1840s. NASA in the USA made practical applications in the early days of space flight.

Various kinds of fuels can be used in a fuel cell, the most popular being hydrogen. Hydrogen is a flammable and explosive gas and should be pressurised, which causes some practical concerns for transportation. Cars have recently used methanol because it is easier to handle and has a higher energy density compared to hydrogen. The key technical challenge of fuel cell technology is to make them at a cost that will be lower than rechargeable batteries (E&HVT, 1998).

Fuel cells should cost less to maintain than diesel engines because they have fewer moving parts. Buses that run on fuel cells could last up to twenty years – nearly twice as long as the average buses using diesel as fuel. The proton exchange membrane (PEM), a recent development, is used to replace the phosphoric acid electrolyte and will reduce a fuel cell's weight by 25 percent, its volume by 40 percent and its cost by 25 percent (Gordon, 1991).

Fuel cell vehicles are very quiet, because of the electric drive, and all that can be heard from these vehicles is the noise from the tyre. Fuel cells generate electricity directly by chemically combining hydrogen with oxygen. The only by-product is water. The electricity then powers the vehicles' electric motor, just like the electricity from a battery powers the motor of an electric vehicle. The fuel cell converts hydrogen, whether obtained from natural gas, petrol, methanol or coal gas, into electricity via an oxidation process. While batteries store the chemicals internally, the fuel cell uses an external fuel storage tank. Therefore, as long as the fuel is supplied, the cell never runs down and also requires no recharging.

Fuel cells have the technical potential to replace the internal combustion engine as a clean, highly efficient source of power for all types of vehicles. These devices would ideally store hydrogen fuel on-board in high-pressure tanks, but because current technology does not permit storage of enough hydrogen to deliver the driving range which motorists are accustomed to, reforming liquid fuels may initially supply hydrogen. However, dramatic technological strides have changed the outlook of motorcar fuel cells. Almost all the major car manufacturers, such as Ford, GM, Daimler Chrysler, Honda, etc, are developing fuel cell vehicles for introduction into the car markets during the current decade (Fuel Cell Vehicles, 2000).

Transporting hydrogen gas on a vehicle will require it to be compressed. When compressed it must be stored in special high-pressure containers. This is similar to the way compressed natural gas is stored on natural gas-fuelled vehicles. The other way to provide hydrogen gas to the fuel cell is to store it on the vehicle in liquid form. To make hydrogen liquid, it is chilled and compressed. Liquid hydrogen is ultra-cold – more than 423.2 degrees Fahrenheit below zero. Another way to get hydrogen to the fuel cell is to use a "reformer", a device that removes the hydrogen from hydrocarbon fuels, like methanol or petrol. When a fuel other than hydrogen is used, the fuel cell is no longer zero-emission, but is nevertheless still very low-emitting.

There is also a type of fuel cell that can be fuelled with methanol directly. This is called a direct-methanol fuel cell. This type of fuel cell does not need a reformer to separate the hydrogen from the methanol. The fuel cell removes the hydrogen from the methanol (Fuel Cell Vehicles, 2000)

Almost all car manufacturers agree that fuel cell vehicles offer the best opportunities for making traffic more environmentally compatible in the medium term, without sacrificing the driving comfort people have become accustomed to with conventional vehicles (E&HVT: 1998). The fuel cells technology is improving in leaps and bounds, and is fast moving out of the laboratory into the market place. The research emphasis has shifted to reducing costs in preparation for mass production. The car manufacturing industry has concluded that within two decades, between 7% and 20% of all new cars sold will be powered by fuel cells (AMI, 2000).

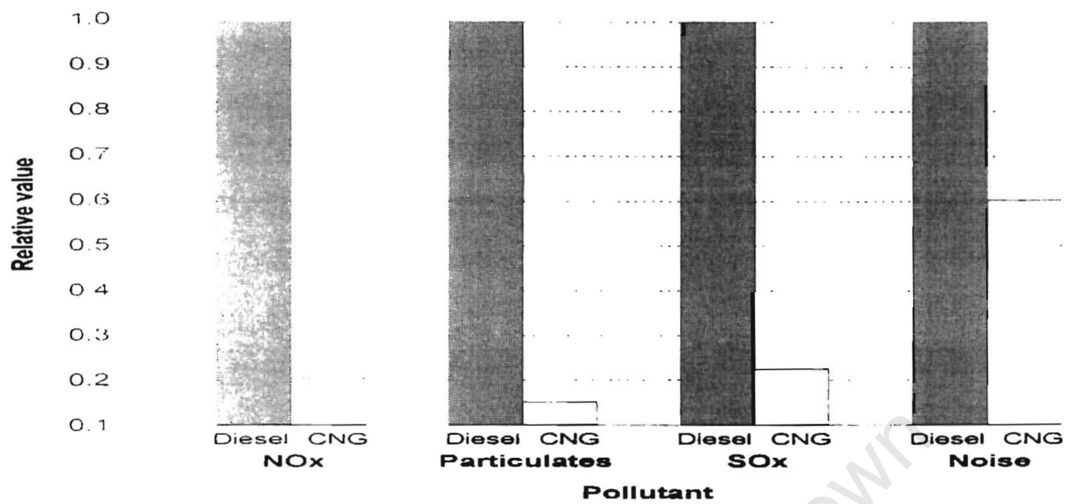


### 2.2.7. Natural Gas

Natural gas can be stored both as compressed natural gas (CNG) and can be liquefied and stored cryogenically (LNG). By 1988 there were more than 700 000 vehicles powered by compressed natural gas. By 1993 over a million vehicles in 25 countries were using natural gas (Poulton: 1994).

As a fuel natural gas is one of the cleanest burning. Emissions from the combustion of natural gas, relative to petrol and diesel in an internal combustion engine, are very low. For example, emissions of carbon monoxide are approximately 70 percent lower, non-methane organic gas emissions are 89 percent lower, and oxides of nitrogen emissions are 87 percent lower compared to the combustion of petrol. Also the combustion of natural gas emits significantly lower amounts of greenhouse gases and toxins including a decrease in the amount of suspected carcinogens found in particulate emissions (http:/www.naturalgas.com). Figure 1, shows pollutant emissions of natural gas when compared to diesel, using a relative value.

**Figure 1** **Comparison of natural gas and diesel emissions**




Source: www.gas.asn.au

As can be observed natural gas is a cleaner fossil fuel. Natural gas combustion results in virtually no atmospheric emissions of sulphur dioxide, small particulate matter, carbon monoxide. reactive hydrocarbons, nitrogen oxides and carbon dioxide compared to the combustion of other fossil fuels.

In the USA the Navistar International Corporation had developed CNG-fuelled buses in early 1994. Apart from these, five demonstration CNG vehicles were also unveiled. Fiat of Italy also produced buses that ran on natural gas by 1993 in its Iveco plant and were working to expand the choice of vehicles powered by CNG (The Clean Fuels Report, 1993)

About the use of natural gas in Canada, Heath (1991) says that natural gas is an excellent fuel for transportation as well as one of Canada's most abundant fuel resources. With 2.5 trillion cubic metres of proved natural resources and a potential reserve base in the area of seven trillion cubic meters, it is understandable why Canada's policy makers and gas producers are promoting an interest in natural gas fuel development. Canada is converting a large number of their fleets to run on CNG. It seems fairly simple to convert existing petrol engines to operate on natural gas as natural gas engines, like their petrol counter- parts are generally spark-ignited.

It has been generally agreed that an increasing and seemingly irresistible concern for environmental deterioration has opened a new and broader window of opportunity for natural gas as a transportation fuel. A number of alternative fuels for the South African transport system have been examined above. However, concentration will be placed on the single alternative that I feel has the greatest potential, i.e. natural gas. Natural gas is more environmentally attractive than other fossil fuels because it is composed of chiefly methane, which is a molecule that is made up of one carbon atom and four hydrogen atoms. When methane is burned completely, the principal products of combustion are carbon dioxide and water vapour. In comparison, oil and coal compounds have much more complicated molecular structures, as a result they do not burn as cleanly. Coal and oil combustion also produce ash particles, which do not burn at all, but are carried into the atmosphere. So, because natural gas burns cleanly it can be an effective means of controlling pollution and greenhouse gas emissions (www.naturalgas.org).

The remaining chapters of this report will, therefore, be dedicated to the utilisation of natural gas in the public road transport sector of South Africa. It is hoped that should NG buses be successfully used in South Africa, the involved infrastructure may be replicated to all the other regions, as well as to the entire continent.

## 2.3. International Experience of Using Natural Gas in Buses

Apart from Canada and Italy, mentioned above, the following countries also use CNG for their transport sectors.

- USA - Presently, the New York bus fleet is 95% diesel, 4,9%CNG, and 0,1% hybrid, with a fleet strength of about 4500. Los Angeles has the country's largest fleet of CNG buses, which make up 35% of its total fleet of 2600. In two years' time it aims to increase that share from 35% to 50%.

- France - Paris runs about 2% of its fleet on CNG. Other cities have larger shares of CNG buses: Nice has 38%, Lille has 32% and Bordeaux 22%. An entire urban route in Strasbourg is equipped with NG powered buses. About 35 additional natural gas buses will be brought into the mainstream within the next two years, and another 15 will be brought in within another year to make it a total of 50 NG buses within three years. There will be 50 refuelling stations built, one for each bus (www.ngvc.com).

- Australia - There is a rapid growth of natural gas use in the Australian transport sector as shown in Table 2. Adelaide has 17% of its fleet of 750 running on CNG. The CNG fleets for the other cities are 175 for Sydney, 30 for Victoria and 53 for Perth.

**Table 2** **AUSTRALIAN CNG BUSES**

| | CURRENTLY IN SERVICE | ON ORDER |
|---|---|---|
| BRISBANE | 15 | 120 |
| SYDNEY | 175 | 265 |
| ADELAIDE | 115 | 100 |
| PERTH | 53 | 5 |
| VICTORIA | 30 | 2 |
| Total | 385 | 485 |

Source: www.gas.asn.au

- Argentina - No country in the world has converted as many vehicles to CNG as Argentina, especially in the commercial category. Today the country boasts 668 480 natural gas vehicles and 923 fuelling stations. Argentina has the second largest gas fields in the whole of South America (Kojima, 2001).

- India - Complying with the High Court directive to increase the number of CNG operated buses to 10 000 by the year 2001, India has, at least, reached half of that figure. About 137 publicly operated CNG buses are in operation and another 1 200 have been ordered. Thirteen diesel buses have been retrofitted with CNG. There are at the moment 35 refuelling stations in operation (Bose, 2001).

- China - Shanghai's city planners in China have been environmental leaders in the country. The result is that air pollution is less severe in Shanghai compared to any other city in China. In the late 1990's they began switching to cleaner-burning liquid petroleum gas (LPG) and compressed natural gas (CNG). The taxi fleet is being currently retrofitted to burn LPG, and the bus fleet is being retrofitted to burn CNG. The first CNG fuelling station in Shanghai opened its doors in 1998 (Zhou, 2001).

- Britain - In Britain the Merseytravel consortium recently launched the most advanced compressed natural gas buses in that country. The project involves sharing the best practice and experience in seeking pollution-busting solutions and energy saving technologies in the development of new and exciting public transport initiatives. The compressed natural gas powered system comprises of four CNG powered low-floor quality buses, six smart eco-shelters, electronic information screens, and the most rigorous gas technology safety programme in the United Kingdom. These low-floor buses are powered by a 5,9litre CNG, water-cooled, turbo-charged engines, fitted with gas oxygen censors. They have a maximum speed of 88 kilometres an hour and a range of 200 miles. The bodywork is made of glass fibre on a steel chassis to reduce weight. The whole body is only 5 metres long and is remarkably manoeuvrable with a turning circle of just 6 metres radius (http://www.liverpoolcollege.co.uk).



**Table 3. COMPARING ALTERNATIVE TRANSPORTATION FUELS BY CRITERIA**

| FUEL | Adequate Resource Base | Manageable Fuel Properties | Greenhouse Gas & Other Emissions | Feasible Hardware Modifications | Cost Competitiveness | Availability | Effect of Regulations |
|---|---|---|---|---|---|---|---|
| **CNG** | + | + | + | + | + | +/- | +/- |
| **LPG** | - | - | +/- | + | + | + | - |
| **Methanol** | - | - | +/- | + | - | - | + |
| **Ethanol** | - | + | +/- | + | +/- | - | + |
| **Electricity** | +/- | +/- | +/- | - | - | +/- | + |
| **Hydrogen** | + | +/- | +/- | - | - | - | +/- |
| **Fuel Cells** | + | + | + | - | - | - | + |
| **Solar Energy** | + | +/- | + | - | - | - | +/- |
| | | | | | | | |

Source: Gordon, 1991

**ADVANTAGES = + DISADVANTAGES = - BOTH = +/-**

A brief summary of existing alternative transportation fuels is presented using different criteria in Table 3. above. This summary was compiled by Gordon in 1991 and data may have changed due to recent developments, improvements and breakthroughs. As can be observed natural gas becomes the preferred option. Over 1,5 million vehicles run on natural gas worldwide, fuelling at more than four hundred refuelling stations.

Over 1,5 million vehicles worldwide run on natural gas and fuel at more than four hundred refuelling stations. The largest NGV market is Argentina, followed by Italy, Pakistan and then the United States of America. The number of NGVs and refuelling stations are shown in Table 4. below.

**Table 4 INTERNATIONAL NATURAL GAS VEHICLE STATISTICS**

| COUNTRY | VEHICLES | STATIONS | AS OF |
|---|---|---|---|
| Argentina | 668 480 | 923 | 2001 |
| Italy | 370 000 | 355 | 2001 |
| Pakistan | 200 0000 | 200 | 2001 |
| United States | 102 430 | 1 250 | 2001 |
| Brazil | 80 000 | 131 | 2001 |
| China | 36 000 | 70 | 2000 |
| Venezuela | 33 586 | 150 | 2001 |
| Russia | 30 000 | 202 | 2000 |
| Egypt | 24 115 | 45 | 2001 |
| Canada | 20 505 | 222 | 2000 |
| New Zealand | 12 000 | 100 | 2000 |
| Germany | 10 000 | 146 | 2000 |
| Colombia | 10 000 | 28 | 2001 |
| India | 10 000 | 11 | 2000 |
| Japan | 8 053 | 138 | 2001 |
| Bolivia | 6 000 | 17 | 2001 |
| France | 4 550 | 105 | 2000 |
| Trinidad Tobago | 4 000 | 12 | 2001 |
| Malaysia | 3 700 | 18 | 2000 |
| Indonesia | 3 000 | 12 | 2000 |
| Australia | 2 000 | 12 | 2000 |
| Chile | 2 000 | 7 | 2001 |
| Sweden | 1 500 | 25 | 2000 |
| Bangladesh | 1 000 | 5 | 2000 |
| Great Britain | 835 | 18 | 2000 |

| | | | |
|---|---|---|---|
| Iran | 800 | 2 | 2000 |
| Netherlands | 574 | 27 | 2000 |
| Spain | 300 | 6 | 2000 |
| Belgium | 300 | 5 | 2000 |
| Mexico | 300 | 2 | 2001 |
| Switzerland | 270 | 14 | 2000 |
| Korea | 245 | 3 | 2001 |
| Turkey | 189 | 3 | 2000 |
| Thailand | 184 | 1 | 2001 |
| Austria | 83 | 5 | 2001 |
| Ireland | 81 | 2 | 2000 |
| Cuba | 45 | 1 | 2001 |
| Finland | 34 | 5 | 2000 |
| Czech Republic | 30 | 11 | 2000 |

Source: Kojima, 2002

# CHAPTER 3:
# THE SOUTH AFRICAN TRANSPORT SECTOR

## 3.1. Introduction

As a prelude to discussing the South African transport situation, it is useful to discuss some factors that led to its uniqueness. These factors will show why South Africa was transformed into such a high carbon intensive country in terms of transport and industrial use compared to other countries in Africa. These factors will also show why the country needs a cleaner transport fuel like natural gas, in order to reduce carbon intensive crude oil imports, to improve air quality and to help mitigate GHG gas emissions. These three inter-related factors will be discussed under: (i) historical background; (ii) the people and the economy; and (iii) the legacies of apartheid.

## 3.2. Historical Background

The early part of South Africa's history was characterised by conflicts among colonial powers as they raced to satisfy their desire for trade advantages. The colonial powers involved then were the Portuguese, the Dutch and the British. In addition, there were inter-tribal conflicts mainly between the Xhosas and the Zulus. Under the provisions of the Congress of Vienna in 1814 the British were formerly handed the Cape Colony. The Dutch farmers generally resented British rule and in 1835 started the great trek into the interior of the country. Many clashes subsequently ensued between the Dutch and the native tribes and the Dutch and the British.

After the discovery of gold and diamonds and subsequently the establishment of the Union of South Africa in 1910, followed by the Great World Depression of the 1930s, many people – black and white, were driven to cities to compete for skilled and unskilled jobs. As a result both African and Afrikaner nationalism emerged. In 1948 the Afrikaner National Party legalised apartheid laws and instituted pass laws, which severely restricted and supervised the movement of non-whites in the country.

During the 1950s support for groupings such as the African National Congress (ANC) and the Pan African Congress (PAC) grew significantly. The enforcement of segregation was met with increasing black resistance and hostility. During the 1960s Umkhonto WeSizwe was formed as an armed military wing of the ANC.

During the 1970s, black opposition to white rule hardened with the advent of organisations such as the South African Students Organisation (SASO), the Black Peoples Convention (BPC), and the Black Community Programme (BCP) under the leadership of Steve Biko.

The 1980s were characterised by worker's strikes, student unrests and international sanctions on the South African government. From 1990 liberal elements within the National Party led to the unbanning of the ANC, PAC and SACP. In 1994 South Africa went to the first democratic elections on a universal franchise and the ANC won the election by a wide margin with Nelson Mandela becoming first South Africa's first Black president.

### 3.3. The South African Economy and Population

South Africa had an estimated population of 43 million people in 2000. Approximately 5 million are Whites and the remaining 38 million comprising of Blacks, i.e. Africans, Coloureds and Indians. Between 1995 and 1999 the population grew at the same rate as the GDP, at 2,3% when measured in the local currency (Statistics SA, 2001).

In 1999 the GDP per capita was about US $3,050. There are, however, huge disparities between the racial groups. The poorest 50% are Blacks with 11% of total income, while the richest 7% are White and receive over 40% of total income. 61% of Africans and 38% of Coloureds are poor when measured on the "poverty line" compared to 5% Indians and 1% of Whites. Unemployment has increased from 19,9% to as high as 40% from 1995 to 2000. Urbanisation has also increased as 51% of the population are now living in urban areas. Most of the country's GDP is produced in the larger metropolitan areas (Statistics SA, 2001).



South Africa faces major social and economic challenges. The majority of the population is poor and illiterate, the tax base is limited, there is a high demand for increased social services, crime rates are high, there are limited skills in the labour force and the health levels are deteriorating especially due to HIV and Aids. The South African government has been struggling to cope with these challenges and has been trying to come up with policies that will satisfy the aspirations of the majority of the poor black people while at the same time allaying the fears of the white section of the population and international investors.

### 3.4. Legacies of Apartheid.

Like many other developing countries, South Africa has many transport-related problems, but many have arisen due to the ills of the past apartheid system, which are discussed above. This legacy can be observed in the entire transport network, land use, and transit supply as will be explained. Below is an overview of the most prominent effects of apartheid on the transport system of South Africa.

### 3.4.1. Skewed Land-use Patterns

Land use patterns in all South African cities exhibit a typical imprint of the apartheid system. An unusual situation exists where the haves live close to their places of work, while the have-nots stay far away, several kilometres from their workplace. Most affluent Whites are dependent on their own cars and live in the suburbs closer to the central business district, while most struggling Black people live in far-flung residential areas away from the central business centres. In South Africa land-use and transport development are not integrated adequately owing to the regulation of the various aspects of land-use and transport infrastructure. This fragmentation, and the legacy of past apartheid policies, has led to low density developments, spatially dislocated settlements and uncontrolled urban sprawl, giving rise to long commuting distances, low occupancy levels and high transport costs (Transport Policy White Paper, 1996).

The government is committed to the implementation of policies that will give priority to the containment of urban sprawl, densification, mixed land-use and the promotion of the development of corridors and nodes. This will not be an easy task as much of the land that could be used for infill is private land that is usually expensive.



### 3.4.2. Poor Public Transport

During the height of the apartheid years in South Africa, all Blacks were systematically relocated to far-flung separate residential areas away from the centres of cities and employment opportunities. This rearrangement created the need for extensive public transport, mainly bus and rail to connect these townships to the urban employment centres. During the off-peak periods of the day very little demand existed for transport services, creating large inefficiences. Transport operators were provided with subsidies in order to keep fares low because commuters were low-income earners. The result was very low levels of service and high subsidies for long routes. Table 5 shows the separation of Black townships from city centres.

**Table 5. DISTANCES OF BLACK RESIDENTIAL AREAS FROM CITY CENTRES**

| City | Distance Between Township and CBD (km) | Average Time Spent (minutes per journey) |
|---|---|---|
| **Johannesburg** | 20 | 77 |
| **Pretoria** | 52 | 75 |
| **Cape Town** | 19 | 65 |
| **Durban** | 20 | N/A |
| **Bloemfontein** | 58 | 86 |
| **Port Elizabeth** | 16 | N/A |
| **East London** | 21 | N/A |

Source: de Saint-Laurent, B. 1998.



The apartheid government allowed the entry of unregulated and informal taxi services, mainly to relieve the government of further subsidies and responsibilities. The result was an explosive growth of minibus taxis, which became well suited for the diffuse patterns created by the system then. These vehicles were, however, extremely cramped in terms of seating and often unsafe because of extended service life and the resultant deterioration of the vehicles, overloading and reckless driving.

### 3.4.3. Synthetic Fuel Production

South Africa has large reserves of coal but no known petroleum reserves. The country had to produce its petroleum from the conversion of coal, mainly due to security reasons as during that period, the country was under international sanctions due to apartheid. This was a very expensive exercise and resulted in major national investments.

Sasol is the second largest industrial company in South Africa and it is recognized for its innovative chemical processing technologies all over the world. It has formed joint ventures with leading international energy companies to further the development and commercialisation of its technologies for converting coal, natural gas and petroleum into liquid fuels and chemicals. Sasol supplies 41 % of South Africa's liquid fuels and produces more than 120 chemical products for local and international markets in more than 90 countries (www.sasol.com).

South Africa's dependence on coal for its energy needs and liquid fuels has resulted in it being a high contributor to global greenhouse gas emissions in comparative terms to other developing countries. Hence, alternatives to coal conversion for liquid fuels will be welcomed. It is for this reason, among others, that the uses of natural gas can be considered.

## 3.5. The Current Transport System of South Africa

There has been a considerable decrease of financial support from government in South Africa. More support has been directed towards more pressing social and developmental projects. The transport industry has been opened up for privatisation. Private enterprises have gone into new transport services, such as the minibus taxis and the new private trucking services. These private companies have taken over many of the transport services previously operated by government.

### 3.5.1. Travel Modes

In South Africa as in most countries worldwide, there are several modes of travel within the transport system. These include road, rail, sea and air.

#### 3.5.1.1. Road

South Africa is a medium sized country measuring some 2 000 km from the Limpopo river to Cape Agulhas and 1 500 km from Port Nolloth to Durban. It is networked with hundreds of kilometres of national, secondary and tertiary roads, making it relatively easy to move from point to point. There are a half a million kilometres of tarred roads and 7 000 km of national roads. There are already over ten toll roads, which offer quick access to major centres and the number is growing. A report on road maintenance states that in 1990 about 5% of the roads were in poor condition and this has escalated to 33% at present. This has resulted in a 10% increase in traffic congestion. In order to prevent further deterioration, the government must double its spending from R3.5 billion to R7 billion per annum (Africa Indigo, 2000)

#### 3.5.1.2. Rail

South Africa has a large number of luxury trains comparable to any in the world. For over a century the Blue Train has enjoyed an international reputation as one of the world's pre-eminent travelling experiences. About 250 000 travel agents in 181 countries have recently voted for it. The Blue Train has created strategic alliances with some of South Africa's leading game lodges and five-star hotels linked to eco-tourism (Africa Indigo, 2000). This, however, is for luxury and entertainment purposes and does very little to solve the country's transport problems.

### 3.5.1.3. Sea

Portnet, a division of Transnet Limited, a South African transport operating company, manages and controls the seven commercial ports on the South African coastline. These are Durban, Richards Bay, East London, Port Elizabeth, Mossel Bay, Cape Town and Saldanha. In line with ports worldwide, Portnet facilitates international trade and contributes to the economic growth of the countries it serves. About 98% of South Africa's international trade is transported by sea. In this regard, Portnet assists clients to access expanding trade opportunities both in South Africa and the rest of the sub-Saharan Africa as well as the other world markets.

### 3.5.1.4. Air

Most international airlines fly into South Africa. These include Swiss Air, British Airways, Air France, Lufthansa, Qantas, KLM, Virgin Atlantic and Iberia. South African Airways has expanded its destinations through partnerships with other airlines. The regional fleet has also been recently upgraded. SAA is in the process of moving from Boeing to Airbus and is considering selling the entire Boeing fleet. British Airways, SAA and Swissair carry each other's passengers under code-share agreements.

## 3.5.2. The Road Infrastructure

The proposed vision of the government of South Africa is to provide a safe and reliable, fully integrated transport infrastructure, which will meet the needs of goods and passenger customers. It aims to improve service and cost in a manner, which will support economic and social development whilst being environmentally and economically sustainable (Transport Policy White Paper, 1996). To be effective, the development of road transport provision must not only be economically and financially sound, but also socially and environmentally efficient. This implies also giving attention to increasing efficiency in the use and management of all the primary elements of the road infrastructure.

In South Africa, roads are classified into three broad categories based on the classification by the government authorities, as shown in Table 6.

**Table 6 EXTENT OF SOUTH AFRICAN ROAD NETWORK**

| CLASSIFICATION | NON-TOLL | TOLL | TOTAL |
|---|---|---|---|
| **NATIONAL ROADS** | 18 000 | 2 000 | 20 000 |
| **PROVINCIAL ROADS** | 340 000 | - | 340 000 |
| **URBAN ROADS** | 165 000 | - | 165 000 |
| | | | |
| **TOTAL** | 532 000 | 2 000 | 525 000 |

Source: DOT, 1998

National roads provide mobility primarily for economic reasons and are regarded as strategic assets vital to the ability of the country to support and improve economic growth. These roads are designed for high-speed travelling and long distance travel. Provincial roads are provided for mobility on a regional context. These roads link and provide access to areas that are not situated on the national road network. They are provided for both economic and social reasons. These are designed for short travel and for moderate speeds. Local roads are provided for local mobility and satisfy social than economic trips. Local government and metropolitan councils are responsible for these roads. Local roads are also referred to as urban roads.

The South African road infrastructure is a combination of well-designed and not-so-well designed roads, by world standards. The world-class standard roads are found in almost all areas where Whites are dominant, and the poorly designed roads are found in areas that are dominated by Blacks. As an example, there is a glaring difference between the roads in Alexandra, an African residential complex and those in Johannesburg's northern White suburbs, just across the road.

There are large areas of rural communities, which remain inadequately serviced by roads. Most blacks live in these areas, situated on the eastern half of the country.

The roads are generally designed for private car transport and to a lesser extent for bicycles and motorcycles or any other two or three-wheelers. No provision has been made for non-motorised transport. There is generally limited funding for social roads which form the bulk of the whole road transport network.

### 3.5.3. Public Transport

There are a variety of transport modes available to serve those without cars. Public and private buses and minibus taxis serve most urban areas. Rail transit also serves the largest cities. Transport choices are influenced by income as shown in Table 7.

#### 3.5.3.1. Minibus Taxis

Probably the most important aspect of public transport in South Africa is the introduction of the "minibus taxi" during the early 1980s. This also explains the decline of rail and bus ridership figures. Currently, minibus taxis account for over two thirds of all transit services and about 32% of all passenger travel in South Africa. The "minibus taxi" is an unregulated and unsubsidised industry, wholly Black owned and also one of the largest Black industries in South Africa, second only to soccer. The downside is that it is highly disorganised, unsafe and violent. The vehicles are not designed for transit use, but as family size nine-seater cars. Extra bench type seats have been inserted so as to squeeze in more passengers. Seating is highly uncomfortable, the vehicles themselves are poorly maintained and some are extremely dilapidated due to extended lives from six to ten years. This results in high energy consumption and high pollutant emissions as the industry is not regulated and vehicles are not adequately maintained. Minibus taxis have come to dominate the provision of passenger transport services. The government encourages this growth in order to support black business and relieve itself of the heavy subsidies made to rail and bus services (Prozzi et al, 2002).

Table 7 shows the modal split in the public passenger area in South Africa.



**Table 7. MODAL CHOICE BY INCOME**

Source: Moving SA, 1998

| Income (R/month) | Train | Bus | Taxi | Car | Walk or Other | TOTAL |
|---|---|---|---|---|---|---|
| <1085 | 8 | 10 | 29 | 10 | 43 | 100 |
| 1085-1735 | 16 | 17 | 28 | 7 | 31 | 100 |
| 1736-3038 | 19 | 16 | 35 | 13 | 17 | 100 |
| 3039-5425 | 13 | 13 | 34 | 26 | 14 | 100 |
| 5426-8680 | 6 | 7 | 20 | 57 | 11 | 100 |
| 8681-13020 | 2 | 5 | 7 | 78 | 6 | 100 |
| >13020 | 2 | 1 | 3 | 92 | 2 | 100 |

#### 3.5.3.2. Rail Transit

Intercity passenger rail has dropped considerably since the 1980s but still remains an important option. The passenger fares on commuter rail have been subsidised and kept low so as to be able to carry workers to and from places of work, back to the townships. Rail subsidies are diminishing but still cover about two-thirds of total expenditure. For example, fare revenues have decreased because of low operating fares and rampant fare evasion by commuters. In 2003, Metrorail, the government-owned public rail corporation, will have to compete with other bidders in order to provide commuter rail services. However, based on international experience, there is no assurance that service will improve.

#### 3.5.3.3.Bus Transport

Bus ridership dropped by almost 30% during the early 1990s due to the introduction of minibus taxis. Initially many bus routes were established with the introduction of apartheid laws and these were designed to connect urban employment centres with the outlying Black townships and homelands. Large bus companies benefited from the large subsidies originally provided for these services.

The government is now replacing the cost-based bus subsidy system with competitive tendering for concession contracts. Companies will bid to provide services on particular routes. The government will then make up the difference between the tendered cost of a service and the revenue from fares.

The current bus sector is a complex mixture of subsidised public and private companies. An exception is the unsubsidised private bus companies such as Translux, Greyhound and Intercape, which expanded during the 1990s. Recently a few others have emerged. All these companies operate luxury coaches between the major centres of South Africa (Prozzi at al, 2002).

### 3.5.4. Car Ownership

The population of South Africa is growing at a rate of around 2,3% per annum. Almost all White families own one or even two cars. Only 10% of Blacks own cars. Most are poor and are dependent on public transport, being unable to afford to own cars (Transport Statistics, 1995). The South African passenger modal split shows that almost 50% consist of private vehicle motors and the other 50% taken by public transport. Very little is being done to promote the use of bicycles and scooters. The road infrastructure has no provision for pedestrian mobility.

South African cities experience a high degree of traffic congestion during peak hours. The city's main roads struggle to carry the present high volume of cars. This is accompanied by a high degree of environmental drawbacks giving rise to the unsightly brown smog over most South African cities.

Generally cars account for 64% of vehicles involved in traffic collisions on South African roads. There are a number of reasons for this, including the already mentioned diffuse land use patterns, poor quality of public transport, especially minibus taxis and the highly subsidised vehicle schemes offered to both private and public sector employees and serve to increase vehicle numbers.

### 3.5.5. Freight Transport

Before the 1980s there were no trucks moving freight on South African roads. All freight was transported by the government-owned railways, which were protected by legislation that prohibited trucks from competing. Trucking was allowed to compete by the Transport Deregulation Act of 1988, resulting in a flood of new trucking companies, and a lowering of freight tariffs. There is general concern among transport authorities that too much competition has been allowed in the freight industry. They feel that it may sink to the level of the minibus situation if not properly controlled. Consensus is growing that some freight should be encouraged to return to rail. Strategies for slowing the growth of trucking companies are under discussion and include stricter enforcement of the country's traffic laws, full cost recovery from road operators, including externality and environmental costs, as well as major improvements in rail services (Prozzi et al, 2002). Fears also are abound that the concessioning off of railway lines by Transnet will close half the country's railroads and put more heavy trucks on the road. South Africa should lower its tonnage limits on the roads in order to encourage more rail transport. Rebates should also be considered for using rail instead of trucks.

### 3.5.6. Energy Consumption by the Transport Sector

Transport accounts for 24% of the total energy consumed in South Africa. About 41% of transport fuels are derived from locally mined coal, and only around 7% come from natural gas. These fuels produce twice as much greenhouse gases as petroleum based fuels. South Africa's liquid fuels provide more than 90% of transport energy. The number of vehicles is increasing fast resulting in annual demand for petrol and diesel of around (16 778 MT) in 1995 from local refineries and synfuels plants (Trollip, 1996).

Ten oil companies operate in South Africa, viz, Shell, BP, Sasol, Tepco, Afric Oil, Caltex, Engen, Excel, Total and Zenex. All South Africa's liquid fuel requirements are manufactured within the country with imports to balance supply and demand. South Africa is one of the few countries in the world with a substantial synthetic oil-from-coal and oil-from-gas industry. Oil-from-coal refineries are situated at Sasol 2and 3 at Secunda and oil-from-gas is refined at Mossel Bay. Recently more gas fields have been discovered off the coast of Saldanah Bay. Imports from the Pande and Kudu gas fields form neighbouring Namibia and Mozambique could also boost this industry.

The oil industry employs about 100 000 people with 29 200 being employed directly by the synthetic fuel refineries. Although South Africa's fuel market is small in global terms, it is far higher than that of most other countries in Africa. The country has approximately 4 million vehicles and sells close to 31 billion litres of oil per year. Synthetic fuels meet about 41% of this demand. The foreign exchange benefit of South Africa through local refining equals to R2, 1 billion with an oil industry turnover of R39, 6 billion. (Fast Facts, 2000).

In summary, the transport sector of South Africa is heavily dependent on imported crude oil resulting in an unusual situation where transport energy pricing is heavily influenced by international supply and demand trends.

> Opportunities exist to increase fuel diversity within the transport sector. Innovative transport technologies, enabling the use of natural gas, hydrogen and electricity as fuels, are reaching stages of maturity, which may make their usage economic for local applications (Energy Policy White Paper, 1998).

The government would be well advised to consider looking into the local use of natural gas for local applications for both economic and environmental considerations.

### 3.5.7. Air Pollution and GHG Emissions

South Africa has introduced unleaded fuel, but continues to use leaded petrol as there is no ban on using leaded fuel. There is minimal air pollution control as exhibited by the smog that is clearly visible over most South African cities. Few cars in the country are fitted with catalytic converters. The long distances by buses and improperly maintained mini-bus taxis result in high levels of pollution. The low occupancy rate of private vehicles results in equally high intensity of emissions. Motor vehicles are a major source of air pollution in South Africa. Most Blacks with cars operate old unregistered ones – some as old as twenty years.

Table 8 shows South Africa's $CO_2$ emissions per capita from the transport sector. As can be seen the country is a relatively large producer of greenhouse gases. South Africa's high contribution to greenhouse gas emissions can comfortably be attributed to its dependence on coal for power and liquid fuels.

**Table 8 CARBON DIOXIDE EMISSIONS FROM THE TRANSPORT SECTOR**

| COUNTRY | CO2 Emissions/capita from transport (kg) | Transport Sector % of total carbon emissions |
|---|---|---|
| CHILE | 1028 | 28 |
| SOUTH AFRICA | 870 | 10 |
| CHINA | 178 | 8 |
| INDIA | 120 | 13 |
| JAPAN | 1971 | 22 |
| U.K. | 2238 | 24 |
| UNITED STATES | 6082 | 30 |

Source: IEA, 2000.



### 3.6. Transport Services in Cape Town

The city of Cape Town has one of the most extensive transport systems in Africa. The length of roads is about 9 602 kilometres, with a replacement value of around R14.5 billion. The length of rail is about 702 kilometres, served by 1009 coaches with a replacement value of 12.5 billion. The city owns some 850 buses with a replacement value of R350 million. More than 6 500 taxis, excluding some 370 metered taxis, service it. There are 183 transport interchanges, which include passenger stations, major interchanges and formal taxi ranks (www.capetown.org.za).

Rail, buses and minibus taxis together convey around 1,2 million passengers daily. Most of these people – in the region of 530 000 – are carried by private motorcars. About 60 000 pedestrians make use of the transport infrastructure when going to and from work. A total of around 100 000 tons of goods are conveyed every day.

There are, however, some interesting facts about the public transport services of the city (www.capetown.org.za). Some of these are listed below:

### 3.6.1. Bus Transport

- The average age of the bus fleet is about 11 years old and is still based on antiquated technology.
- The bus passenger numbers are shrinking, while those of taxis are growing. This is probably due to the fact that taxis are faster and more convenient.
- Bus subsidies that are paid by the Central Government are escalating faster than the current inflation rate, while the Local Government pays no subsidies.
- Competitive tendering is currently being implemented.
- Buses in Cape Town carry more than 100 000 passengers per day.

### 3.6.2. Rail Transit

- Although Cape Town has got an extensive rail network, no major investment has been made in the rail infrastructure for the past ten years.
- The average age of the rolling stock is 26 years and it experiences a critical shortage, which invariably leads to unacceptable levels of overcrowding.
- Fare evasion is rampant. Only 44% of the operating expenditure is recovered by means of fare revenue.
- Safety remains a major problem.
- Rail transit services in the city carry more than 350 000 people every day.

### 3.6.3. Taxis

- The restructuring, formalisation and recapitalisation of the taxi industry has been entirely unsuccessful to date. This has resulted in ill discipline, lack of training and low standards of service.
- Great rivalry between operators still exists, leading to unending violence.
- The minibus taxi industry is a very important segment of the city's public transport system, carrying more than 140 000 thousand passengers a day.
- The tourism business is booming in Cape Town, making metered taxis are a growing enterprise. Better control of the latter is essential so as to maintain standards.
- The minibus taxis have made major inroads into the bus sector passengers and convey an incredible 140 000 passengers a day.

## 3.7. Conclusion

It is against this background that the transport sector of South Africa faces such major adjustment problems. During the apartheid past, large tracts of land were left unused. These tracts of land were deliberately unutilised in order to act as a buffer zone between Black and White. This compelled a huge number of poor people to commute long distances to places of employment in Whites-only areas. Public transport was designed in such a manner that it could transport Black labour to and from employment centres. Hence it is inefficient, expensive and environmentally degrading. It cost the country millions in subsidies and results in ever increasing ugly urban sprawl.



Also, South Africa's synthetic fuel production from coal, for political and security reasons, contributed to a high carbon intensity and resultant GHG emissions. Sasol is now considering the use of natural gas for economic and environmental purposes.

The government is committed to restructuring the transport sector with special emphasis on public transport, through reorganisation and efficient management. The Energy Policy White Paper (1998) welcomes proposals which call for the introduction of less polluting alternative, transport fuels.

In South Africa, the public road transport sub-sector has gradually been taken over by the private sector - specifically the minibus taxi industry. Unfortunately it is uncomfortable and unsafe. It is also the source of a high degree of pollution and greenhouse gas emissions due to poor maintenance, vehicle age, and reckless driving.

Like other developing countries, South Africa is also experiencing an increasing utilisation of cars and trucks. Due to social aspirations, an expanding middle class, lack of an attractive public transport system and a more open and competitive vehicle market, it is widely anticipated that car-use will continue to increase over the next twenty years. The higher the number of cars, the higher the demand for an expensive road infrastructure and energy-use. This also creates more concern for GHG emissions.

# CHAPTER 4:
# AVAILABILITY OF NATURAL GAS, AIR QUALITY AND GLOBAL WARMING CONCERNS

## 4.1. Introduction

Globally the tendency for some countries is a shift away from high carbon intensity fuels to less carbon intensity ones, such as natural gas, in order to satisfy their energy demand. This coincides with the expected major increase in energy demand from developing countries. Studies have shown that by 2020 the total energy demand in the developed countries will increase by 20% while the demand for energy in the developing countries will increase by 100%. This demand is in line with a change in the energy industry, as natural gas becomes the major feedstock of choice. It is believed that demand for natural gas will grow by 60% by 2020 and that 18% of the world's total energy demand will be derived from natural gas (Engineering News, 2002). Shell now produces more gas than oil and says it sees more prospects and options for gas than for oil. The gas industry has come a long way from the days when the production of gas reserves was only exploited in absence of oil.

Some areas that were inaccessible only a decade ago, such as large portions of the Soviet Union and Africa, are now experiencing waves of exploration as oil companies seek new natural gas reserves. Another very important driver for the utilisation of natural gas is the increasing environmental concern, besides climate change, namely, local air pollution and improvement in air quality.

The natural gas industry and markets in Southern Africa is expected to come to fruition and maturity much faster than in Europe or Asia because of "leapfrog" strategies – advanced methods that allow developing countries to go beyond what is presently typically used in developed countries. Developing countries could, for example, leapfrog most of the pollution problems and other pitfalls that the developed countries went through on their way to development, by making use of recently developed innovations such as natural gas fuel technologies and fuel cells, when these become commercially available.

Internationally, the consumption of natural gas has increased markedly, while new demand develops in most countries, replacing traditional fuels in the process. Initially this may not be the case in South Africa yet, because of the country's abundance of coal and the subsequent low cost of electricity.

## 4.2. Potential Use of Natural Gas in Southern Africa

Natural gas can be used as transport fuel for vehicles and has been tried in several countries around the world. It can also be used to produce hydrogen for fuel cells, which are now attracting attention as was mentioned earlier.

Large deposits of natural gas have been found in Angola, Mozambique, Namibia, South Africa and Tanzania. Coal bed methane has also been discovered in the Waterberg area of South Africa. Appendix G shows gas reserves within the South African market scope.

South Africa has limited deposits of natural gas off the south coast in the Mossel Bay area. Other than a coal to gas pipeline owned by Gaskor in the Gauteng area and an old, unused gas system in Cape Town, there is no developed gas market in South Africa. Nonetheless, a thorough study by the World Bank and the Southern African Development Community (SADC) shows that there is potential for a gas market in the area. The identified potential gas market in South Africa appears to be substantial enough for development of a regional gas industry. The forecasted demand indicates that a phased development of regional gas fields could be required (SADC, 1995). South Africa will be an important market for the gas industry in the area. Therefore a strategy of regional co-operation and development is very necessary for the gas industry to be successful in South Africa.

If investments in Southern Africa's gas industry are made along with stimulating markets and efficient pricing, natural gas could displace many uses of coal and some petroleum products and so provide the basis for a strong and vibrant economy. If such a scenario should be achieved, not only would the natural gas industry result in positive side benefits as cleaner air and greenhouse gas reduction, but would also lead to a growing demand for natural gas. This would open up competition between suppliers and customers for the best product at the best price.

A market analysis on gas use in the region has focused on the use of providing heat for industrial applications. Special attention has also been given to a number of large-scale user applications with mineral benefaction, iron reduction, power generation and even natural gas vehicles proving to be the most interesting options.

## 4.3. Demand for Power Generation

New capacity for power generation may be needed around Cape Town from 2007 and gas-fired power stations could be viable for this purpose. The Eastern and Western Cape would be potential natural gas power markets since they are far from the coal producing areas of Gauteng and Mpumalanga. This could promote the introduction of natural gas vehicles for public transportation and other fleet operations in Cape Town. Gas fired power stations providing electricity for electric vehicles (EVs) would also result in zero emission vehicles (ZEVs) for the city.

For environmental concerns, electricity generated from coal could be gradually reduced in South Africa as capital replacement permits. As a start, use could be made of natural gas as the feedstock for electricity generation. As stated earlier, this would drastically cut down adverse emissions that come from coal-fired plants. If all South African metropolitan areas could use natural gas as feedstock for electricity generation, then a significant share of the country's environmental problems will lessen.

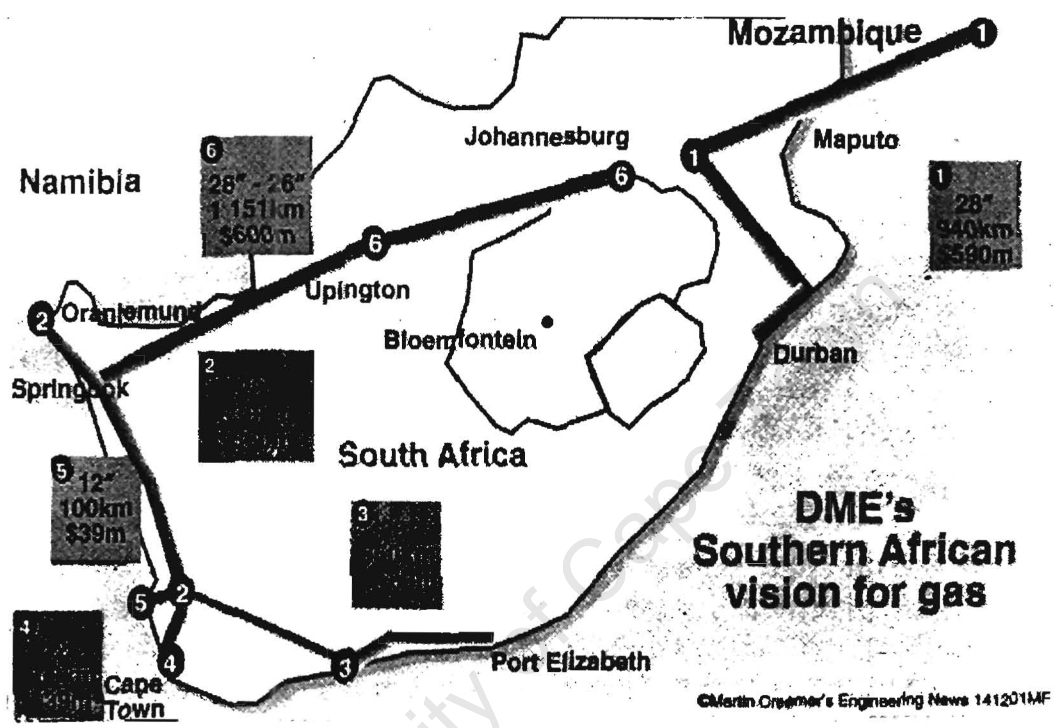
## 4.4. Transmission Pipelines in Southern Africa

Natural gas producers and consumers are normally connected by pipeline transmission and distribution systems ( See Appendix E ). These activities are the most costly and depending on the situation such pipelines are operated as a monopoly. The SADC study has found that pipeline transport would be a preferred option.

Eight different pipelines have been analysed, all aimed at the supply of gas to markets in South Africa, based on resources in Kudu, Bredasdorp, Pande, Ibhubesi and Waterberg (See figure 2 ). Pande and Waterberg (1) could supply the Johannesburg and Natal areas. Kudu (2) could supply the Cape Town area including the potential large-scale gas users at Saldanah Bay north of Cape Town. There is also the possibility that the Mossel Bay (3) gas that is currently being used for synthetic fuel production could be re-routed to Cape Town (Trollip, 1994). Lastly, there is the possibility of gas supply to the deep water harbour development at Coega in Port Elizabeth.

Appendix A shows primary gas user projects as analysed in the SADC study. Appendix B shows regional gas resources and Figure 2 shows the Department of Minerals and Energy's vision of the initial transmission pipelines.

**Figure 2 NATURAL GAS TRANSMISSION PIPELINES**




Source: Engineering News, 2002



If natural gas can be developed and transported to South Africa at a cost below that of converting coal to gas and coal to oil, it would benefit the economy and improve air quality. This is because the synthesising process is energy intensive and therefore when compared to natural gas, large amounts of energy are used to manufacture gas or petroleum.

## 4.5. Natural Gas as Transport Fuel

Natural gas can help South Africa ease its dependence on imported petroleum, thereby resulting in huge foreign exchange savings. It also burns clean, emitting very little carbon dioxide, carbon monoxide and other reactive gases that pollute the air. The physical and chemical properties of natural gas result in good performance in modified vehicles. Natural gas has a higher octane number than petrol. In addition, because it is introduced into the engine as a gas rather than as a liquid, it can provide quicker cold starts with lower emissions.

Natural gas vehicles are refuelled at stations that are especially designed to deliver compressed or liquefied natural gas. Compressed natural gas stations use either "slow fill" or "fast fill" methods. Slow-fill stations are simpler in design and less costly than fast fill stations, but they take several hours to refuel a vehicle in comparison to the two to five minutes associated with fast fill stations.

Liquefied natural gas stations require cryogenic storage vessels to maintain the natural gas in a liquid state and refuelling times are comparable to those of conventional petrol stations. Liquefied natural gas vehicles generally provide longer driving range between refuelling than compressed natural gas vehicles, the driving range of both is shorter than petrol powered vehicles because of the lower density of natural gas.

Among the advantages of natural gas is that it can be used directly, while other fuels like petroleum have to be refined. Natural gas also leads to reduced engine maintenance and longer engine life. Generally, natural gas vehicles burn 60% cleaner than petroleum or diesel vehicles. (www.ngv.org). The disadvantage of natural gas is that it has a limited range when compared to petroleum or diesel, but storing it in its denser form as liquefied natural gas (LNG) may ameliorate this. Other disadvantages include requirements for bulky gas cylinders and the low volumetric energy density of the fuel.

South Africa would be well advised to look into the possibility of using natural gas as a transport fuel option for its public transport system, especially since the fuel is now readily available in the continent. This would greatly enhance both air quality and energy security when compared to crude oil.



**4.6. Safety considerations**

Regarding safety, natural gas ranks higher than petroleum. In the USA a survey of more than 8000 vehicles travelled about 278 million miles from 1987 to 1990 on natural gas. The injury rate for vehicular miles travelled was 37% lower than the entire population of petrol powered fleet vehicles and 34% lower than the entire population of registered petrol vehicles. In addition no deaths were recorded. In contrast deaths associated with the petroleum fleet surveyed came to 1.28 per 1000 million miles travelled. The national average was 2.2 deaths per 1000 million miles travelled for all US petroleum vehicles (www.ngv.org). There are two fundamental reasons cited for this excellent NGV safety record. Firstly, the structural integrity of the NGV fuel system and, secondly, the physical qualities of natural gas as a fuel.

The fuel cylinders used in natural gas vehicles are much stronger than petrol fuel tanks. The design of NGV cylinders are subject to a number of nationally required "severe abuse" tests such as heat and pressure extremes, gunfire, collisions and fires. While storage cylinders are stronger than petrol tanks, the composite materials used to encase the tanks are more susceptible to physical damage than metals under abusive conditions. NGV fuel systems are sealed, which prevents any spills or evaporative losses. Even if a leak were to occur in an NGV fuel system, the natural gas would simply dissipate into the atmosphere because it is lighter than air. Natural gas is non-toxic and non-corrosive and will not contaminate ground water.

The safety aspects of converting vehicles to run on compressed natural gas are of concern to many people. However, the low density of methane coupled with a high auto ignition temperature and higher flammability limits gives the gas a high dispersal rate and makes the likelihood of ignition in the event of a gas leak much less than for petrol or diesel (Poulton, 1994).

## 4.7. Applications in Heavy Public Transport

More metropolitan areas in the United States and Europe are switching to CNG buses, because these buses lead to lower emissions and lower bus upkeep costs as well as better performance and reliability. There is no reason why South Africa should not do the same as soon as the gas industry is up and running so as to enjoy the same benefits.

The Sacramento Regional Transit district reported that operating costs for the 57 natural gas buses were averaging only 33.7 cents per mile compared to 50,3 cents for their diesel vehicles (www.ngvc.com).

As a starting point Cape Town or Johannesburg could be set up as a pilot public transportation project, using compressed natural gas or liquefied natural gas or both.

## 4.8. GHG Emissions and Air Pollution

Greenhouse gas emissions and other air pollutants play a big role in climate change. This concentration of greenhouse gases amplifies the greenhouse effect causing the Earth's temperature to rise beyond its natural level. Increased emissions of greenhouse gases could result in changes in precipitation, ocean currents, seasonal weather patterns, floods and storms. Coastlines could be eroded by rising sea levels, valuable ecosystems could be destroyed, and animal and plant species could be threatened.

The three main gases, namely carbon dioxide ($CO_2$) methane ($CH_4$) and nitrous oxide ($NO_x$) are caused mainly by human activities and together contribute about 80% to the greenhouse effect in South Africa. Many of the pollutants that cause the greenhouse effect are also responsible for acid rain, smog, and depletion of the ozone layer and other pollution problems. Chemical reactions change the emissions of hydrocarbons (HC), nitrous oxide ($N_2O$) and carbon monoxide from the burning of fossil fuels into the brown haze smog that can sometimes be seen hanging over Cape Town during autumn.

The transportation system, amongst other activities, is responsible both directly and indirectly for these pollutants: directly through emissions from vehicle exhaust pipes and indirectly through fuel extraction, refining and distribution as well as infrastructure construction (Gordon, 1991)

Large amounts of fossil fuels have been burned to provide energy and chemical feedstocks in South Africa. The combustion of hydrocarbons result in the release of carbon dioxide, which can readily be emitted into the atmosphere, compared to any other green house gas. Other gases included methane, NOx and sulphur oxide ($SO_x$).

Cars, trucks and buses are important sources of carbon dioxide emissions. Aeroplanes, ships, pipelines and railways have contributed lesser amounts. Coal used in synfuel production also emits large amounts of carbon dioxide. The manufacture of cement from limestone to build roads and other structures also releases a lot of $CO_2$ into the atmosphere. The expansion of agriculture due to the increasing population as well as a demand for timber has also helped to transfer carbon from the soil to the atmosphere (Shackleton et al, 1996).

Vehicle exhausts contribute about 0,35% and landfills about 0,37% to the greenhouse effect in South Africa. (Shackleton et al, 1996). Nitrous oxide comes directly from exhausts of vehicles, vegetation fires, soils and the oceans. Nitrous oxide traps heat about 250 times more efficiently than carbon dioxide does (Gordon, 1991). Nitrous oxide is responsible for about 20% of South Africa's green house warming potential.

Carbon monoxide comes directly from the transport sector. Despite efforts to control air quality it is expected to worsen in the next decade because of the increase in the number of cars on the road.

All air-conditioned filled cars discharge CFCs throughout the vehicle's lifetime. Other CFCs come from degreasing solvents and also from those used for cleaning electronic components and fuel injectors. From as early as the 1980s the world identified the damage of CFCs and has placed a ban on all industrialised nations to limit their use.

Hydrocarbons are pollutants that contain carbon and hydrogen elements. All hydrocarbons react with hydrogen elements. All hydrocarbons react with NOx to form smog except methane. These are usually referred to volatile organic compounds (VOCs). Hydrocarbons are emitted from vehicle exhaust pipes evaporation of petrol and petroleum refining. Improvements in hydrocarbon emissions are likely to be cancelled out by the increasing number of cars on our roads

Particles suspended in the air are composed of a complex mixture of organic and inorganic substances ranging from naturally generated sea salt and oil particles to combustion-created smoke particles. These particles are released during the combustion of fossil fuels, motor vehicles and a wide range of industrial processes. Particulate matter includes emissions of dust, smoke, soot and other suspended matter. Particulates are also responsible for acid rain and some respiratory irritants.

Reactions between nitrous oxides and VOCs in the presence of sunlight and heat lead to the creation of ozone, or smog. The main sources of ozone formation are motor vehicles and power stations. Chemical reactions also create fine particles giving smog its hazy appearance.

Ozone in the lower atmosphere (tropospheric ozone), which is itself, a pollutant is different from ozone in the upper atmosphere (stratospheric ozone). The latter is helpful to mankind in that it plays a vital part in protecting people, fauna and flora by absorbing the harmful ultra-violet rays of the sun, which would otherwise cause skin cancer, cataracts, damage crops and plantation. It is stratospheric ozone that is being damaged by CFCs.

As pollutants combine with heat and sunlight to form smog or troposphere ozone, this creates more heat, which in turn is responsible for more smog. And so the cycle continues, causing more and more smog.

It is therefore very necessary to take some action, and amongst other things to look at the following:

i. Advanced technology for the production of clean coal and oil.
ii. Hydro and solar power.
iii. A high degree of regional co-operation.
iv. Alternative fuels like natural gas, electric vehicles, fuel cells, etc.
v. Renewable fuel technologies.

## 4.9. Climate Change and the Liquid Fuels Industry

In assessing the impact of global climate change on the local oil industry Shackleton et al (1996) say:

> "...it is considered that ozone depletion will not really significantly impact the industry. With respect to global warming, in spite of the controversy surrounding the topic, it must be noted that $CO_2$ emissions are inevitable and as such the oil industry will be impacted. In a South Africa driven by the need for socio-economic development, it is however difficult to commit to specific actions which will result in $CO_2$ limitations".

They say that significant reductions in emissions are possible in the transport sector through the overall reduction in fuel usage through better traffic control in cities, improved public transportation and the introduction of electric vehicles.

When looking at potential impacts of global climate change on the South African oil industry Shackleton et al (1996) found that:

i. Legislation regarding ozone depletion and CFC reduction has no significant impact on the oil industry.
ii. By 2010 urban traffic restrictions could begin to restrict petrol and diesel usage in environmentally sensitive areas.

iii. By 2010 more fuel-efficient vehicles will be available in the market place.

iv. By 2020 a significant number of electric vehicles will operate in urban areas.

In spite of the above, the total emissions may increase due to growing economic development and increased population levels.

### 4.9.1. GHG Mitigation in the Transport Sector

South Africa is concerned about the continued emissions of greenhouse gases, especially carbon dioxide and methane. Being a member of the UN Framework Convention for Climate Change (FCCC), it has a responsibility to address the challenges of climate change.

> "Government will monitor international developments and will participate in negotiations around response strategies to global climate change, in order to progressively balance its environmental responsibilities and development interests, along with health related issues, in these processes." (Energy Policy White Paper, 1998).



Michaelis and Davidson (1996), assert that transport-based $CO_2$ emissions might increase by 40% to 150% between 1990 and 2025 if no new policies are implemented within that period. If strong and reasonably well-understood policies are implemented to introduce energy efficient vehicle technology and to manage road traffic growth, this could reduce projected emissions growth by one-third in 2025. Generally greenhouse gas emissions can be reduced by policies, which are aimed at:

- Reducing energy intensity through vehicle downsizing and introduction of more energy efficient vehicle technology.
- Controlling emissions of carbon dioxide, VOCs, $NO_x$, $N_2O$, carbon monoxide and methane.
- Switching to alternative transport energy sources with low greenhouse gas emissions
- Reducing the use of motorised vehicles through switches to non-motorised transport modes.

Fuel taxes also encourage consumers to buy more energy efficient vehicles. Car sales would also drop, leading to less traffic and more energy efficient driving behaviour.

### 4.9.2. The Situation in South Africa

In 1990 South Africa was ranked as the eighteenth highest producer of greenhouse gases in the world, responsible for some 300 million tons of carbon dioxide annually, as well as methane, CFCs and oxides of nitrogen. South Africa ratified the Montreal Protocol on CFC use in 1990 because it wished to protect human health by arresting the further damage to ozone layer. The country contributes approximately 1,6% to fossil fuel based global carbon dioxide emissions and therefore has cause to be concerned. Because of the nature of its industry, economy, and population structure, and its inefficient energy use, South Africa is an energy intensive society. This results in a higher per capita emission of carbon dioxide (7,7 tons per annum). The main reason for this is the country's dependence on coal as a primary energy source. (Shackleton et al, 1996).

Carbon dioxide emissions are projected to increase at the rate of 3,5% per annum to approximately 800 million tons by the year 2020. South Africa's contribution to $CO_2$ emissions is presently reasonably low, but figures suggest that a substantial increase of carbon dioxide should be expected in the medium term. There is very little scope for a significant reduction in these trends in the short to medium term without harming the essential growth and development of the economy of the country. Care therefore, has to be taken to ensure that emissions of greenhouse gases are minimised in an effective energy efficiency programme (Shackleton et al, 1996).

Three major oceans, the Atlantic, the Indian and the Aghallus have a large effect on the climate surrounding South Africa; therefore any changes in oceanic flow patterns and rising see level will harm the country adversely. The country is also basically dry and any aggravating effects on rainfall would be catastrophic.

Sea level increases as a result of climate change are likely to lead to inundation and displacement of wetlands and low-lying coastal areas, erosion of shorelines, increased probability of coastal flooding, increased salinity or estuaries and salt water incursion on fresh water aquifers. It may also cause tidal ranges in rivers and bays, changes to sediment deposition and decreases in the amount of light reaching the bottom of the water. It therefore becomes clear that preventive planning and action is required in order to avoid severe social and economic disruptions of coastal areas.

Air quality is also cause for concern over large South African cities like Johannesburg, Cape Town and Pretoria. The culprit particularly for Cape Town is emissions from vehicular transport. The average concentration of primary and secondary motor vehicle pollution levels in Johannesburg and Pretoria is also showing an upward trend. Cape Town experiences an increasing number of unacceptably high levels of nitrogen oxide concentrations.

### 4.9.3. A Suggested Climate Change Strategy

Shackleton et al (1996) suggest wider consultation around the development of more specific policies. They assert that the first step would be for a comprehensive report on the status of global environmental change in South Africa to be compiled and updated every now and then. The following are actions they feel are urgently required:

- Greenhouse gas sources and sinks in Southern Africa must be quantified.
- Relevant existing policies should be reassessed in the light of global environmental change.
- Existing and future investigations and quantification of all aspects of energy saving must be co-ordinated and actively promoted. Sources of "clean" energy must be investigated.
- Possibilities for reducing South Africa's emission of greenhouse gases must be examined.
- A comprehensive investigation must be carried out into possible financial or fiscal measures to facilitate the effective control of emissions (e.g. incentives, carbon tax) and to stimulate the development of new technologies where appropriate.
- Comprehensive economic analyses must be made of the financial impacts of various options, scenarios and assumptions relating to global environmental change (including for example, the assumption that more expensive energy would be harmful to economic growth in the South African situation).
- Implications of the ratification of the UN Framework Convention of Climate Change must be assessed.

- South Africa's research and monitoring needs with respect to climate change must be identified, prioritised and costed. This must be followed by the timely implementation of appropriate research and monitoring programmes taking cognisance of regional and international initiatives.

- A South African global climate change scenario document should be published and regularly updated.

- An appropriate and responsible public awareness and educational campaign must be launched to disseminate information both nationally and internationally.

- Water and land – management scenarios should be developed for natural ecosystems, forestry and agricultural land-use and production, and management scenarios developed for fisheries.

- Water management scenarios taking account of the possible impact of global environmental change on southern Africa must be developed.

- A strategy must be developed to procure funding to facilitate the proposed actions.

- Commercial and industrial opportunities arising from global environmental change must be identified.

- The feasibility of South Africa entering into partnerships with other southern African nations in establishing appropriate responses to climate change on a regional basis should be explored.

- In order to facilitate the above, existing administrative structures should be streamlined and utilised to ensure continuity and a co-ordinated and cost-effective response to an enhanced greenhouse effect. It is desirable that such a response, including drawing up a proper plan of action with target dates, be seen as an urgent priority.

South Africa needs to coordinate its climate change regime so as to set streamlined baselines for appropriate CDM projects. One such project is the substitution of C02 intensive transport fuels for cleaner and less polluting fuels like natural gas.

## 4.10. Progress in the Development of a Natural Gas Market

Southern Africa is in the midst of gas development, with promising activities in South Africa, Namibia and Mozambique. Plans to bring natural gas in to South Africa from the Kudu gas field in Namibia. Ibhubesi in the South African west coast and Pande in Mozambique are at an advanced stage. Also, the South African Parliament has now approved the Gas Act that will establish a gas regulator in the country. Based on the Energy White Paper of 1998, and developed in conjunction with local and international experts, the Gas Act (2001) makes provision for pipeline gas transmission, storage, sales and distribution.

There has been good progress in South Africa regarding investments, availability and use of natural gas. These efforts can be summarised as follows:

- Sasol announced an R7-billion capital investment for the current year. They have begun with a natural gas pipeline from the Temane and Pande gas fields in Mozambique to the Sasol Synthetic fuels complex in Secunda, and then on to the Sasol Chemical Industry complex in Sasolburg. Whilst records show reserves of 1.9 tcf, there is strong evidence that Pande-Temane may register reserves as high as 4 tcf.

- Proven reserves of 2 tcf have been discovered in the Kudu gasfields in Namibia. The most likely potential of 15 tcf is the largest within the South African market so far. Although development of the Kudu field will have higher costs than Pande, initial costing and marketing suggests that an economically viable project is a strong possibility.

- In the western coast of South Africa, a local black empowerment group, Mvelaphanda aims to expedite the development of the Ibhubesi gas field together with a controlling consortium, which includes the United States of America exploration and production company Forest Oil. The company has estimated recoverable reserves of 200 billion cubic feet and additional potential of 2.5 tcf (www.gasandoil.com).

- The Department of Minerals and Energy has created a regulatory framework that will effectively promote the orderly development of the piped gas industry in South Africa

It is possible to use some of the natural gas from these gas fields either in compressed form (CNG), or as in liquid form (LNG) so as to meet the demand by the transport sector. A significant proportion of GHG emissions and other pollutant emissions from the transport sector can be reduced if South Africa uses natural gas products as a form of transport fuel as this will set an example to the rest of the continent.

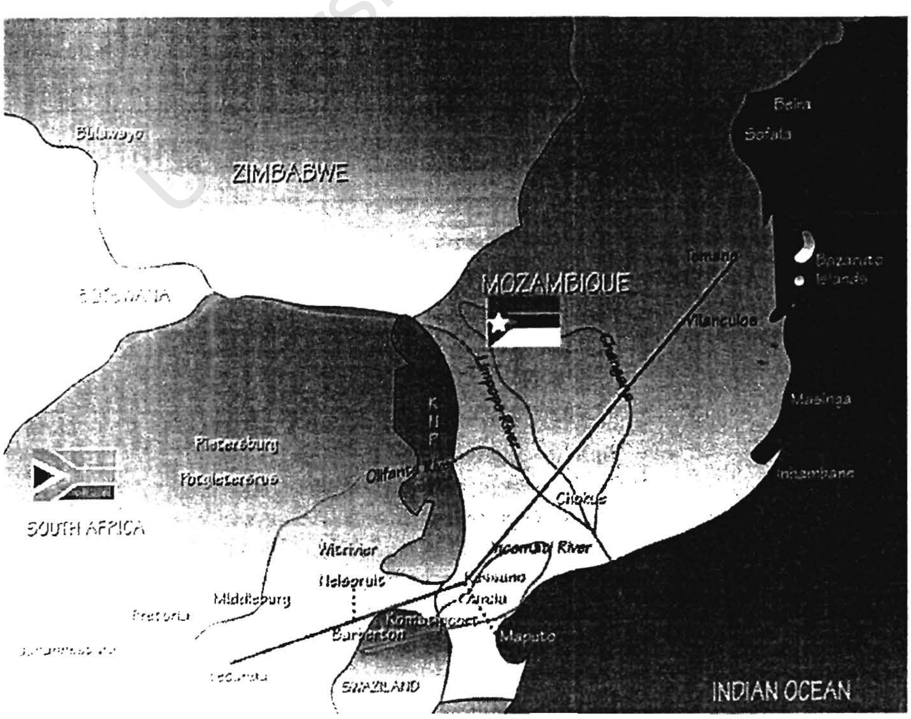
## 4.11. Planned Infrastructure Arrangements

There are significant plans to utilise natural gas in South Africa. Gas be explored from 18 wells in the Temane gas field and from 15 wells from the Pande field, both in Mozambique, giving a total of 33 wells. All this will be done within a period of twelve months. The gas will then be cleaned and compressed in a central processing facility before being delivered to the transmission pipeline for transportation to downstream customers.

The use in South Africa will be through a new 870-kilometre pipeline being built for transporting the natural gas from the Temane and Pande fields to the Secunda petrochemical's plant in South Africa. The new pipeline will handle a volume of between 120 and 240 million GJ per annum, and will be one of the largest pipelines in the world. Figure 3 shows the pipeline route from Temane, in Mozambique to Secunda. The pipeline will be buried about 1 metre below the surface in order to minimise impacts on the environment. Its construction alone will require a capital investment of about US$550 million (African Energy, 2002).



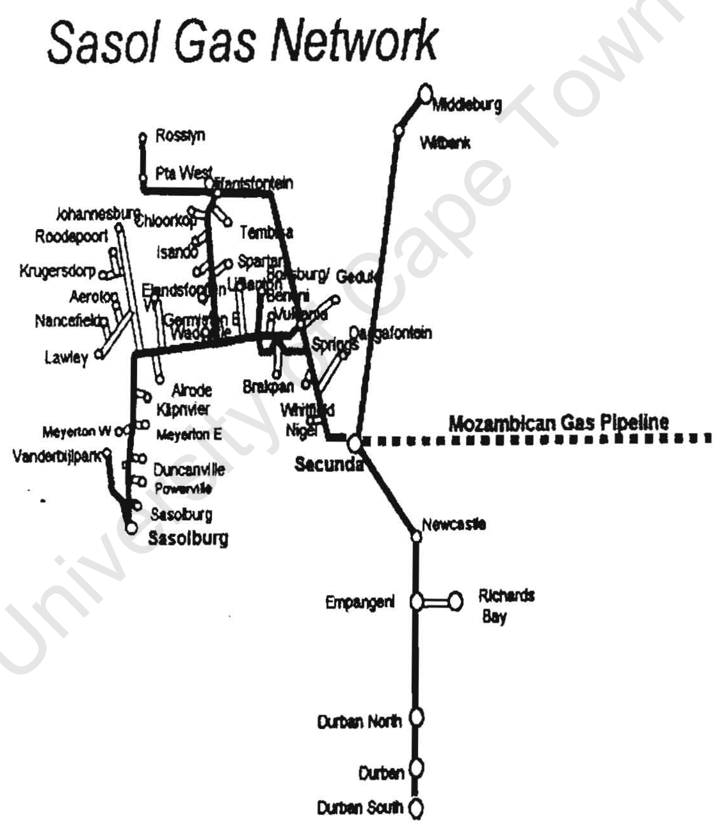
**Figure 3 PIPELINE FROM MOZAMBUE TO SECUNDA**




Source: African Energy, 2002

The 344 kilometre-long South African section of the pipeline continues from Komatipoort on the northern border to Secunda, where it will be linked to the existing Sasol Gas distribution network, as shown in Figure 4. The pipeline will supply an energy equivalent of 6,5 million tonnes of coal per year. The whole project is scheduled to be fully operational around May of 2004 (www.sasol.com).

**Figure 4 THE SASOL GAS NETWORK**




Source: African Energy, 2002

# CHAPTER 5

# FEASIBILITY OF NATURAL GAS USE AS PUBLIC TRANSPORT FUEL

## 5.1. Introduction

One of the benefits of natural gas in developing countries such as South Africa, Mozambique and Namibia is that utilising this fuel will enable these countries to unlock an untapped resource in the region and create opportunities to develop the downstream end of natural gas and in so doing boost their technological and socio-economic development. In utilising natural gas as a transport sector fuel in South Africa, one needs to look at its economic, technological and environmental feasibilities. The ensuing discussions will attempt to outline the feasibilities of using natural gas as a transport fuel in South Africa. However, as a start, the use of natural gas is compared with diesel fuel because at present all public buses, which are expected to use natural gas in the country, use diesel as transport fuel.

## 5.2. Comparison of Natural Gas and Diesel Buses

Considering the use of natural gas in buses will involve comparing its use with that of diesel because it will be replacing the diesel presently being used.

The diesel engine is comparatively more energy efficient and reliable than other engines used in the transport motor industry and has been in use for decades. However, current developmental efforts on improving diesel engines are focused on the reduction of exhaust emissions. Natural gas vehicles on the other hand start with an inherently lower emissions base, and development efforts on this fuel have focused on improving its fuel economy and its reliability (Kojima, 2001). When comparing these two transport fuels, many parameters are possible, but in this work only three parameters will be considered, as they will provide the information required to satisfy the objectives of this work: performance, fuel quality and emissions.

- **Performance**

All diesel engines are compression ignition engines, while all petrol and dedicated natural gas engines are spark ignition engines. The advantages of compression ignition are lower fuel consumption, longer life and safer operation. The lean-burn characteristics of the diesel engine help to increase its efficiency, leading to superior fuel economy. The spark-ignited engines of natural gas vehicles do not have these advantages. The driving range of natural gas buses is lower than that of diesel buses. The driving range of CNG buses is typically about two-thirds that of diesel buses. In the South African situation, this would not be a major concern as transit buses travel mostly in the order of about 220 kilometres a day.

- **Fuel Quality**

The quality of the fuel will affect emissions and vehicle performance. The sulphur content of diesel is a cause for concern. Ultra-low sulphur diesel has very low sulphur content, and can provide some competition to natural gas as a transport fuel. Unfortunately, due to financial and other barriers the widespread commercial use of ultra-low sulphur diesel will take some time to be used widely.

- **Emissions**

At present, diesel fuelled vehicles emit more emissions such as nitrogen oxide ($NO_x$), sulphur dioxide ($SO_2$), volatile organic matter (VOCs) and particulate matter (PM). The most visible emissions from a diesel engine is the black smoke from the exhaust pipe. It consists of solid particles and liquid droplets. Dedicated natural gas vehicles give off considerably less exhaust emissions when compared to diesel engine vehicles, and this is an advantage. In particular, visible smoke found in diesel vehicles is totally eliminated in natural gas vehicles. A comparison of the test results obtained from comparing the emissions from diesel and natural gas is shown in Table 9.



**Table 9 EMISSIONS FROM DIESEL AND CNG FUELED VEHICLES**

| FUEL | CO | NOx | PM |
|---|---|---|---|
| Diesel | 2.4 g/km | 21 g/km | 0.38 g/km |
| CNG | 0,4 g/km | 8.9 g/km | 0.012 g/km |
| **% reduction** | **84** | **58** | **97** |

Source: Frailey, 2000

Based on the above cited parameters, utilizing natural gas as a public transport fuel to replace diesel can be pursued.

### 5.3. Barriers to the Use of CNG in South African Buses

There are no known efforts to use other transport fuels other than diesel in South Africa for buses. This study will therefore be based on the potential of using natural gas. Utilising natural gas as transport fuel in South African buses has many barriers, which can be summarised as follows:

i. Lack of experience in using CNG as transport fuel.

ii. Lack of the associated transport technology in the Southern African region.

iii. Lack of local relevant skills.

iv. Limited natural gas transmission and distribution networks and infrastructure.

v. No partnerships in CNG transport development.



### 5.4. Issues for Utilising CNG as Transport Fuel

There are some general reasons that support the change from diesel to natural gas because of positive impacts. The first is the potential for reduction in particulate matter from the exhausts of diesel vehicle engines. Therefore, using compressed natural gas instead of diesel will result in lower particulate emissions and will lead to improved air quality in the larger cities that are presently experiencing urban pollution.

The second reason is the diversification of transport energy sources to reduce the dominance of petroleum fuels. With the availability of natural gas in the sub-region, South Africa can benefit from this resource and will consequently reduce its oil import bills.

Currently, high emissions of carbon monoxide from petroleum fuels are inhaled by humans and are resulting in a reduction of the oxygen carrying capacity of their red blood cells that is harmful. This can result in paralyses of the whole body and even death. Also, inhaling particulate matter may result in the irritation of the mucous membranes and respiratory organs and is also carcinogenic. Nitrogen oxide and sulphur dioxide may give rise to reduced lung function, impairment of the respiratory system and increased susceptibility to viruses. Lead will result in acute circulatory, reproductive, and nervous systems damage (UNEP, 2001). Hence, using a fuel that gives off fewer emissions can reduce the health risks caused by these fuels.

There are three important groups of issues to be considered for the switch to natural gas in the South African public transit system, namely environmental, economic and technical issues.

**5.4.1. Economic Issues**

There will be cost implications for utilising CNG as transport and these include the following:

i. Gas pipeline costs. In South Africa transmission pipelines will have been in place already. Presently it would be difficult to assess exactly where the distribution network would be required.

ii. CNG filling systems, ranging from US$250 000 to US$300 00 for a slow fill for each bus fleet.

iii. The natural gas compressor station costs about US$2 000 to US$4 000 per vehicle.

iv. Comparative average fuel costs of diesel and CNG are US$, 26/litre for diesel and US$0. 22/litre for CNG (IPCC, 1996).

Initially, only slow fill systems would be necessary, as a system can be created in which all fleets are fuelled centrally during the night. This is suggested because fast fills are much more expensive.

It is being proposed that the existing petroleum companies together with their partners, and Sasol supply the natural gas required for the switching. This arrangement will enable the petroleum companies to work with their developed country partners to supply existing technologies and provide the technical know- how relating to the installation, operation and maintenance of the CNG systems. If it is in their national interest to do so, the government could make pipeline distribution networks part of its development projects. Funds required by the government for the network can be obtained from instituting a fuel or carbon tax system. A tax system can be proposed that may include less tax on CNG than on diesel and petrol fuels. This would assist to promote the use of CNG.

Finance from funding institutions like the World Bank and the African Development Bank will have to be acquired in order to build the gas network, while funds from the Global Environmental Facility (GEF) can be used for demonstration projects, which can also be used for awareness programmes on national and global benefits of using CNG as transport fuel. GEF funds can also be used to establish effective institutional structures for enforcement of regulatory and fiscal measures and to assist with the absorption of the technology as part of capacity building. The project may also present some opportunity for the sharing of GHG credits based on the contributed investment shares of the partners in the project (Zhou, 2000).

After the necessary infrastructure has been put in place, the taxi industry might consider the introduction of CNG fuelled mini bus taxis. All taxis in South Africa at the moment use petrol as fuel. There are much more GHG reduction benefits in substituting petrol with CNG than in substituting diesel with CNG. Using natural gas to run the 160 000 mini-bus taxis in South Africa would not only result in cleaner air, but would cut down greenhouse gas emissions considerably. There would be no need for the retrofitting of taxis, as the whole fleet would come new on stream because the government aims to take the whole fleet of taxis off the roads by 2005, and replace it with more convenient 18 and 35 seater minibus buses as taxis. Regarding the supply of natural gas for use in taxis the same conditions as with buses would apply except that with taxis it may be possible to make use of home pumps when the gas is widely available. The home pump is a slow fill system and would therefore be much cheaper than the fast fill system.

In practice, the minibus taxi industry would make use of most of the natural gas network infrastructure suggested for the bus fleet. It would therefore literally "piggyback" on the strides made by the bus industry. In other words, once the whole natural gas bus transport programme has been completed and fully operational, the minibus taxi industry would simply make use of the existing infrastructure. They, nonetheless, would have to manufacture their own vehicles through their chosen assemblers or manufacturers, and provide for their local distribution networks.

Presently, the government is prepared to provide subsidies to the minibus taxi industry, provided they abide by the resolutions of the recapitalisation process that is being proposed. These funds could help the industry in the laying down of the necessary local distribution networks, compressor stations and home pumps.

As stated earlier, any decision reached on the use of natural gas vehicles would involve high financial investments. Furthermore, the pipeline network would have to be in place, not only for transport purposes, but also for the industrial, commercial and residential sectors as well. In addition to pipeline networks, CNG filling systems and compressor stations would have to be set up.

However, natural gas vehicles are more expensive than conventional fuel vehicles. If a sizeable number of vehicles are used to satisfy the intended needs of each fleet, economies of scale could then be exploited for gains.

### 5.4.2. Environmental Issues

These can be divided between local air pollution and climate concerns.

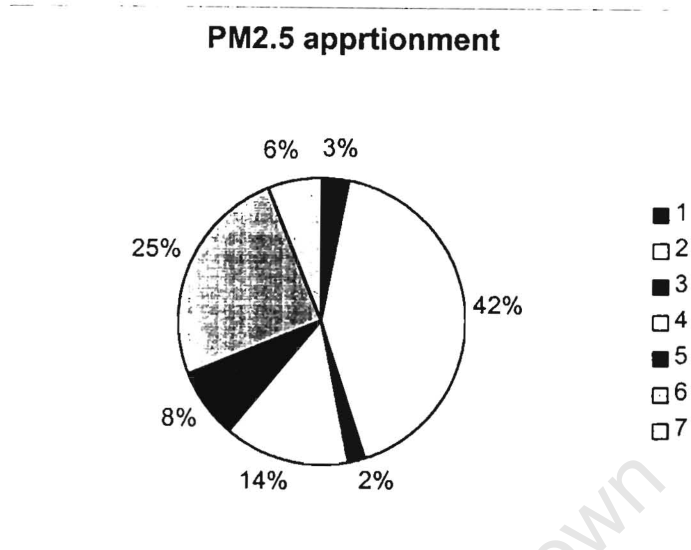
- **Local Air Pollution**

Normally brownish-yellowish smog, popularly known as the brown haze, hangs over Cape Town during autumn and winter. This is mostly due to a strong temperature inversion and windless conditions, which usually prevail during these times of the year. This leads to the build up of pollutants emitted into the atmosphere. The haze has a strong degrading effect on visibility, which is immediately apparent to the general public. Recent concern has been expressed about the increasing incidence and intensity of the brown haze. This has led to a number of enquires in order to establish the main sources of pollutants which are responsible for its existence.

Generally, in urban areas, particulate matter (PM) that is less than 2.5microns in size is the single cause of visibility impairment. They are also the most harmful ranges of particles to human health. Because of the importance of PM 2.5 in the haze, the main focus of this study is a source apportionment of PM 2.5. The apportionment used a receptor modelling approach that required chemical data on the sources and the brown haze itself (Wicking-Baird et al, 1997).

Sources that were included in the modelling (done by the University of Cape Town's Energy Research Institute) were various soils, road dust, sea salt, coal-fired boilers, oil-fired boilers, Caltex oil and gas-fired equipment, ammonium nitrate emissions, diesel combustion, petrol combustion, wood fires, grass fires and tyre burning. After the sampling process, the average PM2.5 source apportionment of the brown haze episodes modelled are shown in Figure 5.

**Figure 5** **PM2.5 Source apportionment of the brown haze episodes**

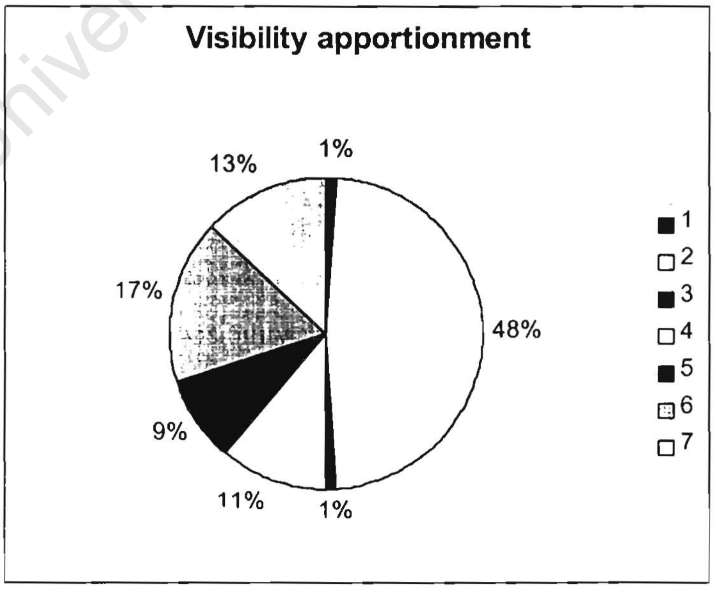



Source: Wicking-Baird et al, 1997

*1 crustal ; 2 diesel ; 3 sea salt ; 4 wood ; 5 unknown ; 6 petrol ; 7 boilers.*

PM2.5 apportionment was converted to visibility apportionment; i.e. contribution to the visual impact of the brown haze. Average visibility apportionment of the brown haze episodes modelled is shown in Figure 6.

**Figure 6** **Visibility apportionment of the brown haze episodes**

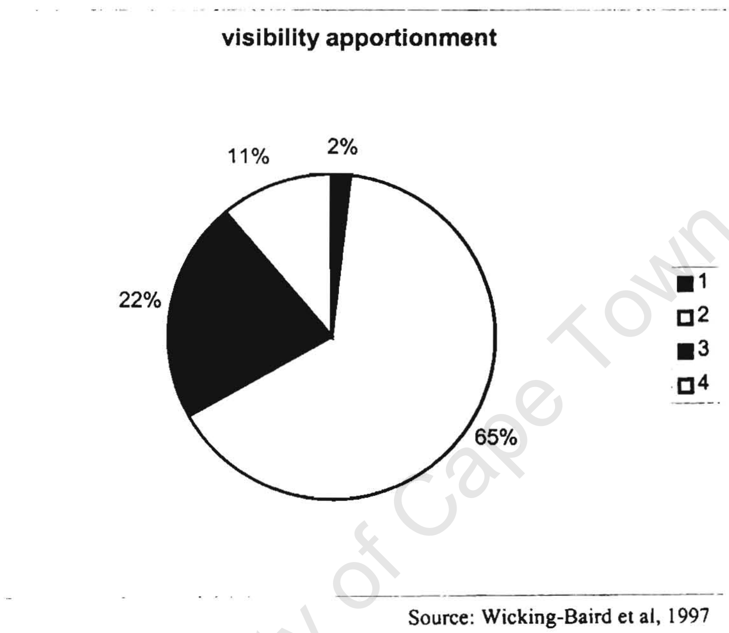



Source: Wicking-Baird et al, 1997

*1 crustal; 2 diesel ; 3 sea salt ;4 wood ; 5 unknown ; 6 petrol ; 7 boilers*

As can be observed. the results show that the major source of the brown haze in Cape Town is vehicles that use diesel and petrol, and from wood burning, and industrial boilers also being evident. A significant unknown source also exists. The likelihood is that this unknown portion is derived from industrial process emissions. Assuming that the unknown portion is attributed to industry, contributions to the brown haze can further be aggregated as shown in Figure 7.

**Figure 7 Final Visibility Apportionment**




*1 crustal ; 2 diesel ; 3 sea salt ; 4 wood .*

It can be concluded that PM2.5 emissions make up most of the brown haze, and are expected to increase as time goes on. It is therefore obvious that the intensity of the brown haze will also increase. It also very likely those PM2.5 health standards will also increase considerably over the coming decades under a business- as-usual scenario.

Table 10 below shows the amount of pollutant emissions from buses in Cape Town, and indicates the possible reduction that could be achieved if natural gas were to be used for bus transport.

**Table 10 EMISSIONS FROM NATURAL GAS BUSES COMPARED TO DIESEL BUSES IN CAPE TOWN (Gg)**

| | DIESEL | NATURAL GAS | NET REDUCTION |
|---|---|---|---|
| | | | |
| Oxides of nitrogen | 0.512 | 0.120 | 0.392 |
| Carbon Monoxide | 0.640 | 0.080 | 0.56 |
| Sulphur Dioxide | 0.088 | --- | 0.088 |
| NMVOC | 0.128 | 0.001 | 0.127 |

As shown, the substitution of local bus diesel consumption (www.gabs.co.za), for compressed natural gas in Cape Town would go a long way in reducing the brown haze.

Natural gas as a transport fuel has a number of environmental advantages over diesel:

- Very low particulate emissions.
- Very low emissions of airborne toxins.
- Very low $NO_x$ emissions.
- Negligible $SO_2$ emissions.
- Quiet operation, with less vibrations and less odours.

The development of a natural gas industry in South Africa over the next several years would be a logical way of improving air quality, energy diversity and enhancing fuel security. It would provide consumers with a wider fuel choice and the whole country with a guaranteed fuel supply.

- **Climate Change Issues**

In order to determine the GHG emissions between diesel and natural gas buses, the IPCC Tier 1 method will be employed. This method requires relevant baseline data. Based on an interview with respective authorities of the local bus company in Cape Town, the baseline data for bus travel is as follows:

- Diesel demand of bus fleet per annum.
- Life span of each bus.
- The number of buses in the country.

- Annual travel per bus.
- Number of passengers per bus.

In 2000 the estimated number of 60-seater buses in South Africa was around 29 900 (Transport Statistics, 1995). The long-term economic growth rate of 2% was assumed to be the driver for bus transport demand. The number of buses in South Africa would be about 42 000 in 2010.The estimated energy intensity of buses which was given for sub-Saharan countries is given as 0.2MJ/p-km to 0.33MJ/p-km for a load factor of 35 to 60 passengers (IPCC, 1996).

The life span of the buses is estimated to be between fifteen and eighteen years. Diesel fuelled buses travel about 900 million kilometres per year and consumed approximately 450 million litres of diesel per annum in 2001 (www.saboa.org.za).

The octane number of natural gas is around 120. The octane number shows the measure of resistance of a fuel to pre-ignition or " knock" when burned in an internal combustion engine. The higher the number, the more the anti-knock quality. Pure methane as the most knock-resistant reference fuel is given a value of 100. The minimum methane number, which is a function of engine technology, is needed to prevent the engine from knocking. The minimum methane numbers for the current technology heavy duty and advanced heavy- duty vehicles are about 80 and 73 respectively (Kojima, 2001).

Another parameter that characterises engine behaviour is the Wobbe index, which is a comparative measure of thermal energy flow through a given size orifice. If the Wobbe index remains constant, changes in gas composition will not lead to a change in the air – to – fuel ratio and hence, gases with the same Wobbe index will be interchangeable. The relative energy efficiencies of engines have to be factored into these figures in order to arrive at accurate vehicle fuel economy.

The Tier 1 approach calculates $CO_2$ emissions by estimating fuel consumption and multiplying it by an emission factor to compute carbon content, computing the carbon stored, correcting for unoxidised carbon and finally converting oxidised carbon to $CO_2$ emissions.

The formula is shown below:

$$Em = SUM\left( [Ef * fc] - Cs\right) * \text{fraction oxidised} * \frac{44}{12}$$

Where Em = Emissions

Ef = Emissions factor

Fc = Fuel consumed

Cs = Carbon stored

The amount of diesel consumed by buses in South Africa is approximately 450 million litres per year and the energy content of diesel is 35MJ per litre, as shown in Table 11.

Table 11 **ENERGY CONTENT OF SELECTED FUELS**

| FUEL | MJ/litre | Relative to petrol | Relative to diesel |
|---|---|---|---|
| Petrol | 32 | 1.0 | 0.9 |
| Diesel | 35 | 1.1 | 1.0 |
| CNG | 10 | 0.3 | 0.3 |
| LNG | 19 | 0.6 | 0.5 |

Source: Kojima, 2001



The total amount of energy in megajoules used by South African diesel buses was 15 750 million MJ or 15 750 TJ in 2001.

Using the equation above and assuming that :

Diesel Consumption per year = 15750 TJ

Carbon Emission Factor = 20.2 tc/TJ * 15750 TJ

Carbon Content = 318.1 Gg C

Carbon Oxidised = 0.99

Actual Carbon Emissions = 314.9 Gg C * 44/12

**Actual CO2 Emissions = 1154.8 Gg $CO_2$**

Assuming that the amount of natural gas consumed by buses would be equivalent to that of diesel, that is, approximately 450 000 000 litres per annum. The energy content of natural gas being 10 MJ per litre, the total amount of energy in megajoules consumed by South African natural gas buses would therefore amount to 4500 000 000 MJ, or 4500 TJ.

Using the above formula the amount of $CO_2$ emissions from natural gas buses used in South African conditions would be as follows:

Natural gas consumption per year = 4500 TJ

Natural gas Emissions Factor = 15.3 tc/TJ * 4500 TJ

Carbon Content = 68.8 GgC

Carbon Oxidised = 0.995

Actual Carbon Emissions = 68.5 Gg C * 44/12

**Actual CO2 Emissions = 251.1 Gg CO2**

Using natural gas as fuel for South African buses would therefore result in a CO2 difference of 1154.8Gg CO2 – 251.1Gg CO2 = **903.7 Gg CO2 per annum. An effective 78,2% carbon dioxide net reduction per year.**



Table 12 below shows the comparison of GHG and non-greenhouse gas emissions to natural gas and diesel.

**Table 12 COMPARISON OF GHG AND OTHER GAS EMISSIONS FROM NATURAL GAS AND DIESEL (Gg)**

| | Natural Gas | Diesel Baseline | Reduction / % saving |
|---|---|---|---|
| Carbon Dioxide | 251.1 | 1154.8 | 903.7 = 78.2% |
| Methane | 0.3 | 0.078 | 0.222 = -74% |
| Nitrous Oxides | 0.0014 | 0.0094 | 0.0080 = 85.1% |
| Nitrogen Oxide | 2.9 | 12.6 | 9.7 = 76.9% |
| Carbon Monoxide | 1.6 | 12.6 | 11.6 = 92.0% |
| NMVOCS | 0.03 | 3.15 | 3.12 = 99.0% |
| Sulphur Dioxide | – | 0.0021 | 0.002 = 100% |

Using natural gas will result in even less GHG and other pollutant emissions in the country, should natural gas be used as fuel for the 1 6000 plus taxis running on South African roads. The total amount of petrol used by taxis is in the region of 606 million litres per annum (Prozzi and Sperling, 2002). This figure multiplied by 32, the energy content of petrol amounts to 19 392 000 000 MJ, or 19 392 TJ.

On the other hand if taxis should run on natural gas they would consume 606 000 000 litres multiplied by 10, the energy content of natural gas, and this would amount to 6 060 million megajoules or 6 060 TJ.

When calculating $CO_2$ and other emissions from petrol, the IPCC Tier 1 formula is still employed, precisely in the same manner as with diesel.

Table 13 below, shows the achievable reductions when comparing petrol to natural gas.



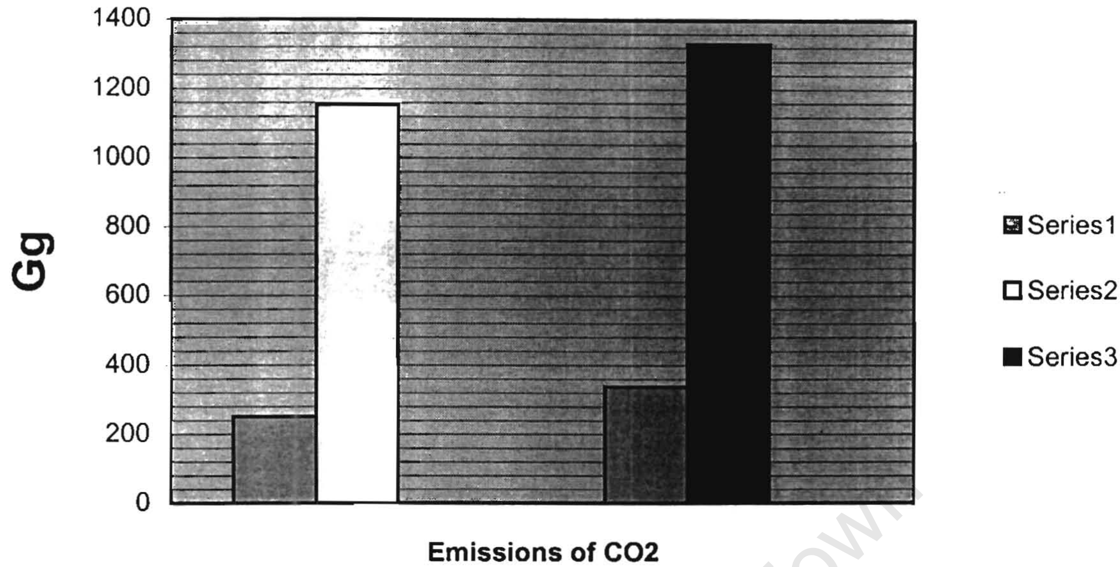
**Table 13 COMPARISON OF GHG AND OTHER GAS EMISSIONS FROM NATURAL GAS AND PETROL (Gg)**

| | Natural Gas | Petrol Baseline | Reduction / % saving |
|---|---|---|---|
| **Carbon Dioxide** | 338.7 | 1330.4 | 991.7 = 74.5% |
| **Methane** | 0.30 | 0.38 | 0.08 = -26.6% |
| **Nitrous Oxide** | 0.6 | 11.6 | 11.0 = 94.8% |
| **Nitrogen Oxides** | 3.6 | 11.6 | 8.0 = 68.9% |
| **Carbon Monoxide** | 2.4 | 155.1 | 152.7 = 98.4% |
| **NMVOCS** | 0.03 | 29.1 | 29.07 = 99.8% |
| **Sulphur Dioxide** | - | 0.86 | 0.86 = 100% |

As can be observed, diesel and petrol definitely emit more greenhouse gases and other pollutant emissions when compared to natural gas, with the exception of methane.

Figure 8 below, shows the amount of CO2 emissions from using natural gas, compared to diesel and petrol.

Figure 8 $CO_2$ EMISSIONS FROM NATURAL GAS, DIESEL AND PETROL




*1 : natural gas ; 2 : diesel ; 3 : petrol*

Mechanisms will have to be set in place for data monitoring. The data to be monitored pertains to growth in bus and taxi numbers and the potential diesel and petrol demand as determined by both the growth in public road transport vehicles and their energy efficiency or fuel economy. The annual travel and load factors to determine passenger per kilometre and life spans of vehicles will also need to be monitored (Zhou, 2000).

### 5.4.3. Technical Issues

The transfer of technological know-how and the number of persons trained with skills related to CNG technology and capacity building will be some of the performance indicators reviewed. The number of people employed in the CNG industry; the growth of CNG fuel share and country expansion of CNG depots will also be periodically reviewed.

- **Refuelling Arrangements**

It is suggested that refuelling of buses be undertaken centrally at the bus depots during the night and make use of slow-fill methods. Existing refuelling appliances combine gas compression with quiet, automated and simple to operate controls and software. This will assist the refuelling process. These can be installed anywhere, including commercial establishments and residential homes. Amongst other benefits that the modern vehicle refuelling appliances have are components for fuel leak detectors, remote monitoring, over-fill prevention and in-door/out-door refuelling. Safety features include automatic shut-off during the detection of any leak or abnormalities and faults. They also have electronic and mechanical measurement controls to ensure unattended and reliable operation (www.fuelmaker.com).

- **Implementation Arrangements**

A number of potential implementation issues exist in the application of alternative fuel options for current vehicles. Table 14 provides an overview of the technical feasibility and potential time-frames for the implementation and use of such fuels, along with the associated environmental impacts for each fuel type as suggested by UNEP.

One of the most important components of a successful natural gas vehicle programme is the extensive training of mechanics and drivers, and the availability of qualified engineers for technical support. Training is needed, not only for proper maintenance and safe operation of vehicles, but also to dispel misperceptions and build the acceptance and commitment of the operators involved (Kojima, 2001).

**Figure 14 TECHNICAL FEASIBILITY AND TIME-FRAME FOR IMPLEMENTATION**

| Fuel Option | Examples | Status | Technical Feasibility | Conversion Efficiency | Environmental Impact | Market Potential Time Frame |
|---|---|---|---|---|---|---|
| **Natural Gas** | Onboard Storage | Demonstration fleets<br><br>Fuels commercially available | Range extension needed | Close to petrol with engine adaptation | VOCs, CO2 and particulate emissions | 0-5 years |
| **Hybrid Vehicles** | Battery Powered and CNG | Demonstration fleets | Adopting hybrid drives can overcome many limitations of current electrical system options | Dependent on base fuel | VOCs, CO2 & particulate emissions | 0-10 years |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Hydrogen in an ICE** | Neat H2 in ICE | R & D and prototypes | Infinite source of supply | Dependent on feedstock and storage systems | Substantial reduction in all pollutants | +/- 30 years |
| **Electric Vehicles** | Batteries<br><br>Fuel Cells<br><br>Solar photovoltaic cells<br><br>Hybrids | Demonstration fleets<br><br>Field trials in niche markets | Range and cost limitations<br><br>Adopting hybrid drives may increase use options | | Reduction to zero of all vehicle emissions<br><br>Benefits to be gauged against overall fuel cycle | 10 years |

**Source: UNEP, 2001**



The best option for the South African situation would seem to be a combination of a number of technologies for mass transit. An example would be an aerodynamic, original equipment manufactured natural gas designed bus or minibus that has had its weight reduced by using aluminium, magnesium and plastic. The vehicle would have hybrid specifications and reduced rolling resistance and may also be fitted with turbo-chargers. This would further cut down emissions and ensure even higher fuel efficiencies. Battery powered and CNG systems in hybrid vehicles promise, not only cleaner air, but also emit reduced GHG emissions as well.

Utilising natural gas as fuel in buses will need to be done in stages. The first step would be the progressive reduction of the number of buses that use diesel for a period of about eight to ten years. After this period, all buses would then use natural gas as fuel. By then, no retrofitting would be necessary, as all buses would be designed for CNG use. This strategy will result in diesel buses being gradually phased out over the eight to ten year period.

Post-factory retrofits have been found to be problematic for a number of reasons. Firstly, the quality of the conversion is usually mixed because auto-mechanics may not have the expertise needed to do the conversion. Secondly not all mechanics are well qualified to do the job. Thirdly an engine system optimised for one type of fuel is being converted to run sub-optimally on a totally different fuel, and with the advent of electronic controls, the challenge is even greater. Lastly, the process of retrofitting is generally costly (Bose et al, 2001).

## 5.5. Development Benefits and CNG Use

There are short- and long-term environmental and socio-economic benefits from using CNG as a fuel for public transport in South Africa. These benefits include the following :
(i) developmental aspects, (ii) technology and capacity building and (iii) opportunities for the rest of Africa ( Zhou, 200C ).

### 5.5.1. Development Aspects

Development aspects in the CNG project are as follows: -

a) **Locally improved air quality, as buses using CNG will reduce pollution as compared to those using diesel.** This is because natural gas burns cleaner, emits far less particulate matter and far less NOx and SOx .

b) **Direct and indirect employment creation, resulting in visible poverty alleviation within the project site.** Many jobs are likely to be created, as the CNG will be additional to the already existing and expanding petroleum and diesel industry.

c) **Debt relief and improvement of balance of payments for the region.** This will be a result of using locally sourced natural gas reserves.

d) **Increased economic efficiency and market competitiveness for companies implementing clean fuel-based public transport systems.** Synthetic fuel conversion will be less expensive using natural gas, and the whole process will be much cleaner.

e) **Creation of an infrastructure for long-term use.** The new infrastructure that will be laid will benefit future generations, as it will be used for decades and even centuries to come.

f) **Natural gas utilisation could be the key to the regional integration of the area.** Gas represents the first real economic opportunity for Southern Africa to achieve the much-needed economic integration of the region.

### 5.5.2. Technology Transfer and Capacity Building

The CNG project will encourage the transfer of technological know-how to relevant personnel including engineers, and to technicians and system operators for the maintenance and servicing of CNG systems. If done properly it can be carried out on a continued basis. Through a deliberate effort by the recipient country of the technology to formulate a policy that ensures the participation of local technicians and managers in the project so as to equip them to unpack, adapt, manage and maintain the in- coming technologies is required. This will lead to the initiation of research and development that is a prerequisite for the creation of capability for indigenous growth technologies in the future. Capacity to design and maintain equipment and infrastructure and efficiently manage CNG transport vehicles will be required in order to ensure sustainability.

### 5.5.3. Opportunities for Diffusion to the Rest of Africa

Most countries in the region are already importing petroleum fuels and equipment through or from South Africa. This would form a channel for the dissemination or propagation of a new transport fuel like CNG. When the technology becomes available in South Africa; it will then become more accessible, particularly to the Southern and Eastern regions of Africa. Also, a precursor for future technology improvement and replication in the country and for the African region will be achieved as the success of CNG use in the transport sector in South Africa will bring in new technological know-how, which will be transferred to the rest of Africa.



### 5.5.4 Conclusion

It would be advisable to use some of the gas from the Southern African gas fields either in compressed form, or in liquid form, to meet demand from the transport sector. A significant proportion of GHG emissions and other pollutant emissions from the transport sector can be reduced if South Africa uses natural gas products as a form of transport fuel as this would then be used as an example of how the use of natural gas products would benefit the rest of the continent.

# CHAPTER 6

# POLICY ISSUES AND RECOMMENDATIONS

## 6.1. Introduction

South Africa is presently preparing to use natural gas in the industrial, commercial and electricity generation sectors. This move supports the need to investigate the use of this fuel in the transport sector as natural gas is a very clean burning fuel and is in use in many developed and developing countries as an economical and an environmentally friendly transport fuel.

The natural gas from Mozambique and Namibia, if adequately tapped into should satisfy all economic sectors in South Africa in addition to their domestic needs. In addition there is natural gas inside the country from the Mossel Bay area already in use for the synthetic fuel industry, as well as more deposits from the recently discovered Ibhubesi gas fields off the south western coast of South Africa.

Environmental concerns with the aim of utilizing less coal and oil in the economy should be the main drive behind the use of natural gas, coupled with a desire for a wider fuel resource base. Natural gas also has the potential to be an effective tool for much needed regional integration of the Southern African countries.



## 6. 2. Lessons from International Experience

Some lessons might be learnt from the experience of other countries that have utilized natural gas in the transport sector.

- **Argentina:** A country with the most successful NGV programme in the world. The large price difference was compensated by an appropriate fuel tax structure. The government has not given subsidies in form of financial incentives to the CNG industry.

- **United States of America:** The country with the most extensive experience with urban natural gas buses. The federal government heavily subsidizes the purchase of transit buses. The government supports the natural gas programme by imposing lower highway taxes on CNG and LNG buses.

- **Australia:** The government has introduced some measures to boost CNG use in the transport sector. These include providing funding to the installing of public refuelling facilities, the conversion and the purchasing of new natural gas vehicles.

- **Canada:** The use of natural gas has been motivated primarily by the considerations of emissions improvements, especially after 1982. The second important factor is the abundance of natural gas in the country.

- **New Zealand:** The use of natural gas as transport fuel failed in New Zealand due to inappropriate government policies. There was little public awareness and few people had technical expertise. Moreover, the government gave subsidies that were too high and which could not be withdrawn without affecting the viability of the programme.

## 6.3. Overall benefits for South Africa and the Entire Sub-Region

South Africa can gain enormously from the development of a natural gas industry. These benefits may, however, take some time to come to fruition and will need careful study. The country will need to allow some competition between the different energy supplies in the market. These also include a diversified energy mix, growing regional cooperation, sustainable economic development, enhanced energy security and expanded employment opportunities.

Expected benefits to Mozambique, for example, will include a 20% increase in GDP, an improved infrastructure, job creation and revenue from royalties (African Energy, 2001). The development of the natural gas industry would also benefit Namibia through increased GDP, as well as additional job opportunities.

## 6.4. Suggested Areas for Policy and Strategies

The South African Energy Policy White Paper (1998: 22) encourages the use of alternative fuels in order to "stimulate energy-efficient and environmentally friendly transport energy technologies".

Operating vehicles on alternative fuels such as electricity, natural gas or diesel could derive major benefits. Research is required on government's role in the promotion of such vehicles, the technical and economic feasibility of such technologies and the key requirements for their successful promotion. Research is also required to develop and stimulate energy-efficient and environmentally friendly transport energy technologies.

There is need for different policies and measures to be implemented in South Africa in order to develop the use of natural gas for the transport sector in the country. These policies and measures fall into the following categories: (i) environmental (ii) economic and (iii) technical.

### 6.4.1. Environmental Policies

The transport sector has become a focal point for air quality issues in cities like Cape Town. The city's air pollution problem is increasing due to transportation, as was demonstrated earlier. The following measures should be considered by the government:

- Progressive targets that lead to a deadline should be set for the use of natural gas for all public transport. An effort similar to that of India ( where a target was set by the High Court to increase the number of natural gas buses to 10 000 by the year 2001) should be followed.

- Measures should be set for quality air controls, especially in the transport sector.

- Measures should also be set for the mitigation of greenhouse gases in the transport sector.

### 6.4.2. Economic Policies

Utilising natural gas as fuel for the country also has economic implications. The following are some of the factors that can be considered:

- Set fuel taxes to reflect carbon emissions. In essence taxes should reflect environmental and health risks caused by the respective fuels. Because diesel emissions are more harmful than natural gas emissions, diesel vehicles should therefore be asked to pay more in order to reflect the price that society pays.

- Natural gas should be used for conversion to liquid fuels. The process of converting coal to liquids is very energy intensive, and should be substituted with natural gas. This would cut greenhouse gas emissions from coal by a considerable amount.

- Improved regional cooperation should be encouraged through the use of transport fuels that have been sourced from the SADC region.

### 6.4.3. Technical Policies

Technical policies that may be considered for natural gas use in transport may be the following:

- Opportunities should be created for the transfer of a natural gas transport technology. This will result in transcribed capacity to design and maintain equipment infrastructure, and also to efficiently manage natural gas vehicles.

- A natural gas infrastructure should be in place. The volume of gas consumed in the transport sector is never sufficient to justify the construction of natural gas distribution pipelines even if this is done in very large cities. Therefore, without the existence of a network of pipelines for other users of natural gas such as industry, commerce and residence a viable natural gas vehicles programme cannot be possible (Kojima, 2002). In the case of South Africa the introduction of natural gas was specifically for the last mentioned users, and so the natural gas network would already have been in place for the transport sector to use.

- The structure and specifications of public transport vehicles should favour the use of natural gas as a fuel.

- An effort should be made to have a pool of trained personnel on how the industry operates. Locally trained engineers, technicians, systems operators and administration staff will need to be created.

## 6.5. Other Policy Aspects

Other recommendations include a regulatory framework, a commitment to the switch, funding and improvement of accessibility.

### 6.5.1. Regulatory Framework

South Africa already has a natural gas regulatory framework in place. This helps to eliminate market distortions, create a level playing field, ensure safe operations and increase efficiency and quality of service through competition.

The natural gas industry is, like any other in the country, subject to a variety of laws that govern the performance of contracts, liability to third party damages and other issues that arise in the day to day conduct of running any business. There are, however, no stringent special laws at the moment that apply only to the natural gas industry. The principal supplier of gas, Sasol, bases its tariff structure on the collective willingness of its customers to pay and its own cost structure (Economic Insight, 1996).

South Africa might choose to leave the above situation as it is, or it can use one or a combination of many options. There are many advantages to continuing with this situation as it is, that is, treating the gas industry like any other, and not singling it out for special regulation:

- There is no compelling reason for government involvement based on right-of-way problems as transmission lines both from Pande and Kudu are not expected to cross areas of high population density. Also, the cost of any investment mistakes will be borne by the investors themselves, and not by consumers or taxpayers.

- The time and money that government would spend on research and tracking the gas industry could be spent in training, education and other vital matters.

- There is already stiff inter-fuel competition in South Africa, so involved companies will not be able to take an advantage and charge consumers abnormally high prices.

Sasol, as an original South African organization should perhaps be given an extension of the ten years that they have been granted as a monopoly supplier; if not for a guarantee of their return on investment, then for ensuring an acceptable legislative framework for effective operation of the new industry. Such a franchise would also reduce the risk on the project and actually induce new investments.

Yet the country has other regulatory options to choose from:

The **monopoly franchise** reduces uncertainty for potential investors and ensures a rate of return to investment that is high enough to quickly move on with the construction of the pipelines. However this raises concerns about the question of monopoly abuse by the transmission pipeline owners.

The **open access** option seems to be the preferred one by the Department of Minerals and Energy. Under this regime the pipeline transportation is treated as a separate and distinct entity. Regulators do not have to be concerned about gas production and burner tip prices of large customers. They only focus on the issue of gas transmission that can be relatively easy to regulate. The main advantage of the access option is that it preserves the principle of competition and does not guarantee the pipeline investor a long-term monopoly.

There is also the **hybrid option**, where the companies that are willing to build the pipeline act as sole merchants for a sufficient number of contracts that will ensure the viability of the project.

Internationally accepted standards for gas cylinders, refuelling stations, gas dispensing units, natural gas vehicles and engine manufacturers or assemblers, service garages and quality gas must be set. Most importantly, there must be adequate monitoring and inspection systems in place to enforce these standards.

### 6.5.2. Commitment to the Fuel Switch

Total commitment is needed in order to have a safe and successful natural gas transport programme. Among other things, there must be a realistic plan to train maintenance staff, adequate monitoring and enforcement mechanisms, long-term government subsidies.

financially sound transit bus operators, a commitment to reduce greenhouse gas emissions and improvement of air quality and above all, a readiness to get involved in the programme.

The decision to switch from diesel to natural gas for use in bus and taxi transport is not an easy and straightforward one. For starters the regulatory and administrative arrangements must be in place in order to ensure the financial sustainability of the transit operators who would be using natural gas. Vehicle taxes should reflect marginal social costs of health damage from air pollution.

If these conditions are met, then African countries with ample supplies of natural gas and with a gas pipeline network in place, as well as those with a serious urban pollution problem, should certainly consider this fuel option

**6.5. 3. Funding and Financing**

The anticipated public transport system should be funded with a stable and consistent funding source. The funding should come from national and provincial budgets as well as from user-charges imposed on private motorcar users.

Further increases on vehicle and fuel taxes would generate substantial additional revenue for the government to finance the natural gas programme. This would simultaneously restrain car ownership and use of private vehicles, thereby also restraining energy use and greenhouse gas emissions.

**6.5.4. Improvement of Accessibility**

Perhaps the most important step to be taken by the authorities is to increase measures to improve accessibility and mobility within South African cities. This would help in promoting less vehicular travel and increase the use of non-motorized travel.

Densification of transport corridors, promotion of public transit services and the restructuring of the public transport system through better integration of rail and bus services were identified by Moving South Africa (1999) as the necessary steps to redirect behaviour and investments in order to create a more economical and socially beneficial transport system.

# CHAPTER 7

# CONCLUSION AND FUTURE WORK

## 7.1. The need for alternative fuel use in the transport sector

The air quality in South Africa's large cities is a cause for concern. Diesel and petrol contribute more than 40% and 20% respectively to visibility apportionment (Wicking-Baird et al , 1997). Cape Town is an example of this situation where the "brown haze" problem is acute. Finding an alternative fuel such as natural gas would help reduce much of these emissions and improve the overall quality of the air.

Apart from contributing to the poor air quality, emissions from motorised transport contribute to the potential threat of global warming because of CO2 and other GHG emissions. This is because transport is abundant in South Africa and the reliance on petroleum products for most of its transport energy needs is significant.

The greatest factor that influences transport use in South Africa is land-use arrangements. The past apartheid laws ensured that cities were developed primarily on the basis of race and subsequently, class. The working class lived in far-removed areas in the outskirts of the central business districts of cities, in what became known as townships and homelands.

The distances and commuting times between these areas and cities were long and thus limited access to employment and other services. This created the need for public transportation, in the form of trains, buses and taxis. More than 40 million of the county's population depend on public transport to get to places of work, schools, hospitals and other social amenities.

Another important factor that contributes to South Africa's GHG emissions is the carbon-rich synthetic fuel conversion. Since the country does not have oil deposits but large reserves of coal. the government financed the formation of Sasol to produce synthetic oil from coal. Sasol's synthetic petrol and diesel fuels made from coal resulted in about twice as many GHG emissions per vehicle k.lometre, on a life time basis, as petrol and diesel made from petroleum (Prozzi et al, 2002).

## 7.2. The drive towards the use of natural gas as transport fuel

Several alternative fuels for the transport sector have been tried and tested. Among these are ethanol, methanol, bio-diesel, electricity, natural gas and hydrogen. This report has emphasised specifically the use of natural gas because of its relative success globally in transportation and the relative abundance of the gas in the region. Natural gas combustion results in virtually no atmospheric emissions of sulphur dioxide, small particulate matter, carbon monoxide, reactive hydrocarbons, nitrogen oxides and carbon dioxide compared to the combustion of other fossil fuels. Natural gas is more environmentally attractive than other fossil fuels because it is composed of mainly methane, which is a molecule that is made up of one carbon atom and four hydrogen atoms. When methane is burnt up, the by-products of combustion are carbon dioxide and water vapour. In comparison, oil and coal compounds have much more complicated molecular structures, as a result they do not burn as cleanly. Coal and oil combustion also produce ash particles, which do not burn at all, but are carried into the atmosphere. So, because natural gas burns cleanly it can be an effective means of controlling pollution (www.naturalgas.org).

Natural gas can make a significant contribution towards improving air quality in the field of transportation. The combustion of natural gas produces virtually no SO2 and very little NOx and carbon monoxide.

Natural gas piped from Mozambique is expected to play a major role in the energy economy of South Africa, with plans to feed it into the industrial gas pipeline network. Sasol will use this relatively more environmentally benign energy resource as a supplementary feedstock to its plants and to expand the heating fuel markets in South Africa.

The natural gas will be used in the manufacturing of many different products such as steel, non-ferrous metal, bricks, sheet and glass mouldings, foundry products, fibreglass, chemicals, food products and paint. Other applications for pipeline gas include heat treatment, forging, melting, casting, galvanising, power and steam generation.

It is anticipated that by 2004 some 80 million GJ of natural gas will be imported by Sasol from the Pande – Temane complex. This is expected to grow to approximately 120 million GJ by the end of the decade. About 50 million GJ of this is expected to go into Sasol's factories. This translates to about 10% of Sasol's hydrocarbon requirements, and the balance will continue to come from the conversion of coal.

The Temane and Pande gas fields are jointly envisaged by Sasol to contain enough natural gas to sustain about 120 million GJ for more than twenty years. Sigma, Sasol's major coalmine will soon close, and the petrochemical operations at Sasolburg will eventually be operated solely on a natural gas feedstock. Natural gas will thus create a clean alternative to developing a new coalmine in the area. Natural gas will, in fact, deliver the heat equivalent of almost 5 million tonnes of coal every year. That is equivalent to a relatively large coalmine.

New market opportunities for natural gas have already been identified in Sasolburg and Secunda, as well as refineries and chemical plants. Expansion of the existing market is also anticipated, with steam and power co-generation playing a major role.

Natural gas will also be used in other projects like mineral beneficiation, chemical plants, gas-fired power stations and even for natural gas vehicles and steam generation plants.

A further advantage of the Mozambique natural gas is that it contains low levels of impurities such as hydrogen sulphide, thus providing further environmental benefits. From the baseline of the combustion of coal and oil to generate energy, and also from the use of coal and oil as feedstock for the production of more value-added goods, the switch to natural gas will definitely lead to much more reductions in emissions. This is because natural gas has a lower emission factor compared to both coal and oil, making it more environmentally benign.



## 7.3. Reality of natural gas as transport option

Utilising natural gas as a transport fuel can be realised in South Africa within less than a decade. Natural gas is available within the country and in the immediate neighbouring states, and South Africa will, for the time being, be the only major gas market.

More African countries should form CDM regimes in order to identify potential projects such as this one. The introduction of natural gas into the transport sector surely has the potential to cut down a huge amount of greenhouse gases for the region.

### 7.3.1. Air quality control and GHG mitigation

The number of buses in South Africa is close to 30 000. These buses travel about 900 million kilometres and consume more than 450 million litres of diesel per year, over a period of fifteen to eighteen years. South Africa also has about 160 000 taxis on the roads, using approximately 600 million litres of petrol. Buses and taxis emit about 1154 Gg and 1330 Gg of carbon dioxide respectively into the atmosphere every year. If natural gas were to be used as transport fuel, the carbon dioxide emitted into the atmosphere would be about 251 Gg for buses, and 338 Gg for taxis. There would also be fewer amounts of the other polluting gases as well (Transport Statistics, 1995).

On the local front, the brown haze study in Cape Town has shown that substituting diesel and petrol with natural gas for public transport could yield reductions of between 50% to 75% in locally polluted air over the city.

### 7.3.2. Additional benefits

Apart from environmental gains, other additional benefits include economic, technical and social benefits, as stated above.

## 7.4. Measures to be taken

The most important measures that need to be implemented are probably the ones that are policy related. The government needs to put in place a set of policies that will encourage the use of natural gas as transport fuel without compromising the use of other fuels.

### 7.4.1. Fuel Levies

As stated before, South Africa needs to adjust its fuel levies to cover the cost of externalities. Polluting fuels should be taxed higher than less polluting fuels. It is a fact that diesel emissions are harmful to public health and so carry a higher external cost than natural gas.

### 7.4.2. Inter-fuel Competition

Inter-fuel competition in South Africa is, fortunately, very healthy. If a supplier of one type of fuel raises his prices too high, consumers can always shift to a competing source of energy. This situation should be maintained in order to encourage such competition.

### 7.4.3. Financing and Subsidies

Some form of government subsidies need to be made towards the implementing of a natural gas network. All countries with a successful natural gas programme have gone that route. Money for the network could be raised through some kind of fuel or carbon taxes, and also from foreign aid agencies.

### 7.4.4. A Clear Regulatory Framework Structure

There should be a clear and consistent regulatory framework in place for the use of natural gas. This should include safety regulations and standards for equipment, as well as for enforcement and monitoring. Investments in natural gas programmes involve high amounts and investors need to be assured that a solid regulatory framework is in place before taking that big financial risk.

### 7.4.5. The Need for Technology Transfer and Capacity Building

The introduction of a new natural gas networks should be accompanied by the latest and up to date technological improvements in the field. Space should be cleared for effective capacity building, education and training. There should be enough qualified managers and engineers to support the implementation of the programme.

## 7.5. Information Exchange and Future Work

Much more work needs to be done in this area. Technology transfer modalities need to be worked out and proper baseline studies in public transport and related fuel demand also need to be undertaken. In this study only a fixed lump figure has been quoted. Other factors that still need to be examined are natural gas market shares to the transport sector as well as market response to new transport technologies.

As more and more countries – both developed and developing, carry on with natural gas programme experimentation, systematic and clear collection of data should continue. This valuable information and data should form the basis for the exchange of ideas and innovations in educating policymakers and relevant institutions for better use of natural gas as a future transport fuel.

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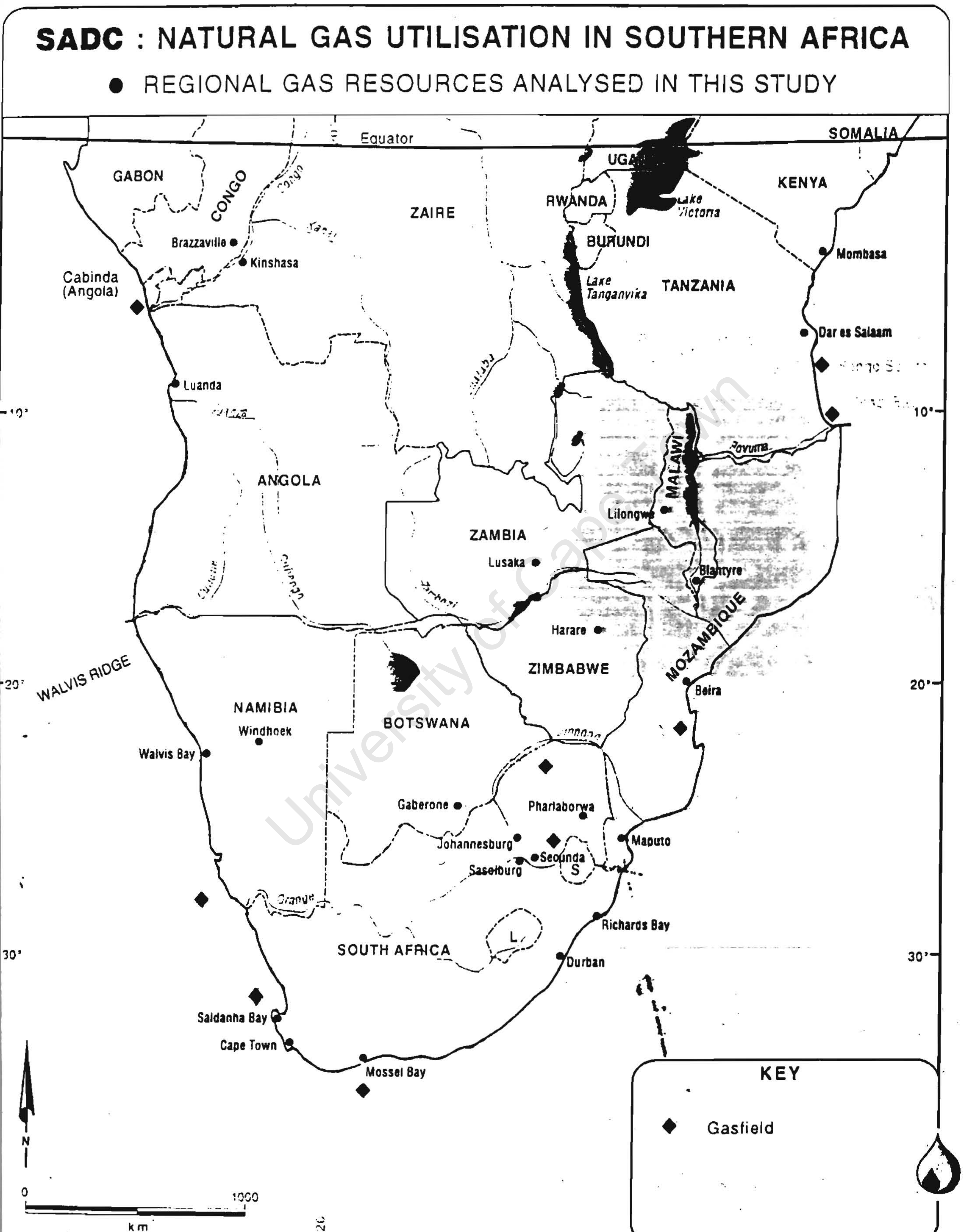
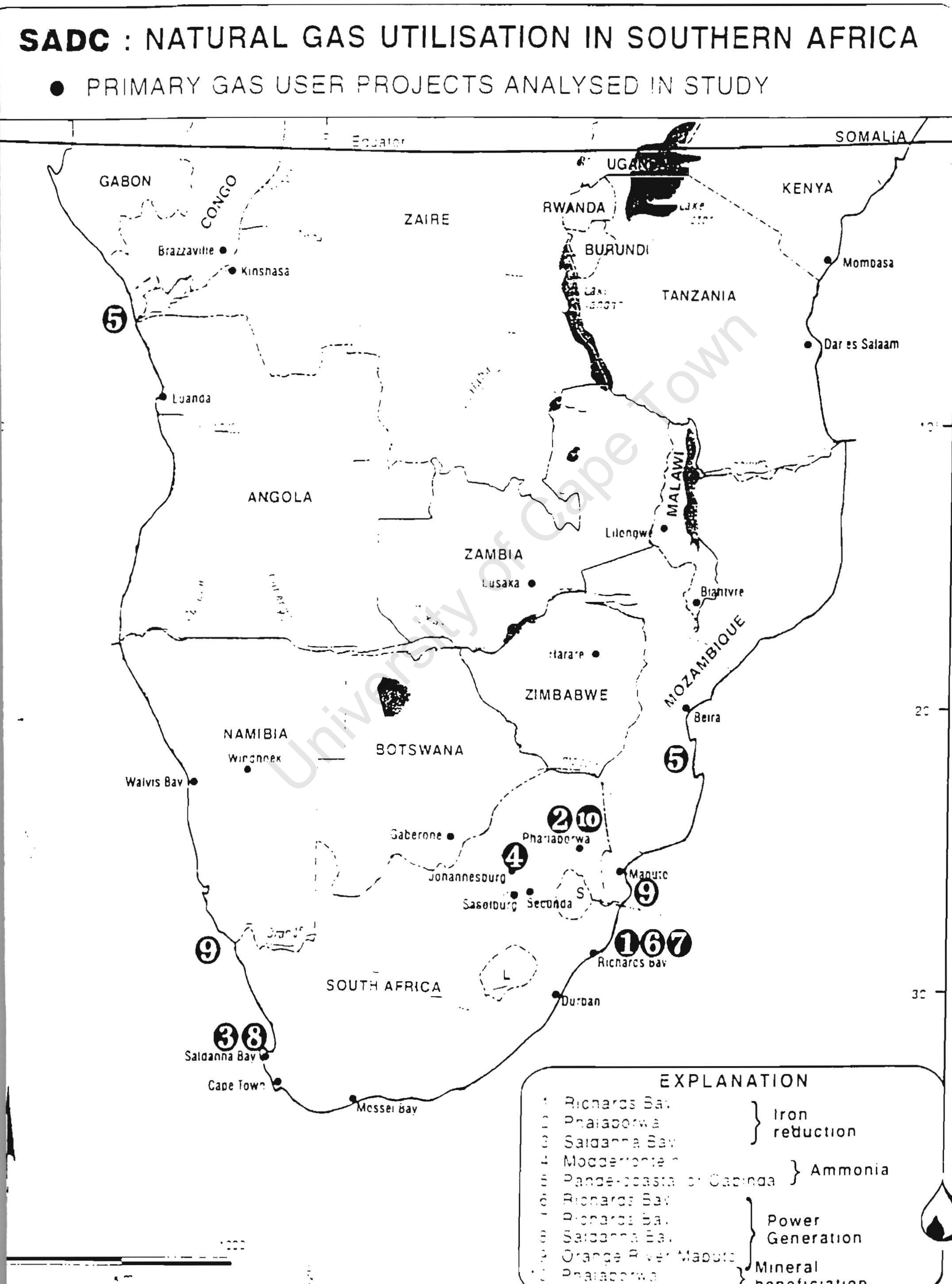
A

## Map of gas resources in Southern Africa



Primary gas user projects analysed

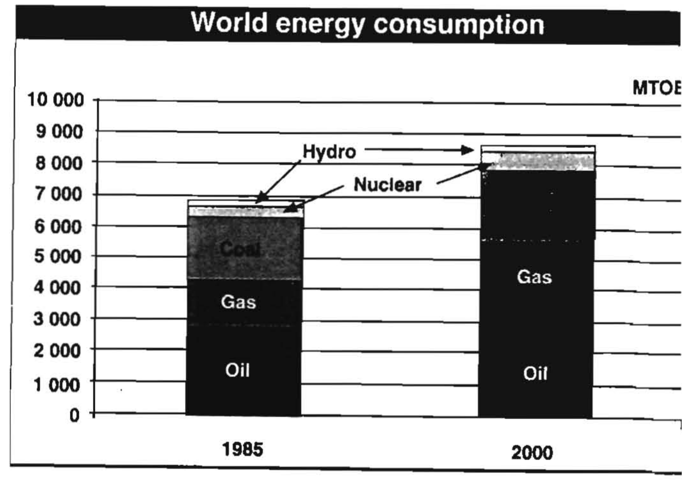


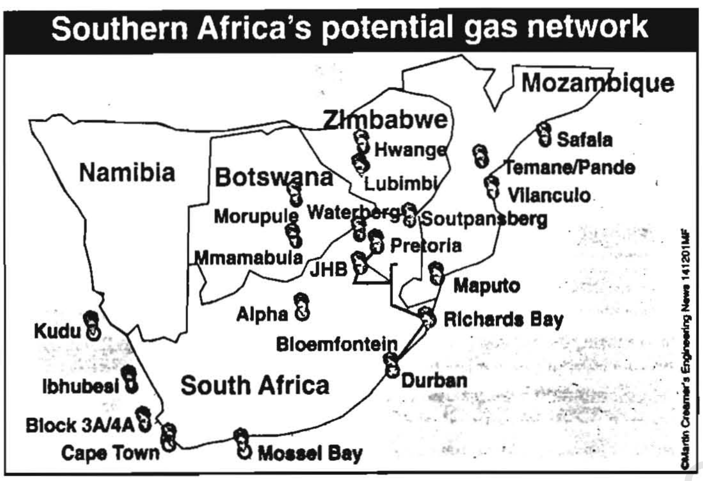
C

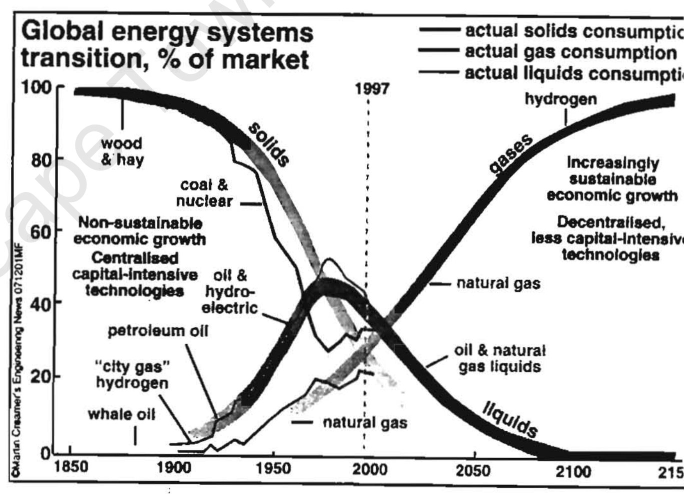
# NATURAL GAS

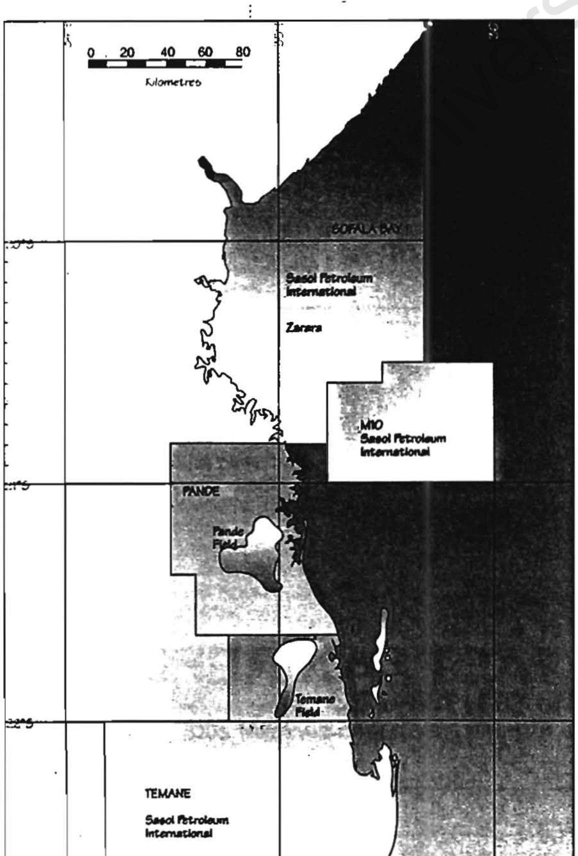
# IN

# SOUTH AFRICA

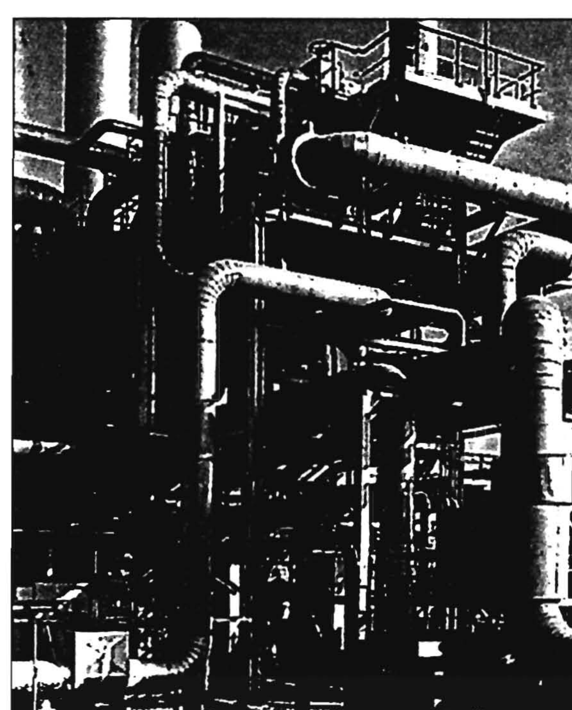


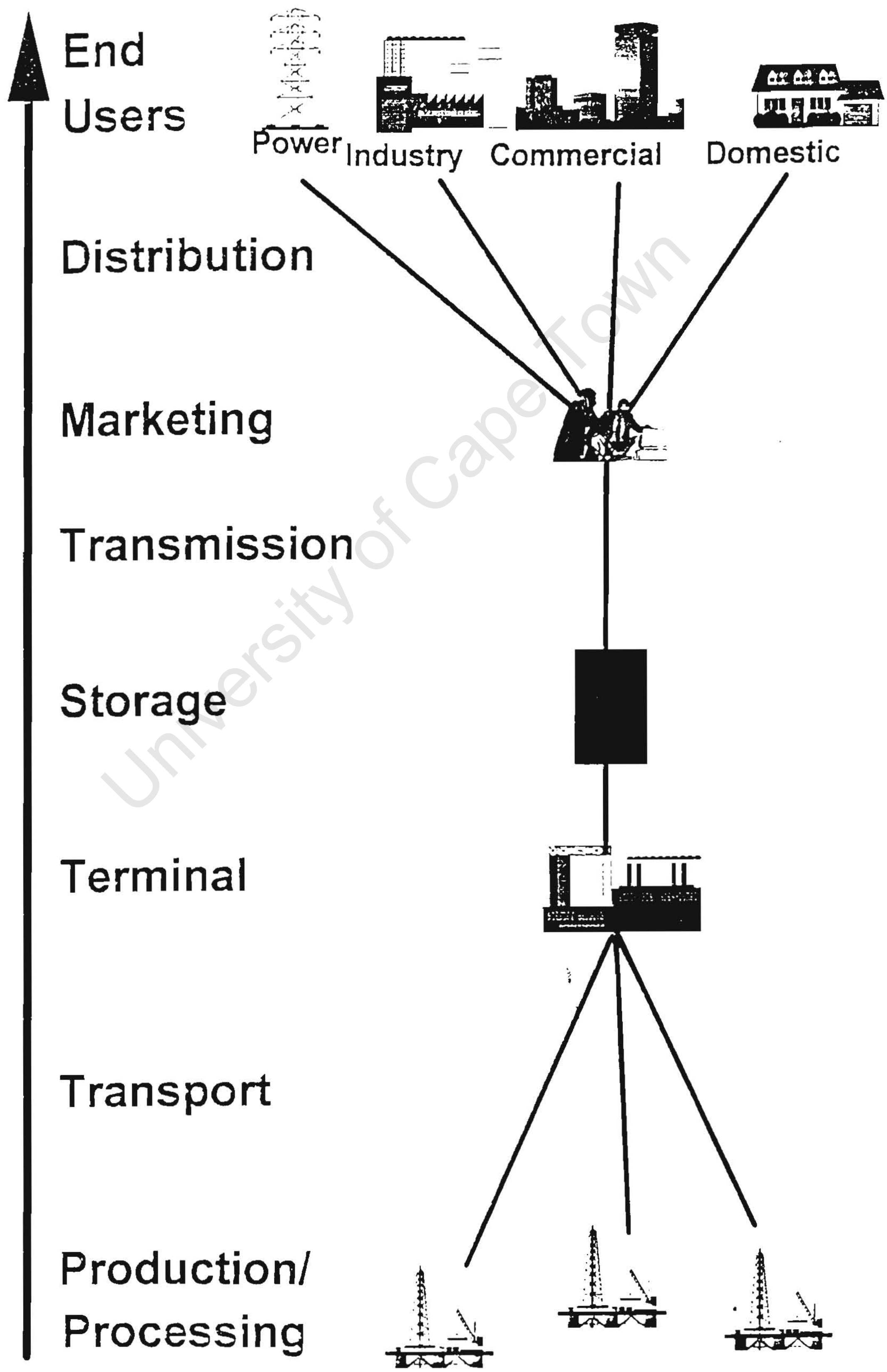

*Mozambique's gas fields*



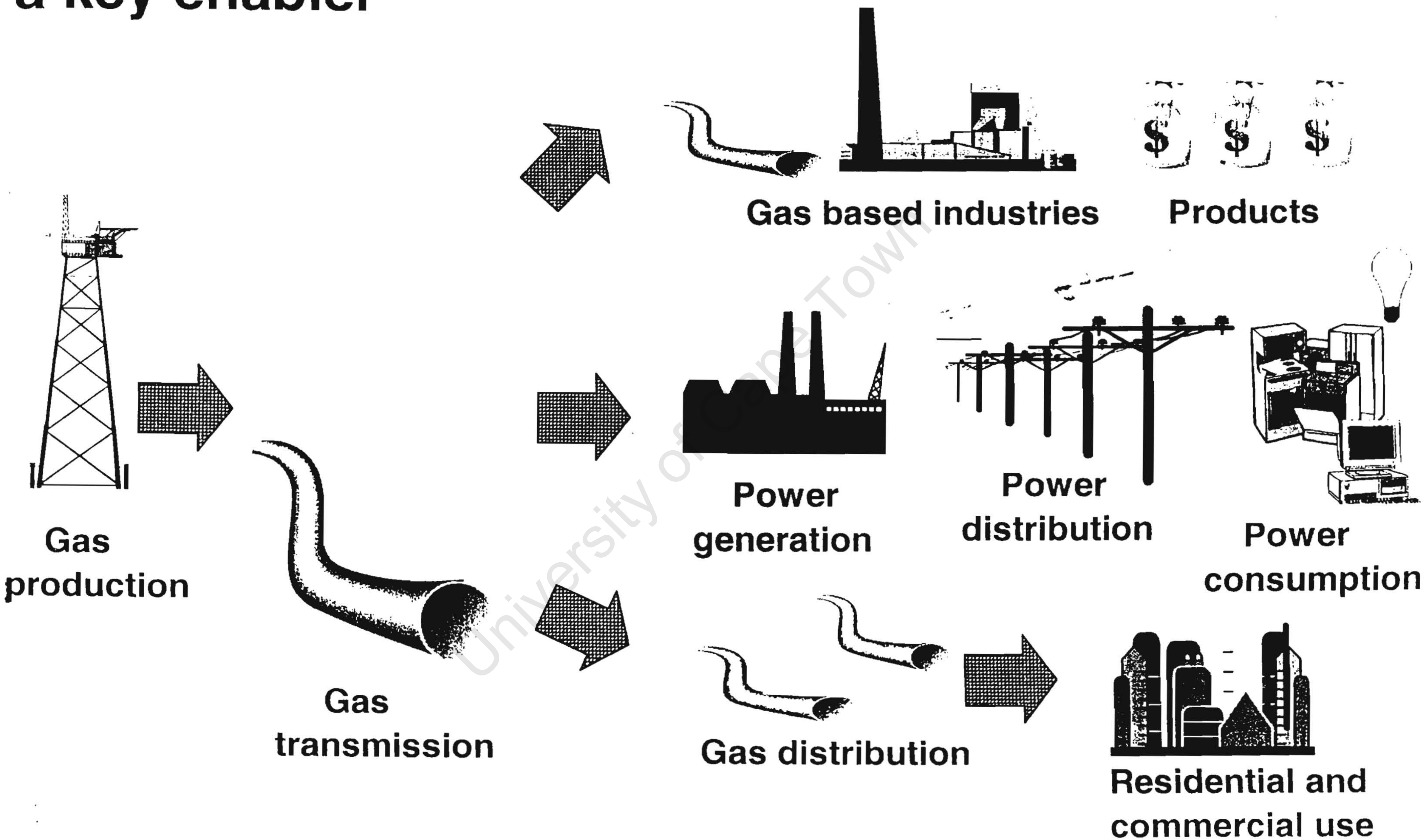
*Current Sasol gas network*

D

The gas value chain



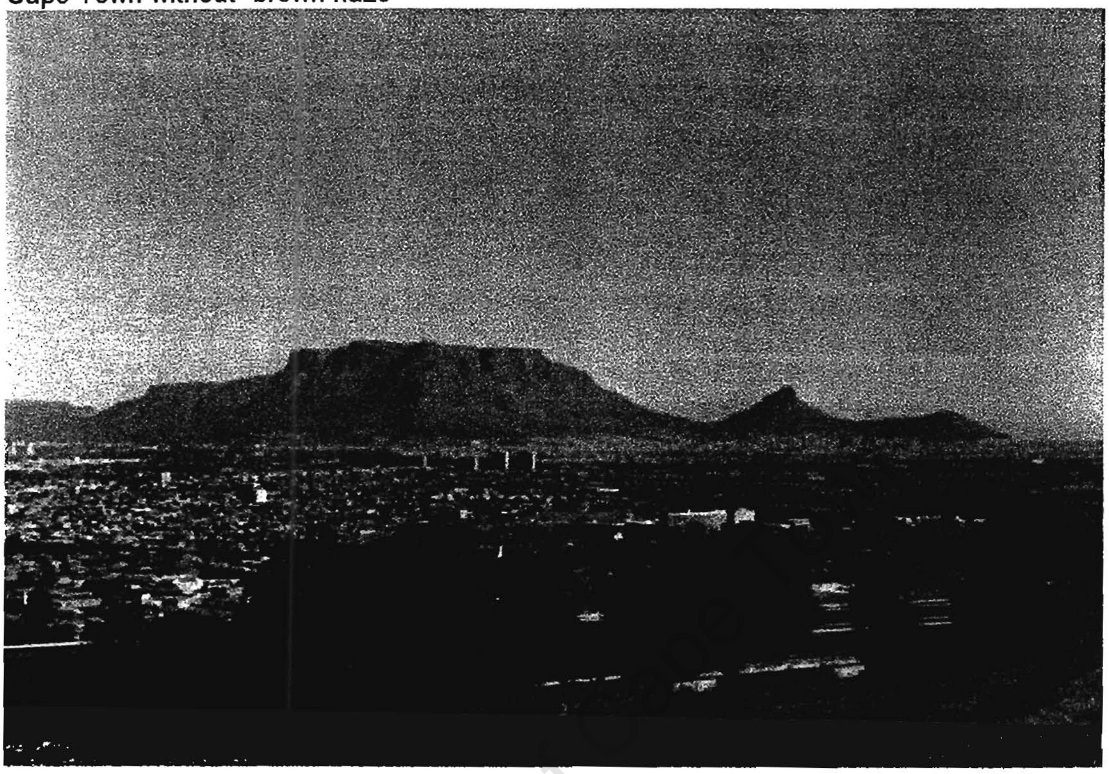
# a key enabler



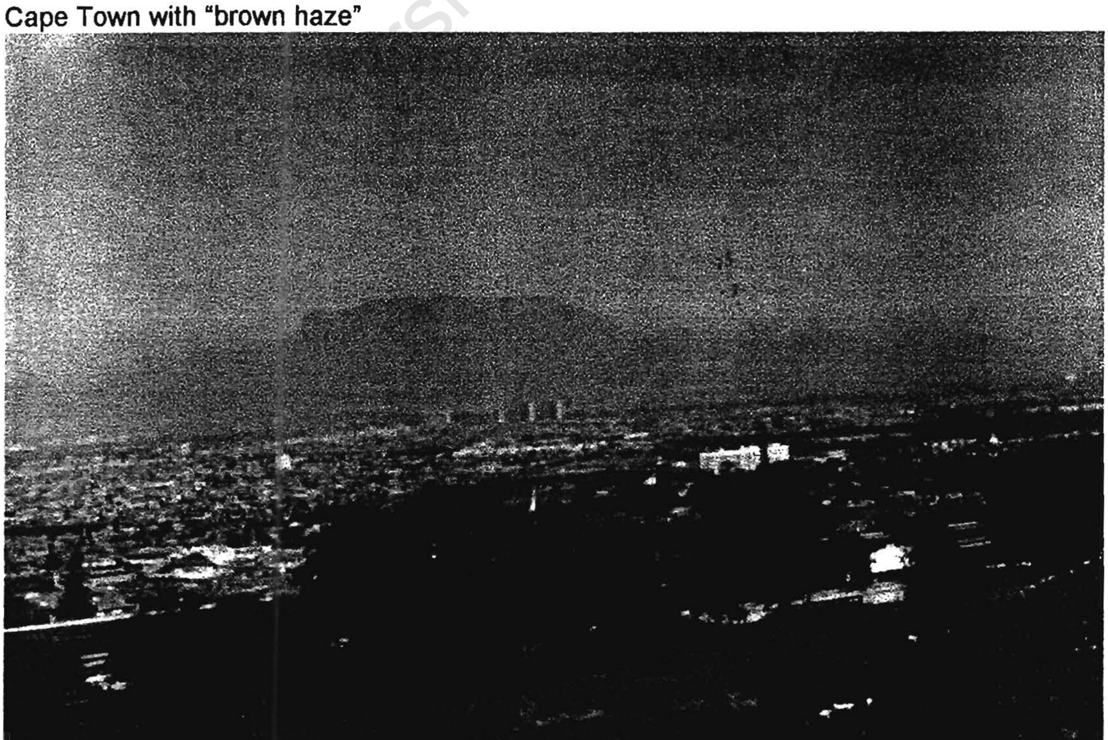
F

# The Cape Town "brown haze"

Cape Town without "brown haze"



Cape Town with "brown haze"



G

GAS RESERVES WITHIN SOUTH AFRICAN MARKET SCOPE (Tcf)

| BASIN | RESERVES | DISCOVERIES | POTENTIAL RESOURCES | | |
|---|---|---|---|---|---|
| | | | MINIMUM | LIKELY | MAXIMUM |
| SA south coast | 0.7 | 1.5 | 1.5 | 2.8 | 6.0 |
| SA west coast | - | 0.1 | 2.0 | 5.0 | 13.0 |
| SA onshore coal-bed | - | - | 1.0 | 3.0 | 7.0 |
| NAMIBIA off-shore | - | 2.0 | 4.1 | 15.0 | 50.0 |
| MOZAMBIQUE | 1.9 | - | 1.7 | 4.0 | 10.0 |
| TOTAL | 2.6 | 3.6 | 9.2 | 29.8 | 46 |
| | | | | | |

Source: SOEKOR,1994

- **ANGOLA'S 17.5 Tcf OF NATURAL GAS COULD BE WITHIN SOUTH AFRICA'S MARKET SCOPE BUT IS NOT CONSIDERED FOR THE PURPOSE OF THIS PAPER.**

- **TANZANIA IS NOT CURRENTLY SEEN AS BEING WITHIN THE SOUTH AFRICN MARKET SCOPE.**