REPORT NO. GEN 147

FINAL REPORT

ELECTRICITY-ECONOMICS RELATIONSHIP IN SOUTH AFRICA

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March 1992

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Duration of Project: 1990-02-01 TO 1992-02-01
NEC DIVISION: Energy Economics
Project Ref No: 731 01 01 004

CERTIFIED AN OFFICIAL FINAL REPORT DATE: 18/7/92.

Copies of this publication may be purchased from the NEC
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EXECUTIVE SUMMARY

An analysis has been made of the relationship between energy and gross domestic product for South Africa, and of the relationship between electricity demand and total energy demand in the final energy sector. The relationships have been derived from extrapolation of historical data and by using the relationship of the energy demand per Rand of Gross Domestic Product (energy intensity) and its variation with the increase in the level of industrialization in South Africa.

It is shown that the energy intensity has been decreasing at a rate of 2,2% over a ten-year period. This decrease was reversed in the 1980's and it is postulated that this effect was a consequence of international sanctions on the make-up of the economic activity and that the future trend will be for a decreasing energy intensity. It has been shown that the energy intensity versus time curve for South Africa is following the curve of other countries.

The electricity-energy relationship has shown a high growth rate of electricity relative to the total energy demand, and that this relative growth rate has been decreasing over the last decade. It is postulated that this is due to the electricity saturation curve having already passed the inflection point and that over the next decade the relative growth will decrease to zero.

Using the relationship between energy and economy, and electricity and energy, it is calculated that electricity demand to the end of the century will grow at a rate between 5,8% and 7,8% depending on what growth rate is assumed for the growth of the economy. The range of growth in the economy has been taken as between 0 and 2,4% for the GDP per capita figure in real terms.

The report has also assessed the cost to the economy of possible errors in the forecast of electricity demand. It has been calculated that a 1% over-estimate of the maximum demand would cost the economy 0,02% of GDP, whilst a 1% under-estimate would cost the country 0,09% of GDP.

It is also postulated that the concept of electricity elasticity in the economic sense has little application to electricity forecasting in South Africa.

CHAPTER 1

ENERGY-ECONOMICS RELATIONSHIP

1.1 INTRODUCTION

Research on the relationship between energy consumption and economic development has been well documented on a world-wide basis. Figure 1 shows the relationship between GDP and energy consumption on a per capita basis for a number of countries for 1980. From this figure it is obvious that as wealth increases more energy must be consumed in creating that wealth. However, although there is a general trend in this graph, it can be seen that there are significant departures for a number of countries from the mean line.

These differences arise because of the differences between countries in terms of the mix of consumption sectors. For instance, one country may have a higher proportion of agricultural component in its energy consumption mix than another. Moreover, there are also significant differences between countries in terms of climate, size of motor cars, building styles, etc. which can further shift individual countries from the general world trend line. South Africa is itself far from the trend line and would warrant closer investigation as to the reasons for this. This sort of analysis has already been carried out for a number of countries. For instance, Darmstadter et al[1] carried out an in-depth study of the energy consumption of the USA in order to determine why it uses apparently so much more energy than most other countries.

Besides the relative differences in energy consumption on a per capita basis between different countries, there is also a change in energy consumption for an individual country as it progressively becomes richer. This is illustrated in Figure 2 where the per capita energy consumption for South Africa is shown as a function of GDP per capita (at 1985 prices) over the period 1933 to 1986.

This graph is characterized by a gradually increasing energy consumption pattern, even during the period of decreasing GDP per capita during the war years. From 1973 the trend line is confused, with GDP and energy on a per capita basis both increasing and decreasing at different times.

FIGURE 1. ENERGY - GDP RELATIONSHIP
PER CAPITA (1980)

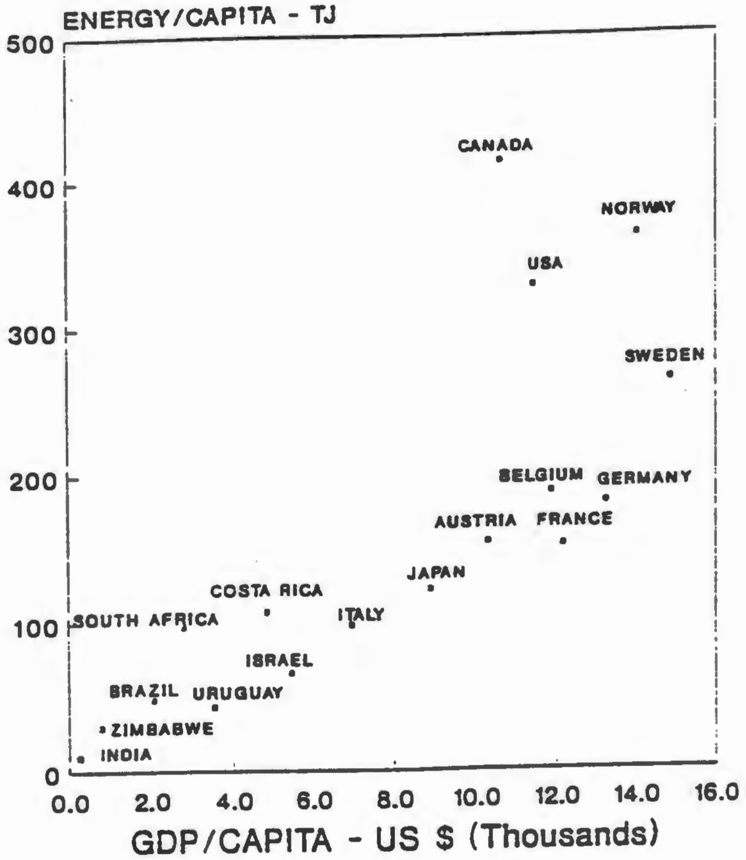
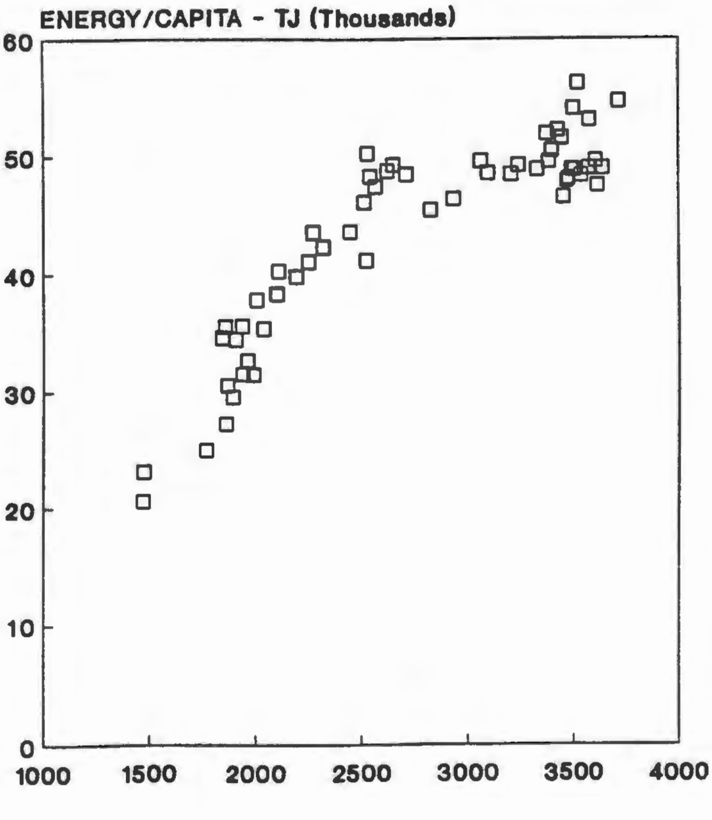


FIGURE 2. SOUTH AFRICA - RELATIONSHIP
BETWEEN GDP/CAPITA & ENERGY/CAPITA.
(1985 RAND)



The desire to be able to predict energy consumption in the future requires a basis for such prediction. The events over the period 1973 to the present have shown that it is not possible to carry out linear or exponential extrapolations in an attempt to judge what the future will bring. Such extrapolations implied that the future was going to be like the present but slightly larger in size. It is obvious that economic growth is the motivator of energy consumption but unless the components of economic growth can be related to energy requirements there is little chance of obtaining an accurate correlation. Thus as a country moves from an agricultural economy into heavy industry, the energy requirement will shift from the need for diesel fuel to the need for coal and electricity. Also, as the industrial sector changes in its mix of industries, so the energy intensities will change. This is illustrated for South Africa in Figure 3 which shows the changes in energy intensity with time. Energy intensity in this context is defined as the amount of energy required to produce a monetary unit of GDP.

Figure 3 shows that the energy intensity of the South African economy has been increasing up to 1950 when it reached a peak. In the 20-year period 1950 to 1970 energy intensity was decreasing, but since 1970 the energy intensity has again been increasing. This decrease followed by an increase has been noticed in other countries and Stoffberg[2] has highlighted this for the USA and the UK. Such a change in trend could be construed as a decrease in efficiency in the utilisation of energy. However this effect could also be due to the change in the industrial mix, or a change in the pattern of fuel or energy source mix. The effect is a complicated one and no simple explanation can be expected.

1.2 ENERGY IN SOUTH AFRICA

The growth of energy consumption has shown a steady exponential rise with time[3]. The mix of energy has also been changing with time and Figure 4 shows that the swing has been away from coal and towards electricity. Whilst the proportion of petroleum was increasing up to 1973, the petroleum crises since then have caused a decrease in petroleum usage. The increase in the percentage of electricity in the secondary energy mix has been quite dramatic and will be discussed in more detail later.

Lack of adequate energy statistics does not allow of an accurate assessment of how this energy is utilized. For instance, Kotze[3] only breaks down the energy

FIGURE 3. ENERGY CONSUMPTION IN SOUTH AFRICA PER UNIT OF REAL GROSS DOMESTIC PRODUCT (1985 RAND)

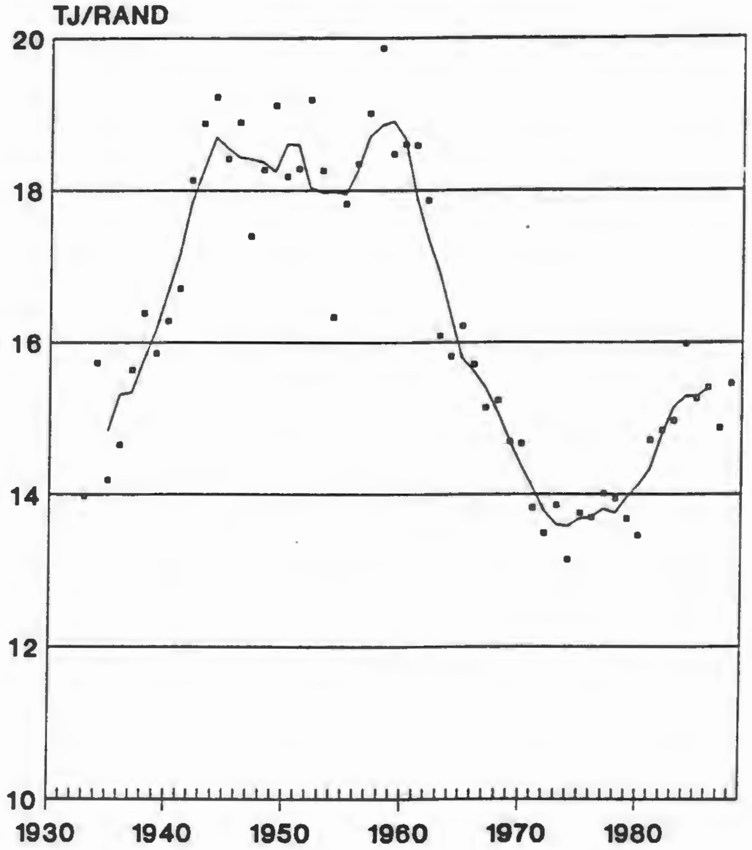
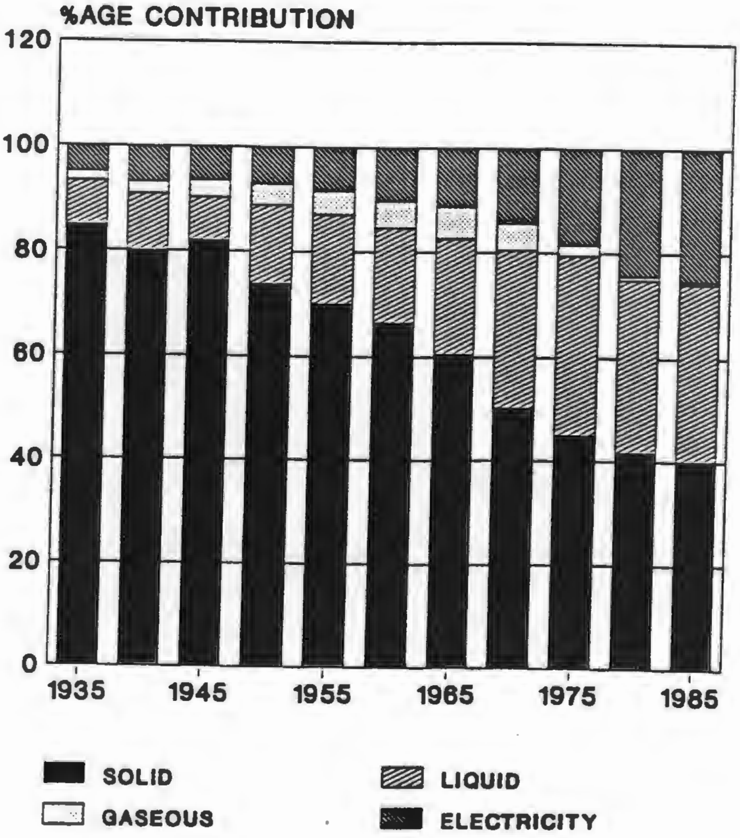


FIGURE 4. CONTRIBUTION OF ENERGY SOURCES TO FINAL ENERGY DEMAND IN SOUTH AFRICA



usage into four sectors, namely, household, industry, mining, and transport. In this context the domestic sector includes agriculture, whilst the industrial sector includes commerce. Figure 5 shows the disposition of energy consumption under these four headings for South Africa for 1933 and 1988. There has been a large swing from the need for energy in the transport sector to its use in the industrial sector.

This has also been accompanied by a swing from the use of coal for transport purposes to the use of petroleum-based fuels It is instructive however to investigate how the various energy forms are used by the final consumer. This is shown in Table 1 for the two years 1933 and 1988.

Table 1: Energy sectorial mix (%age) in 1933 and 1988

	Electricity	Gas	Liquid	Solid Fuels	Total Fuels
<u>1933</u>					
Domest/agric	1	0	1	20	22
Indust/comm	1	1	0	5	8
Mining	3	0	0	24	27
Transport	0	0	7	36	44
Total	6	1	9	85	100
<u>1988</u>					
Domest/agric	5	0	0	3	8
Indust/comm	13	1	13	33	60
Mining	7	0	0	1	8
Transport	1	0	23	1	25
Total	26	1	36	38	100

The movement of the energy mix over the 50-year period considered has been, for instance, from the inefficient usage of coal for transport purposes to the more efficient use of liquid fuels. Similarly, in the mining sector the move has been away from the low efficiency of coal for the powering of steam driven winding-engines to the more efficiently driven electric winding-engines.

FIGURE 5a. FINAL ENERGY CONSUMPTION
1933

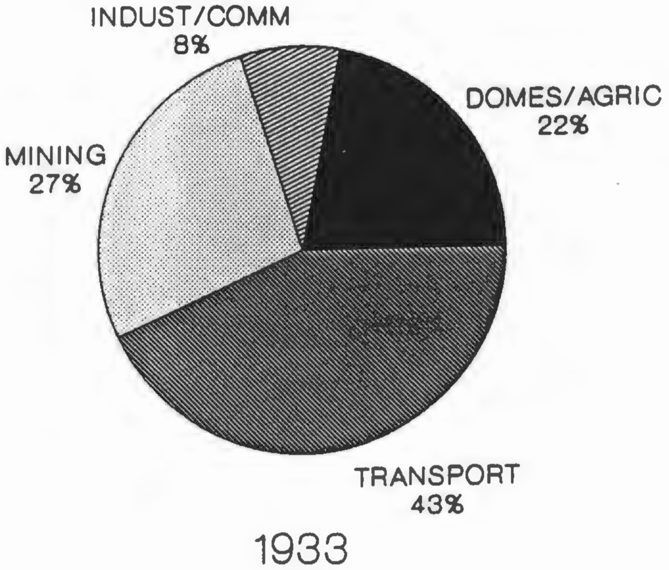
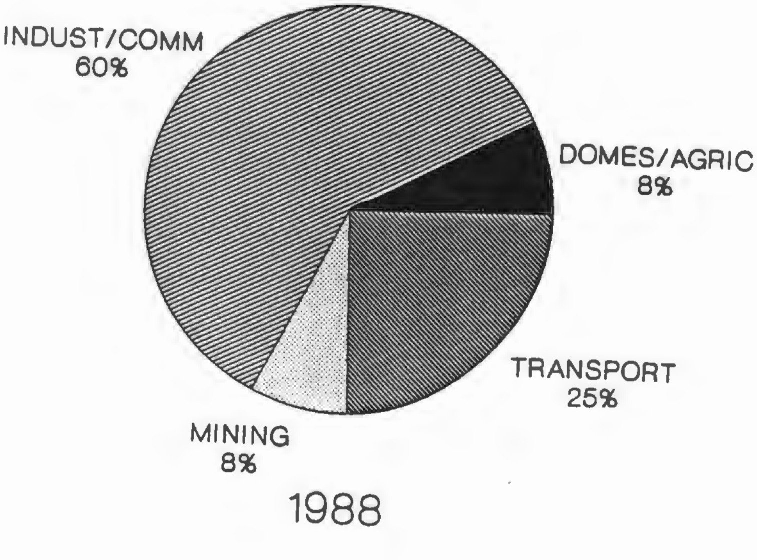


FIGURE 5b. FINAL ENERGY CONSUMPTION
1988



1.3 ENERGY AND ECONOMY

As the sectorial mix of the GDP has been changing in South Africa, so also has the energy mix has been changing. Whilst some of this change is reflected directly in energy utilisation, i.e. the move from energy in the transport sector to energy in the industrial sector, there are other aspects of economic growth that are not as obvious. Thus the movement from an agrarian to an industrial economy can be seen in the relative contribution to the GDP. Figure 6 shows this relationship where the ratio of GDP contribution by agriculture to the contribution by industry is plotted against time.

Since this graph is in terms of monetary value of the output of the sectors, it cannot be converted easily to energy terms because of the changing mix of the products in each of the sectors, as well as the changing value over time of even a single commodity due to market forces, both internal as well as external.

It has been shown in Figure 1 that South Africa has a higher energy consumption per capita than the world trend. This is shown also in Table 13 in Chapter 6 which compares the energy situation in South Africa with a number of European countries and with Japan and the USA. The comparison is made in terms of 1972 values in order not to include the temporary instability introduced by the 1973 energy crisis.

With increasing industrialization and increasing wealth, the energy consumption per capita will increase at a rate determined by the economic mix, by the efficiency of energy conversion, and by the effect of energy conservation by the final consumer. During the last 15 years the energy consumption per unit of GDP has been rising at approximately 1% per annum, as shown in Figure 3, and it is likely to continue at this rate for the next few years whilst the economic sectorial mix is changing at the present rate. Figure 7 shows how the GDP per capita has increased over the last half century. The growth rate, expressed as a three-point moving average curve, is shown in Figure 8 and it is seen that the growth rate has been averaging at approximately 1,2% per annum but with significant swings in the economy.

The significant decreases in growth rate during the Second World War, and during the recessionary periods between 1973 and 1979, are plainly visible. The political effects on the economy since 1982 are also evident.

FIGURE 6. RATIO OF GDP CONTRIBUTED BY AGRICULTURE TO GDP CONTRIBUTED BY (INDUSTRY + MINING + CONSTRUCTION)

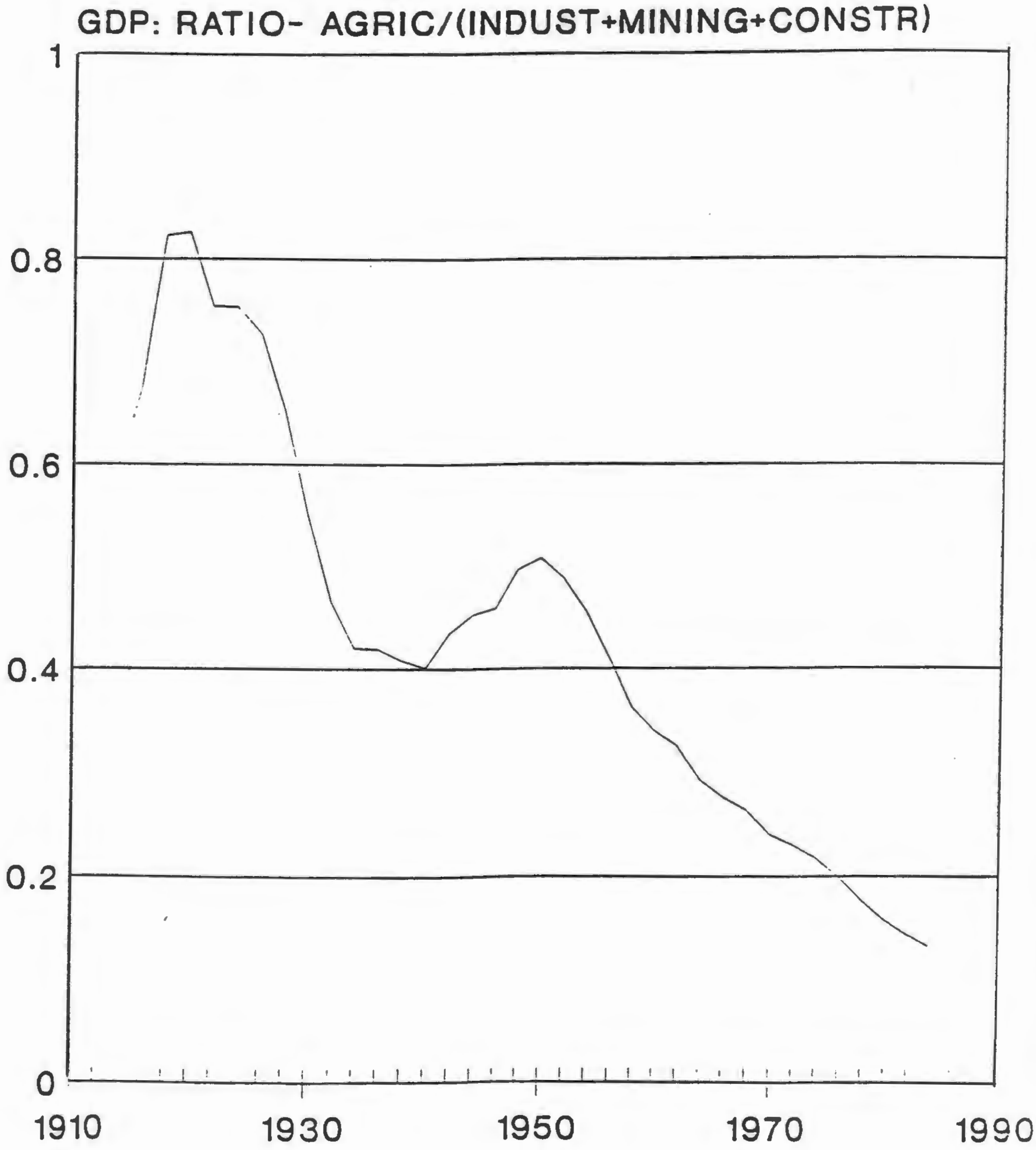


FIGURE 7. CHANGES IN THE REAL (1985) GROSS DOMESTIC PRODUCT PER CAPITA IN SOUTH AFRICA.

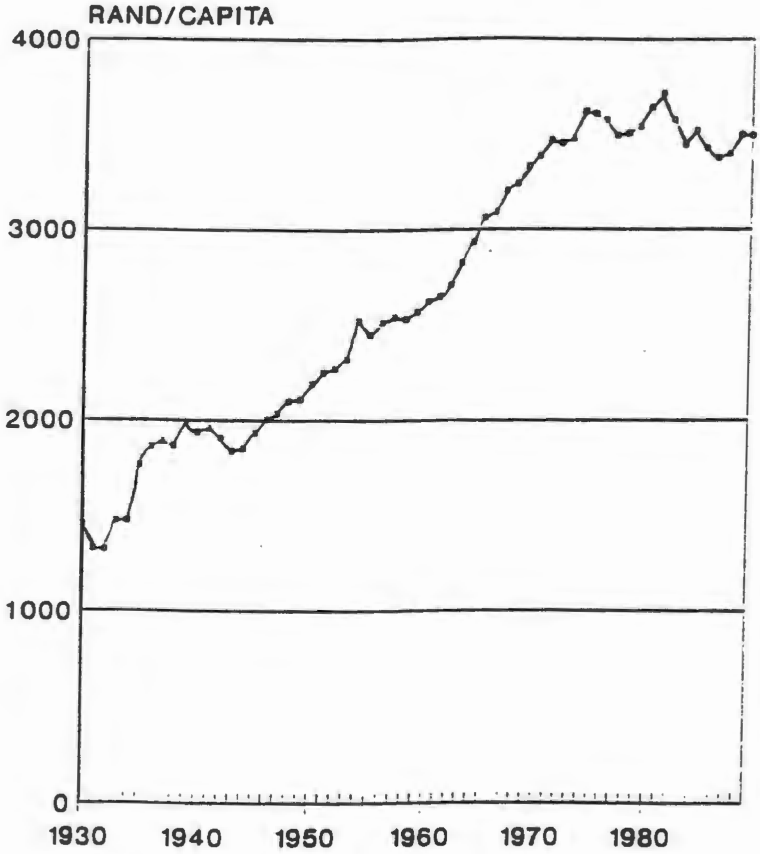
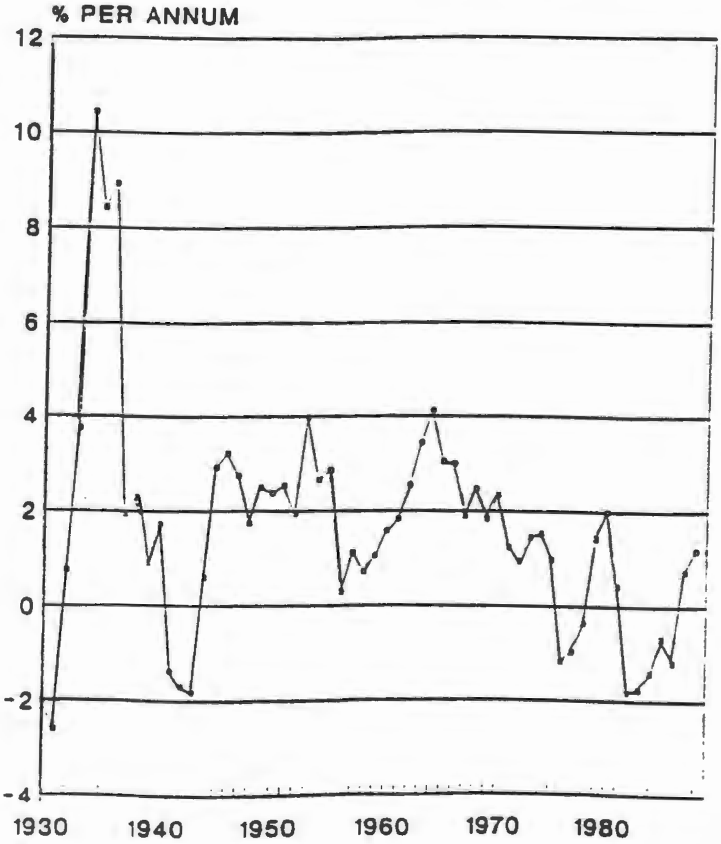


FIGURE 8. REAL GDP (1985) PER CAPITA GROWTH % PER ANNUM - 3 PT M.A.



1.4 POPULATION

The previous discussion has used the concept of per capita evaluation of energy, GDP, etc. The South African population, including the independent Homelands, etc., has been rising at rates up to 3,2% p.a. in the mid-1960's, but the rate has been dropping with a present growth rate of around 2,6%. This population growth and growth rate are illustrated in Figures 9 and 10.

The following Table produced by Spies[4] shows the present and future estimated population in South Africa.

Table 2: Present & projected population in South Africa

	(Millions)		
	1985	2000	2015
Whites	4,8	5,5	5,9
Asians	0,9	1,1	1,2
Coloureds	2,8	3,5	4,0
Blacks	23,5	34,8	48,0
Total	32,0	44,9	59,1

The growth in the labour force is such that at present the required job creations per day to satisfy the increase in the population coming onto the labour market is 1094 per day. By the turn of the century the number of new job opportunities will have to be 1830 per day. Spies[4] has estimated that the income category will spread with proportionally more people in the lower socio-economic classes, as shown in the following Table.

Table 3: Socio-economic population distribution (1978 & 2000)

Socio-economic class	Percent of population	
	1978	2000
I	2	1
II	9	6
III	36	34
IV	53	58

FIGURE 9. SOUTH AFRICA - POPULATION

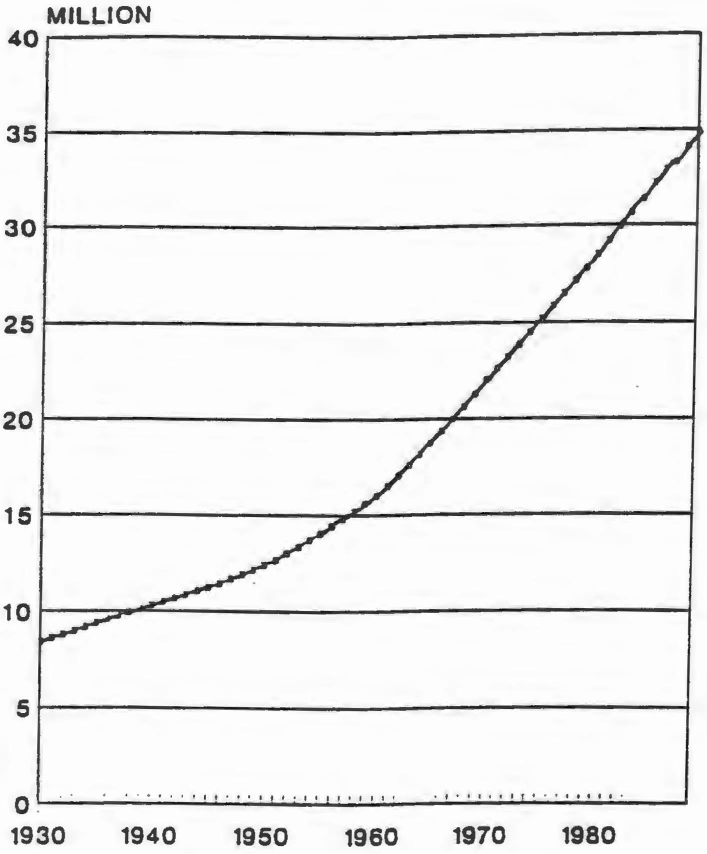
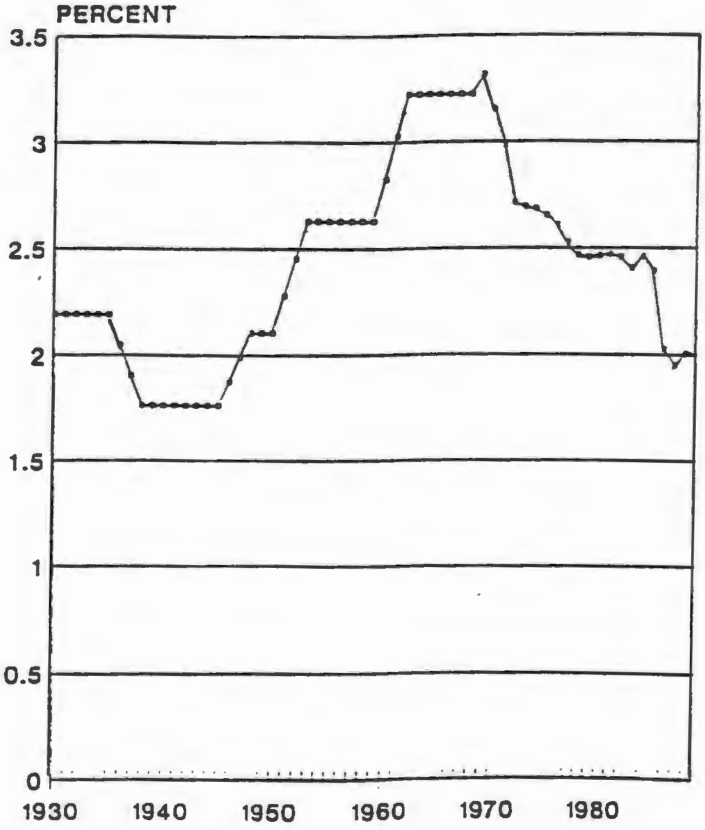


FIGURE 10. SOUTH AFRICA - POPULATION
GROWTH RATE - % p.a.



These two Tables indicate that the population growth rate over the next 15 years will be 2,3% (and possibly 2,4% p.a. over the smaller scale of the next ten years), and that the problems of the underdeveloped sector of the population will get worse not better.

1.5 CONCLUSION

The energy consumption of a country is a function of the sectorial economic activity of the country. In South Africa the economic mix has been changing from reliance on agricultural products and on mining, to an economy dependent primarily on industry. The energy intensity of the industrial sector is always greater than that of agriculture, and in the South African context it is also greater than that of mining. Therefore in the future, with an increasing proportion of industrial activity, the energy intensity in South Africa will increase. Over the last 15 years this increase in energy intensity has averaged at approximately 1% per annum. It may be assumed that the change from primary to secondary industrial activity will continue at the present rate for at least the next 10 years. It is therefore likely that the growth in energy intensity in the near term will be at the same level as shown in Figure 3.

Whilst it can be forecast that the energy intensity will change by an average of 1% p.a. over the next decade, it is not possible to forecast what the rate of growth of the GDP will be. During the period 1944 to 1974 the real GDP per capita has been rising at 2,4% per annum, but over the last 10 years it has fallen by 0,6% per annum. During the last 15 years the population has been growing at a rate of 2,9% p.a., after reaching a peak of 3,2% p.a. during the mid-1960's. It appears that the population growth rate will continue decreasing and over the next ten years it will be about 2,4% p.a.

If the extremes of GDP per capita growth rate are taken as +2,4% and -1%, then together with a population growth rate of 2,4% the GDP may be expected to grow by between 4,8% and 1,4% per annum. The actual growth will depend on economic and political factors, but the lower limit would have a marked effect on the stability of the political situation in South Africa and it must be the main government priority to steer the country to a GDP growth rate of at least 2,4%. If it fails to achieve this, it would mean a much lower growth rate in the longer term because of political instability.

Since planning cannot be done on a worst case scenario, it has to be assumed that the range of GDP growth must be between 2,4% and 4,8%. To this growth must be added the rate of growth in the energy intensity due to increasing industrialization. Taking the energy intensity growth rate as 1% per annum for at least the next 10 years, then the total growth in energy consumption up to the year 1995 will be in the range 3,4% to 6,4% per annum.

If the rate of growth of energy production were to fall below that required by economic growth, then power production would become the limiting factor on economic growth. Thus any arbitrary decision on the growth rate of the power industry because of other factors, either political or economic, which is below that required by the economy, would have a self-fulfilling effect since it would stunt economic growth to that level dictated by the availability of energy. Examples of this effect can be found amongst many of the underdeveloped countries where the supply of energy is inadequate and erratic and is a brake on development.

CHAPTER 2

ELECTRICITY-ENERGY RELATIONSHIP

2.1 INTRODUCTION

In Chapter 1 it has been estimated that the growth rate of energy consumption in South Africa will be between 2,4% and 5,4% per annum over the next ten years and thereafter it will change by an amount dictated by the changes in the energy mix and by economic growth rates. These factors must be considered in more depth for an analysis of energy demand over a longer period, but the above estimate will suffice for the analysis required for this study.

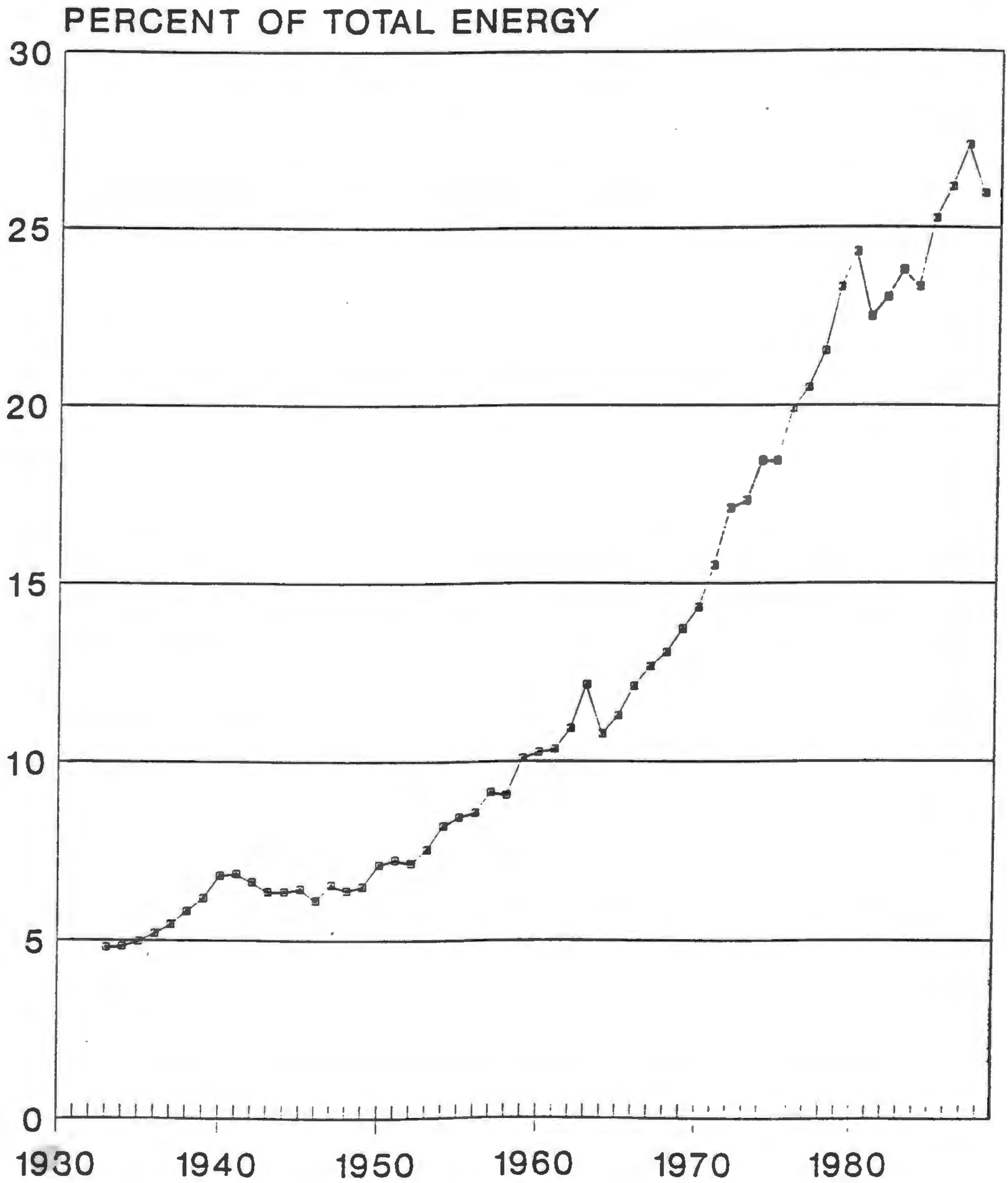
In order to determine the probable growth rate in the demand for electricity, the role played by electricity in the energy mix must be evaluated. It is known from the history of other countries further along the path of industrialization that electricity becomes progressively more important as an energy source in the final demand sector as the percentage contribution of the industrial sector to the Gross Domestic Product increases. It is therefore the purpose of this Chapter to investigate the changing role of electricity in the South African energy mix and to compare this with other countries, and especially with the U.K.

2.2 ELECTRICITY CONTRIBUTION TO FINAL ENERGY

The percentage of electricity in the final demand sector has been rising steadily over the last 50 years. This growth is illustrated in Figure 4 and in more detail in Figure 11. This rise has been from 5% of total final consumption in 1933 to 24% in 1984.

It is to be expected that the proportion of electricity demand will increase along an "S" type of saturation curve. There are certain applications which will, for the foreseeable future be supplied by energy forms other than electricity. For instance, the use of process heat for industrial applications might be better served by coal boilers rather than by electricity, though this must still be evaluated.

FIGURE 11. ROLE OF ELECTRICITY IN FINAL ENERGY CONSUMPTION

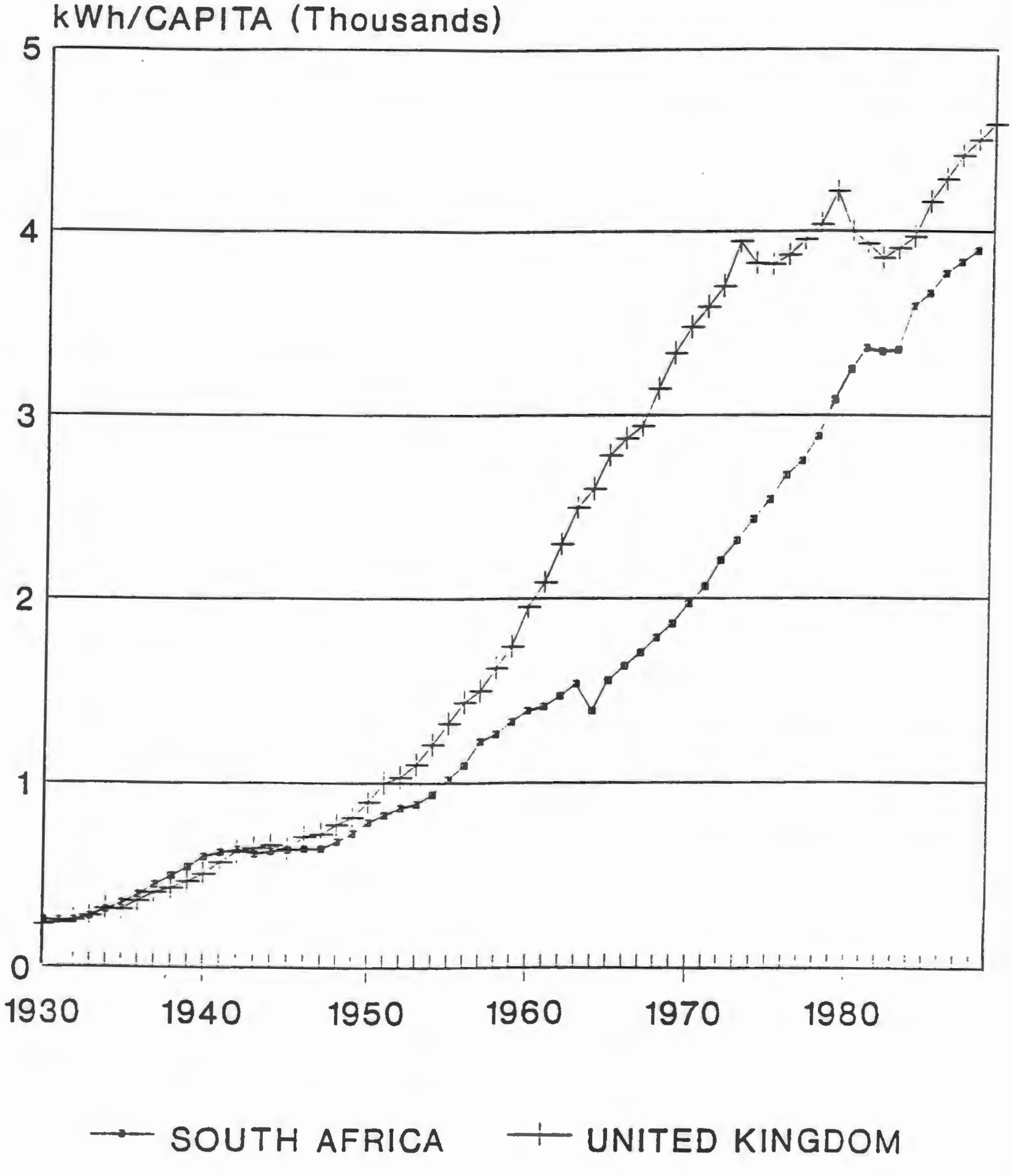


Similarly, it is unlikely that electricity would have more than a modest penetration in the road transport sector. Thus the curve in Figure 11 must be a portion of such an S-curve which is asymptotic to some value below 100%. The value to which this curve would be asymptotic would vary from country to country depending on the economic sectorial mix and the alternative sources of energy and their price. Thus in South Africa much of domestic space heating would be by electricity because of its low cost and its convenience. In the U.K. where natural gas is readily available much of the house-heating demand is based on gas. It is however of interest to compare South Africa with the U.K. in its use of electricity. Figure 12 shows such a comparison between the two countries on the basis of electricity consumption in the final demand sectors in terms of units of electricity per capita.

It will be seen that until 1945 the consumption of electricity was very similar for the two countries, but thereafter the consumption increased more rapidly in the U.K.. From 1980 the role of electricity in the U.K. has declined mainly because of competition from gas. Eden and Evans[5] show that by 1972 gas had achieved a market share of final energy demand (on a heat supplied basis) equal to that of electricity. By 1978 it had twice the share of electricity. Since the role of energy consumption in the domestic sector is relatively small in South Africa (17% in 1984), the relative role of electricity in the overall energy demand will be greater in the South African context.

There is also currently little competition between gas and electricity since the home heating market is not a large section of the energy demand and in the wealthier homes electricity is preferred to the more inconvenient coal. In the homes of the less well-off the preferred fuel is coal. It is likely that with the growing awareness of the pollution aspects of coal firing in the township areas and the move towards electrification much of this coal-firing will, with time, be taken over by electricity. It is to be expected therefore that in the foreseeable future the saturation level for electrical energy in South Africa is likely to be higher, on a per capita basis, than in the United Kingdom. Therefore the South African S-curve for electricity saturation is still far from the asymptote, even though there has been a reduction in the slope of the kWh/ capita curve, as depicted in Figure 11, from 1981. This reduction in the slope of this curve from 1981 should be compared with the slope reduction from 1958 to 1960 and again from 1963 to 1965. These were local reductions because of short-term economic disturbances

FIGURE 12. ELECTRICITY CONSUMPTION IN SOUTH AFRICA AND IN THE UK.



and were not indicative of the long-term trend. The present trend in the growth rate is therefore likely to continue in the medium term. It is of interest that it is anticipated[6] that in France where electricity accounted for 23% of total final energy demand in 1973, it is planned that it will grow to 50% by the turn of the century.

The relationship between electricity and energy growth rates is shown in Figure 13. The per annum growth rate for electricity has been substantially above the growth rate for energy. Figure 13, which is a 3-point moving average of the difference between the yearly per capita growth rates, shows that except for the war years and the period 1962 to 1966 the growth of electricity has been well above the growth of total energy and has varied from a high average of 8% per annum in 1935 to the present average of 3%.

The war years and immediate post-war years are characterized by low values of the difference between electricity growth and total final energy growth, reaching a low of -2,7% p.a. The war and post-war years were characterized by a shortage of electricity because of the inability to construct new power plant during the war years. Electricity was rationed by a pooled arrangement between various large consumers and Electricity Supply Commission (ESKOM) and other arrangements were made to boost electricity supply such as the operation of power stations at an increased frequency. These problems stunted economic growth and were a brake on the economic recovery in the immediate post-war years. This is indicated in Figure 12 which shows a flat electricity per capita section in the period 1940 to 1947. The growth rate difference is presently at a value of 2% per annum which seems to indicate that South Africa is on the upper section of the electricity saturation S-curve. The point of inflection most probably occurred in the second half of the last decade.

The shape of the electricity and energy per capita curves is shown more clearly in Figure 14 where the values of per capita consumption of total energy and of electricity are plotted relative to the values at 1984 as 100%.

The shape of the South African electricity curve in Figure 12 is seen to have an increasing slope with time. There are a number of localized departures from this general trend. During the last few years the slope has been decreasing because of the local decrease in GDP per capita. However, it is expected that the decrease in slope at this point is a temporary instability since it is of too sudden and small-scale a phenomenon to be part of a longer term trend.

FIGURE 13. DIFFERENCE BETWEEN ANNUAL GROWTH RATE (ELECTRICITY - ENERGY) 5 POINT MOVING AVERAGE

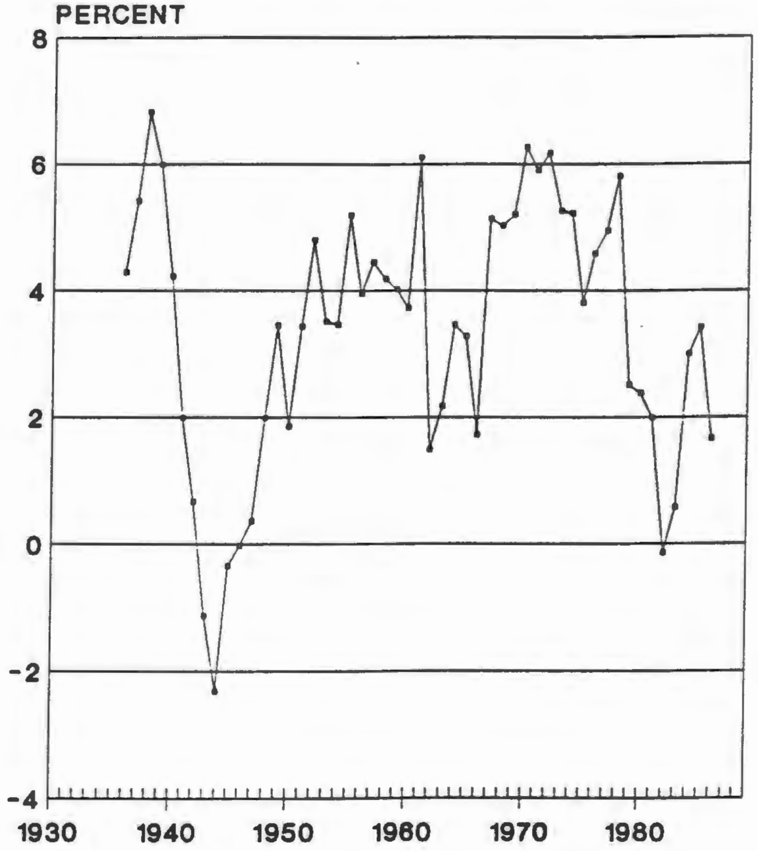
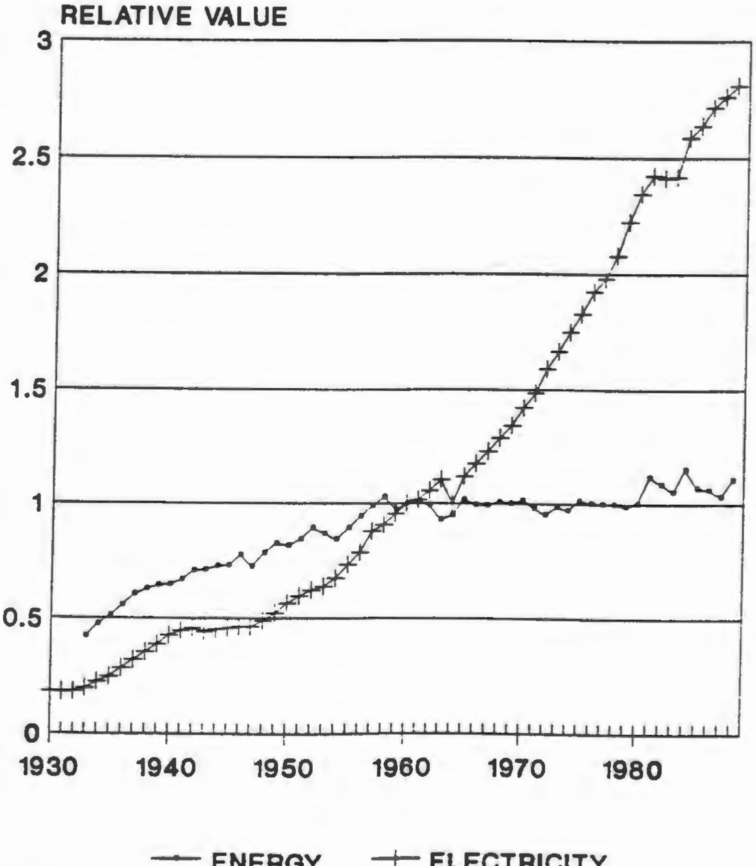


FIGURE 14. ENERGY & ELECTRICITY PER CAPITA RELATIVE TO 1960



2.3 FORECAST OF ELECTRICITY GROWTH

From the above discussion it can be seen that the growth in electricity consumption will, in the next decade, grow at a rate of approximately 2% above the growth in energy consumption by the final demand sector. It has been shown that the growth in total energy is made up of three components, namely, a growth in population, a growth in energy intensity, and a growth in GDP. Taking all these components into consideration, the medium-term growth rate in electricity consumption is given by the combination of these factors. The components of this growth are shown in Table 4.

Table 4: Growth rate of energy/economic factors

Energy per unit of GDP/capita	1%
Electricity relative to total energy	2%
Population	2,4%
GDP per capita	-0,6 to +2,4%

Therefore total growth in electricity consumption, which is a product of the above factors, will be between 5,9% and 9,1% per annum.

However, as explained in the text, the negative value of GDP per capita cannot be maintained for any length of time since it would lead to political instability. Therefore the government must ensure that this growth rate is at least zero and preferably positive. It must therefore be assumed that the electricity growth rate will be at least 6,4% above the GDP per capita rate. It is therefore likely that the electricity growth rate will be between 6,4% and 9,4% per annum over at least the next ten to fifteen years.

2.4 CONCLUSION

Electricity is increasing its share of the final energy demand in South Africa. In turn, energy intensity in the country, i.e. the amount of energy per unit GDP, is also increasing as industrialization continues at the expense of the agricultural and transport sectors.

It is estimated that the growth of electricity, above the growth of GDP per capita, will be 6,54%. It is expected that the range of possible GDP per capita growth rates will be 0% to 3% per annum with a resulting electricity growth of between 6,5% and 9,1%.

CHAPTER 3

PROBLEMS OF ELECTRICITY SHORTAGE

3.1 INTRODUCTION

There are two main factors associated with a shortage of electricity. The first concerns the psychological interpretation of a shortage, and the second refers to the economic consequences of not being able to meet a demand.

On the psychological side the effect of a brown-out or a black-out is perceived by the suppliers of electricity as a slur on their engineering ability since a shortage should have been forestalled by better design, better maintenance, or by better planning. However, the price of better planning is more reserve capacity, or smaller unit size, both of which imply more expensive electricity. From this point of view the amount of spare capacity should be analysed as a public relations exercise. The correct amount of spare capacity is available if the reaction of the press to forced outages elicits only a minimal response. If however, press comment occurs frequently, then inadequate spare capacity has been provided. Thus spare capacity is related to the amount of publicity given by the press. Consequently South Africa has a surplus reserve capacity since the only comments are on the rare occasion that there is a catastrophic failure of generating plant or distribution equipment. However the reserve capacity on the South African electricity system, and specifically within the ESKOM, has been growing and requires discussion.

With regard to the economic consequences, the cost of not meeting a required demand has a deleterious effect on the country's economy, which might be estimated in financial terms.

3.2 ECONOMICS OF SHORTAGE

In theory it is possible to equate the supply and demand for electricity by suitably adjusting prices, and this is what is considered by various utilities in terms of the marginal cost concept. However it is not possible nor even desirable to adjust prices on an instantaneous basis. It is therefore necessary to maintain reserve capacity to ensure that demand can be realized with an adequate probability.

The price to be paid for providing reserve capacity could be worked out if the economic cost of being without electricity were evaluated. This cost however would vary with the length of time for which the shortage occurred, the time of the day and the time of the year at which it occurred, the amount of forewarning that could be given of an impending shortage, and on the class of consumer. Thus a short duration outage with a long period of forewarning may be no more than an irritation, whilst a long outage with no warning might well be economically disastrous. Furthermore, the cost of an outage would vary from consumer to consumer.

For the consumer to whom electricity is vitally important, i.e. in a hospital or in a computer bureau, the cost of electricity not supplied can be equated to the cost of the alternative energy sources, such as stand-by generators, which the organization is prepared to put in by itself.

Some countries, e.g. Sweden, make a distinction between a capacity shortage and an energy shortage, the former being the inability to supply because of inadequate generating equipment or distribution equipment, and the latter the inability to supply because of insufficient fuel. The energy shortage can usually be forecast well in advance and is usually due to factors such as inadequate hydropower because of drought, as occurred in South America during the mid-1970's, or due to other causes such as strikes, as occurred in the United Kingdom during the miners' strikes in 1985. In the South African context there is unlikely to be a major energy shortage and the main consideration is the capacity shortage due to inadequate generating plant.

Andersson and Taylor[7] have analysed the various methods of predicting the cost of an electricity shortage ranging from the opportunity cost of alternative back-up power, through the observed willingness to pay for planned production, to the basis of the losses in production value for various goods and services affected. They also raise the question of whether marginal or average costs should be used. It is apparent, in the South African context, that a shortage of capacity, as opposed to an energy shortage, would be felt mainly during peak periods when all plant is working, and therefore only average costs should be considered. Andersson and Taylor also point out that the cost of lost production should ideally equate to the other two methods of assessment since, with perfect knowledge, electricity consumers would be prepared to pay for a secure supply of the amount required to negate the loss in production. The authors also point out that the true cost of an outage will be significantly higher than the value of lost production because of the effect on the suppliers of services or goods to the consumer who experience the outage.

The cost of an outage is also dependent on the length of the outage, a factor which has been taken into account by a few studies. A recent study in Sweden, reported by Andersson and Taylor, is summarized in the Table below to illustrate the effect of a capacity shortage of various durations and to various classes of consumers.

Table 5: Cost of capacity outage for different periods - Sweden[6]

Outage cost	(US$/kWh - 1980)		
Duration	0,5h	2h	8h
Consumer			
Industry	2,41	5,55	14,75
Households	0,24	1,27	14,75
Agriculture	0,48	2,19	13,20
Offices	6,14	25,25	106,44
Commerce	5,43	14,60	51,45
Railroads	1,94	5,78	21,21
Entire country	2,08	6,42	26,38

These values are specific to Sweden, but it is reported that the magnitudes of these figures for other studies in Finland and Canada are similar to the Swedish figures. The above values are maxima, applying at the peak periods but not at other hours, i.e. outside office hours the value to the office consumer would be zero.

This analysis would yield very high costs of lost energy because of the knock-on effect described above. This is possible for limited and relatively short duration outages since an outage in one part of the country may effect sub-contractors in other parts of the country where outages did not occur. For a longer term, or more regular outages, the outage cost could be the cost of the net production loss. Telson[8] argues that the cost of loss in production is the cost of the delay in production since as soon as the outage is over the delayed production can continue. In this case the cost of the outage is the cost of salaries and wages incurred during the outage which then, in the specific accounting period, have to be written off over a smaller production output. This could be possibly the lower bound of the outage loss, but it would discount the cost of idle capital capacity. It seems therefore that a more realistic assessment would be the loss in output in terms of total cost and, in the limit, it would be the loss in GDP due to the outage.

3.3 SHORTAGE IN SOUTH AFRICA

In view of the fact that it is reported that the figures quoted in Table 5 and compiled from the data of Andersson and Taylor, are of the same order of magnitude for countries as diverse in size and economic make-up as Sweden, Finland, and Canada, then, as a first estimate, it may be assumed that they will also apply to South Africa if adjusted for differing costs of power production.

It will be assumed that with a shortage of generating capacity the outages will occur at the peak demand time during the day. It is also assumed that with good overhaul planning, generating units are maintained during the year so as to follow the maximum demand curve. In this case the shortage of supply could occur during the peak demand hours on any working day throughout the year.

The figures in the Table 6 below have been adjusted for the difference in economic activity between Sweden and South Africa. They have also been adjusted for the exchange rates. The resulting cost of outage in terms of Rand per kilowatt when plotted on log-log paper exhibit an exponential form, and it is possible to determine the relevant costs for various periods of outage.

Table 6: Cost of outages for different periods - South Africa

Duration of Outage - Hours	R/kWh (1980 values)
0,5	1,7
1,0	2,6
1,5	5,1
2,0	6,9
4,0	8,9
8,0	19,0

The cost penalty for not meeting the desired load can now be calculated using the above figures and by truncating the load demand curve for the country. It is assumed that the load demand curve for ESKOM in 1983[9] can be assumed correct for the whole country. If the load-demand curve is progressively truncated at various distances from the top, the amount of energy lost in the truncated section can be determined. The total time during which the outage occurred can also be determined. Using the outage costs as a function of time, as determined above, and the known lost units of electricity, the total cost of an outage can be evaluated.

It is assumed that for a shortage of capacity, i.e. a forecast which resulted in an installed capacity lower than that which would have been required for the unfettered growth of the economy, the lost units are calculated by the difference between the normal load-demand curve and the truncated curve. If, moreover, the calculations are carried out on a normalized load-demand curve, then the results can be used for predicting future outage costs.

The results of such a calculation procedure are shown below using the 1980 Rand as a basis and expressing the results for the year in which the maximum demand for the whole country rose to 20000 MW (approximately in 1986). The GDP was then R61 334 M (1980 values). The results have been expressed in terms of a percentage shortage in the forecast for the maximum demand and the resulting cost and its value expressed as a percentage of the GDP.

Table 7: Annual cost of various levels of capacity shortage in South Africa

Shortage as a %age of the maximum demand	Yearly cost of outage R Million (1980)	%age of GDP
1	640	1,0
2	2 330	3,8
3	10 260	16,7
4	17 990	29,0

As discussed above, this would be an extreme case and strictly only applicable to a short duration outage, although in the Table above the calculations have been made on the basis of a regular daily shortage. The analysis will now be repeated using the Telson criteria of the losses in salary and wages, and then using the criteria that the outage loss is reflected in a loss in the total output from the country, i.e. a proportional loss in the GDP.

In this latter calculation it will be argued that it is possible to use the value of the country's energy intensity ratio, ie. the ratio of energy used per unit of GDP, and the number of units of electricity which could not be provided during the outage to determine the financial effect of an outage. During 1980 the energy intensity for South Africa was 7 kWh per Rand of GDP. This, however, is for total energy usage. It is reasonable to assume that with an electrical outage all industrial activity would cease since the use of other energy forms is almost always linked to the use of electricity. Thus an establishment operating coal-fired boilers relies on electricity for fans, stokers, etc. If this is considered, then the energy intensity for this calculation comes out at 1,8 kW per unit of GDP.

The Table below summarizes the cost of electrical outages of the type caused by miscalculation of load growth and are presented in terms of the percentage of maximum demand by which the installed capacity is below the required demand, i.e. the error in the assessment of the forecast maximum demand. The calculation has been made on the basis of the year in which the maximum demand reaches 20 000 MW. Once again the monetary values are based on the 1980 Rand.

Table 8: South Africa. Financial penalty per year of a loss of electrical capacity

Loss of capacity as a %age of the maximum demand	Financial penalty in terms of Rand Million (1980 value)	
	Lower limit (wages & salaries)	Upper limit (effect on GDP)
1,0	19	54
2,0	56	157
2,5	89	249
3,0	129	362
3,5	171	480

In the case of South Africa at present, and in the medium term, manufacturing capacity will remain idle during an outage and its cost must be included in the outage cost. It is therefore considered that the upper bound, i.e. the cost of lost GDP, is the more applicable for the financial analysis.

The calculation is based on a maximum demand of 20 000 MW, therefore the 1% shortage represents a 200 MW shortage on the system.

The cost of erring on the conservative side and supplying more than sufficient plant is the yearly capital cost of the excess generating plant installed. Using again 1980 values and the cost of generating plant from the de Villiers Report, then the cost of the excess plant at an annual charge of, say, 15% is as given below.

Table 9: Cost of having excess electrical plant on the grid - South Africa

Excess plant as a percentage of maximum demand	Yearly cost of surplus R Million (1980)	%age of GDP
1	14	0,02
2	28	0,05
3	42	0,07

For ease of comparison the cost of surplus capacity and the cost of a shortage of capacity is given in the next Table where the outage or shortage capacity is based on the GDP value, i.e. the upper limit in the Table above. The values have also been converted to a percentage of the GDP.

Table 10: Summary of yearly cost of shortage or excess of plant on the electrical grid

Shortage or surplus plant as a % of max demand	Yearly cost of shortage or excess			
	Rand Million		%age of GDP	
	Shortage	Surplus	Shortage	Surplus
1	54	14	0,09	0,02
2	157	28	0,26	0,05
3	362	42	0,59	0,07
4	480	56	0,78	0,09

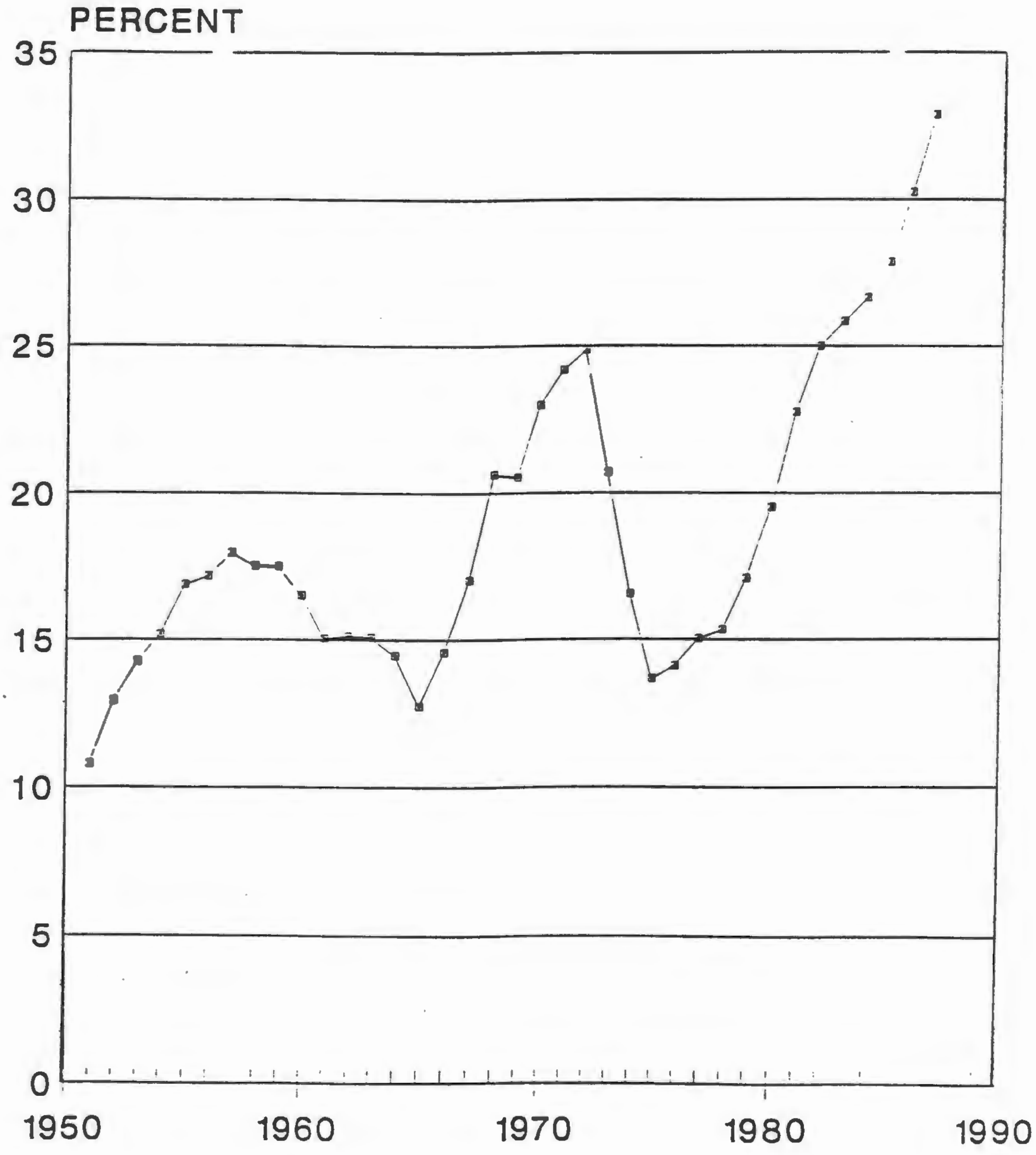
This calculation demonstrates the importance of correct forecasting since the financial effects of being wrong, in either direction, are large. It also demonstrates the vital role of electricity in the economic activity of the country. The cost of providing insufficient capacity is the resultant decrease in the productive output of the country. It is apparent that it is preferable to err on the surplus side of the forecast since excess capacity will have an economic effect until the load growth meets the required demand. However, a decrease in the economic activity takes many years to recover, as the picture of the growth of economic activity after the war years will testify.

3.4 RESERVE CAPACITY

The tendency in electrical utilities is to provide sufficient reserve capacity so that black-outs never occur. That black-outs and brown-outs still occur is due to normally unforeseeable catastrophic failures which take place in spite of adequate spare capacity and are more often the result of technical failure in the distribution system than a lack of generating equipment. This is also true of other countries. Telson[2] reports that a United States Federal Power Commission showed that "..... almost all of the incidents reported over the past few years were due to distribution system, rather than generation system, failure". However, in South Africa recent reasons for capacity shortages have been the poor availability of new large units on the system and the longer than anticipated teething problems of large power units. This is illustrated in Figure 15 which shows the changing percentage of reserve capacity from 1950 to 1984. From a low base of 15% reserve capacity it has now climbed to 23%.

Telson quotes USA experience (in 1968) of a reliability of 99,98%. The equivalent figures for the next highest countries, France and the United Kingdom, were 99,93% and 99,8% respectively. This approximates to a reserve capacity of 28%[10]. Telson maintains that this level of reliability is inordinately high and a reduction would lead to significant financial savings. However this cost saving spread over all the consumers is relatively invisible, whilst the power interruptions are highly visible.

FIGURE 15. RESERVE CAPACITY ON THE ESKOM SYSTEM AS A PERCENTAGE OF INSTALLED CAPACITY (3-PT MOVING AVERAGE)



In part the decrease in the availability of units on the South African grid system, and in other countries as well, has been due to the rapid increase in set size and the inability of research and development to keep up with the technical problems in moving to larger units.

The increase in set size is illustrated in Figure 16 which shows the growth in size from 1935 onwards and indicates that during the period 1960 to 1980 the growth in set size was exponential with an increase of 12% per annum. This growth rate has decreased in recent years due to poor plant availability and the coincidental decrease of energy growth rates world-wide because of worsening economic conditions. This decrease in growth rate has resulted in a decrease in the need to increase set size by turbine and boiler manufacturers.

The question remains as to the required amount of reserve on a system. Other countries have been through the same learning process in determining the optimal reserve capacity. The similarity between the reserve capacities on the ESKOM system and in the United Kingdom's CEGB is illustrated in Figure 17.

ESKOM has consistently had a lower reserve capacity compared with the CEGB. From a high reserve of over 45% of installed capacity in 1929 the CEGB reserve dropped and during the period 1955 to 1970 the amount of reserve was the same on the two systems. During the next 12 years, until 1983, ESKOM had a lower reserve than the CEGB. From 1983 the two systems again show an identical reserves. Whilst it is difficult to compare the need for reserve capacity on two different systems, it does appear that both systems required large reserve capacities at periods when the availability of new large units was poor. In recent times the reserve capacity has been dictated more by a poor correlation between forecasted and actual demand, rather than because of unit operating problems.

FIGURE 16. GROWTH IN TURBO-GENERATOR UNIT SIZE ON THE ESKOM GRID

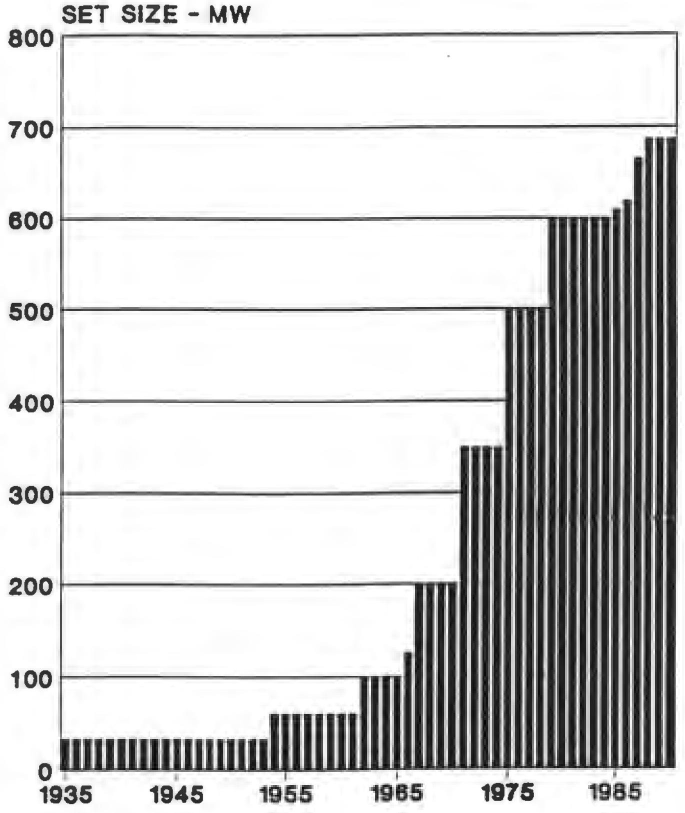
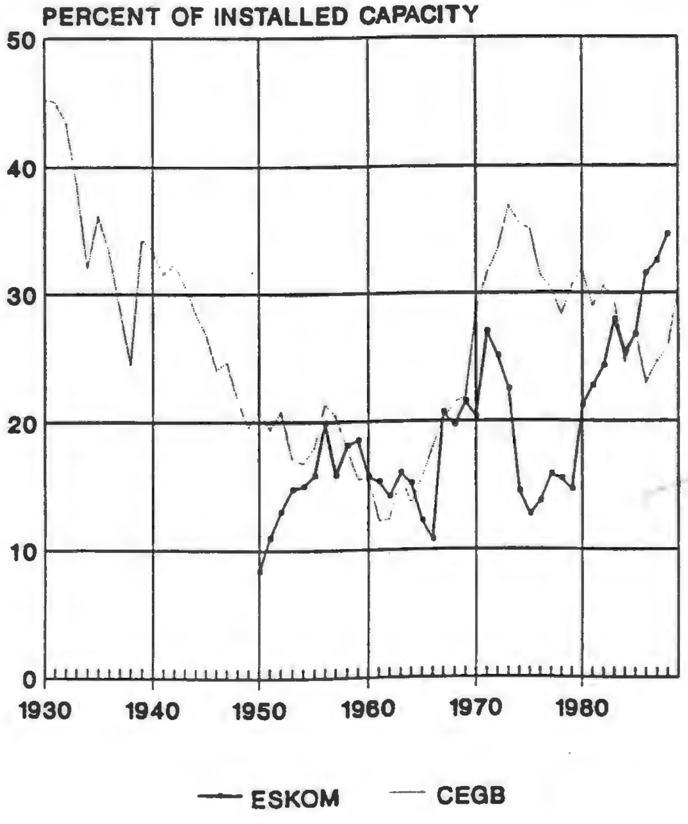


FIGURE 17. RESERVE CAPACITY ON THE ESKOM AND CEGB SYSTEMS



CHAPTER 4

ELECTRICITY PRICES

4.1 INTRODUCTION

Electricity, like any other commodity, obeys the traditional supply and demand laws of economics. In any assessment of the role of electricity it is therefore important to analyze the effect of price on the demand for electricity and its effect on the national economy.

The price of electricity is made up of two components - the cost of capital employed in its production, and the operating cost, made up mainly of fuel costs, water cost, and the cost of maintenance.

In the past the pressure on increasing turbine and boiler sizes has been due to the economies of scale possible with increasing blocks of power introduced into the system. At the same time as unit sizes were being increased there was a world-wide requirement for increasing the efficiency of these units in order to decrease the operating cost. The pressure on reducing operating costs was particularly high in Europe due to steeply rising coal costs. It was therefore profitable to increase power station efficiencies, even at the cost of an increased capital cost. Thus "reheat", with its attendant capital cost increase, was introduced into Europe, whilst in South Africa and in Australia, where coal was relatively cheap, its introduction was delayed by some years. The peculiar situation then arose where South Africa and Australia were ordering non-reheat stations of a size which was larger than any non-reheat stations which had been built in Europe. Thus ESKOM's Camden Power Station and the Hazelwood Power Station in Australia had the dubious distinction of having 200 MW turbine units which were the largest non-reheat sets in the world. As non-standard sets they suffered from commissioning problems which caused their availability to be very low.

The increase in efficiency required by utilities was achieved by going to higher pressures and by introducing reheat and increasing stages of feed heating.

FIGUERE 18. EFFECT OF BOILER PRESSURE ON POWER STATION EFFICIENCY - ESKOM.

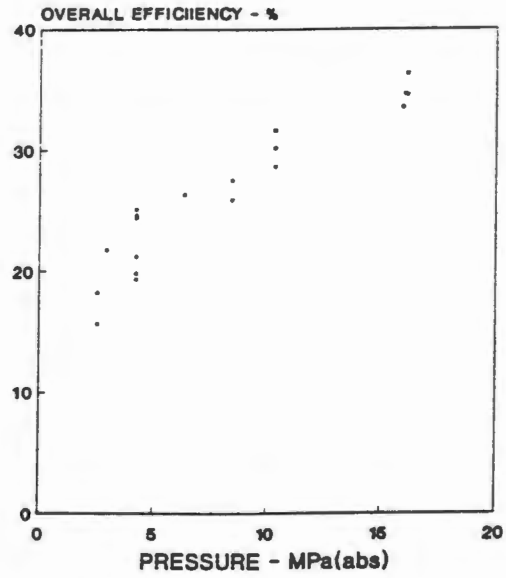


FIGURE 19. ELECTRICITY PRICES (CURRENT) ON THE ESKOM AND CEGB SYSTEMS.

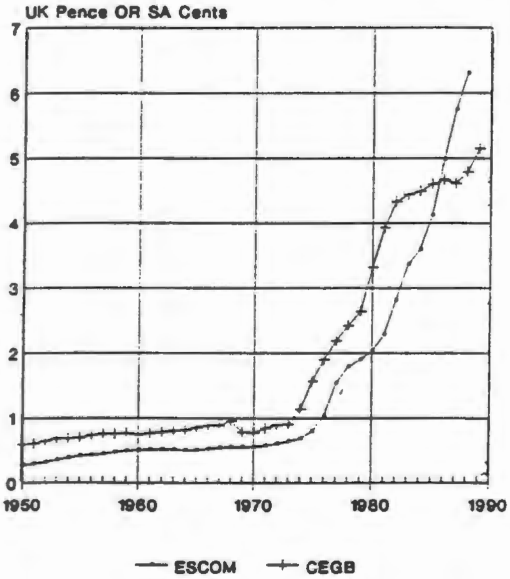
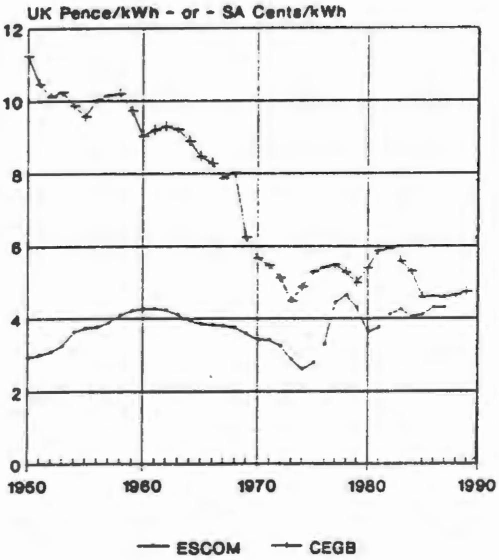


FIGURE 20. ELECTRICITY PRICES (REAL) ON THE ESKOM AND CEGB SYSTEMS. RELATIVE TO 1985



The effect of these measures is one of diminishing returns and this can be seen in the effect of pressure on efficiency for ESKOM units shown in Figure 18. It is doubtful therefore that any further significant decreases in cost could be expected because of increasing efficiencies, except perhaps by the use of combined cycles.

4.2 PRICES OF ELECTRICITY

It is to be expected that as unit sizes increase in power stations the price of electricity will decrease. Similarly, as station efficiencies increase the operating cost will decrease. This decrease in price will be offset by increasing capital cost due to measures taken to increase efficiency. In addition, fuel cost, in real terms, will increase due to the progressive mining of more difficult coal seams.

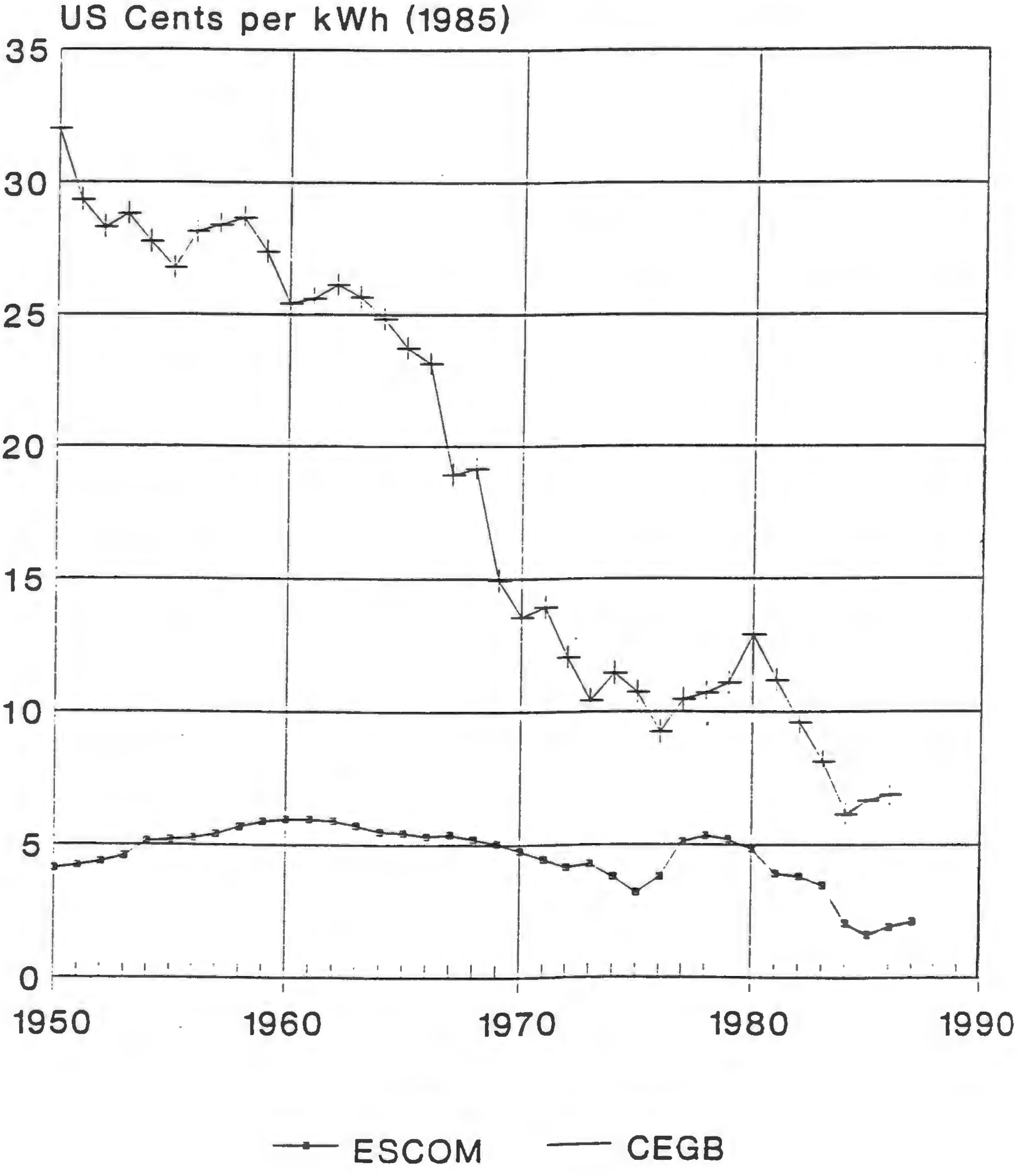
The effect of these factors is illustrated in Figures 19 and 20. Figure 19 shows the price of electricity in the ESKOM and in the CEGB systems. Figure 20 shows the same prices but expressed in real terms using the GDP deflator and 1975 as the base year.

It is seen that there is a great similarity between the two systems in terms of the current prices (Figure 19). There is, in both cases, a steep rise in price from 1973 onwards due to the rapidly escalating inflation rate.

When deflated (Figure 20), the prices show in general a steady price decrease due to the factors enumerated above. The ESKOM curve shows an increase in price up to 1950 but a decline thereafter. The ESKOM system was not experiencing any significant growth in unit size in the early years, the economies of scale only becoming apparent from the time of construction of Taaibos and Highveld Power Stations when the first 60 MW sets were built and rapidly followed by the 100 MW sets. The CEGB price shows a consistent downward trend. Over the last ten years the two systems show a great similarity, even to the extent that minor variations in price are mirrored in the two utilities, with the ESKOM price showing a lag of one year relative to the CEGB price. Figure 21 shows the two prices expressed in US$ terms relative to 1985.

With a flattening out of both the set-size curve (Figure 16) and the efficiency curve (Figure 18) it is apparent that the price decreases of previous years will not be

FIGURE 21. ESKOM & CEGB PRICES
US cents - RELATIVE TO 1985 $



continued and a rise in the real price of electricity is to be expected until some technical development takes place to decrease the capital cost of power plant or some means can be found for increasing the efficiency of power stations. The capital cost of plant could be reduced in the future by the adoption of the fluidized-bed combustion process. Efficiencies could also be increased if the combined-cycle concept were adopted. Both of these are possible together in the fluidized-bed combined-cycle concept using a fluidized bed for gasification followed by a gas-turbine and waste-heat boiler with its own steam turbine. With the present rate of development in this technology and the lack of incentive at present for any increase in this slow rate of development, it is not anticipated that there will be any significant penetration of this technology into the ESKOM system until the end of the century. Therefore in the foreseeable future it is unlikely that any new technologies will make an impact on the price of ESKOM electricity.

4.3 PRICE ELASTICITIES

Since electricity is a commodity in an economic system, it is subject to the normal economic laws. The main one of interest is the relationship between price and demand where as price increases the demand will decrease. The slope of the demand-price curve multiplied by the ratio of price over demand is known as the price elasticity. Expressed mathematically this appears as:

$$a = (dQ/Q) / (dP/P)$$

where a is the price elasticity, P is price, Q is electricity demand, and dQ and dP are the changes in P and Q respectively. As the price of electricity increases, as discussed above, so the demand will decrease.

The above expression, if expressed in percentage terms, can be expressed as the ratio of the percentage change in electricity demand to the percentage change in the price. However, the change in the demand for electricity is made up of two portions, the first being the effect of price as described above and the second being the effect of national income (GDP) as described in Chapter 1. The effect of these two parameters is usually separated econometrically. In the general form the relation between energy, price, and income can be expressed by an equation of the form:

$$E = f(Q,P)$$

where E is the energy demand in the year under consideration, Q is the GDP in that year and P is the price for Energy. Each of the two terms, Q and P, have an elasticity associated with them and it is the unraveling of their simultaneous effect that gives energy economists problems. These two elasticities can be determined only if the form of the equation for energy in the above equation is fully known. It is also complicated by the fact that there are other parameters that might be of importance which are not included in this simplified equation. Thus for instance the demand for energy in a cold country is influenced, in a particular year, by the average temperature during the year or during the winter.

Price elasticities have been reported for various countries, but there is a large variation between the countries and even for the same country at different times. For instance, Beenstock and Willcocks[11] show that the price elasticity in industrialized countries has been calculated at values between -0,098 and -0,66. Common[12] calculates the price elasticity for energy in the UK for the period 1968 to 1978. Depending on the assumptions he makes concerning the required parameters in his analysis, he obtains elasticities from -0,199 to -0,277. The price elasticity for the South African electricity demand has been calculated by Pouris[13] at -0,097 for the short run elasticity and -1,01 for the long run elasticity.

This spread in the quoted elasticities by various authors has resulted in the assessment by Kouris[14] that there is no "true" elasticity but it depends on the model of the energy-economy adopted and that even if there were a "true" elasticity it would be a quantity which would change with time. It would therefore be wrong to assume that a calculated elasticity could be used to determine the energy requirements for the future. What is more important according to Kouris is the pattern of change in the elasticity and its use for extrapolating the elasticity in a sensible fashion to the future.

In the South African context the price elasticity has possibly less meaning than in, say, the UK because of the lack of substitution potential. The price-demand relationship rests on the premise that if the price of one commodity goes up relative to other goods, then people will purchase less of that commodity and more of another cheaper one. This involves the concept of substitution. If bread becomes more expensive people will change over to maize or potatoes. In the UK in recent years there has been a large move from electricity to gas. This move has been caused by the rapidly increasing amounts of gas available and by the artificially low price for gas. Thus a significant proportion of the final energy demand has moved from expensive electricity to cheap gas. This move has been made possible because of the large amount of heating used in the final demand sectors in the UK.

By comparison, in South Africa, because of the smaller proportion of energy used in the domestic sector, and because of a more equitable climate, the possibility for substitution by gas over electricity is reduced. Moreover most of the energy demand occurs in the Witwatersrand-Vereeniging area were natural gas is not available and gas is supplied from Sasol at prices compatible with substitute energy costs. If there is little scope for energy type substitution then the only effect of price on energy demand is through an overall decrease of energy or by a more efficient utilization of energy.

In the electrical utilizing sectors there is little scope for doing with less electricity without adversely affecting output. There is scope for more efficient utilization of energy and this will be discussed further below. However, the apparent price elasticity for electricity has more to do with the perceived price for electricity rather than a more aware study of real price rises. In most industrial sectors energy is only a small proportion of production cost and is by far the least contentious of the problems facing industry. It has been found, for instance, that it is difficult to encourage managers to consider energy conservation schemes because of the "cheapness" of electricity. Whilst there was concern about the use of petroleum products during the 1970's, most of the possible conversions to other forms of fuel have already been carried out.

It must be therefore considered that the demand for electricity, where much of it is used for motive power, is relatively price-inelastic, at least in the range of electricity prices in the past and in the foreseeable future. The apparent price elasticity reported has therefore possibly more to do with the effect of exogenous forces which affect electricity demand and price in the same direction. Thus a high level of inflation would decrease economic activity as well as pushing up the price in current terms. Secondly, there is a natural increase in electricity price due to the decreasing effect of economies of scale as discussed above. If there is no potential energy substitution, industry and commerce have to absorb the increase at the expense of expenditure in other areas. Usually the first area of financial saving is in expansion, leading to a brake on future economic development and to a decrease, or a slowing down, in energy demand.

4.4 TARIFFS

Electricity is supplied at a price dictated by a tariff, with various tariffs being applicable to, for instance, the domestic consumer, the small industrial consumer, the large industrial consumer, etc. The simplest tariff is that for the domestic consumer which is based only on the energy used. This tariff is an acceptance of the fact that it would be impossible to apply, economically, a more complex tariff to a large number of small and unsophisticated consumers. The other tariffs contain a maximum demand component and an energy-related component. The purpose of such a tariff is to recover, in an equitable fashion, the capital cost of operating a generating and distribution system and the operating cost of the system, i.e. fuel, water, maintenance, etc. The relative components of such a tariff should reflect the importance of each of the components to the total delivered cost of electricity.

In the past in South Africa, and in particular in ESKOM, the tariff has included a component for the cost of delivering power to the consumer. Thus a consumer far from a power station was charged more than a consumer near a power station. This has recently been changed, because of consumer pressure, to a more uniform tariff though still maintaining a small geographical component. This move has much to recommend it since, with the general expansion of the grid system, the geographical differences are decreasing and since it was difficult to accurately estimate a true cost to each consumer. This has led in the past to certain inconsistencies where consumers close to each other could be charged different rates depending on the route by which electricity was delivered to them.

Although the uniform tariff is easier to apply it does have the effect that it eliminates the need for industry, especially an energy-intensive industry, to plan its geographical locality in such a way as to minimize its exogenous costs. Thus an industry should so position itself that it minimizes its total cost of energy, water, manpower, transport of raw material, and transport of finished goods to market. In so doing it also minimizes cost to the country and thus maximizes industrial productivity. This negative aspect of a uniform tariff is however of limited effect since most of the industrial activity in the country is centered in the vicinity of the coal fields and thus of the area of main power generation.

4.5 CONCLUSION

With the relatively low cost of electricity in South Africa and its predominant role for motive power in industry, it is considered that for forecasting purposes the short to medium term price of electricity may be considered to be inelastic. This lack of elasticity is further reinforced by the relative lack of potential for energy substitution. The major portion of electricity demand is in the industrial sector where substitution is difficult. In the domestic sector home heating, the area where gas substitution has made a significant impact in the UK, is only a small proportion of demand and no cheap gas substitute is available.

In the short to medium term new developments in power generation, such as combined cycles, will not make a significant contribution towards changes in power station efficiency or capital cost. However, rapidly rising labour costs and progressively worse coal-mining conditions will inevitably push up the operating cost of electricity generation in real terms. It is therefore likely that the price of electricity in South Africa will increase in the future.

CHAPTER 5

THE ELECTRICITY INDUSTRY AS PART OF THE ECONOMY

5.1 INTRODUCTION

The electricity-generating industry can be considered as a component of the economic activity of the country and as such creates job opportunities and contributes to the growth in the GDP. The industry here includes both the power plant and associated head office activities of the electricity producers, as well as the contribution of the contracting industry and the effect of construction on all levels of the economy. Thus the construction of a unit of generating capacity requires economic activity by the main contractors to the generating authority, as well as that of the subcontractors, sub-subcontractors, etc. It has a domino effect all the way down to activities at the iron-ore mining companies, steel producing companies, etc.

The effect of growth in electricity demand on the growth of the economy can therefore be handled under two headings: construction and generation.

5.2 CONSTRUCTION

It is difficult to analyze accurately the effect of an increase in generating and distributing capacity at the subcontractor, sub-subcontractor, etc. level with the present scarcity of information. It is possible however to look at the requirements for resources, including capital, and determine the effect of a programme of expansion in power capability in terms of gross effects on the country's economy.

The cost of constructing power stations can be analysed using the information in the de Villiers[15] report. Taking the figures for the construction costs of Tutuka, Lethabo, and Matimba, and using the power station expenditure pattern with time as shown in the de Villiers report, then if the costs are deflated to 1980 prices, the capital cost per kW of sent-out capacity is as shown in the Table below.

Table 11: Capital cost of thermal power plant in South Africa (1980 prices)

Power Station	Rand per kW (1980 Prices)
Tutuka	785
Lethabo	872
Matimba	864
Average	840

The above figures refer to nominal 600 MW units at stations with 4 or 6 units. It is doubtful whether before the end of the century sets would be installed with sizes greater than, say, 800 MW. Therefore the figures quoted above can be assumed to be representative of any future developments before the end of the century.

Using this figure of R 840 per MW of installed capacity, the cost implications of an expansion programme may be calculated as follows. If it is assumed that in 1986 the maximum demand increased at 5% of the previous year's maximum demand, then this would mean an increase of 893 MW. This would result in an expenditure, in terms of 1980 prices, of R750 Million. This cost must be increased by two factors. The first one concerns the ratio of installed capacity to sent-out capacity of a power station which, using ESKOM statistics, is typically 1,07. The second factor relates to the need for installing more power capacity than required by local demand considerations to allow reserve capacity on the system to cater for regular and forced maintenance. The reserve capacity is typically 25% giving a factor of 1,25. Therefore the combined factor would be 1,34 resulting in an expenditure in 1986 (but in 1980 prices) of R1005 Million.

In 1985 the ratio of interest paid by ESKOM on generation relative to interest paid on distribution was 28,6:12,7[16]. If it is assumed that the current expenditure on generation and distribution is at the same ratio as the historical average, then the total expenditure per MW of new capacity would be R 1450 Million for the assumed growth rate of 5% p.a. This amount represents 2,5% of the Gross National Product.

If the effect of the construction programme is spread through the economy at the same average as exists in the national economy, then the result of a construction programme in the electricity industry is as follows.

Table 12: Result of construction programme

Growth in electricity demand (assumed)	5%
Contribution to GDP	2,5%
Employment (number of jobs)	217 250
Salaries/wages earned (1980 prices)	R1040 Million

5.3 OPERATION

Bringing into service new generating and distribution capacity also creates job opportunities directly within the generation authority for operators, maintenance, and administrative personnel in the power plant and in the distribution system. The number of personnel in service in ESKOM in 1986 was 60 800, which amounted to 0,518 per million kWh sold. Assuming that the system load factor remains constant, then the 5% growth rate referred to above would result in an increase in staff by 3040. However, the number of staff per kWh sent out has been decreasing steadily during the last five years and it is likely that the figure could decrease from 0,518 persons per kWh sold to some 0,40 within the next decade. Therefore the job creation in the future, in percentage terms, is likely to be less than that evaluated above.

The wages and salaries of the personnel in the generation and distribution sectors averaged out in 1986 at R11 762 per annum[17]. To this must be added the overhead costs of staff and the combined cost of staff is R17 574. The total salary and wages for the incremental staff required to operate the 5% increase in generating capacity assumed above therefore becomes R53,4 Million or 0,05% of GDP.

5.4 MINING

Since electricity from coal-fired power stations provides 90% of electricity generation in the country the role of the coal mining activity on the economy must also be considered. The effect of increasing electricity production is to increase coal production which requires manpower, stores, etc, but also requires the construction of new coal producing capacity. The effect of these two components must be combined because of inadequate information at the disaggregated level, and the cost of the additional coal produced can be assumed to contain the cost component on a yearly basis of the new mining capacity.

In 1986 the average cost of coal to ESKOM was R14,87 per ton. In terms of 1980 prices this translates to R7,7 per ton. The amount of coal used at the newer power stations was 0,46 kg per kWh of sent-out capacity which for the 5% growth rate assumed above would be 2,8 million tons per year. In 1980 prices this would mean an annual expenditure of R22 Million or 0,04% of GDP. The S.A. Statistics[18] for 1981, the latest figure available, give a productivity index for South African coal mines of 1 296 tons per man-year. This includes both labour intensive bord-and-pillar mining and less labour intensive open-cast mining. However this average figure may be used for comparative purposes since future mines will eventually have to revert to underground mining.

Using a figure of 1296 tons per man-year for mine productivity, the 5% increase in electricity generation assumed above would result in the creation of 2 160 jobs.

5.5 RESOURCE REQUIREMENTS

The power station construction programme would require the provision of various commodities, the main ones being steel and concrete. The requirements for these commodities for a 5% increase in generating capacity at the 1985 levels (and based on 600 MW units) would be:

Turbine steel	4 110 tons
Boiler steel	15 360 tons
Structural/reinforced steel	9 560 tons
Total steel	29 030 tons
Concrete	57 150 cubic metres

The comparative figures for a nuclear station (but based on 1000 MW units) would be:

Reactor steel (imported)	714 tons
Turbine steel (local)	1 662 tons
Turbine steel (imported)	1 774 tons
Structural steel	1 340 tons
Reinforcing steel	6 700 tons
	12 190 tons

5.6 SUMMARY

The South African electricity generating industry contributes to the national economy not only by providing the energy requirements for the economy to function but also by providing job opportunities. It is shown that a 5% increase in electrical generation, at 1986 levels, would create 222 450 job opportunities for the country as a whole and the expansion would represent 2,6% of the GDP.

In addition, the normal operation of the existing power plant and distribution facilities represents a 0,6% contribution to the GDP.

CHAPTER 6

ENERGY INTENSITIES

6.1 INTRODUCTION

The energy consumption in a country is a function of the wealth of the country, as discussed in Chapter 1, but it is also a function of the mix of the country's economy since the various sectors of the economy use different amounts of energy to produce a unit amount of GDP. Thus as the relationship changes so also will the total energy consumption, even if the GDP were to remain fixed. This has already been illustrated in Figure 3 which shows that the energy consumption per unit of GDP, the energy intensity, has changed significantly over the last fifty or sixty years.

The energy intensity for South Africa has been calculated for the period 1971 to 1988, the only period for which there is sufficient disaggregated information, and is shown in Figure 22 for the agriculture, mining, construction, transport, and commerce sectors, whilst Figure 23 shows the energy intensity of the manufacturing sector.

It is obvious that a change in the GDP sector from agriculture to manufacturing will have a large effect on the total energy consumption for a fixed economic activity. The changes of the energy intensity for a given sector with time could be due to one of two factors. Either the efficiency of energy use is changing or the real cost of the sector is changing. Not enough is known about the South African energy scene at the moment to allow a better analysis or understanding of the underlying forces affecting energy usage in the future.

6.2 INTERNATIONAL COMPARISON

A comparison has been made of the relative energy intensities for a number of countries as shown in Table 13. It will be seen from this Table that South Africa has a much lower energy consumption per capita - 52 GJ per capita - compared with the range from 100 for Italy to 348 for the USA for the developed countries. The energy per GDP is much higher than that of any of the developed countries considered - 63,2 compared with the range of 35,4 to 73,8 for the selected countries.

FIGURE 22. S.A ENERGY INTENSITIES RELATIVE TO 1985 RAND

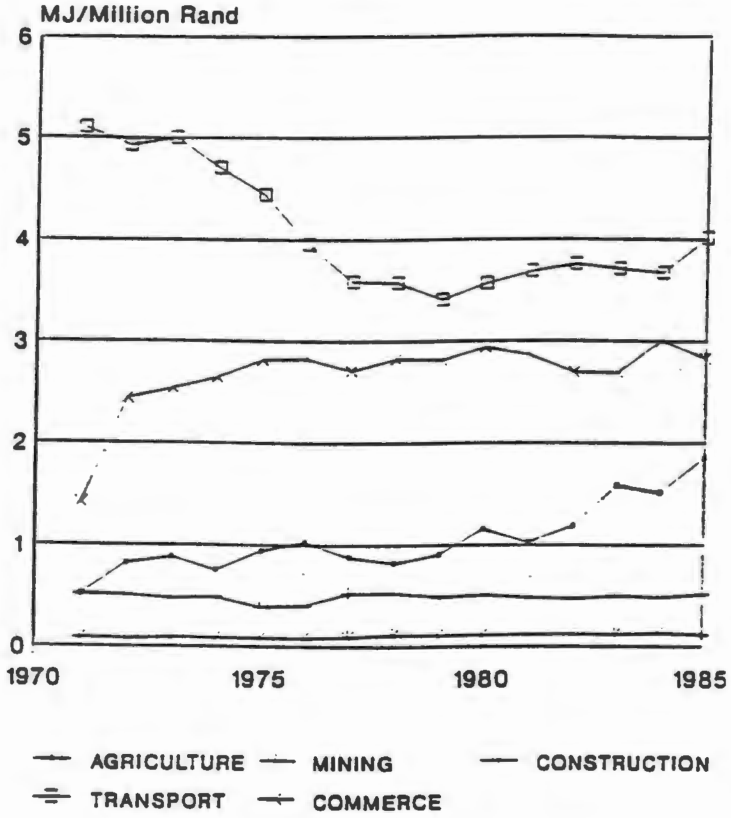
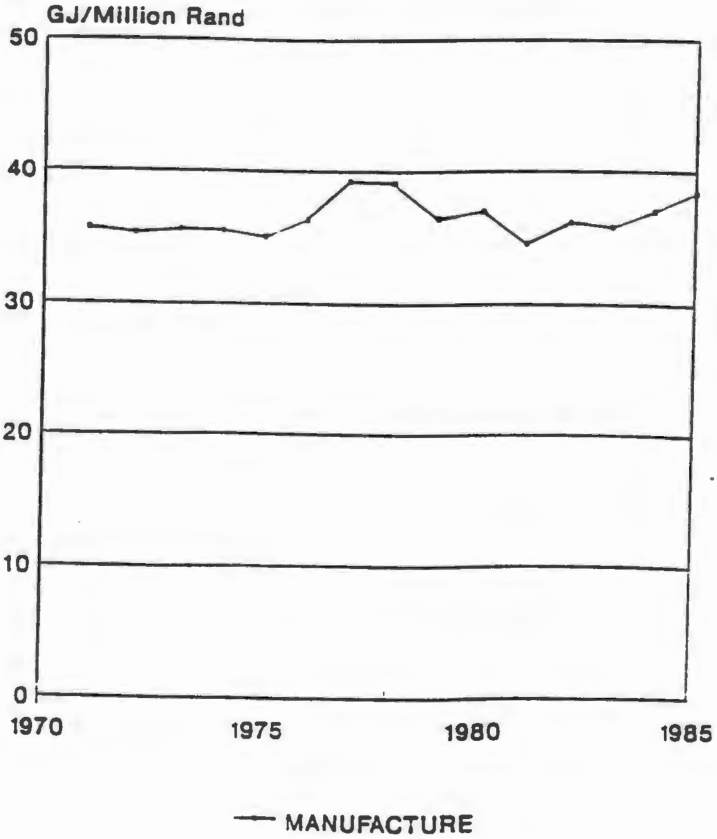


FIGURE 23. S.A ENERGY INTENSITY FOR THE MANUFACTURING SECTOR (1985 RAND)



The comparison with Brazil in the same Table shows however that one cannot easily extrapolate what has happened in the developed countries with what is now happening in developing countries.

Table 13: Relationship between GDP and energy intensities for selected countries (1972)

	GDP/Energy			Energy/GDP-(TJ/Million$)			
	Cap $	GJ/Cap	Total	Indust	Transp	Agr	Dom/ Comm
U.S.A	5643	348	61,7	12,9	13,6	1,1	15,6
France	4168	138	73,8	9,1	4,9	0,5	9,3
F.R.G.	3991	172	42,9	12,5	5,5	0,3	12,6
Italy	2612	100	38,1	11,8	5,7	0,6	9,2
U.K.	3401	159	46,7	13,3	6,0	0,5	11,4
Sweden	5000	221	44,3	11,5	5,0	0,5	14,6
Japan	3423	121	35,4	13,8	4,4	0,3	6,9
S.A.	829	52	63,2	90,7	202	3,4	18,9
Brazil	577	14	24,7	26,1		5,3	

It has been recognised that historically energy intensities increase during periods of rapid growth of heavy industry, followed by a reduction in energy intensity as the economy matures and shifts towards services and high value-added manufacturing processes. Reister[19] has traced the movement of energy intensities for the UK, the USA, and Italy and shows that the peaks for these countries occurred in 1880 for the UK, 1920 for the USA, and 1970 for Italy. Figure 3 shows that the peak occurred in 1950 for South Africa, though the picture is complicated by the increasing trend for energy intensity from 1970 onwards. Brazil is another country which shows the same characteristics and it would be interesting to analyze why such a trend exists.

6.3 CONCLUSION

Changes in energy intensity with time will change the overall energy demand for the country. In general the energy intensity reaches a peak at the end of the heavy industry growth point in the economy. The energy intensity curve in South Africa has also exhibited such a peak, but other forces appear to be causing the energy intensity to increase once again.

In the short term, i.e. over the next ten years, the changes in energy intensity are unlikely to have any great effect on the overall demand picture for energy, but these changes must be considered for any longer term forecasting.

CHAPTER 7

COMPARISON WITH THE USA

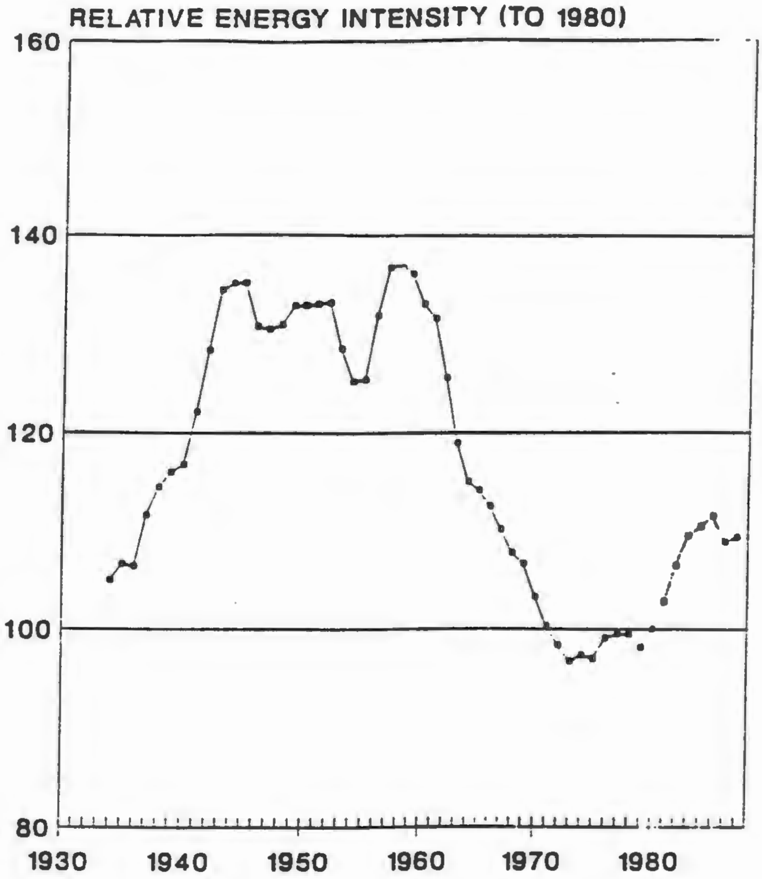
A comparison has already been made with the electricity supply industry in the United Kingdom and with the gross energy-GDP figures for a number of countries in Table 13. There is always the fear when comparing with other countries that the stage of development might be so different in the comparison as to make tit meaningless. It would therefore be of interest to compare the development in South Africa with that of a highly developed country in order to see whether there is any possibility of drawing comparisons. One possible comparison is that with the USA.

Schurr et al[20] have analysed the contribution of electricity to the country's economy in some detail, detail which is presently not possible in South Africa because of the paucity of data. However it is of interest to investigate the trends that have taken place in the USA with trends in South Africa.

Schurr et al make a point that the efficiency of energy usage has been increasing over the years in line with the growing contribution of electricity to the overall energy demand. Whilst this may be true there are too many other variables, both affecting energy use and affecting the economy to be able to draw firm conclusions. In the case of South Africa much more information would be required in the individual sector energy intensities before such an analysis would be possible.

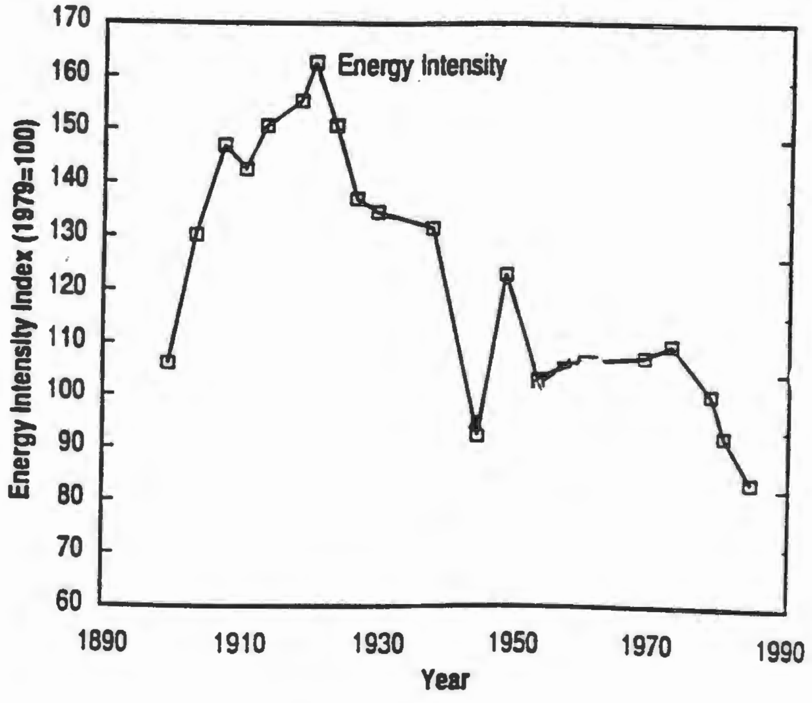
A comparison is however possible between the USA and South Africa in terms of the overall energy intensity against time. Schurr et al give a historic trend of the energy intensity since 1899 to 1985. South Africa's records do not go that far back but if it is assumed that South Africa is some years behind the USA in its pattern of energy utilization then the data that is available may be sufficient. The available data for energy intensity in South Africa has been transformed to a relative value to 1980 and plotted in Figure 24. In this figure there is include the data form Figure 13.1 of Schurr.

FIGURE 24. ENERGY INTENSITY
IN SOUTH AFRICA



SOUTH AFRICA

Figure 13.1 Energy Intensity
Total United States, 1899–1985



UNITED
STATES

NOTE: Energy intensity measured as ratio between total energy input in U.S. and the gross national product (GNP). Data points refer to business cycle peak years, except for final year shown.

It is apparent from Figure 24 that the pattern and event the relative values are similar for the two countries. There is however and off-set of approximately 30 years in the two curves. The USA reached a peak energy intensity in about 1920 and the relative intensity has been decreasing since then. There was a dip in the curve during the World War II days but apart from that energy efficiency has been increasing. In South Africa the peak energy intensity would have occurred in the late 1940's but the war depressed the peak because of shortage of energy. Since then the energy efficiency has been increasing but the trend was reversed in the late 1970's. Whether this is a temporary reversal, as it was in the USA, can not be determined at this point in time since too little data is available. The last few point on the curve seem to indicate that the efficiency is again increasing. A better understanding of the phenomenon would require a comparison of the GDP sectorial change in the two countries.

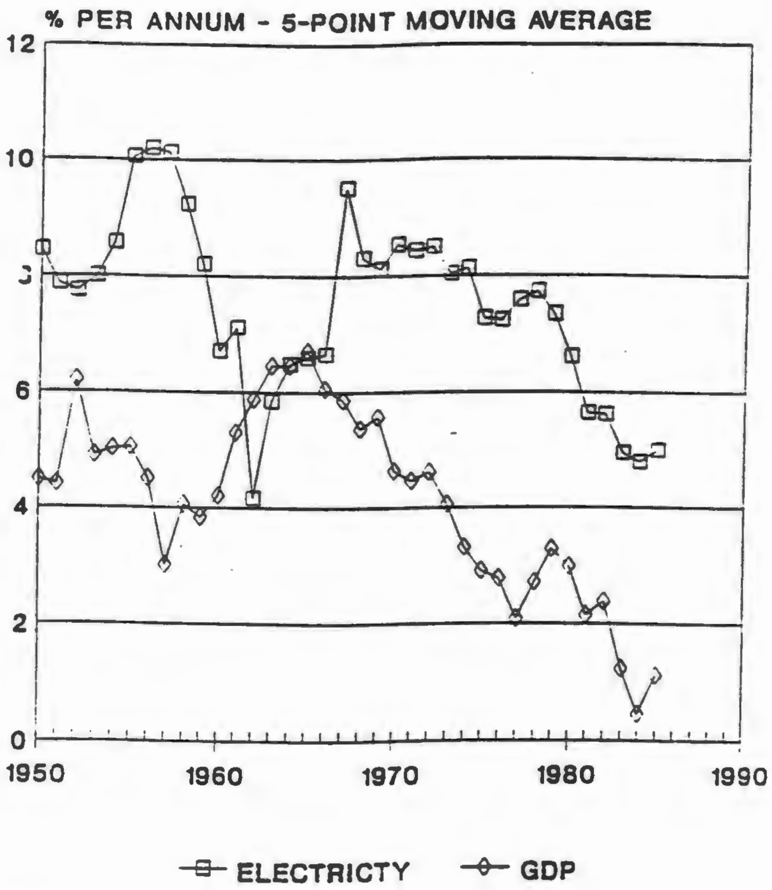
A comparison between the two countries can also be made on the basis of the growth rate in electricity as compared with the growth rate of the economy as a whole. Schurr et al have made this analysis in their figure AI.5 which compares the annual growth rate for electricity and GNP. They have also plotted the ratio between these two growth rates. Again South African data has been used to produce the same comparison. The only difference in the data used for the two countries is that the USA figures are based on the GNP whilst the South African figures are based on GDP. However the small difference between GNP and GDP in the South African context is not expected to make any difference especially since the curve plotted is on the basis of annual growth rate.

Figure 25 shows the similarity in the growth rates for the two countries. The peaks and troughs of the GDP/GNP curves are very similar with possibly a five or six year lag in the South African figures relative to those of the USA. The recent minimum occurred in about 1981 whilst the South African minimum seems to take place in 1984. The electricity growth curves for the two countries are also similar and lag their respective economy curves by a few years. Electricity growth rates for both countries rose to 10% per annum in the mid 1950's and have been decreasing since then, though both countries passed through a local minimum in the late 1950's in the case of the USA and in early 1960's in the case of South Africa.

There is however one significant difference in the curves for the two countries and that relates to the difference in the growth rates of the two components in recent

FIGURE 25. ANNUAL GROWTH RATE OF ELECTRICITY AND GDP IN SOUTH AFRICA

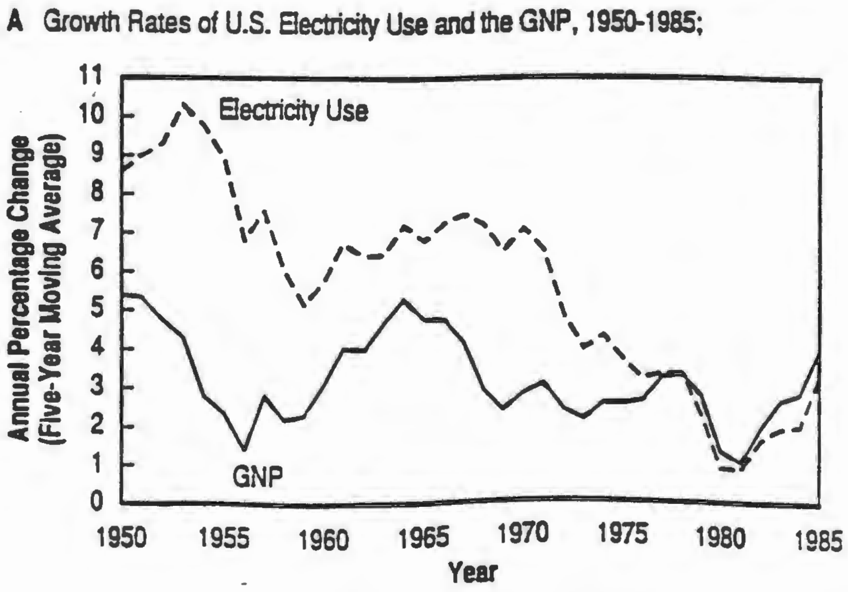
SOUTH AFRICA



129/SAENEC

Figure AL5 (A) Growth Rates of U.S. Electricity Use and the GNP, 1950–1985;

UNITED STATES



times. In the case of the USA the two growth rates have been identical since about 1978. In the case of South Africa the two rates are still very different and there was a difference of 4 percentage points in 1985. This difference seems to indicate that in the USA the approach to the saturation curve for electricity relative to total energy is much nearer than in South Africa which is still far from that point and is most probably only approaching the inflection point on the electricity saturation curve.

Figure 26 is a comparison between the ratio of the annual electricity growth rate over the annual GNP/GDP growth rate. There is a strong similarity between the curves of the two countries until 1970 with the peaks and troughs occurring at approximately the same time. However the South African curve continues to rise after 1970 and reaches a peak in around 1977. The ratio in 1982 in South Africa was 2,4 whilst that for the USA was less than 1. The South African curve has been truncated at 1982 because after that date the ratio goes very high (10) for a year before coming down again. This point is worthy of further investigation but is outside the scope of this report.

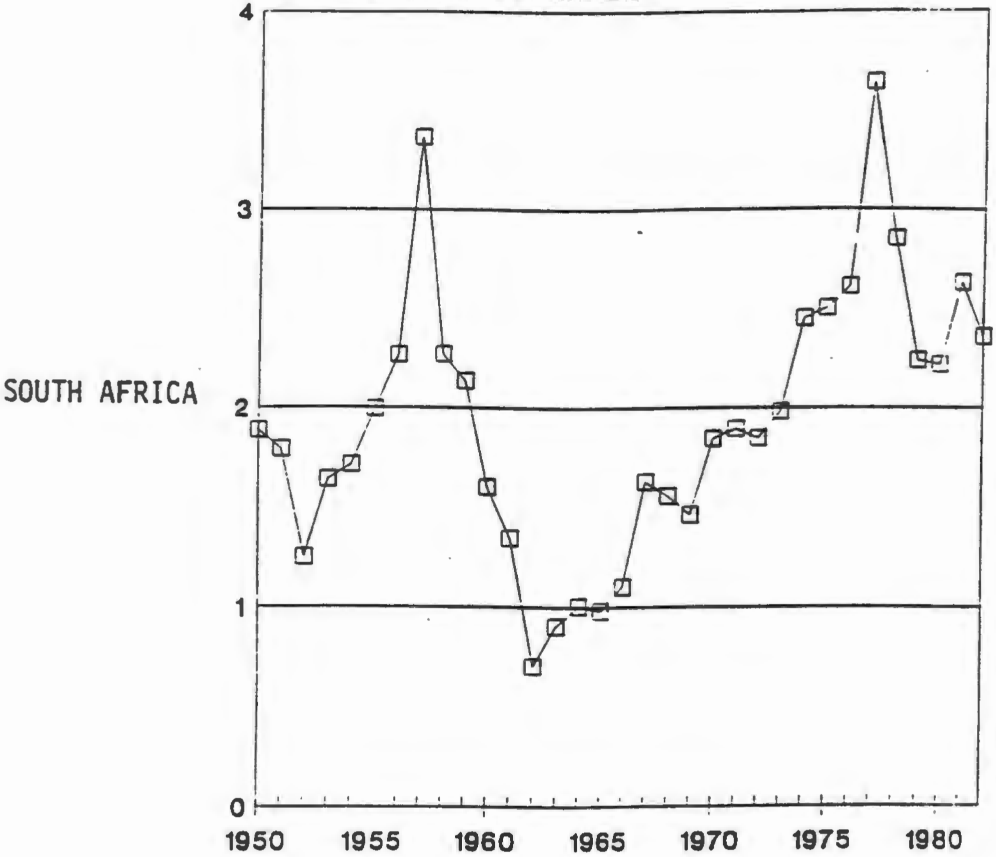
For the USA Schurr et al have divided the economic/technological history into three main groupings:

1899-1920.	A period during which production expanded to increase through-put but reliance was placed on non-electric forms of energy. Electricity was considered a minor adjunct to the use of steam for power.
1920-1948.	During this period the emphasis moved away from increases in production size to achieve greater through-put and went to increases in speed of through-put i.e emphasis on the efficiency of resource utilization.
1948-1985.	The emphasis again changed away from speed of through-put to an increase in flexibility of operation. This has resulted in greater use of electricity.

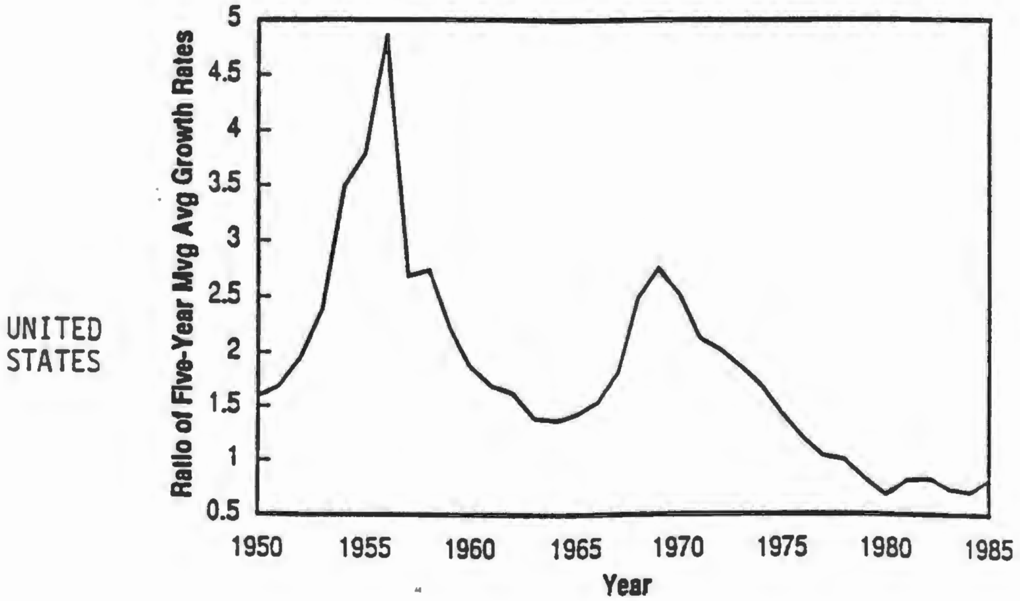
Figures for output growth rate and productivity growth rate in the USA over these periods are given in Schurr et al and show that there is a growing contribution of capital to out-put productivity.

FIGURE 26. RATIO OF ELECTRICTY TO GDP ANNUAL GROWTH RATE

5-POINT MOVING AVERAGE



B Ratio of the Growth Rates, 1950-1985



SOURCES: Based on data from Edison Electric Institute, *Statistical Yearbook of the Electric Utility Industry* (Washington, D.C.: EEI, various issues); U.S. Bureau of Economic Analysis, *The National Income and Product Accounts of the United States, Statistical Tables,* Supplement to *Survey of Current Business* (Washington, D.C.: GPO, various issues).

In South Africa the comparable time periods would be the early agricultural period which lasted until the end of the 19th Century. This was followed by a capital intensive period which represented the period of growth in the mining industry and the setting up of the industrial infra-structure such as steel and chemical plant. This period coincided with the rapid increase in electrical generating capacity and the production of electricity which was so cheap that it was a minor factor in the cost of most industries and therefore there was no pressure on using energy efficiently. This period is only now giving way to the next period identified by Schurr, a period which will be characterized by the growing importance of capital utilization and a realization that energy costs will have a significant effect on overall production costs.

CHAPTER 8

8.1 INTRODUCTION

Various research workers have shown that there is a relationship between the economic development of a country and its energy consumption. Whilst this is true in a general sense, there are enough departures from the mean international economics-energy correlation to show that the relationship has to be derived for each country independently.

It is obvious that this energy-economy relationship also changes with the changes occurring in the sectorial mix of the country's wealth as expressed, for example, in terms of gross domestic product mix. One way of expressing, and observing, the changes in energy demand with changes in economy is to observe the changes in the energy intensity - the value of the energy requirement per unit of gross domestic product. Typically, the energy intensity firstly increases as a country moves from an agrarian economy to one based on primary industry, thereafter falling as primary industry is replaced by secondary industry.

If the total secondary energy requirement for a country could be evaluated using energy intensity values, then the amount of electricity could be evaluated from a knowledge of the rrelationship between electricity and other energy in the secondary energy sector.

This report evaluates these quantities in order to determine the medium-term increase in the use of electricity. The report also investigates the economic effects of the situation where incorrect planning results in the inability of the electricity utility to supply the electricity required by industry to satisfy its production demand.

8.2 ELECTRICITY-ECONOMICS RELATIONSHIP

8.2.1 Energy-economics:

Figure 3 in Chapter 1 shows that in South Africa the energy intensity peaked during the 1950's and declined during the next 15 years. During the 1980's the value increased due, most probably, to the effect of international sanctions on the economy of the country. It is likely however that the energy intensity will continue its downward movement once the country gets back to the pre-sanctions condition.

The decrease in the energy intensity has been approximately 10% over a fifteen-year period or approximately 2,2% per annum. If the same rate of change occurs over the period 1990 to 2000, then the energy intensity at the end of the century will be 12 TJ/Rand at 1985 prices.

The relative shape of the energy intensity curve for South Africa is very similar to that for a developed country. For instance, Figure 24 shows that the shape is similar to that for the USA. However, the peak of the South African curve occurred in the 1950's compared with a peak in about 1920 for the USA. The USA also showed a temporary upward trend following the war years, indicating that local short-term disruptions to the economy can, for a short term, disrupt the general downward trend of the energy intensity index.

8.2.2 Electricity-energy relationship:

The percentage of electricity in the final total energy demand sector has been rising steadily over the last 50 years. By 1988 electricity had risen to 26% of total energy, and it appears that the rate of increase is slowing down, indicating that the saturation curve of electricity is well past the inflection point. This trend is illustrated in Figure 25 where the annual growth rate of electricity is compared with that for the USA. The shape of the curves for the two countries is similar, and even the maximum growth rate of 10% per annum is the same. Whilst a more detailed analysis of the saturation curve for electricity is required, it is reasonable to assume that the percentage of electricity in the final energy demand will continue to increase, and it is estimated (Section 2.3) that the growth rate of electricity will be approximately 2% above that of the growth of total energy (as shown in Figure 13) and that by the end of the century electricity will amount to approximately 30% of total energy.

8.2.3 Forecast of electricity growth:

It has been shown that there is a link between electricity and energy demand, and between energy and the economy. The growth in electricity will therefore depend directly on the growth of the economy. It is not the purpose of this report to analyze the possible growth in the economy, but it is assumed, for the forecast of electricity, that the economy is likely to grow at a rate such as to make the GDP/capita grow by between 0 and 2,4%. This would mean a GDP growth rate of between 2,4% and 4,8% per annum. Together with the energy per GDP growth rate of 1% and the electricity growth rate of 2% above the energy growth rate, the electricity growth rate will be between 5,8% and 7,8% per annum.

8.2.4 Effect of the electricity industry on economic growth:

Like any other industry, the electricity industry contributes towards wealth creation due to the construction and operation of the system. A calculation in Section 5 has shown that typically a 5% growth in the electrical industry would result in a 2,6% growth in the GDP and would result in the creation of 222 450 direct and indirect job opportunities in the country.

8.3 EFFECT OF INCORRECT ELECTRICITY FORECAST

An estimate has been made in Section 3 of the possible implications on the country's economy of an error being made in the forecast of electricity demand. Such an error would result in either a shortage of electricity during peak demand periods, or of an over-supply of capacity. It is estimated that a 1% excess generating and distribution capacity would result in a cost to the country of 0,02% of the GDP. A 1% shortage of capacity would lead to the limitation of economic growth and would result in a loss to the economy of 0,09% of the GDP.

8.4 ELECTRICITY PRICE

The price elasticity for electricity, defined as the ratio of the slope of the price demand curve divided by the ratio of price over demand, has been calculated by a number of authors for various countries. However, the spread in elasticities is very large, and it is considered that there is no true elasticity and that even if it were possible to obtain a logical measure of the elasticity, it would change significantly with time and is therefore of little use in determining the effect of price on demand.

8.5 RECOMMENDATIONS

Whilst the present report analyses the electricity-economics relationships, it has highlighted two areas that would require additional work:

(1) The relationship between electricity and energy has been based on the extrapolated relationship between electricity and total secondary energy demand. A more detailed analysis of this relationship is required, based on the assessment of the saturation level of electricity in the final demand sector. This requires an estimate of the final saturation level and the time relationship for this saturation to be achieved. This work has already been started.

(2) The energy per capita relationship for South Africa has been shown to be consistently above that for countries with the same level of GDP/capita as South Africa. This has been put down to the inefficiency of energy usage in South Africa and to the heavy mining load. Preliminary analysis has shown that this is not the case and the high level is most probably due to the level and type of industrialization compared with that in other countries. More work requires to be carried out in this area of analysis.

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REPORT NO. GEN 147

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FINAL REPORT

R K DUTKIEWICZ MARCH 1992

ENERGY RESEARCH INSTITUTE