Some Recommendations towards Reducing Electricity Consumption in the South African Manufacturing Sector

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ABSTRACT

This paper investigates the means of reducing electricity consumption in the South African manufacturing sector. It concludes that neither the price of electricity, nor taxes, subsidies or legislation are likely to bring about the required change. A change in the production structure using relatively more labour and less capital is also unlikely in the immediate future, given the socio-economic and legislative milieu currently prevailing in South Africa. The only feasible solution that seems likely is a change in technology, which includes the more efficient use of electricity. Given the possible international agreement regarding global climate change commitments and procedures, clean development mechanisms may therefore yet provide the answer.

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1   INTRODUCTION AND PROBLEM STATEMENT

Few would deny the importance of electricity or of a strong manufacturing sector in the economic development of a country. Within the context of global climate change and the negative environmental impact of the externalities associated with the generation of electricity, it is increasingly important to reduce the levels of electricity consumption without jeopardising the manufacturing base of the economy. It is therefore valid to ask what measures are necessary to reduce electricity consumption by the manufacturing sector.

In an attempt to answer the question, this paper starts by giving an overview of the consumption and production of electricity in South Africa, followed by a discussion of the research method used. Then the price elasticity of electricity demand is investigated. This, in turn, is followed by a discussion of the production structure of manufacturing, and the correlation between the use of capital and electricity. Finally, some concluding remarks are made.

2 CONSUMPTION AND PRODUCTION OF ELECTRICITY IN SOUTH AFRICA: AN OVERVIEW

2.1 Demand for Electricity

Electricity is an essential input in any economy, particularly in a developing country, since without it little development is possible. It is therefore not surprising that the *Reconstruction and Development Programme* (RDP) stresses the importance of an increased provision of electricity in the following terms (ANC, 1994: 108): "The benefits of cheap electricity presently enjoyed by large corporations must be extended to all parts of the economy."

From this statement it follows that, from the outset, it was the aim of the ANC to continue to supply cheap electricity and to extend its consumption to as many people as possible. There is no question that this objective has enjoyed high priority and that considerable progress has been made in pursuit of it (NER *Annual Report*, 1998). This is supported by the fact that the average annual growth in electricity consumption is highest in the residential sector, namely 4 per cent (see Table 1).

From Table 1 it is also clear that manufacturing is the largest single consumer of electricity (comprising approximately 41 per cent of total demand). Furthermore, the rate at which electricity consumption is growing in this sector is faster than the national average of 1,8 per cent a year over the period 1989-1995, namely 2,1 per cent. Since manufacturing is such a major consumer of electricity, this paper focuses on this sector only.

Table 1   Electricity consumption in South Africa: 1989-1995 (GWh)

Consumer	1989	% of total	1992	% of total	1995	% of total	Annual growth rate
Mining	34963	24.94	33359	23.49	33612	21.59	-0.7%
Transnet Ltd.	4915	3.51	4347	3.06	4036	2.59	-3.2%
Domestic use	21125	15.07	23834	16.78	26663	17.13	4.0%
Manufacturing	56163	40.07	54474	38.35	63801	40.99	2.1%
Commerce, construction, and other business	14282	10.19	15715	11.06	17513	11.25	3.5%
Other purpose	8721	6.22	10301	7.25	10034	6.45	2.4%
Total	140169	100	142031	100	155661	100	1.8%

Source: Stats SA, *Census of Electricity, Gas and Steam 1995.*

2.2 Supply of Electricity

ESKOM is by far the largest single producer of electricity in South Africa, and is currently the fifth largest electricity utility in the world in terms of both sales and capacity (ESKOM *Annual Report*, 1999). Not only is it such a large producer of electricity, its share in domestic production has also increased considerably since 1960. As is indicated in Table 2, ESKOM produced 62.3 per cent of the total electricity in 1960, and 98.3 per cent in 1999, mainly through its coal-based fire stations. In 1960, all of the electricity produced was coal-based, but due to other technologies such as nuclear power, coal's contribution has declined slightly to approximately 93 per cent in 1999. Consequently, ESKOM is the largest single consumer of coal in South Africa, absorbing approximately 40 per cent of the total coal production in 1999. Its consumption of coal increased more than seven fold over the period under consideration from 12.5 million tonne to 88.5 million tonne. For comparative purposes, this consumption of coal should be seen in the light of the fact that total coal exports comprised 29.5 per cent of the market in the same year. (South Africa is the world's second largest exporter of coal with Australia being first and America third).

Table 2   Selected energy and electricity statistics in South Africa: 1960-1999

	Coal production (million tonnes)	Coal consumption for elect. generation (million tonnes)	Coal consumption by ESKOM (million tonnes)	Total electricity generated (GWh)	ESKOM's contribution to local electricity supply (GWh)	Electricity supply: coal fired ESKOM pwr plnt (GWh)
1960	38.1	16.4	12.5	25840	16094	17306
1965	47.6	22.1	16.7	34490	23143	24583
1970	53.1	29.5	21.6	50791	34890	37321
1975	69.1	39.1	34.2	74894	57869	60400
1980	113.1	55.0	46.8	98951	87539	82342
1985	172.0	67.4	59.5	141384	112305	113941
1990	184.1	76.2	70.9	165516	144440	134744
1992	176.1	78.0	75.9	166260	146392	136830
1995	212.5	87.6	79.4	174571	161848	151730
1997	224.5	93.6	90.2	190700	181372	170464
1999	220.74	93.4	88.5	191734	177934	165665

Sources: DME, *South African Energy Statistics No. 2*, 1995. DME, *South Africa's Mineral Industry 1998/99*, 1999. ESKOM, *Annual Report,*

various issues.   NER, *Annual Reports*, various issues. Stats SA, *Census of Electricity, Gas and Steam 1995*, 1995. Chamber of Mines, *Mining Statistics in Brief 1999*, 2000.

2.3   Electricity Prices

ESKOM has committed itself to be one of the producers of electricity at the lowest cost in the world (ESKOM *Annual Report*, 1999). ESKOM's tariffs are much lower than those of many developed nations with electricity utilities of comparable size, for example Japan, Germany, the United Kingdom and the United States (Van Horen, 1996: 8).   According to Doppegieter (1999: 52) South Africa has the second cheapest electricity in the world, beaten only by New Zealand.   In the national context, electricity prices have declined in real terms since ESKOM announced its *price compact* in 1991. In announcing and motivating the *price compact*, ESKOM was convinced that cheap electricity is essential for rapid economic growth (Van Horen, 1996: 9). In terms of this *price compact,* ESKOM undertook to decrease the real price of electricity substantially over the period 1992-2000. The achieved price reductions over the period 1970-1999, are shown in Table 3. From this table it emerges that the real price of electricity (1995 = 100) for all economic sectors declined by 7.8 per cent, and that for the manufacturing sector by 21.1 per cent over the whole period. Since 1990, the price of electricity for all sectors declined by 29.5 per cent and that for manufacturing by 35.6 per cent.

Table 3   Real electricity prices in South Africa: 1970-1999 (c/kWh)

	Ave: all sectors		Manufacturing			Ave: all sectors		Manufacturing	
	Real price	% change	Real price	% change		Real price	% change	Real price	% change
1970	10.29		10.20		1985	14.31	-1.24	14.32	-1.45
1971	10.04	-2.43	9.97	-2.25	1986	14.60	2.03	14.73	2.86
1972	10.02	-0.20	9.86	-1.10	1987	14.51	-0.62	13.80	-6.31
1973	9.70	-3.19	9.55	-3.14	1988	14.09	-2.89	13.15	-4.71
1974	9.16	-5.57	9.48	-0.73	1989	13.46	-4.47	12.63	-3.95
1975	9.42	2.84	9.74	2.74	1990	13.45	-0.07	12.50	-1.03
1976	11.05	17.30	11.34	16.43	1991	12.54	-6.77	11.52	-7.84
1977	14.71	33.12	14.99	32.19	1992	11.90	-5.10	10.62	-7.81
1978	15.41	4.76	15.50	3.40	1993	12.01	0.92	9.88	-6.97
1979	14.46	-6.16	14.41	-7.03	1994	11.15	-7.16	9.68	-2.02
1980	13.54	-6.36	13.55	-5.97	1995	11.15	0.00	10.40	7.44

Table 3 continued

	Ave: all sectors		Manufacturing			Ave: all sectors		Manufacturing	
	Real price	% change	Real price	% change		Real price	% change	Real price	% change
1981	13.24	-2.22	13.25	-2.21	1996	10.53	-5.56	9.41	-9.52
1982	14.19	7.18	14.30	7.92	1997	10.17	-3.42	9.25	-1.70
1983	15.17	6.91	15.24	6.57	1998	9.86	-3.05	8.84	-4.43
1984	14.49	-4.48	14.53	-4.66	1999	9.49	-3.75	8.05	-8.94
					Over period	-7.77		Over period	-21.08

Source: DME, *South African National Energy Prices,* 2000: 70.

The low and declining price of electricity encouraged the consumption of electricity to grow at the average annual rate of 5.4 per cent from 1960 to 1999. From 1990 to 1999, the average annual growth rate of electricity consumption was 1.9 per cent, which is marginally higher than the increase in the real Gross Domestic Product of 1.6 per cent over the same period. However, according to Doppegieter (1998: 3-59) such figures are misleading. Electricity is consumed wastefully in South Africa and much electricity can be saved. The inefficient use of electricity is attributed to a number of reasons, amongst others the low coal and electricity prices and large coal reserves.

One of the major factors contributing to the low electricity price is the relative cheap coal that ESKOM buys. In 1998, ESKOM paid an average price of R41.31/tonne, compared to the R54.55/tonne Sasol paid, and the R156.36/tonne the metallurgic industries paid. These price differences can be attributed to different contract arrangements, entitlements and differences in the quality of coal (DME, 1999).

2.4   The Social and Environmental Cost of Electricity Generation

The increase in the consumption of both coal and electricity contributes not just to economic growth, but also to the increase in negative social and environmental externalities. From Table 4 is it clear that ESKOM is a dominant polluter of greenhouse gases in South Africa, contributing to more that 45 per cent of domestic emissions. These emissions are mainly derived from the coal-based plants of ESKOM.

Table 4   Carbon dioxide, Sulphur dioxide and Nitrogen emissions in South Africa: 1990, 1994 and 1995

	CO$_2$ (Million tonnes)			SO$_2$ (Thousand tonnes)			NO$_x$ (Thousand tonnes)		
	ES-KOM	SA	ESKOM % of SA	ESKOM	SA	ESKOM % of SA	ES-KOM	SA	ESKOM % of SA
1990	132.75	293.386	45.2	1088.32	1760.0	61.8	913.8	2268	40.3
1994	142.94	317.861	45.0	1166.80	-	-	961.2	-	-
1995	146.95	305.805	48.1	1198.17	-	-	-	-	-
1997	-	345.000	-	-	-	-	-	-	-

Sources: Doppegieter, 1998: 3-69 & 3-80. Van der Merwe & Scholes, 1999. UNFCCC, 2000.

Viewed from an international perspective, South Africa was the 15th highest emitter of carbon dioxide in 1995 and 1997 in absolute terms (Doppegieter, 1998: 3-69 & UNFCCC, 2000). South Africa was hence the 10th highest non-Annex 1 (*cf.* developing country) polluter of carbon dioxide per capita in both 1995 and 1997, or 28th overall (including the developed economies) (Doppegieter, 1998: 3-69 & UNFCCC, 2000). These rankings do not reflect the country's economic strength and are clearly disproportionate.

Chronic exposure to emissions of this magnitude has serious mortality and morbidity implications, such as chronic bronchitis and other respiratory diseases. Acid deposition in water bodies also severely impacts on the quality of surface and even ground water. This health hazard is further magnified by the fact that there is sufficient evidence to believe that global climate change is mainly due to anthropocentric (economic) activities (Houghton *et al.*, 1996).

In the light of these environmental and social costs due to the externality associated with coal-based electricity generation (see also Van Horen, 1996 & 1997), there is a need to reduce the generation of electricity from this source. This can be achieved in one of two ways, or a combination of both. ESKOM can change its production technology, that is divert from coal to alternative energy sources, or there should be a decline in the consumption of coal-based electricity. A possible change in the production technology of ESKOM and its associated cost will, however, not be discussed here. The remainder of this paper will focus on the demand for electricity by the largest single consumer of electricity, the manufacturing sector, and an appropriate policy required to bring about a reduction in the consumption of electricity.

3   METHOD AND DATA

In the attempt to find an appropriate policy to reduce the consumption of electricity in the manufacturing sector, this study investigates the effect of a change in the price of electricity on the consumption of energy by calculating the price elasticity of electricity demand. Because of data limitations, a static approach had to be used and elasticity was calculated on the *ceteris paribus* assumption, that all other factors that might influence electricity demand remain constant. This exercise produced some surprising results, which caused the authors to investigate the production structure in manufacturing by means of a Cobb-Douglas production function, estimated for each year in the sample period. These estimates indicate that the production structure in South African manufacturing has changed rather drastically and that this change has socio-economic as well as environmental consequences. Based on these results, the effect of the change in production structure on electricity consumption in South Africa was tested and some policy proposals for the reduction of electricity consumption in manufacturing were made.

The data used in the empirical tests was obtained from Statistics South Africa's census of manufacturing and the Department of Mineral and Energy Affairs' yearbooks. The sample years included in the study are 1972, 1976, 1979, 1982, 1985, 1988, 1991, 1993 and 1996. The manufacturing sector has been disaggregated into 27 subsectors. This implies a cross-sectional data set for nine years across 27 subsectors.

The data for estimating the price elasticities are the price of electricity measured in R/MWh and the total consumption of electricity measured in MWh for the 27 subsectors. The data used for estimating production functions for the manufacturing industry, and in calculating the effect of structural change in production on electricity use, are net production (i.e. turnover less consumption of fixed capital), the value of fixed capital stock and the cost of electricity. These aggregates are expressed in constant 1995 prices. Each of these three variables is then expressed as a ratio of the number of labourers employed. All variables are published in nominal terms only, and the GDP deflator was used to deflate fixed capital stock whilst the CPI was used to deflate the other variables.

4   PRICE ELASTICITY OF ELECTRICITY DEMAND IN THE SOUTH AFRICAN MANUFACTURING SECTOR

There exists, at least theoretically, a negative correlation between the volume consumed of any commodity and its price, *ceteris paribus*. One of the easiest, and generally accepted, methods to measure the quantity to which electricity

consumption will change with a change in price is, by calculating the price elasticity of electricity demand[2]. The calculated price elasticity of demand for electricity is reported in Table 5:

Table 5   Price elasticity of demand for electricity in 27 manufacturing subsectors in the South African economy: 1976-1996

	1976	1979	1982	1985	1988	1991	1993	1996	Ave. over period
Food	0.743	0.074	0.659	-0.281	0.300	-2.179	4.406	-0.674	0.156
Beverage industries	1.203	-0.231	0.385	-0.031	0.654	-2.877	2.763	-0.503	0.105
Tabacco products	1.007	0.405	0.187	0.243	0.882	-0.406	1.220	1.367	0.720
Textiles	0.540	-0.052	-0.013	-0.023	-4.486	5.043	-1.550	0.709	-0.047
Wearing apparel, except footwear	0.707	-0.019	0.384	-0.040	0.673	-1.816	8.752	-0.143	0.451
Leather and leather products	0.712	-0.318	0.181	-0.142	0.860	-2.336	3.305	1.082	0.172
Footwear	0.536	-0.160	0.345	0.040	0.615	-0.775	2.584	-0.669	0.232
Wood and wood and cork products, except furniture	0.745	-0.255	0.884	-0.019	0.806	-2.194	5.467	0.287	0.389
Furniture and fixtures, except primarily of metal	0.615	-0.056	0.986	-0.260	1.080	-2.367	9.345	-2.130	0.316
Paper and paper products	0.620	0.182	-0.522	1.524	0.319	-2.157	-1.490	1.313	0.255
Printing, publishing and allied industries	1.214	-0.641	0.495	0.295	0.778	-2.217	5.403	-0.643	0.299
Industrial chemicals	1.60	0.512	0.439	0.222	1.085	-1.018	6.227	0.715	0.831
Other chemical products	-0.248	0.170	0.251	1.883	0.658	-1.180	-17.946	1.692	-0.250
Rubber products	2.498	-0.208	0.090	-0.313	0.146	-1.040	4.186	0.330	0.760
Plastic products, not elsewhere classified	1.122	0.202	1.020	0.342	0.661	-1.236	3.811	1.557	0.793
Pottery, china and earthenware	0.552	-0.150	0.781	0.058	-0.414	-1.173	3.746	1.046	0.302
Glass and glass products	0.564	-0.504	0.527	-0.099	0.716	-2.715	1.546	0.274	-0.099
Other non-metallic products	0.417	-0.250	0.485	0.722	-1.841	-1.635	-1.077	0.494	-0.306
Iron and steel basic industries	0.597	0.666	0.119	0.252	1.224	-1.974	3.460	0.805	0.571
Non-ferrous metal basic industries	0.580	0.402	0.137	0.567	1.085	-2.509	6.172	2.921	0.708

Table 5 continued

	1976	1979	1982	1985	1988	1991	1993	1996	Ave. over period
Fabricated metal products, except machinery and equipment	0.825	-0.020	0.790	-0.507	0.352	-1.298	2.409	0.103	0.292
Machinery, except electrical machinery	0.678	0.109	0.846	-0.286	0.203	-1.882	3.242	-1.994	0.030
Electrical machinery, apparatus, appliances and supplies	1.116	0.242	0.262	-0.161	0.74	-1.653	6.329	-0.607	0.485
Motor vehicles, parts and accessories	0.547	0.054	0.852	-0.278	0.450	-1.567	6.720	0.167	0.428
Transport equipment, except motor vehicles, parts and accessories	0.564	0.106	0.950	-0.652	0.39	-2.500	-7.425	5.264	0.209
Professional and scientific, measuring and controlling equipment, photographic and optical goods,	0.134	-0.214	-0.220	1.586	0.171	-2.355	7.066	-2.825	-0.111
Other manufacturing industries	0.502	-0.115	0.869	-0.236	0.258	-1.182	2.243	3.042	0.517

Source: Own analysis.

Two things are evident from Table 5. Firstly, in most subsectors an increase in the price of electricity has not resulted in a decrease in the use of (i.e. quantity demanded of) electricity. One might at least have expected that in the majority of cases price elasticity of demand would have a negative sign, but this is not the case. Secondly, the price elasticities are small and lie between 1 and -1, indicating that electricity consumption is price inelastic.

One may therefore conclude that the manufacturing sector is not sensitive to the price of electricity in its decision-making. This outcome is in line with earlier results (Van Horen, 1997: 66).

As mentioned above, electricity is cheap in South Africa and its price declining. This has resulted in the cost of electricity as a percentage of total cost for almost all subsectors and in all the years being less than 10 per cent, with an average of 4.5 per cent over all the years and subsectors. This can be seen in Table 6. These results indicate that there should be other, non-price, factors causing electricity consumption to change in the South African manufacturing sector.

These results reiterate that the price of electricity is a very weak instrument to bring about a change in electricity consumption in South African manufacturing. The following section examines the change in production technology in the South African manufacturing sector since 1972, to determine what does in fact cause electricity consumption to change.

Table 6   Electricity cost as percentage of total cost in 27 manufacturing subsectors in South Africa: 1972-1996

Industry: Description	1972	1976	1979	1982	1985	1988	1991	1993	1996	Ave.
Food	6.624	8.687	10.189	11.632	9.138	9.136	3.632	4.481	1.043	3.082
Beverage industries	4.649	11.765	10.581	10.547	9.905	8.045	2.301	2.574	0.658	2.209
Tabacco products	1.635	3.303	4.074	8.981	7.631	4.203	3.440	3.267	1.051	2.108
Textiles	5.272	7.453	9.563	8.445	8.111	0.921	4.167	4.515	1.773	3.389
Wearing apparel, except footware	1.190	1.724	2.448	2.217	2.062	2.884	1.185	1.794	0.631	1.195
Leather and leather products	3.390	4.515	5.249	5.253	5.349	6.366	2.353	2.714	0.687	1.751
Footwear	1.467	1.848	2.182	1.931	2.061	2.419	1.328	1.611	0.598	1.205
Wood and wood and cork products, except furniture	5.660	7.189	7.935	9.207	8.493	10.678	4.365	6.530	1.796	4.004
Furniture and fixtures, except primarily of metal	2.069	3.263	4.465	4.414	3.893	5.309	1.858	3.868	0.931	2.214
Paper and paper products	9.254	9.196	19.376	11.675	15.361	16.988	6.451	5.579	1.916	4.985
Printing, publishing and allied industries	1.326	2.527	2.440	2.427	2.369	3.090	1.260	1.750	0.607	1.312
Industrial chemicals	8.968	14.685	19.051	18.620	16.282	33.086	14.148	11.038	3.941	7.806
Other chemical products	6.575	5.539	7.129	7.146	7.636	9.871	5.215	1.947	0.827	3.482
Rubber products	1.542	7.960	8.882	6.850	7.307	6.490	3.731	4.784	1.932	3.660
Plastic products, not elsewhere classified	3.181	4.892	6.248	7.393	6.960	7.277	3.645	4.262	1.779	3.144
Pottery, china and earthenware	10.531	14.093	18.643	16.216	16.882	13.876	7.493	10.498	2.844	6.282
Glass and glass products	16.910	23.100	23.531	20.112	23.829	22.790	7.138	9.796	3.421	8.689
Other non-metallic products	16.995	20.295	23.892	26.052	32.903	16.515	8.115	8.115	3.313	9.415
Iron and steel basic industries	13.349	13.913	24.010	23.719	28.248	49.209	21.144	29.991	9.028	17.876
Non-ferrous metal basic industries	25.672	31.471	41.959	44.116	40.261	60.832	19.289	34.814	11.176	19.404

Table 6 continued

Industry: Description	1972	1976	1979	1982	1985	1988	1991	1993	1996	Ave.
Fabricated metal products, except machinery and equipment	3.147	4.262	5.505	5.736	5.211	6.322	3.256	4.004	1.279	2.825
Machinery, except electrical machinery	2.649	3.121	4.324	3.955	4.428	5.202	2.013	2.902	0.658	1.994
Electrical machinery, apparatus, appliances and supplies	2.106	3.100	4.851	4.387	4.179	4.960	2.339	3.451	0.959	2.131
Motor vehicles, parts and accessories	2.848	3.185	4.423	4.847	3.496	4.507	1.945	2.915	0.560	1.372
Transport equipment, except motor vehicles, parts and accessories	1.825	2.423	3.413	4.270	3.789	3.007	1.406	1.136	1.450	1.993
Professional and scientific, measuring and controlling equipment, photographic and optical goods	2.992	3.351	3.998	2.515	3.330	3.363	1.563	1.741	0.372	1.229
Other manufacturing industries	2.092	2.818	3.093	4.125	3.808	4.386	1.758	2.326	0.889	1.567

Source: Own analysis.

5   PRODUCTION FUNCTIONS FOR THE SOUTH AFRICAN MANUFACTURING SECTOR

To calculate the change in production technology in the South African manufacturing sector since 1972, Cobb-Douglas production functions have been estimated for each of the sample years over the 27 subsectors. The function estimated for each year is given by:

$$Q_i = cL_i^{\alpha} C_i^{\beta} \varepsilon_i$$

with Q_i = Production in subsector i
L_i = Number of labourers employed in subsector i
C_i = Capital employed in subsector i
ε_i = Error term
α = Elasticity of labour
β = Elasticity of capital

The results of this estimation are reported in Table 7.

Table 7   Results of estimation of Cobb-Douglas production functions for the South African manufacturing sector: 1972-1996

Date	α	β	α + β	C
1972	0.669556	0.276535	0.946091	3.619703
	(7.813961)	(4.155798)		(5.133022)
1976	0.562570	0.366546	0.929116	3.514579
	(7.189039)	(6.210758)		(6.298416)
1979	0.515375	0.425608	0.940983	3.173307
	(7.179832)	(7.818833)		(5.776759)
1982	0.562756	0.398406	0.961162	3.153122
	(9.790596)	(9.570515)		(7.280743)
1985	0.500285	0.382278	0.882563	4.037432
	(6.153849)	(7.093315)		(6.752536)
1988	0.458135	0.423226	0.881361	3.963550
	(6.727693)	(9.085144)		(7.676274)
1991	0.415977	0.480410	0.896387	3.624855
	(5.576698)	(9.034326)		(6.771560)
1993	0.492383	0.392499	0.884882	4.076646
	(6.696717)	(7.811565)		(6.712788)
1996	0.462675	0.451166	0.913841	6.592393
	(4.804403)	(6.854599)		(8.855874)

Source: Own analysis.

From Table 7 one may conclude that the South African manufacturing sector is producing at constant returns to scale. This is indicated by the sum of the two elasticities (α + β) which remained approximately 0.9 from 1972 to 1996, and is not statistically significantly different from 1.

The most interesting result that emerges from these estimations, however, is that the elasticity of labour decreased significantly from 1972 to 1996. In 1972 the elasticity of labour was 0.66 and it decreased by approximately 30 per cent to 0.46 in 1996. In contrast to this, the elasticity of capital increased by approximately 67 per cent from 0.27 in 1972 to 0.45 in 1996. This indicates that capital's share as input in the production process increased considerably while that of labour decreased. It also implies that labour has been substituted by capital. If the increase in the use of capital results in an increase in the use of electricity, the substitution of capital for labour has an effect on the natural environment through an increase in emissions. This relationship between capital

as input in the manufacturing sector and the use of electricity in manufacturing will be investigated next.

6   CAPITAL AND ELECTRICITY USE IN THE SOUTH AFRICAN MANUFACTURING SECTOR

Firstly, the correlation coefficients between capital and electricity use from 1972 to 1996, within each subsector, were calculated to test whether a relationship exists between the use of capital in the manufacturing sector and electricity. The results from this estimation are reported in Table 8.

Table 8   **Correlation coefficients between capital input and energy input in 27 subsectors in the manufacturing sector of South Africa: 1972-1996**

Industry: Description	Correlation coefficient between capital input and electricity input
Food	-0.100
Beverage industries	-0.133
Tabacco products	-0.770
Textiles	0.289
Wearing apparel, except footware	0.629
Leather and leather products	-0.257
Footwear	-0.207
Wood and wood and cork products, except furniture	0.030
Furniture and fixtures, except primarily of metal	0.428
Paper and paper products	0.688
Printing, publishing and allied industries	-0.007
Industrial chemicals	0.833
Other chemical products	0.707
Rubber products	0.101
Plastic products, not elsewhere classified	0.817
Pottery, china and earthenware	0.230
Glass and glass products	0.217
Other non-metallic products	0.774
Iron and steel basic industries	-0.564
Non-ferrous metal basic industries	0.774
Fabricated metal products, except machinery and equipment	0.761

Table 8 continued

Industry: Description	Correlation coefficient between capital input and electricity input
Machinery, except electrical machinery	0.738
Electrical machinery, apparatus, appliances and supplies	0.630
Motor vehicles, parts and accessories.	-0.031
Transport equipment, except motor vehicles, parts and accessories	0.315
Professional and scientific, measuring and controlling equipment, photographic and optical goods	0.580
Other manufacturing industries	- 0.360

Source: Own analysis.

These results indicate a positive correlation between capital and electricity input in 19 of the 27 subsectors. This positive correlation indicates that an increase in capital will result in an increase in electricity input and *vice versa*.

Using another form of analysis, the results from the correlation coefficient calculation are confirmed by cross-sectional ordinary least squares estimation of the simple function,

$$E_i = \alpha_i + \gamma K_i + \varepsilon.$$

with E_i =   Electricity input for subsector i

K_i =   Capital input for subsector i

εi =   Error term

α_i =   Constant

This has been done for all the sample years. The estimated coefficients are reported in Table 9, and confirm that an increase in capital does indeed result in an increase in energy input for each of the sample years. In each cross-sectional estimation the coefficient on capital is highly significant as indicated by the t-values.

**Table 9   Results from cross-sectional ordinary least squares estimation
of capital on energy input**

	Constant (t-value in parenthesis)	Coefficient (t-value in parenthesis)	Adj. R²
1972	92168.75 (0.633830)	0.587700 (11.89110)	0.848850
1976	458800.3 (2.569611)	0.407422 (12.18968)	0.850220
1979	-6209.79 (-.242557)	0.662099 (16.70959)	0.917549
1982	645645.7 (1.449727)	0.407459 (6.103691)	0.591870
1985	932277.2 (1.600755)	0.342793 4.370171	0.410409
1988	620388.1 (0.701271)	0.713901 (4.161447)	0.385599
1991	-5677.44 (-.1048)	0.514078 (6.337707)	0.601022
1993	581618.6 (0.969181)	0.457981 (4.667230)	0.444243
1996	303616.9 (0.443322)	0.615572 (5.386630)	0.518659

Source: Own analysis.

The increase in the use of capital over time and across the 27 subsectors thus
resulted in an increase in electricity consumption by manufacturing.   This
conclusion has been reached from the calculation of the correlation coefficients
between capital and energy within each subsector over the time period and the
estimation of the simple regression of energy on capital across all the subsectors.

7   REDUCTION OF ELECTRICITY CONSUMPTION IN THE SOUTH AFRICAN MANUFACTURING SECTOR: SOME POLICY OPTIONS

It has been established that the low electricity prices (based on low coal prices)
contribute to the high and increasing, but often inefficient, consumption of
electricity.   This consumption of electricity contributes significantly to the
emission of greenhouse gases and other negative social and environmental
externalities. Since 1970 the production structure in the manufacturing sector,
the single most important consumer of electricity with the highest energy

intensity[3] of all economic sectors (Doppegieter, 1999: 67), has changed dramatically in favour of capital at the expense of labour. The increased use of capital has also contributed to the increased use of electricity as a productive input. Furthermore, the price of electricity is a weak policy instrument to manage the consumption of electricity. Diesendorf (1996) concludes also that correct pricing of electricity is not sufficient for efficient electricity consumption.

Since electricity consumption is not sensitive with respect to price, it is likely that a tax on electricity consumption would have little, if any, impact as well. The probable outcome of such a tax is that it would be viewed as an additional cost item and passed on to the final consumer, depending on the price elasticity of the final product. In such a scenario, there will be high social welfare loss. O'Connor (1999: 96) supports this view, arguing that a tax on electricity is only effective if price elasticity is high and substitutes cause less pollution. Whalley (1999: 123) is concerned that environmental tax policy may become so complex, that it would be of little use given its difficulty of implementation.

Another policy option is to prescribe maximum levels of electricity intensity per industrial subsector by legislation. This would mean a cap on electricity consumption per unit of production. Such legislation however implies high transaction costs on account of the policing and implementation of such a system, and is open to abuse. The required institutions to implement and manage such environmental legislation in developing countries tend to be weak and ineffective. This further adds to the high transaction cost of this policy option (see also Da Motta, Huber & Ruitenbeek, 1999: 184).

In principle, a subsidy is an inefficient policy instrument since it causes social welfare losses (Rosen, 1998: 295-97). Under some circumstances, one could convincingly argue that a subsidy is a temporary measure to facilitate the change between two different policy and operational regimes. Such regimes might include a change in technology to bring about a reduction in pollution. In this regard, however, Da Motta, Huber and Ruitenbeek (1999: 186) view subsidies for abatement investments as having a limited impact, stating:

> Subsidies for abatement investments have, however, been of limited impact since environmental enforcement has not been effective enough to increase firms' demand for these expenditures. Moreover firms are using these incentives inadequately because of the lack of proper follow-up procedures, in fiscal and environmental terms to monitor their investments.

From the above discussion it follows that conventional policy measures to bring about a change in electricity consumption behaviour of firms are likely to have a negligible effect. This is so, because these policy measures address the symptom of the problem, the electricity consumption and the ensuing emissions, and not the cause, which is an inappropriate production method and high capital intensity of the production structure.

Murthy, Panda and Parikh (1997) and Pimentel *et al.* (1994) are convinced that electricity conservation is possible only through a change in technology and the more efficient use of electricity, brought about by a change in the production structure (i.e. capital and labour input) and method. Which technological changes are then required to bring about the desired reduction in electricity consumption? Table 10 highlights the main procedures to reduce CO_2 emissions in manufacturing. These measures are in addition to those offered by Doppegieter (1998: 4-66 - 4-74), Van der Merwe and Scholes (1999), Halnaes, Callaway and Meyer (1999) and the World Bank (1998).

Table 10   Selected   mechanisms   for   reducing CO_2 emissions   in manufacturing

CO_2 reduction mechanisms	Application	Reduction potential	Need for new technology
Energy intensity reduction	Housekeeping (mainte-nance) Conservation	Low	Low
		High	Medium
	Fundamental process changes	High	High
Energy source switching	Coal/oil to natural gas	High	Low
	Fossil fuels to electricity	High	High
	Co-generation	High	Medium
	Fossil fuels to biomass	Low	Medium
Flow changes	Materials recycling	High	High
	Materials substitution	High	High
	Process integration	High	High

Source: International Energy Agency, 1994: 132.

From Table 10 it may be concluded that technology options for reducing electricity consumption are in fact available. One major objection to the introduction of these technologies would be the additional cost burden that it would imply. This is, however, not necessarily true. South African industry may greatly benefit from international trade using the flexible mechanisms (*cf.* clean development mechanisms (CDM)) considered under the banner of global climate change policies within the Kyoto protocol framework (see Zhang, 2000).

South Africa acceded to the Kyoto Protocol on 13 June 2001. Many studies have indicated that developing countries, such as South Africa, have a lot to gain from CDM projects (World Bank, 2000; OECD, 1999 & KPMG, 2000). Pending international agreement on the CDM process and mechanisms, a way does exist of gaining superior, clean, technology without having to pay the full bill.

8   CONCLUSION

Electricity intensity in the South African manufacturing sector is particularly high. This in itself may not be a problem, but it contributes greatly to the generation of electricity, which in turn significantly contributes to the emission of greenhouse gases and other pollutants. These negative externalities have very high social and environmental costs. It is therefore important to reduce the electricity consumption of the manufacturing sector.

Electricity consumption in the manufacturing industry is, however, not price sensitive. To use price as a policy tool to reduce the consumption of electricity will therefore not contribute much. Therefore, to reduce consumption one of three options is available. Apply conventional policy mechanisms, use electricity more efficiently through a change in technology or substitute labour for capital.

From this study it seems that none of the conventional policy mechanisms, that is, taxes, legislation or subsidies, would achieve the objective of a cost-effective permanent reduction in electricity consumption. The substitution of labour for capital in South Africa, however laudable, is likely to be restricted by numerous socio-political factors.

The global climate change debate, in terms of the Kyoto protocol, and especially the flexible instruments such as clean development mechanisms (CDM) proposed by the protocol, has brought a unique opportunity for South African firms. South African firms can exchange their old technology for a better one, gain in foreign direct investment and contribute to a cleaner environment. This seems an effort well worth investigating.

ENDNOTES

1   The authors would like to thank all those who have contributed to this paper, but are solely responsible for all remaining errors and the views expressed here are those of the authors and do not reflect those of the

authors and do not reflect those of any institution that they may be involved with.

2   The price elasticity of electricity demand is calculated as the percentage change in the demand for electricity divided by the percentage change in the price for electricity. This implies that the change in demand is solely due to a change in price.

3   Calculated by dividing the real GDP at factor costs by final energy use.

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