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Editor:
B H A Winter

Production Editor:
Y Blomkamp

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It is the policy of the Journal to publish original research covering the technical, economic, political and techno-social aspects of energy in Southern Africa. Only previously unpublished work will be accepted. However, conference papers delivered but not published elsewhere are also welcomed. Short comments, not exceeding 500 words, on articles published in the Journal are also invited. Announcements of relevant publications, reviews, conferences, seminars and meetings will be included.

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Enquiries may be directed to:
The Production Editor, Journal of Energy R&D in Southern Africa, Energy Research Institute, University of Cape Town, P O Box 33, Plumstead 7800, South Africa
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EDITORIAL

B H A WINTER

With this, the final issue of Volume 3 of the Journal, we have now been publishing for just over two years. During this time, the Editorial Board has paid much attention to the evaluation of the Journal with an eye to improving its degree of acceptability to its subscribers. This included an analysis of the responses to a questionnaire sent out earlier this year to all who receive our Journal regularly, including authors and referees of papers. Information was sought on the overall impression and quality of the Journal, suggestions for articles and other items for inclusion in future issues, views on the inclusion of advertisements, and the level of staff reading the Journal in various organisations.

These suggestions were most helpful to the Editorial Committee in implementing certain changes in our editorial policy which we will put into practice in Vol.4 No.1, the first issue in 1993.

(i) A new cover has been designed which will, we believe, highlight in a dramatic way the essence of the Journal.

(ii) In addition to the technical papers, which will continue to form the backbone of the Journal, items of more general interest in the energy field will be included in the form of news, comments and short technical reviews on energy and related subjects, interviews with and CVs of important persons in the Southern African and African region as a whole, energy statistics, and book reviews. These items will, however, be restricted to a small proportion of the content of the Journal. From time to time, we will produce special issues which will focus on a specific theme, such as, electrification.

(iii) Accordingly, we are also effecting a slight change in the title of the Journal, which will henceforth be called *Journal of Energy in Southern Africa*. The dropping of the words "R & D" does not mean that there will be any change in the scientific integrity of the Journal. It will possibly widen its scope for potential contributions.

We thank our contributors and subscribers for their support in the past and look forward to an expanded interest in our Journal in the future.

*RECENT HYDROLOGICAL TRENDS IN THE ZAMBEZI BASIN AND THEIR EFFECT ON THE PRESENT ELECTRICAL ENERGY SITUATION IN ZIMBABWE AND ZAMBIA

** A P DALE

This paper attempts to provide an up-to-date overview of the present hydrological and generation situation at Kariba, as well as the effects on Zambian hydroelectric generation at Kafue Gorge. Thus the effect of the drought on the production of hydroelectricity, present and future, and the implications for the region are examined.

KEYWORDS: hydroelectric power; Kariba; Zambezi; drought; Zimbabwe; Zambia

DEFINITION OF UNITS

Water

1 cumec = 1 m^3/second

1 cumec flowing for one year = 31,536 million m^3/annum
= 0,031536 milliards/annum

Electricity

Power is defined as the rate of producing (or using) *energy*

MW = Megawatt = 1000 kW (kilowatts), or 1 million W (Watts) of *power*

GWh = Gigawatt hour = 1 million kWh (or units) of electrical *energy*

1 kW generated (or used) continuously will produce 8760 kWh in one year

1 MW generated (or used) continuously will produce 8,76 GWh in one year

1000 GWh of energy production in one year will require 1000/8,76 = 114,16 MW of continuous (or average) generation during that period.

GLOSSARY

ZESA = Zimbabwe Electricity Supply Authority
ZESCO = Zambian Electricituy Corporation
ZRA = Zambezi River Authority

INTRODUCTION

This paper is a follow-up to an earlier one[1] presented to the Fourth Meeting of the SADCC Electricity Sub-Committee. At the time of this presentation, the author was a member of staff of the Zambezi River Authority (ZRA) and as a result, the paper concentrated on the situation at Kariba, with its two power stations (666 MW at Kariba South and 600 MW at Kariba North).

This new paper attempts to provide an update of the present hydrological and generation situation at Kariba as well as to provide information on its effects on Zambian hydroelectric generation at Kafue Gorge. This latter 900 MW power station is also of considerable importance to Zimbabwe because the two power systems concerned, Zimbabwe Electricity Supply Authority (ZESA) and Zambian Electricity Supply Corporation (ZESCO), are closely interconnected. This is shown in Figure 1, while Figure 2 shows in diagrammatic form the location and extent of the existing and possible future power stations in the Zambezi basin, excepting for the Luangwa and Shire (Malawi) sub-basins.

The catchment areas for the two main power reservoirs, Kariba and Kafue, that are being considered in this paper are illustrated in Figure 3.

The Kariba catchment area is sub-divided into two sub-basins, namely, the Upper Catchment above the Victoria Falls, and the Lower Catchment which lies between Kariba and the Falls. As can be seen in Figure 3, the bulk of the Upper Catchment lies in Zambia and Angola, with most of the Lower Catchment situated in Zimbabwe.

For Kafue, the catchment area is much smaller than for Kariba, but in power and energy terms this project is approximately three-quarters of the size of Kariba. Because of the generating head at Kafue, the existing Upper Gorge station needs about one-quarter of the amount of water required at Kariba to produce the same power and energy. The Kafue Catchment lies entirely within Zambia. The proposed Lower Gorge station has yet to be built.

* Based on a paper presented at the Association of Mine Engineers of Zimbabwe, Juliasdale, 2-5 July 1992.
** Powerplan Consultants (Zim) (Pvt) Ltd, 32 Kingsmead Road, Borrowdale, Harare, Zimbabwe

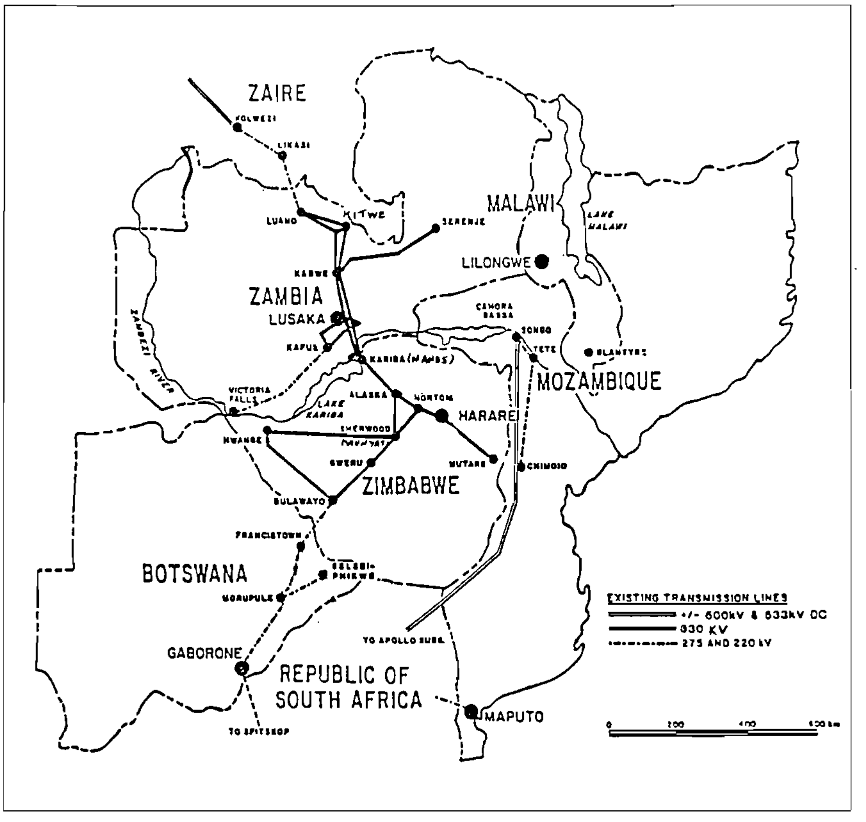

Figure 1: *Map of the interconnected systems*

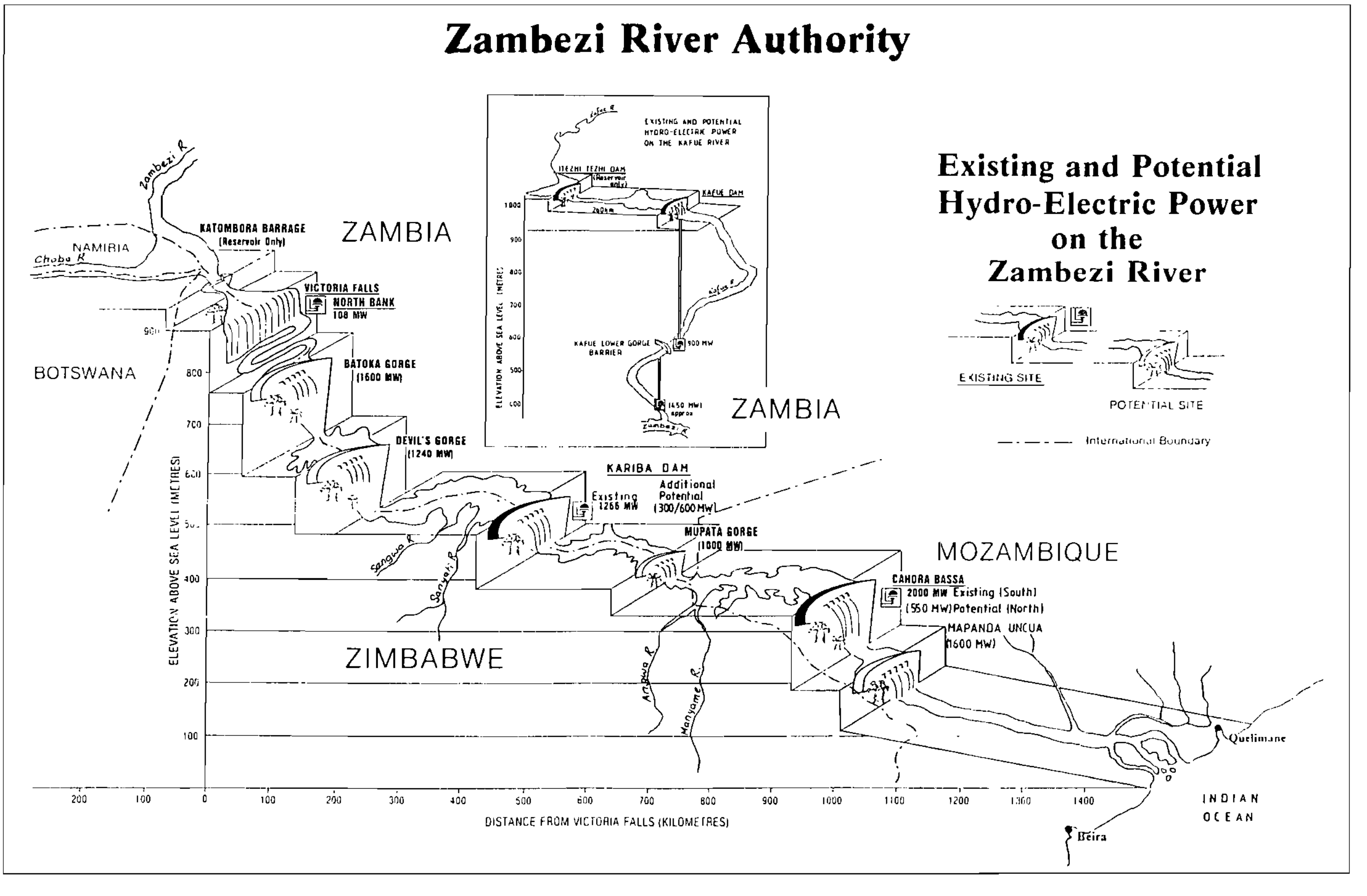

Figure 2: *Existing and potential hydroelectric power sites on the Zambezi River*

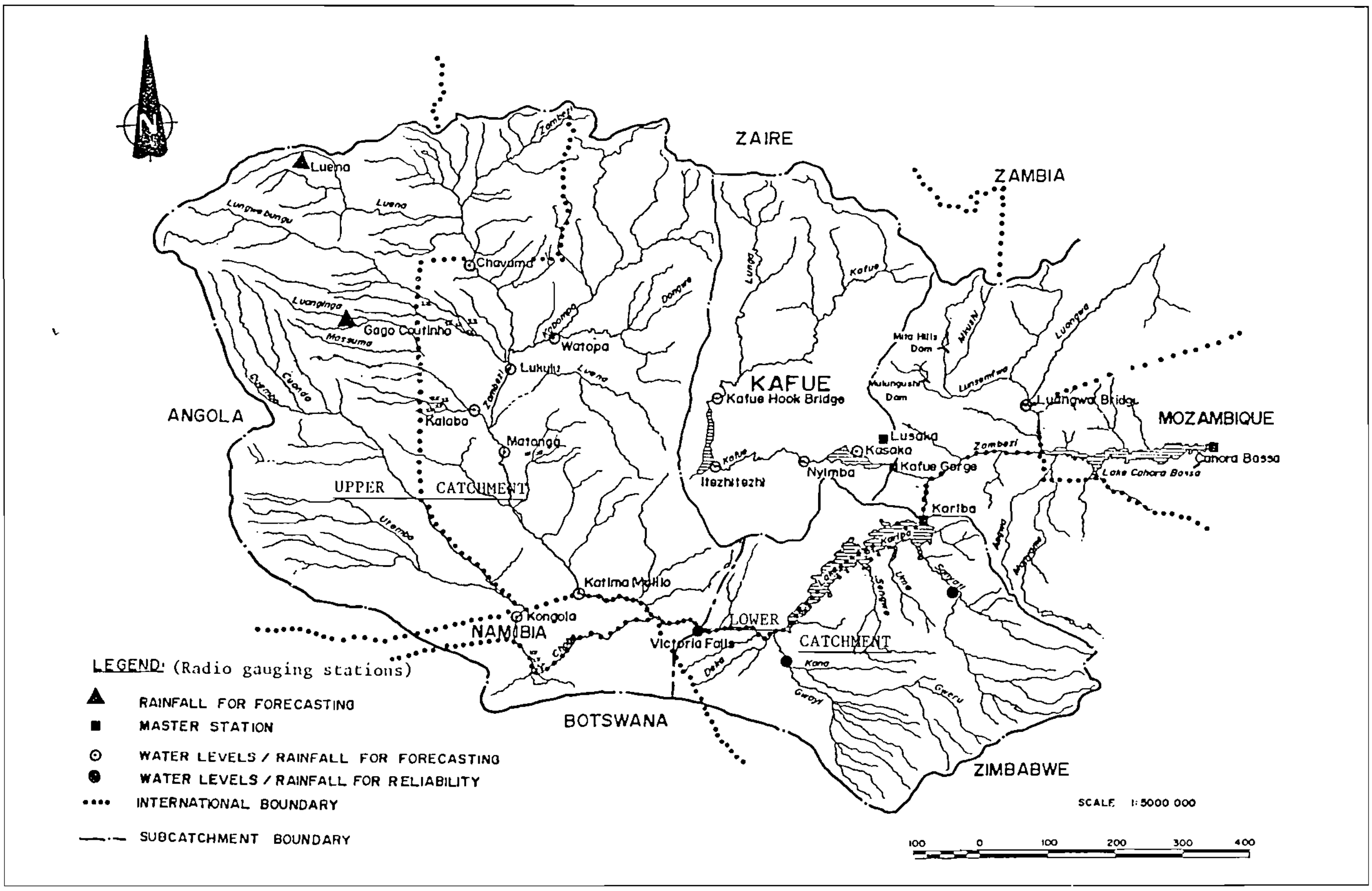

Figure 3: Map of the Kariba and Kafue catchment areas

HYDROLOGICAL TRENDS IN THE ZAMBEZI BASIN

UPPER ZAMBEZI (Kariba Catchment)

Records of the Upper Catchment have been kept since early in the century by gauging the Zambezi above the Victoria Falls at Livingstone (initially) and later on the Zimbabwe side. The cumulative run-off mass curve shown in Figure 4 graphically illustrates the hydrological flows at Livingstone/Victoria Falls for the hydrological years 1924/25 to 1990/91. (*Note:* The hydrological year in Zambia and Zimbabwe runs from 1 October to 30 September in the following year).

Figure 4 demonstrates three different hydrological regimes for the Kariba Upper Catchment: one running to 1946/47, a second but higher run-off regime from 1947/48 to 1980/81, and a lower regime from 1981/82 to the present date. The present hydrological difficulties at Kariba stem from this recent ten-year period of lower flows, with these flows being even lower than those prevailing until 1946/47. However, it must be noted that it takes several years before any new regime becomes evident. In fact, it was probably first recognised in 1986 in the Gilbert Commonwealth Master Plan for Zimbabwe although, even then, it was considered more likely to be a short-term problem rather than the beginning of a new trend.

Run-off measurements for the Lower Catchment (plus rain on the Lake) at Kariba are more difficult to assess. In

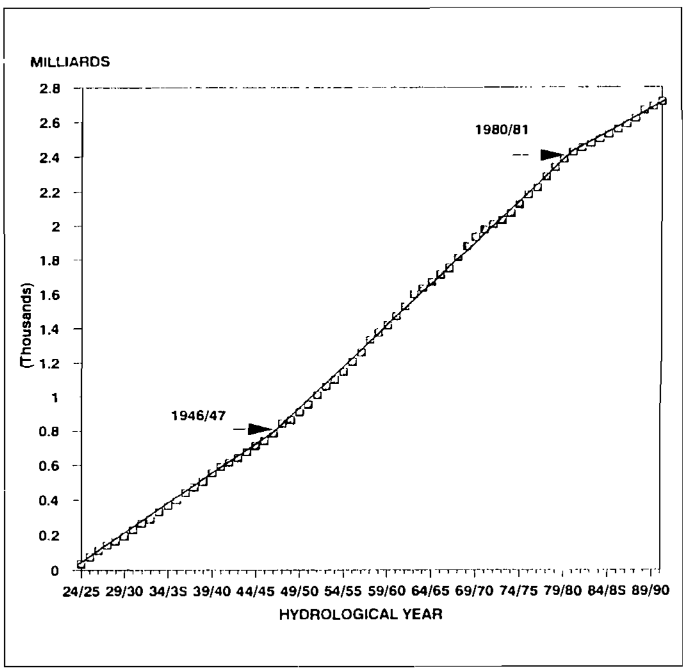

Figure 4: Cumulative run-off (mass) curve of the Zambezi at Livingstone/Victoria Falls

practice these are achieved by water balance calculations based on the Victoria Falls flows and measurements of the water-level, water flows (turbine + floodgate) and evaporation at Kariba.

While computer models based on rainfall records have been used to produce estimates of Lower Catchment run-offs in earlier years, water balance measurements as described above are only available from the time that storage commenced at Kariba in 1961/62. The figures concerned are tabulated in the right hand column of Figure 5.

CONTRIBUTION OF LOWER CATCHMENT AND RAINFALL ON LAKE TO THE INFLOW OF LAKE KARIBA

Data derived from annual water balances and expressed in milliards

YEAR	INFLOW minus	UPPER CATCHMENT INFLOW	=	LOWER CATCHMENT INFLOW PLUS RAIN ON LAKE
1961/62	63.64	59.24		4.4
1962/63	90.49	70.69		19.8
1963/64	43.87	38.74		5.13
1964/65	39.51	35.75		3.76
1965/66	49.98	42.87		7.11
1966/67	39.84	35.88		3.96
1967/68	65.43	62.38		3.05
1968/69	84.58	71.48		13.1
1969/70	62.95	53.96		8.99
1970/71	48.18	40.07		8.11
1971/72	41.21	31.03		10.18
1972/73	23.71	24.48		-0.77
1974/75	70.67	52.38		18.29
1975/76	69.23	54.02		15.21
1976/77	48.06	41.62		6.44
1977/78	97.92	63.6		34.32
1978/79	58.74	52.45		6.29
1979/80	56.08	46.99		9.0
1980/81	62.21	41.78		20.43
1981/82	26.02	24.95		1.07
1982/83	28.42	25.74		2.68
1983/84	29.33	25.79		3.54
1984/85	41.3	28.31		12.99
1985/86	39.04	28.36		10.68
1986/87	33.22	30.8		2.42
1987/88	38.78	29.61		9.17
1988/89	57.69	46.3		11.39
1989/90	28.51	22.04		6.47
29 YEAR MEAN	52.066	42.131		9.935

Figure 5: Kariba Lower Catchment: Tabulation of flows since 1961/62

An examination of these figures illustrates wide variability in Lower Catchment flows (including possibly some measurement errors) and no readily evident trend can be discerned. However, as the Lower Catchment flow is on average only a little more than 20% of the Upper Catchment flow, trends on the latter are of considerably greater importance.

Table 1 illustrates the overall water situation at Kariba since 1981/82, together with some historical figures for comparison purposes.

Year (Oct-Sept.)	Upper Catchment	Lower Catchment plus rain on Lake	Gross Inflow	Evaporation	Net inflow (avail for gen.)
1981/82	24,95	1,07	26,02	10,43	15,59
1982/83	25,74	2,68	28,42	9,63	18,79
1983/84	25,79	3,54	29,33	9,28	20,05
1984/85	28,31	12,99	41,30	8,90	32,40
1985/86	28,36	10,68	39,04	7,80	31,24
1986/87	30,80	2,42	33,22	8,74	24,48
1987/88	29,61	9,17	38,78	8,25	30,53
1988/89	46,30	11,39	57,69	8,20	49,49
1989/90	22,04	6,47	28,51	8,30	20,21
1990/91	29,00	3,80	32,80	8,60	24,20
10 Year Average	29,09	6,42	35,51	8,81	26,70
1972/73	24,48	-0,77	23,71	9,40	14,31*
30-Yr Mean (61/62-90/91)	41,69	9,74	51,43	8,72	42,71
65-Yr Mean 24/25-90/91	40,75	–	–	–	–
20-Yr Mean (61/62-80/81)	47,99	11,45	59,44	8,68	50,76

* Lowest year on record since Kariba was commissioned.

Note: Net inflows for 1991/92 appear likely to be of the order of 13,3 milliards.

Table 1: Inflows in milliards to Kariba Lake 1981/82-1990/91 inclusive

The above figures reveal the following:

(i) The average net inflow of water available for generation at Kariba over the last 10 years is only 63% of the 30 year figure (1961/62 - 1990/91). When compared to the previous 20 years (1961/62 - 1980/81), the net inflow over the last 10 years reduces to 53% of the former figure.

(ii) The three-year period from 1981/82 to 1983/84 is the driest three-year period on record, with an average annual net inflow of only 18,14 milliards.

(iii) Even though, as previously mentioned, the inflows from the Upper Catchment are of considerably greater importance, Lower Catchment flows in 1984/85 and 1985/86 prevented a three-year dry period from becoming a five-year one. Lower Catchment flows are thus still important.

The operating (live) water-level at Kariba ranges from level 475,5 m to 488,5 m (i.e. a difference of 13 m) between low water and high water. When full (i.e. at the upper level) the reservoir holds 64,8 milliards of (live) storage. Sixty-one percent of the total storage at Kariba is "dead" in hydroelectric terms.

KAFUE CATCHMENT

The cumulative (mass) run-off curve for the Kafue River at Itezhi-Tezhi is shown in Figure 6.

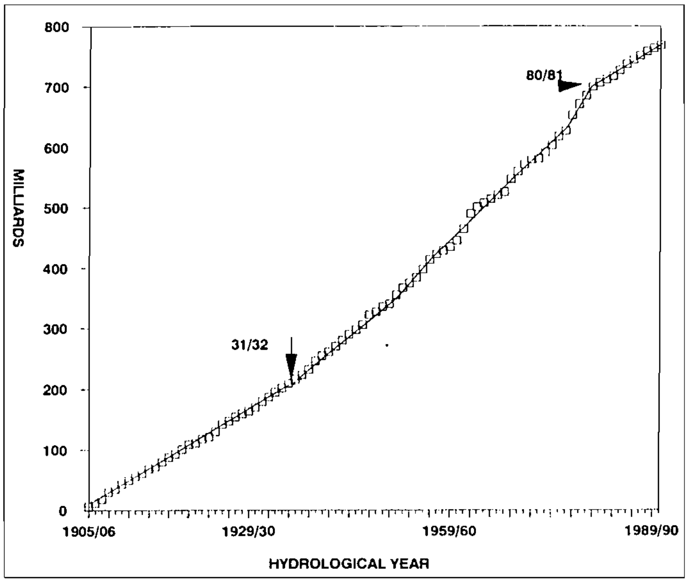

Figure 6: Cumulative run-off (mass) curve of the Kafue at Itezhi-Tezhi

Again, as for the Zambezi, three different regimes are evident. The first is a low flow regime lasting until 1931/32 (approx.), followed by a second regime with a steadily increasing annual flow from 1931/32 to 1980/81 when, as for Victoria Falls, a new low flow regime commenced. However, the average flows during these last 10 years are similar to those evident in the period before 1931/32 and are not lower, as is the case for Victoria Falls.

The main reservoir for the Kafue Gorge hydroelectric scheme is located at Itezhi-Tezhi. Evaporation and inflow tend to equalise each other in the Kafue Flats between Itezhi-Tezhi and the power station at Kafue Gorge, and they are therefore not included in the following tables and calculations.

Table 2 illustrates the overall water situation at Itezhi-Tezhi since 1981/82, together with some comparisons with earlier years.

The following figures reveal the following:

(i) The average flows on the Kafue have been considerably reduced over the last ten years, in fact, they are more reduced in percentage terms than is the case for Kariba. The average flow available for generation over the last ten years is 55% of the 30-year mean figure (1961/62-1990/91) and only 45% of the previous 20-year figure (1961/62-1980/81).

(ii) The relative order of the years of higher and lower flows during the last 10 years on the Kafue does not coincide exactly with those at Kariba (e.g. the highest flow on the Kafue during the last 10 years occurred in 1985/86, whereas at Kariba it was in 1981/82).

Year (Oct-Sept.)	Gross Inflow	Evaporation & other uses	Net Inflow (avail for gen. at Kafue Gorge
1981/82	6,37	2,21	4,16
1982/83	5,83	2,21	3,62
1983/84	5,20	2,21	2,99
1984/85	9,30	2,21	7,09
1985/86	10,25	2,21	8,04
1986/87	6,40	2,21	4,19
1987/88	7,82	2,21	5,61
1988/89	7,06	2,21	4,85
1989/90	4,76	2,21	2,55
1990/91	5,74	2,21	3,53
10-Year Average	6,87	2,21	4,66
1920/21	2,02	2,21	–0,19*
1972/73	2,68	2,21	0,47**
30-year mean (61/62-90/91)	10,73	2,21	8,52
85-year mean (05/06-90/91)	8,88	2,21	6,67
20-year mean (61/62-80/81)	12,66	2,21	10,45

* Lowest year on record

** Included for comparison with Kariba

Note: Net inflows for 1991/92 now appear likely to be slightly negative.

Table 2: Kafue Inflows in milliards (as measured at Itezhi-Tezhi) 1981/82-1990/91 inclusive

An examination of the long-term record of flows at Itezhi-Tezhi (given in cumecs in Figure 7) shows that prior to the present year (1991/92), serious hydroelectric hydrological failures (i.e. when evaporation and other uses approximate the gross flow) appear only to occur on the Kafue on a single year basis. Such failures occurred in 1921/22 (64 mean cumecs or 2,02 milliards), 1923/24 (75 mean cumecs or 2,37 milliards) and 1972/73 (85 cumecs or 2,68 milliards).

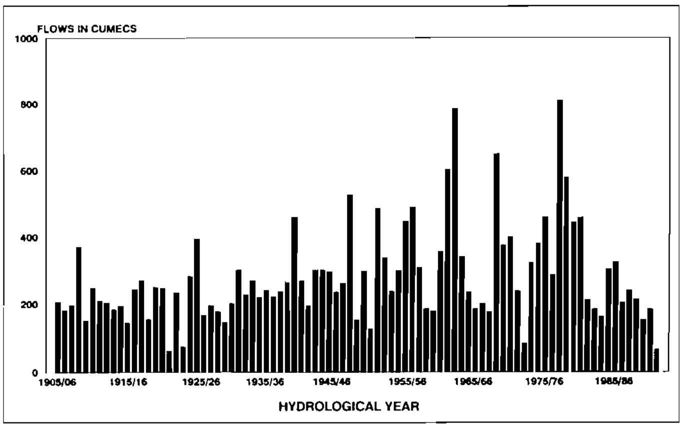

Figure 7: Long-term mean annual flow records at Itezhi-Tezhi

Most of the water stored at Itezhi-Tezhi is theoretically available for generation at the downstream Kafue Gorge power station. Unlike Kariba, there is very little (12%) "dead" storage. When full, the Itezhi-Tezhi reservoir holds 5,0 milliards of live storage, i.e. 7,7% of the live storage at Kariba.

THE PRESENT HYDROLOGICAL YEAR (1991/92) TO DATE

The hydrographs referred to below cover a variety of years, including those for the present year (1991/92 up to mid-May), at the following gauging stations:

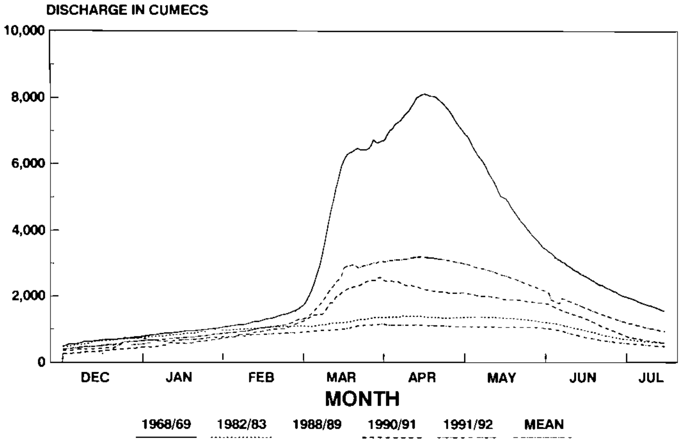

Figure 8: *Various (flow) hydrographs of the Zambezi at Victoria Falls*

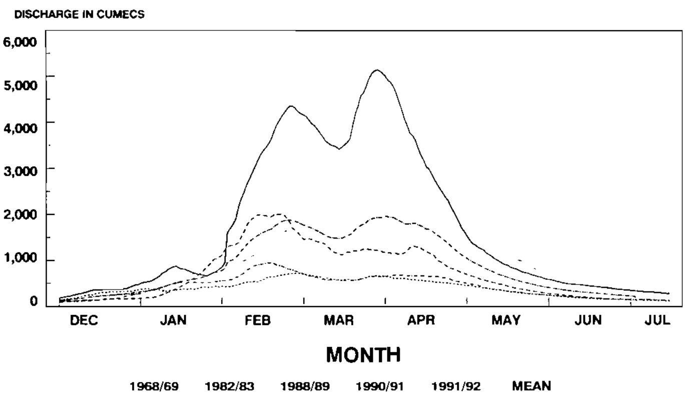

Figure 9: *Various (flow) hydrographs of the Zambezi at Chavuma*

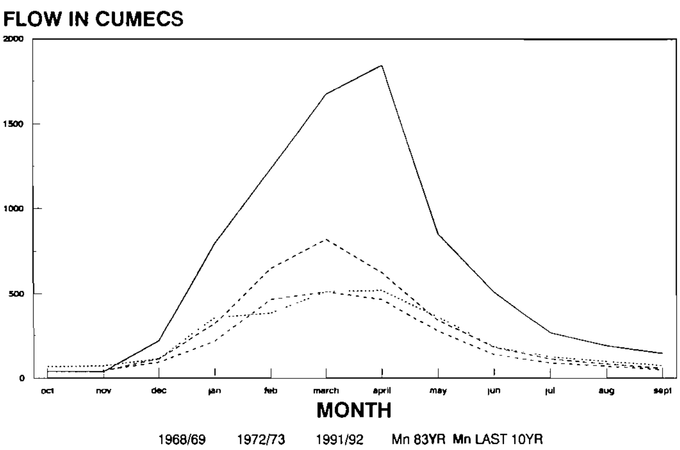

Figure 10: *Various (water-level) hydrographs of the Zambezi at Lukulu*

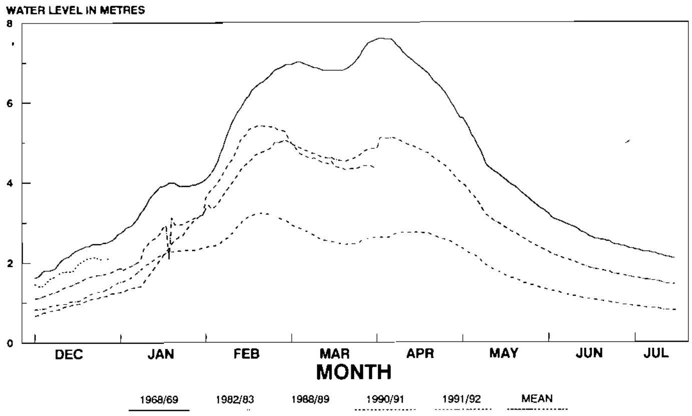

Figure 11: *Various (flow) hydrographs of the Kafue at Itezhi-Tezhi*

Examination of these hydrographs illustrates the seriousness of the present hydrological season. In particular, the following may be noted:

(i) Flows at Victoria Falls (Figure 8) in 1991/92 are below those measured in 1982/83, a year when the Upper Catchment flow was only 5% above that measured in 1972/73. Measurements show that 1991/92 flows up to 20 May 1992 are running approximately 6% below those measured in 1972/73.

(ii) There is no evidence at Chavuma (Figure 9) and Lukulu (Figure 10) of a late flow in 1991/92 in the Upper Catchment from Angola. Also, as flows from the Lower Catchment are largely determined by the rains in Zimbabwe, no significant inflow from this source is now expected. Thus it can be anticipated that the inflow into Lake Kariba in the present season may well equal or even fall below that of 1972/73.

(iii) The situation at Kafue is even worse. Records at Itezhi-Tezhi (Figure 11) so far this season indicate the probability of there being a further (fourth) hydrological failure since 1905, with little or no net generation inflow water being likely to be measured. In fact, flows at Itezhi-Tezhi to 30 April 1992 appear to indicate that the 1991/92 season will be worse than that experienced in 1972/73. It might even emulate the 1921/22 season, which is the lowest recorded at Itezhi-Tezhi to date. (*Note:* This has since been confirmed.)

POSSIBLE FACTORS INFLUENCING RECENT TRENDS

There are many views and explanations being proffered for the recent 10/11-year dry spell that has been experienced on the Zambezi and Kafue since 1981/82. These vary from it being part of a normal weather cycle to it being due to permanent weather change arising from atmospheric warming and the greenhouse effect.

With regard to the cyclical explanation, Tyson and Dyer[5] referred to the (previously) predicted above-normal rainfall of the 'seventies and the likelihood of droughts in the 'eighties in South Africa.

On the other hand, a recent World Bank-ESMAP Draft Report[2] on regional generation and interconnections in the SADCC region summarises its understanding of the subject by stating that "a scenario can be outlined which explains the physical cause for the start of the (latest African) drought and suggests that it may well persist for many years to come". Reasons for this scenario are explained by "increases in man-made CO_2 in a general warming of the atmosphere; a warming of the oceans, particularly in the Southern Hemisphere and the North Indian Ocean; increased frequency of dust storms and decreased soil moisture, which aid the persistence of drought." The author then goes on to suggest that "rather than accepting past (long-term) flow records as indicative of future catchment behaviour, alternative scenarios should be investigated which allow for reduced yield and diminishing water resources in those regions which, since the 1970's, have experienced reduced rainfall."

The above comments have arisen from reference to various meteorological studies using global models carried out in the United States and the United Kingdom. There appears to be a general expectation that temperature rises of between 3 and 4°C can be expected in Southern Africa by the year 2030. Some work in the United Kingdom has also shown a strong correlation between the Atlantic surface-water temperatures and the behaviour of the Southern Ocean Oscillation with rainfall in the Sahel region of West Africa.

However, in spite of all the studies that have been or are being carried out, the experts are not of one mind. Nevertheless, a clear new and lower flow hydrological regime commenced on the Zambezi and Kafue at the beginning of the 'eighties. The best that can now be done, in terms of hydroelectric planning and operations, is to assume that it will continue until such time as a new trend becomes evident. It is presently not known when this will occur.

EFFECT ON POWER GENERATION

Effect at Kariba

After allowing for the normal operational variation in head arising from changes in the water-level at Kariba, the power stations there use, on average, 4,324 milliards of water per 1 000 GWh of energy production. Nevertheless, the head at Kariba is still important as turbine efficiencies there increased by approximately 0,7% per metre of extra head.

The average net inflow to Kariba of 26,60 milliards/annum during the period 1981/82-1990/91 inclusive, is equivalent to generation of 6 150 GWh/annum*** as against nearly 9 875 GWh/annum average over the last 30 years, or 11 740 GWh/annum during the preceding 20 years (1961/62-1980/81). (*Note:* At the time the Kariba North Bank station was initially commissioned, a firm annual energy capability of nearly 10 000 GWh/annum was expected from the total Kariba complex.)

During the driest three-year period on record (1981/82-1983/84), the average annual inflow of 18,14 milliards into Kariba was equivalent to only 4 195 GWh/annum. The net inflow during the lowest year on record (1972/73) was equivalent to only 3 310 GWh.

Annual average generation at Kariba during the latest 10-year period amounted to 6 855 GWh/annum. This is 705 GWh/annum greater than the generation capability of the average net inflow during the same period. As a result, the level of the Lake has been generally dropping over the last decade (Figure 12).

*** This reduces to 5 900 GWh/annum when including the present (1991/92) season at the 1972/73 level.

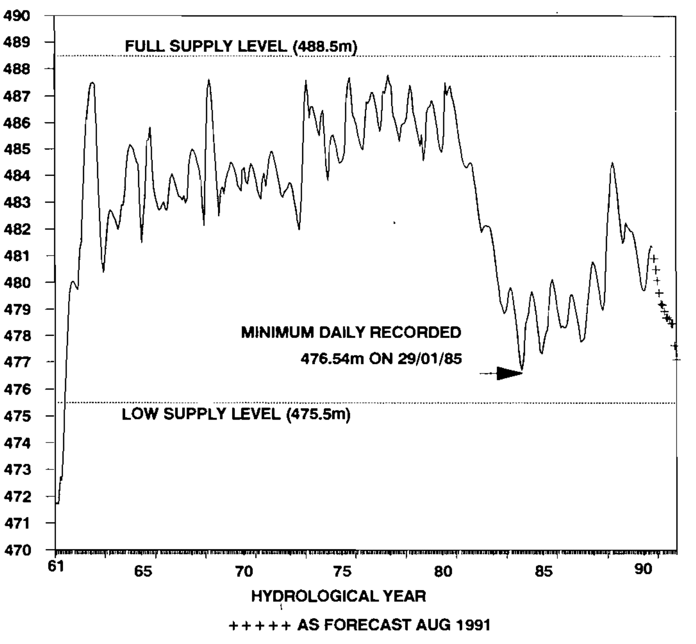

Figure 12: Kariba Reservoir: Recorded end-of-month levels (1960-1991)

The ZRA's water allocation to ZESA and ZESCO for the twelve months commencing 1 August 1991 amounted to 6 000 GWh (i.e. 3 000 GWh each). The effect of this on the level of the Lake, assuming generation at the rate of 6 000 GWh/annum continues into 1992/93, and also assuming that the 1991/92 and early 1992/92 inflows are equivalent to that in 1972/73, is shown by the dotted line in Figure 12, i.e. there will only be one metre of live storage (or approximately 1 000 GWh of energy) left in the Lake on 31 January 1993. As previously mentioned, this pessimistic scenario for 1991/92 now appears to be likely. (*Note:* This has since been confirmed.) Prudent power planning also requires that 1992/93 should be treated, at this stage, as being the same as 1972/73, or 1991/92, should the latter's net inflow turn out to be lower than that of 1972/73.

When full (i.e. at level 488,5m), the amount of energy stored in the Kariba reservoir amounts to approximately 15 000 GWh of energy, or 2,44 years worth of the average annual energy inflow into Kariba over the last decade.

Effect at Kafue

The average net inflow available for generation at Kafue Gorge of 4,16 milliards/annum during the last ten years (1981/82-1990/91 inclusive) is equivalent to generation of 4 500 GWh/annum****, as against 8 240 GWh/annum over the last 30 years, or 10 100 GWh/annum over the preceding 20 years (1960/61-1980/81). (*Note:* In practice, because of power station constraints and the hydrological behaviour of the Kafue Flats, maximum annual production at Kafue (Upper) Gorge would not normally exceed 7 000 GWh, i.e. the figures of 8 240 and 10 000 GWh/annum given above are "theoretical".) The construction of a second station at the Lower Gorge at Kafue with a head of approximately 150 m will, of course, significantly increase generation there while using the same water as the existing (Upper Gorge) station.

**** This reduces to 4 140 GWh/annum when including the present (1991/92) season at the 1972/73 level.

Assuming the present (1991/92) flows are equivalent to those measured in 1972/73, the period 1989/90-1991/92 inclusive, will become the driest three-year period on record at Itezhi-Tezhi. Average annual generation capability during this time will reduce to only 2 110 GWh/annum. (*Note:* This is not the case at Kariba where 1981/82-1983/84 is still likely to remain the driest three-year period on record.)

However, where Kariba, on average, requires 4,324 milliards of water per 1 000 GWh of energy production, Kafue only requires 1,034 milliards per 1000 GWh. Also, with a head of 400 m (vs. approx. 100 m at Kariba), as well as the nature of the small reservoir at the Gorge itself, variations in head are of little significance in terms of generating efficiency at Kariba.

When full, the amount of energy stored at Itezhi-Tezhi amounts to approximately 4 800 GWh, or 1,07 years worth of the annual average energy inflow over the last decade. This represents only 32% of the energy storage of Kariba, i.e. Kariba has nearly three times more annual reserve capacity than does the existing Kafue complex.

POSSIBLE FUTURE OPERATIONAL MEASURES THAT MIGHT BE TAKEN

Conjunctive Operations

(i) The non-coincidence phenomenon of inflows into Kariba and Kafue, as previously mentioned, is of value to the joint ZESA-ZESCO system as it permits each reservoir, if operated jointly in an optimal manner, to provide some reliability support to the other. This increases the firm energy availability of the two reservoirs above the sum of the firm energy of the two reservoirs operated independently. That is, extra firm energy can be accessed for no new capital investment. Furthermore, the Zambezi River Authority Act of 1987 (Clause 7, Annexure I of Article 23)[7] foresaw the benefit of conjunctive operations by stating that, "In the spirit of acquiring maximum benefit for the two States (Zimbabwe and Zambia), the Kariba generating schemes shall, as much as is reasonably practicable, be operated in conjunction with the other generating schemes (e.g. Hwange, Kafue and any other future schemes)".

(ii) A SADCC study carried out in 1989/90, assessed the benefit of operating Kariba and Kafue in a conjunctive manner at 963 GWh/annum or 7,4% of extra (99% probability) firm energy. This extra energy is obtainable without cost. It is worth nearly US$10 million per annum to the interconnected ZESA and ZESCO system. While it must be noted that this figure is a theoretical one which will probably need reduction in the light of practical operations and continuing dry years, such reduction will be offset, to some extent, by introducing Hwange into the conjunctive operations process.

(iii) Unfortunately, the maintenance of a low water-level at Kariba seriously inhibits the successful conjunctive operation of Kariba and Kafue. In those apparently single years, when the hydrology at Kafue fails, it is essential that the resulting energy shortfall is made up by increasing generation at Kariba. In the case of a low water-level at Kariba, as is presently the case, this cannot be done, to the disadvantage of both Zimbabwe and Zambia. Further, as already indicated, increasing the average level at Kariba by 10 m would result in a 7% gain in energy production for the same amount of water. However, additional detailed studies are required on the subject in order to optimise the overall benefits to both States of conjunctive operations in the future and particularly for the remainder of this decade.

Other Possible Measures

(i) ***Improved generating efficiency and metering***

At present, the costs of operating the Zambezi River Authority (ZRA) are shared equally between Zimbabwe and Zambia through ZESA and ZESCO. The ZRA allocates the amount of water to be made available to them each year in terms of GWh of electricity. As such, neither ZESA nor ZESCO are required to pay directly for the water they each use (metering is performed on the total daily electricity produced), regardless of how efficiently this is generated. When one considers that six machines at Kariba South, each generating at 45 MW, use 11% more water than three machines generating at 90 MW each, the scope for efficiency improvement becomes immediately evident. Even a modest 1% improvement would result in water savings worth US$600 000/annum in electrical terms. It is, however, quite likely that in practice a 5% improvement could be effected.

However, in order to do this an improved computerised metering system needs to be introduced at each of the Kariba South and North Bank power stations. The cost of installing such equipment is likely to be quite modest. A pay-back period of as short as 4-6 months can be expected if only a 1% generation efficiency improvement were to result. Furthermore, the commissioning of such equipment would increase the accuracy of water measurement at Kariba and it would also permit the ZRA, in practice, to measure water rather than electricity production. The water could then be sold (at an appropriate market value), to ZESA and ZESCO as a "fuel", thus leading the ZRA to financial self-sufficiency while also encouraging improved water use efficiency and conservation by the main users, ZESA and ZESCO.

(ii) ***Short- and medium-term forecasting***

In the case of Kariba, the first time in which it is possible to assess the likely hydrological flow in any particular hydrological year occurs in late February/early March, with even such an estimate being very subjective because of the possibility of late flows from Angola. For the Kafue, the first indication of likely flow occurs in early January, with this also being subject to the possibility of a late flow. Work recently done in Britain on the correlation of Atlantic Ocean surface conditions and the Southern Ocean Oscillation with Sahel rainfall does indicate a possibility for similar forecasting work to be carried out for the Zambezi Basin. This might then provide hydroelectric power operators and planners with additional and earlier information to supplement simple probabilistic assessments, which inevitably tend to be pessimistic.

Additionally, with a new lower flow trend being so evident since 1981/82, perhaps the time has now arrived when power system hydrologists (and meteorologists in general) should start comparing flows and rainfall as each season progresses with new "normal" averages, i.e. those based on figures since 1981/82 and not just the long-term ones published each week.

CONCLUSIONS

The new lower trend in hydrological flows in the Kariba and Kafue catchment areas now appears to be firmly established, resulting in a reduction in average electrical energy production of the order of 40%. This is a significant drop with a considerable knock-on economic effect on the energy sector and macro-economies of Zimbabwe and Zambia. Until such time as a newer (higher or lower) trend becomes evident, the trend that commenced in 1981/82 must now be considered as the prevalent one.

As a result, new thinking is required in terms of power planning, future investments and system operations. Immediate actions that should be taken in order to maximise generation from the existing hydroelectric stations in Zimbabwe and Zambia include:

(i) The introduction of conjunctive operations between the generating facilities of ZESA and ZESCO should, as required by the ZRA Act, be introduced without further delay. This will require the progressive raising of the water-level at Kariba for it to become effective. The rate at which this should best be done can only be determined by further study. It will also require the development of a closer relationship between all the authorities responsible for electrical energy in Zimbabwe and Zambia than has been evident in recent years.

(ii) Increased efficiency in the use of water for electrical generation at the two Kariba power stations should be effected by the introduction of improved water-metering together with the establishment of a market value water tariff by the Zambezi River Authority.

(iii) Co-operation should be encouraged between the hydrologists, operators and planners working in the power sectors of Zimbabwe and Zambia and those meteorologists dealing with seasonal forecasts using more modern regional and global seasonal forecasting techniques.

ACKNOWLEDGEMENTS

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(3) Various hydrological, engineering and planning colleagues in ZRA, ZESA, ZESCO, the SADCC 3.0.4 Hydrological office in Lusaka, the World Bank and the SADCC Energy TAU in Luanda.

(4) The interest of various power sector consulting colleagues in Harare and the U.K. with whom discussions were held on the subject of hydroelectric hydrology in general is also acknowledged;

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REFERENCES

(1) DALE A P (1992). Some observations on recent hydrological trends in the Kariba Catchment and their effect on electric power generation. Paper presented on behalf of the Zambezi River Authority to the Fourth Meeting of the SADCC Electricity Sub-Committee, Lusaka 3-5 March.

(2) EPD CONSULTANTS (1992). Regional generation and transmission strategies including inter-regional pricing policies. Draft Report, April, prepared for SADCC Energy Project AAA 3.8.

(3) SANTA-CLARA J (1978). Reappraisal of the power generation potential at Kariba. Part I. Central African Power Corporation.

(4) SANTA-CLARA J (1980). Reappraisal of the power generation potential at Kariba. Part II. Central African Power Corporation.

(5) SOUTHERN AFRICAN DEVELOPMENT COORDINATING CONFERENCE (1991). Simulation of the joint operation of major power plants in the Zambezi Basin. Prepared by the SADCC Project 3.0.4. Hydroelectric Hydrological Assistance Project Office, Lusaka. Final report. September.

(6) SOUTHERN AFRICAN DEVELOPMENT COORDINATING CONFERENCE (1990). Simulation of the Kafue Gorge Power plant operation. Prepared by the SADCC Project 3.0.4 Hydroelectric Hydrological Assistance Project Office. April.

(5) TYSON P D and DYER T G J (1978). The predicted above-normal rainfall of the seventies and the likelihood of droughts in the eighties in South Africa. *South African Journal of Science*, Vol.74, pp.372-377

(6) UNIVERSITY OF EAST ANGLIA.CLIMATIC RESEARCH UNIT (1985). Climatic trends for tropical Africa: A research report prepáred for ODA by the Climatic Research Unit, University of East Anglia. July.

(7) ZIMBABWE (1987). Zambezi River Authority Act, No.19. Government Printer, Harare.

ENERGY UTILISATION IN THE BREWING INDUSTRY IN SOUTH AFRICA

*** M G DE VILLIERS, ** D M FRASER and *** R K DUTKIEWICZ**

A case-study was conducted on the brewing industry in South Africa to illustrate the potential for improved energy management in industry. Ohlsson's Brewery in Cape Town was analysed in detail, and by means of comparisons with other large breweries in South Africa, national energy savings were calculated. South African breweries use 220 MJ/(hl beer produced), which is greater than that for breweries in the U.K. and Germany. No single large energy saving scheme was identified, but rather a wide range of moderate schemes were proposed. Economically viable energy saving schemes can result in a 7-14% reduction in overall energy usage and a 6-15% reduction in electricity demand. Further research is required into schemes that may affect beer quality but which can further reduce energy usage significantly.

KEYWORDS: brewing industry; energy management; energy conservation; pinch technology

INTRODUCTION

The industrial sector is the main energy user in South Africa, using about half of the national total and, compared to most other industrialised countries, South Africa has a high industrial energy intensity (i.e. energy usage per unit monetary sales). Improved industrial energy management is thus of the utmost necessity. The malt brewing industry (SIC 3133) was chosen as a case-study industry to illustrate the potential for improved energy management in South African industry. This malt brewing industry consumes 4,92 PJ/annum[1] compared with 90,1 PJ/annum[2] for the food, beverage and tobacco industries and 786,3 PJ/annum[2] for all industries (these are net energy uses, excluding liquid fuels).

Ohlsson's Brewery in Cape Town was analysed in detail and energy management improvements identified for that brewery were expanded to include the malt brewing industry in general. Ohlsson's Brewery was first built in 1869 and has since undergone a number of redevelopments, the latest being the current expansion of the brewery from a maximum beer production of 49 000 hl/week to 85 000 hl/week by September 1992. In 1991, the brewery was consuming about 34 x 10^6 MJ/month of primary energy in the form of coal, fuel oil and electricity. Specific energy consumption is about 230 MJ/hl beer, which is close to the median for malt breweries in South Africa.

THE MALT BREWING INDUSTRY

In the malt brewing process malt, liquid sugar, hops and water are the major raw materials, with the malt having been processed from barley in a malting-plant (which was not considered in the study). The process is shown in Figure 1.

Brewing

Starch is converted to fermentable sugars by first soaking the malt in water (steeping), after which the malt is gravitated to the mills. After milling the malt is pumped to the mash tun where the contents are soaked at various temperatures to produce sweet wort. The contents are then pumped to the lauter tun where the sweet wort is separated from the grains by gravity filtration. The sweet wort is then pumped to the wort kettle where sugar and hops are added and they are brought to the boil for about 90 minutes.

Fermentation

The wort is cooled to about 9C, yeast is added, and the wort is allowed to ferment for about two weeks at 11-14°C. Fermentation is exothermic and the fermentation vessels are maintained at a constant temperature by varying refrigeration. During fermentation, alcohol and CO_2 are produced. Part of the CO_2 is removed and purified to be used later in the process. Towards the end of the fermentation cycle the temperature in the vessels is lowered to about 6°C to reduce yeast activity and to allow the yeast to settle at the bottom of the vessel from where it is withdrawn. The beer is then stored at -1°C for four days.

Conditioning

The beer is filtered and diluted with de-aerated water.

Packaging

Returnable bottles are washed, and bottles and cans are filled with beer and injected with CO_2. The bottled and canned beer is then pasteurised at 64°C and mechanically placed into crates or wrapped in plastic.

* Research Engineer, Energy Research Institute, P O Box 33, Plumstead 7800, South Africa

** Senior Lecturer, Department of Chemical Engineering, University of Cape Town, Private Bag, Rondebosch 7700, South Africa

*** Director, Energy Research Institute, P O Box 33, Plumstead 7800, South Africa

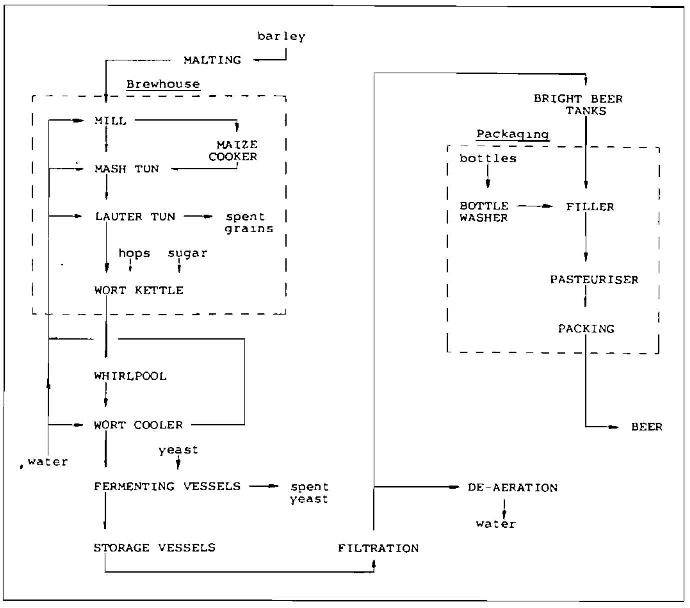

Figure 1: Diagram of the brewing process

ENERGY USAGE IN THE SOUTH AFRICAN BREWING INDUSTRY

In 1991-1992, South African breweries, producing over 200 000 hl beer/year (11 breweries all belonging to South African Breweries), used an average of 181 MJ coal/hl beer and 39 MJ electricity/hl beer, giving an average specific energy requirement of 220 MJ/hl beer. Fuel oil usage is small and has been included in the coal usage figures. Factors which appear to significantly affect energy requirements are the size of the brewery, the age of the brewery, the usage of steam accumulators, and the effectiveness of energy management.

Breweries in the U.K.[3] and Germany[4] have specific energy requirements about 80% that of breweries in South Africa, once local conditions have been accounted for. The discrepancy can be attributed to:

(1) government incentive schemes,
(2) higher energy costs relative to production costs,
(3) stricter environmental legislation,
(4) greater energy conservation awareness amongst management and staff.

ENERGY USAGE IN OHLSSON'S BREWERY

Ohlsson's Brewery operates 24 hours/day throughout the year. The majority of measurements and data were collected between April and September 1991. Primary energy sources are electricity, coal, and heavy fuel oil (HFO), with the monthly energy usages given in Table 1.

	USAGE/ MONTH	GJ/MONTH	RAND/GJ	RAND/ MONTH
Elec.- energy	1 750 MWh	6 300	17,33	109 200
- demand	3 854 kVA			67 300
Coal	1 053 ton	29 484	6,75	199 000
HFO	32 876 ℓ	1 407	9,49	13 400
Total/Average	10 331 MWh	37 191	10,45	388 900

Table 1: Primary energy usage

The ratio of the quantity of beer brewed in the brewhouse to that packaged varies substantially from month to month because of the three week delay between brewing and packing. However, energy usage is closely linked to both quantities, and thus specific energy requirements were calculated using the average of these quantities (referred to as beer produced). Figure 2 shows the variation in the quantity of beer brewed, packaged, and produced. More beer is packaged than brewed because after brewing the beer is diluted with water.

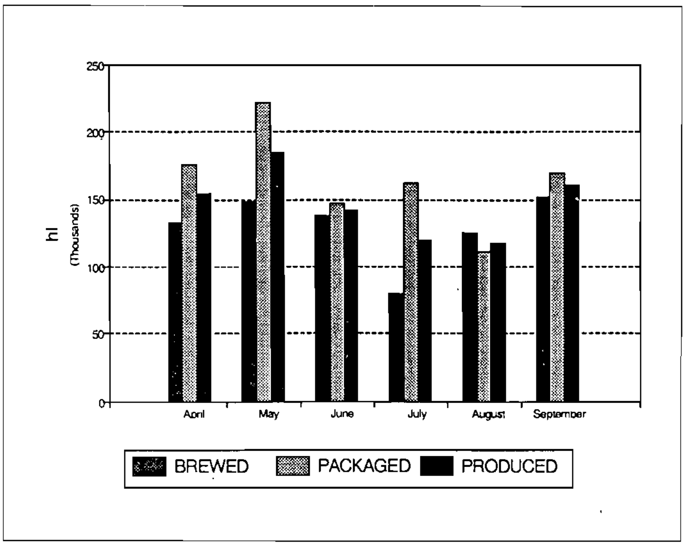

Figure 2: Monthly quantities of beer brewed, packaged and produced

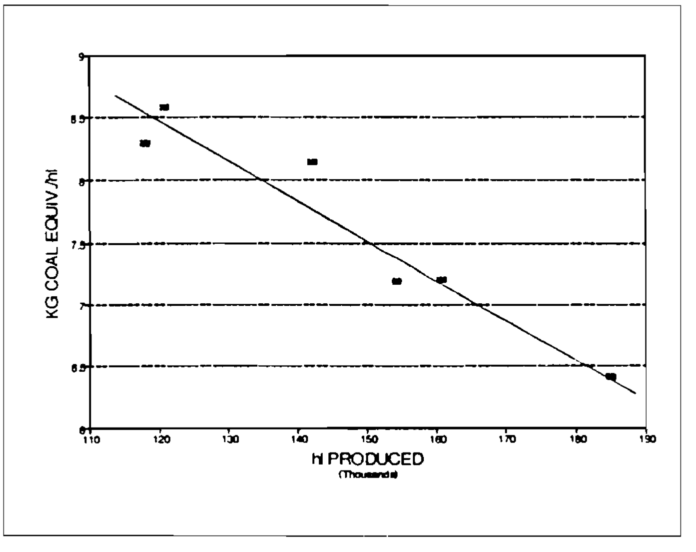

Figure 3: Specific coal equivalent requirements for various monthly quantities of beer produced

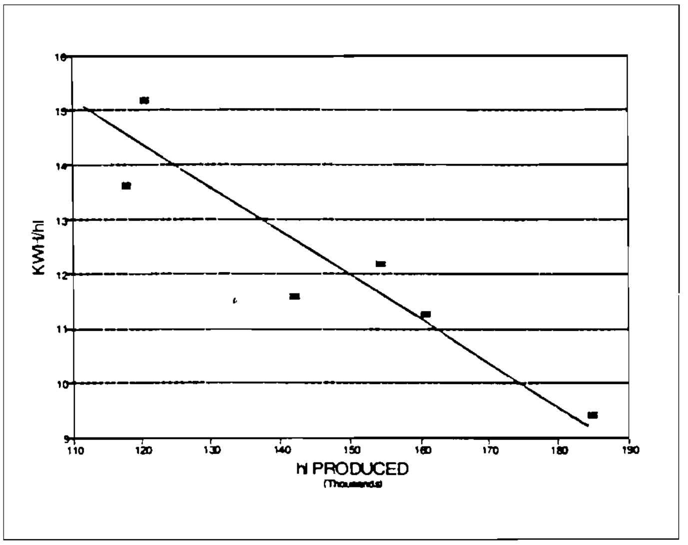

Figure 4: Specific electricity requirements for various monthly quantities of beer produced

Figures 3 and 4 show specific coal equivalent and electricity requirements for various monthly quantities of beer produced. The trend of decreasing energy requirements with increasing beer production is evident in both figures.

Steam is generated at 900 kPag and generally used at 450 kPag, with about 40% of the condensate being returned to the boilers (from the brewhouses). The brewhouses and the packaging-hall account for most of the steam used on the plant. There are two brewhouses which are operated so that wort boiling, which is energy intensive, is staggered. Each brewhouse starts a new batch every five hours, but this time is to be reduced to under three and a half hours in order to increase the output rate. Because of the batch nature of the brewhouses instantaneous steam demand varies between 0 and 16 400 kg/hr, as indicated in Figure 5. In packaging, the main steam users are the bottle-washers and pasteurisers. There are four packaging lines which sometimes operate simultaneously. Steam usage in packaging is more uniform than in the brewhouses but can be especially high when machines are heating up, which can take from 45 minutes to two hours.

Boiler efficiency was calculated to be between 55% and 75%, and distribution losses were estimated to be 10%. Figure 6 is a Sankey diagram of the fuel and steam system, and Table 2 summarises important features of the diagram.

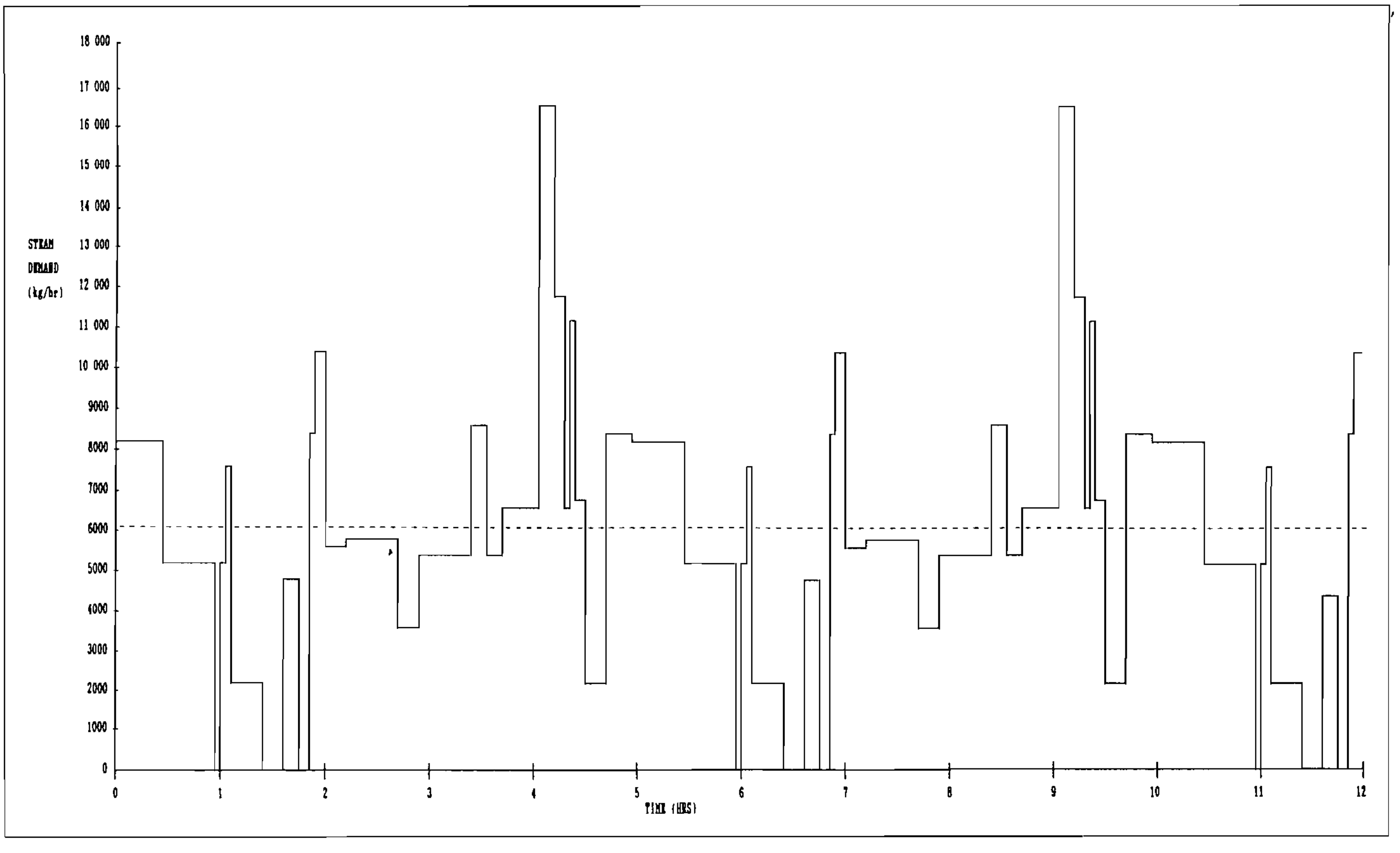

Figure 5: Steam demand profile for the brewhouses operating on a five-hour cycle

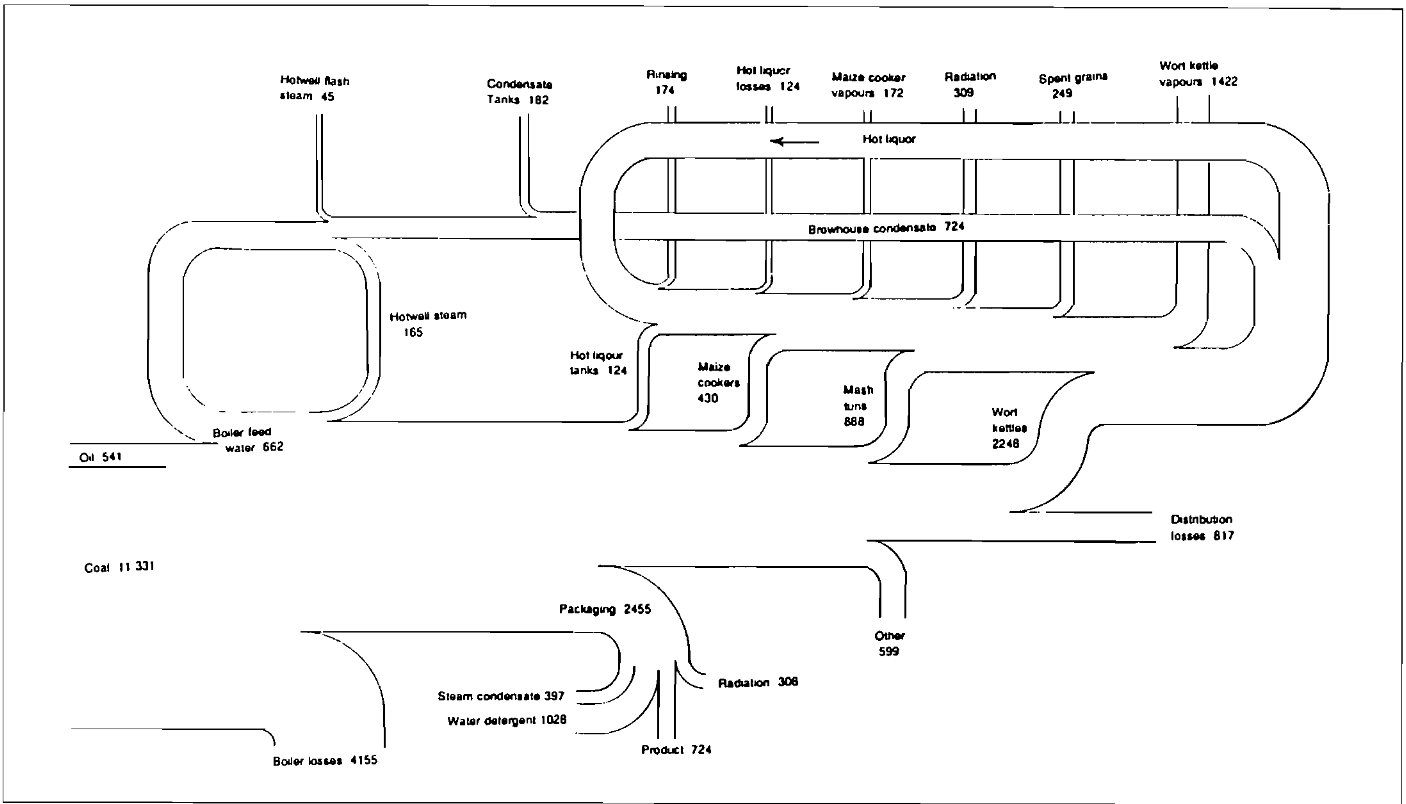

Figure 6: Sankey diagram for fuel and steam

	PROCESS USAGE (kW)	LOSS (kW)	TOTAL USAGE (kW)
Boiler losses	0	4 155	4 155
Brewhouses	2 588	856	3 444
Packaging	724	1 731	2 455
Miscelaneous	407	594	1 001
Distribution losses	0	817	817
Total	3 719	8 153	11 872

Table 2: Fuel usage and losses

The main uses of electricity are refrigeration (34%), packaging (15%), air compression (8%) and the CO_2 plant (7%). Ammonia is the primary refrigerant used, with glycol and chilled water being used as secondary refrigerants. The average total refrigerant load is 1 976 kW with the breakdown given in Table 3.

REFRIGERATION LOAD	PROCESS USAGE	LOSS	TOTAL
Fermenting vessels	499	34	533
Wort cooling	378	32	410
De-aeration plant	280	37	317
Fermenting to storage	158	0	158
Filtration	118	0	118
Pumping losses	0	139	139
Miscellaneous	231	70	301
Total	1 664	312	1 976

Table 3: Average refrigeration loads (kW thermal)

PINCH ANALYSIS

In recent years many industrial plants have benefited from the application of pinch technology, which is a method of analysing energy networks thermodynamically. A pinch analysis gives the minimum practical hot utility (heating) and cold utility (cooling) requirements, and identifies a pinch temperature which is such that any heat exchange that occurs across the pinch temperature increases both the minimum hot and cold utilities by amounts equal to the amount of energy exchanged across the pinch (cross pinch heat exchange).

A pinch analysis was performed on Ohlsson's Brewery with the assistance of a computer software package UCT-NET[5]. Conclusions of the analysis over the entire plant were:

1. Hot utility usage is 13% greater than the thermodynamic minimum, and cold utility usage is 39% greater than the thermodynamic minimum.
2. 430 kW of cross pinch heat exchange exists but, due to spatial and timing constraints, cannot be avoided.
3. When the 430 kW cross pinch heat exchange is compared to the 8 153 kW energy losses (69% of primary energy usage), it is evident that attention should rather be given to reduction of energy losses.

A pinch analysis of the brewhouse showed that only 33 kW of cross pinch heat exchange occurs. Little scope exists to reduce utility requirements, by improved process heat exchange, in the brewhouse.

ENERGY MANAGEMENT OPPORTUNITIES

Opportunities for improved energy management were evaluated in detail for Ohlsson's Brewery using ideas from a literature review, the analysis of energy usage at Ohlsson's Brewery, and the pinch analysis. Process sensitive opportunities, which are strongly related to beer quality and taste, were identified but could not be evaluated in detail. Low-capital (under R20 000) and medium-capital schemes were considered feasible if their payback time was less than two years, whilst high-capital (over R0,5 million) schemes were considered feasible if the rate of return was more than 20%.

Table 4 summarises those schemes and their potential savings that have been found to be feasible for Ohlsson's Brewery (excluding any process sensitive schemes). Once the expansion is complete these savings will be even greater.

	% COAL REDUCTION	% ELEC. REDUCTION	% MAX DEMAND REDUCTION
Low-capital schemes			
Housekeeping	3,5 ± 1,5	3,5 ± 1,5	3,5 ± 1,5
Boiler control	2 ± 1		
Compressor sequencing		2	
kVA monitoring			3,5 ± 1,5
Rescheduling			2
Lighting		1	
Medium-capital schemes			
Condensate recovery	2,5		
Flash steam recovery	1,5		
High-capital schemes			
Steam accumulator	6 ± 2		
Vapour condensation	5 ± 1		
TOTAL	20,5 ± 5,5	6,5 ± 1,5	9 ± 3
SAVING (Rand/month)	40 795	7 098	6 057

Table 4: Feasible energy management schemes for Ohlsson's Brewery

The low-capital schemes are most attractive because they offer almost immediate returns for little investment. Improved housekeeping, including maintenance, can produce significant savings across the whole spectrum of energy usage. Improved boiler control increases boiler efficiency. Optimal compressor sequencing ensures that compressors operate longer near their peak efficiency. More extensive kVA monitoring will help identify the main contributors to maximum demand, after which relevant measures can be taken. Rescheduling of fermentation operations can reduce the maximum demand.

Condensate recovery from the packaging hall and flash steam recovery from the condensate return tanks of the brewhouse will improve the overall efficiency of the steam system.

The installation of a steam accumulator is attractive because of the excessive fluctuations in steam demand, particularly in the brewhouse. During wort boiling all the boiling energy is lost in the vapours. It is common practice in many breweries overseas to recover this energy by condensing the vapours.

Taking into account the differences between Ohlsson's Brewery and other breweries in South Africa, potential energy savings for the entire brewing industry were estimated and are summarised in Table 5.

	% COAL REDUCTION	% ELEC. REDUCTION	% MAX DEMAND REDUCTION
Low-capital schemes			
Housekeeping	3 ± 1	3,5 ± 1,5	3,5 ± 1,5
Boiler control	1,5 ± 0,5		
Compressor sequencing		2	
kVA monitoring			3,5 ± 1,5
Rescheduling			2
Lighting		1	
Medium-capital schemes			
Condensate recovery	1,5		
Flash steam recovery	1,5		
High-capital schemes			
Steam accumulator	1,5 ± 0,5		
Vapour condensation	1		
Other	1,5 ± 1,5	1,5 ± 1,5	1,5 ± 1,5
TOTAL	11,5 ± 3,5	8 ± 3	10,5 ± 4,5
SAVING (Rand/month)	122 000	132 000	110 000

Table 5: Potential energy savings for the brewing industry in South Africa

The most significant difference between Ohlsson's Brewery and other breweries is the high price of coal at Ohlsson's Brewery which makes schemes, such as, vapour condensation more attractive at Ohlsson's Brewery. Some breweries already have steam accumulators. The overall potential reduction in primary energy requirements is between 7% and 14% (excluding process sensitive schemes), which reduces the specific energy requirement to 189-204 MJ/hl which is still considerably higher than the target of 147 MJ/hl suggested for large breweries in Germany[6], and the actual energy requirement of about 175 MJ/hl in Germany[4] and the U.K.[3] (Note: These figures have been adjusted to local conditions.)

Process sensitive possibilities are the lowering of evaporation percentage during wort boiling, wort boiling under pressure, and continuous wort boiling. The amount evaporated during wort boiling at Ohlsson's Brewery is between 10% and 12% of the wort kettle volume, but it is claimed[7] that reducing evaporation to as low as 2% produces no significant change in beer taste, although most brewers might disagree. Reducing the evaporation to 8% would result in a total primary fuel reduction of 3%. In most pressure wort boiling systems the evaporation is half that for atmospheric boiling (as practiced at all breweries in South Africa), which means primary fuel usage would be 6% lower. Continuous wort boiling systems require only a quarter of the energy required for conventional systems, which means primary fuel usage would be 9% lower.

RECOMMENDATIONS

In addition to the schemes identified above, the following is also recommended:

(1) The establishment of a centralised energy committee for the brewing industry to gather and disseminate information to each brewery, give advice on energy management programmes, and monitor the success of these programmes.

(2) The establishment of an energy management committee at each brewery to set energy targets, organise channels of accountability, develop and implement action plans, and report results to relevant persons. These committees should comprise of representatives from the electrical, engineering, projects and planning, brewing, and fermenting departments.

(3) Initially an assessment should be made at each brewery to decide where additional monitoring is required, to enable the setting of energy efficiency targets, the monitoring of the progress of energy efficiency schemes, and for energy usage accountability.

(4) Each brewery should produce a detailed monthly energy report with statistics on each major section of the plant.

(5) Each section of the plant should have a person who is held accountable for the energy usage of that section.

(6) Energy awareness should be fostered amongst employees, during training and on the job, and energy statistics should be displayed on a monthly basis to all employees. Motivated and energy aware employees may then propose energy saving schemes on their own initiative, and also point out areas of blatant energy loss, such as, steam leaks.

(7) Housekeeping should be given more attention, which would include improving maintenance and inspection programmes.

(8) Additional research is required into the process sensitive schemes mentioned, especially the reduction of total evaporation, which would immediately reduce energy consumption with no capital investment.

ACKNOWLEDGEMENTS

The staff at Ohlsson's Brewery are thanked for their contribution in collating energy usage information on the brewery. The Projects Division of South African Breweries is also acknowledged for rendering all relevant information available and for organising visits to some of their breweries.

REFERENCES

(1) DE VILLIERS M G (1991). Energy management in industry: A case-study on the brewing industry. Unpublished U.C.T. MSc.(Eng) thesis, April.

(2) RAND AFRIKAANS UNIVERSITY. INSTITUTE FOR ENERGY STUDIES (1990). South African Energy Use Database, 1990. Rand Afrikaans University.

(3) EASTWOOD A (1990). Designing the energy efficient brewery of tomorrow. *Brewing and distilling International*, Vol.20 No.10, pp.22-23.

(4) UNTERSTEIN K (1990). Rationeller Energieeinsatz und Einsparing an Primarenergie in Klein-, Mittel-, und Grossbetrieben. *Brauwelt*, No.49.

(5) GILLESPIE N E and FRASER D M (1989). UCTNET: A program for the analysis and design of heat exchanger networks. Presented at: Symposium on Personal Computing and the Process Industry, Northern Transvaal Branch of SAICHE, Pretoria.

(6) PENSEL S (1988). Potential and limits to energy saving. *Brauwelt International*, No.3, pp.294-298.

(7) BDI'S BREWING CORRESPONDENT (1985). Putting pressure on the cost of brewing. *Brewing and Distilling International*, Vol.15 No.3, pp.24-25.

A COMPARATIVE STUDY OF ELECTRICITY USE IN TWO LOW-INCOME AREAS IN THE WESTERN CAPE

***P THERON and *S THORNE**

This paper describes aspects of a project carried out by the Energy for Development Research Centre (EDRC) to examine electricity use in newly electrified, low-income urban settlements in the Western Cape. The project involved the collection and analysis of energy consumption, and relevant socio-economic information on households in Khayelitsha (a new township) and Langa and Gugulethu (two older townships). In the paper, the low-income areas examined are described, followed by an analysis of key issues, such as, appliance ownership, household energy use, the affordability of electricity, attitudes to electricity, service quality, and the determinants of electricity consumption levels. Finally, the relevance of these findings for the electrification of similar areas is discussed.

KEYWORDS: electricity consumption; Khayelitsha; Langa; Gugulethu; electrification

INTRODUCTION

Electricity consumption in the low-income, mainly Black, townships of Greater Cape Town shows an interesting contrast in the recently electrified areas, such as Khayelitsha, and the more established townships, such as Langa and Gugulethu, which have had electricity for over 20 years. This paper describes aspects of a project carried out by the EDRC to examine electricity use in these areas[2].

The methodology followed in this project was to collect and analyse information from two main sources. Firstly, all available information was collected on electricity consumption levels of households in Langa and Gugulethu (currently about 8 900) and in Khayelitsha (currently about 5 000). This information was obtained from the Distribution authorities serving these areas (Cape Town City Council and the Lingelethu West City Council).

Secondly, a survey of 108 electrified households in low-income areas was carried out. Seventy-nine households in Khayelitsha were surveyed. These houses were constructed and electrified during the course of 1989 and 1990. A further 29 households in the older electrified areas of Langa and Gugulethu were also surveyed. The average household size in Khayelitsha was found to be 4,3 persons, and in Langa and Gugulethu, 7,7 persons.

Figure 1 provides aggregated frequency distribution diagrams for income levels in Khayelitsha, and Langa and Gugulethu respectively. Incomes in Langa and Gugulethu were generally lower than those in Khayelitsha. Seventy-eight percent of the whole sample had incomes below R2 000 per month. Eighty-three percent of those in the older areas, and 75% of those in Khayelitsha, fell below this figure. The mean and median in Langa and Gugulethu were R1 283 and R1 120 respectively. The mean and median in Khayelitsha were R1 611 and R1 234 respectively.

The houses surveyed were not chosen randomly. Rather, in each area to be surveyed, households were chosen on the basis of having high, medium or low monthly electricity consumption levels. In this way, the basis was laid for examining the determinants of high and low consumption levels.

* Energy for Development Research Centre, University of Cape Town, Private Bag, Rondebosch 7700, South Africa

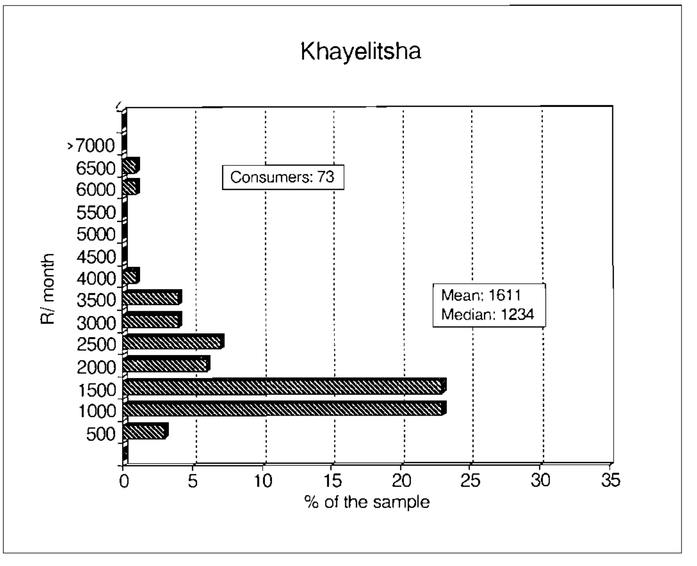

Figure 1a: Income frequency distribution in Khayelitsha

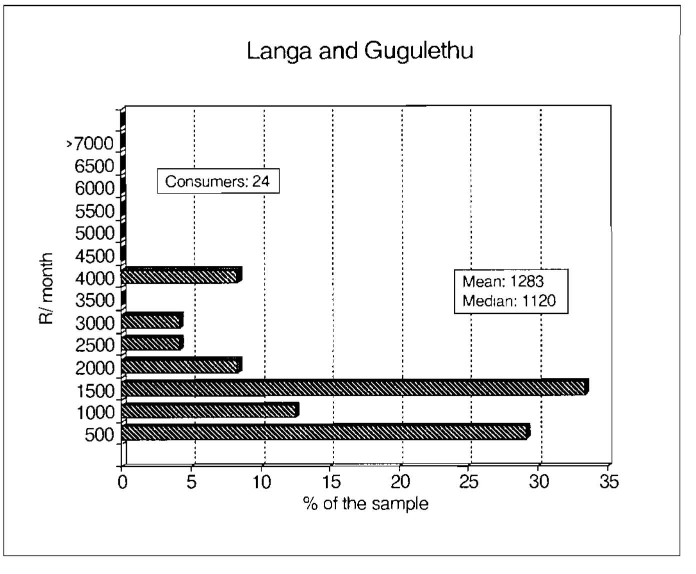

Figure 1b: Income frequency distribution in Langa and Gugulethu

KHAYELITSHA

As already mentioned, Khayelitsha is a newly electrified township. All of the consumers in the area have been connected over the last four years. Within Khayelitsha a number of areas have been electrified: parts of Town 1 (the initial 'core' housing area), Town 2 (the newer formal housing area), and Jonkersdam and Bongweni (the new, up-market areas).

Average consumption levels for all consumers with prepayment meters in Khayelitsha are 175 kWh/month (summer mean) and 344 kWh/month (winter mean). The annual average level is 252 kWh/month. An examination of electricity consumption data shows a steady and consistent increase over time, presumably as newly electrified households buy electric appliances.

There are substantial variations in average levels in different areas. For example, winter levels in Bongweni are up to 23% higher than average. Winter levels are 44% lower than average in Town 2 Village 3.

LANGA AND GUGULETHU

These areas are representative of the older, more established low-income areas in the Western Cape. Langa was proclaimed a township in 1922 and Gugulethu in 1948. A portion of houses in both areas were electrified in the 1960's. Levels of domestic electrification are about 60% in Langa and 80% in Gugulethu. As already mentioned, households in Langa and Gugulethu are very large in size (average 7,7 in the sample) due to the prevalence of backyard shacks. Average consumption levels of households in the sample in Langa and Gugulethu are 585 kWh/month (summer mean) and 644 kWh/ month (winter mean). The average amount for which these consumers are in arrears for non-payment of electricity accounts is about R1 200 per household.

APPLIANCE OWNERSHIP

Ownership and daily use of electric appliances (particularly stoves) is well-established in households in Langa and Gugulethu. In Khayelitsha, a wider range of appliances is used (Figure 2a, b, c, d). Where electric appliances are not used, paraffin appliances are more prevalent than gas appliances in Langa and Gugulethu. The reverse is true in Khayelitsha. Geysers are found only in the newer houses in Khayelitsha.

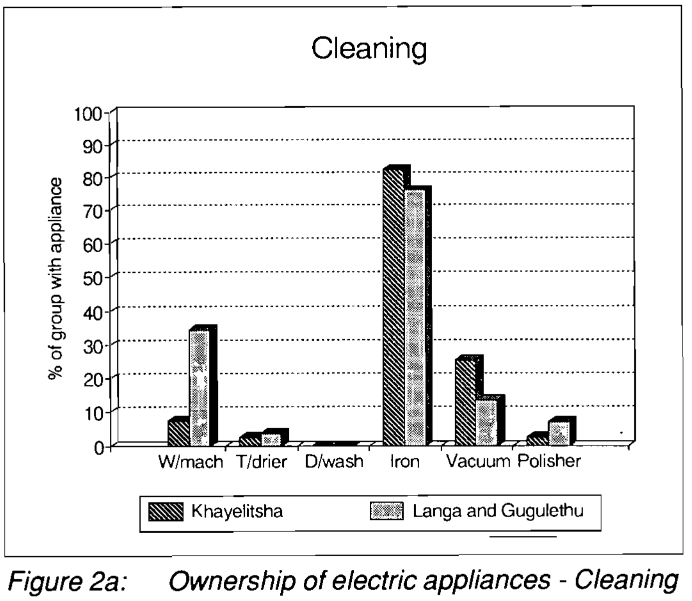

Figure 2a: Ownership of electric appliances - Cleaning

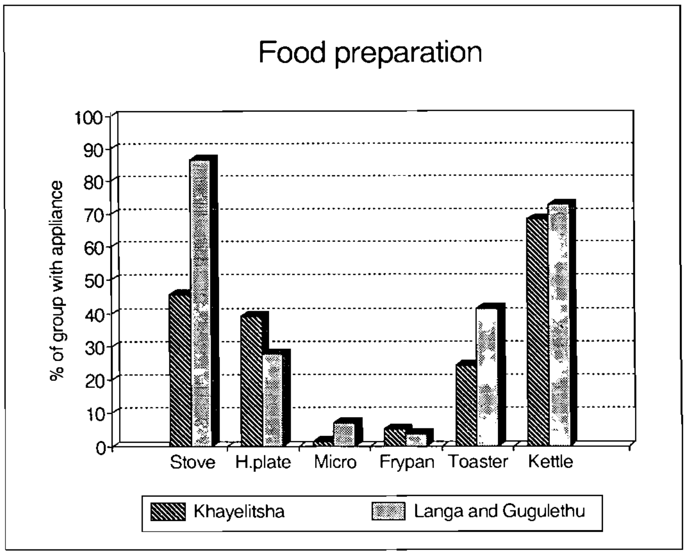

Figure 2b: Ownership of electric appliances – Food preparation

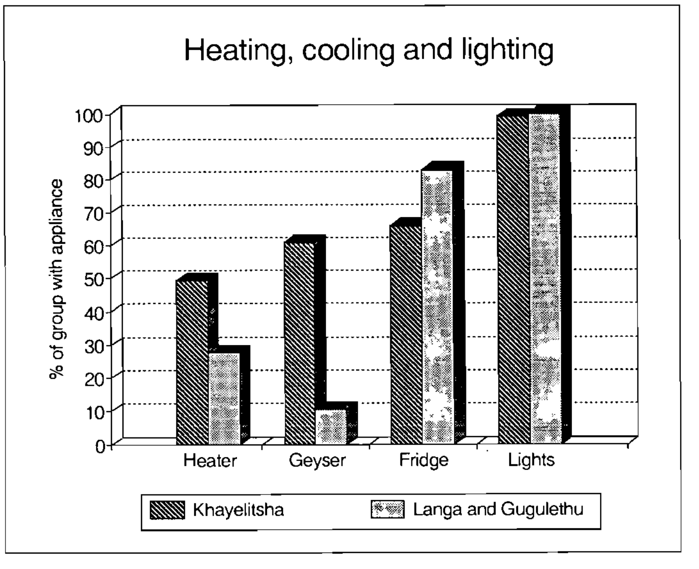

Figure 2c: Ownership of electric appliances – Heating, cooling and lighting

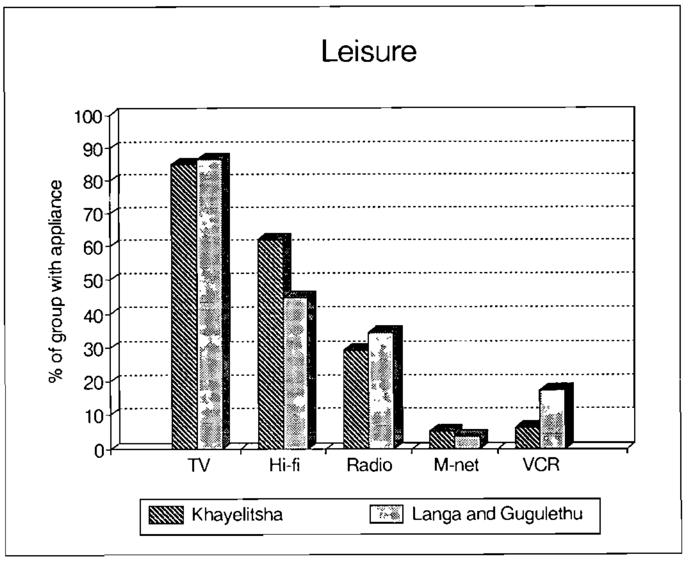

Figure 2d: Ownership of electric appliances – Leisure

About half of all households in Khayelitsha cook primarily on a multi-plate electric stove (see Figure 3). The rest are evenly spread between electric hotplates, gas stoves and a mix of cooking appliances (a "mix" here refers to households that do not use only one type of cooking appliance on a daily basis). About one-fifth of households indicated that they intend to purchase new electric stoves at some time in the future.

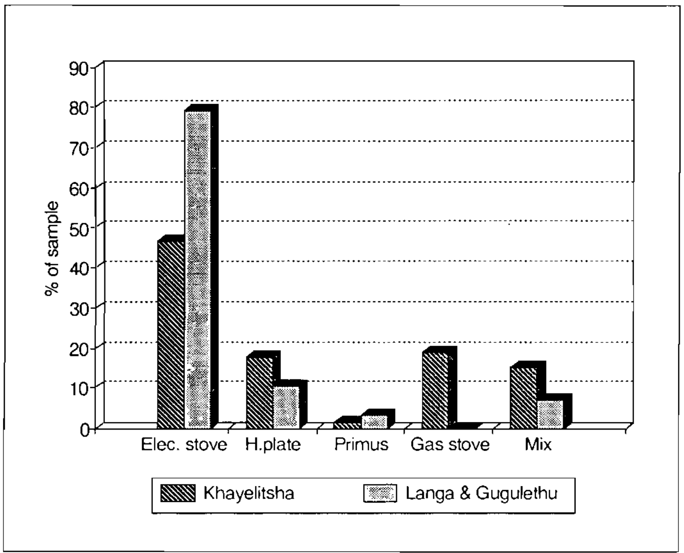

Figure 3: Primary appliances used in cooking

A closer study of those cooking primarily with gas in Khayelitsha showed that the major reason for doing so was the high cost of electric stoves. However, three-quarters of these households claimed that they would probably buy an electric stove in the future.

HOUSEHOLD FUEL USE

About one-fifth of electrified households in the areas surveyed still use paraffin and gas daily. Dependence on electricity, where it is the only fuel used daily, occurs more in the older areas of Langa and Gugulethu. There is some evidence that households retain paraffin and gas appliances because of problems of reliability in the supply of electricity.

Wood and coal are not normally used, except for the cooking of traditional meals and braais.

In order to compare the actual quantities of energy consumed it is necessary to express amounts in *useful* energy terms. This involves converting the physical quantity of each fuel used into *net* energy terms (in megajoules) by multiplying this quantity by the average energy content of the fuel, and then converting it into the amount of *useful* energy actually available by multiplying the amount by the average appliance efficiencies. These appliance efficiencies are shown in Table 1.

Appliance	Efficiency (%)
Electric stove	80
Electric hot plate	80
Gas stove	70
Primus	50

Table 1: Conversion efficiencies for cooking appliances

On this basis, useful energy consumption in the areas sampled was found to be roughly equal to average useful energy consumption of households in the area of supply of the Cape Town City Council's Electricity Department (Figure 4). Useful energy consumption was higher in high-income households.

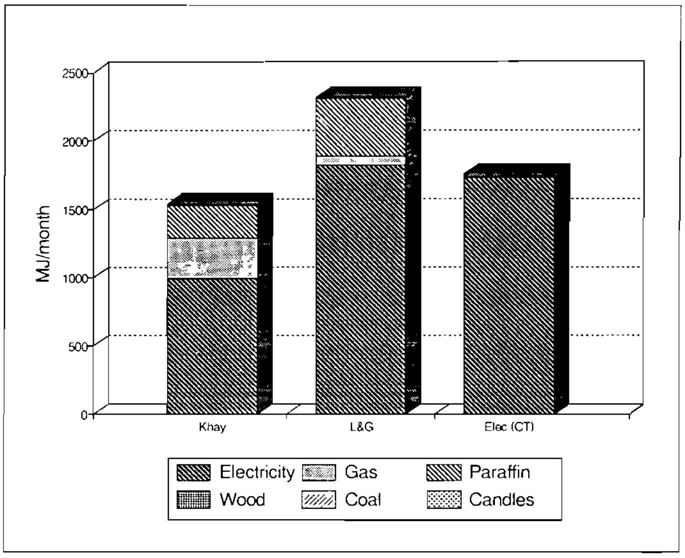

Figure 4: Average monthly useful energy consumption

Hire-purchase (HP) payments on electric appliances contribute significantly to household energy costs, particularly in the newly electrified areas. In Khayelitsha, HP costs make up 45% of the average monthly energy bill (Figure 5). HP payments were also shown to be highest in high-income households.

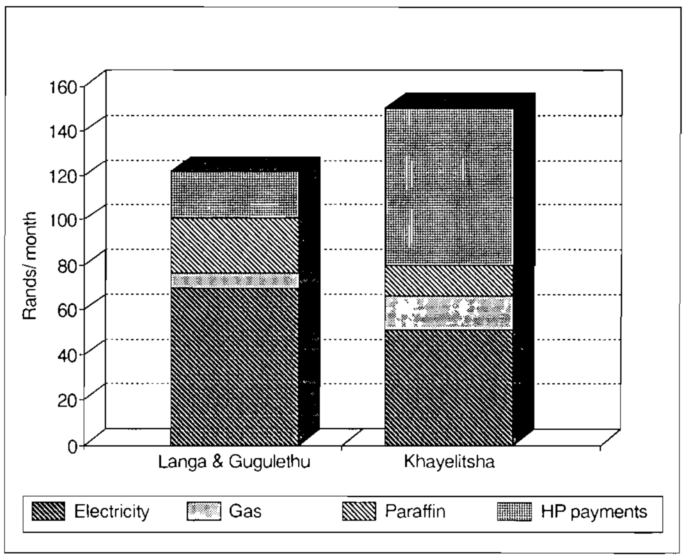

Figure 5: Average monthly energy costs

Energy costs make up between 10% and 20% of the total household budgets. The percentage contribution of energy is higher for poorer households (Figure 6).

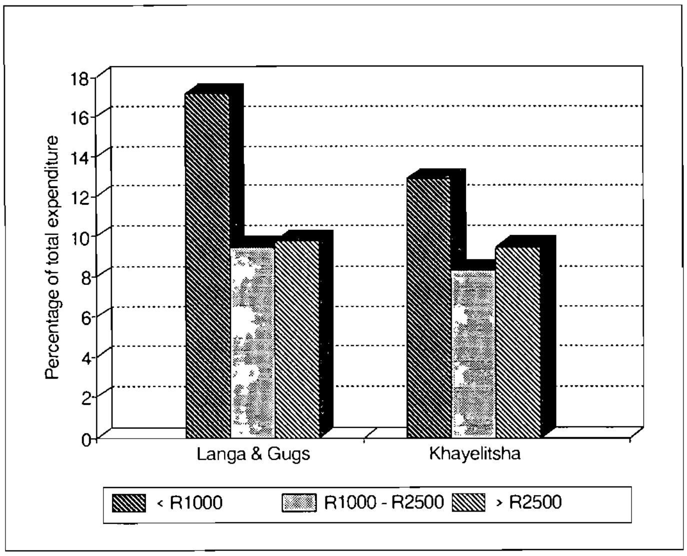

Figure 6: *Energy costs as a percentage of household budget*

THE AFFORDABILITY OF ELECTRICITY

Electricity was found to be the cheapest fuel, in useful energy terms, for cooking in the areas surveyed. In Langa and Gugulethu, where electricity tariffs are slightly lower, electricity is clearly cheaper. In Khayelitsha, the margins were found to be much smaller (Figure 7).

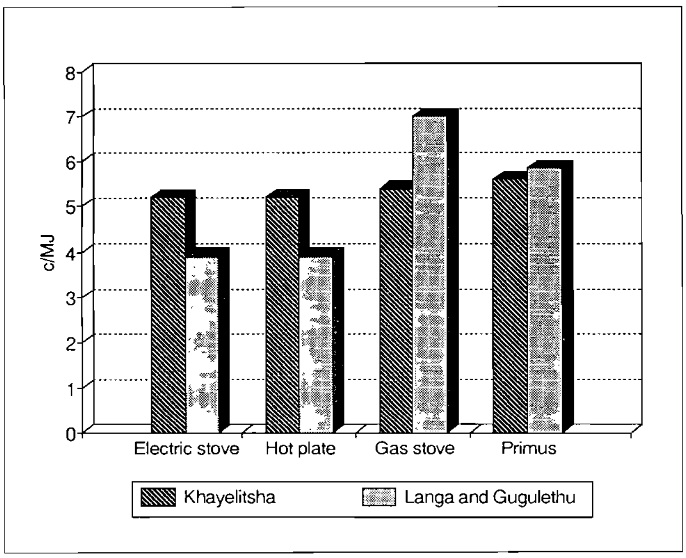

Figure 7: *Useful energy costs for cooking appliances*

It was found that consumers with credit meters perceived electricity to be unaffordable. Many consumers with credit meters are presently in arrears with their electricity payments.

ATTITUDES TOWARDS ELECTRICITY

Attitudes towards credit meters and pre-payment meters were very mixed. In the survey respondents were asked to list the advantages and disadvantages of credit and pre-payment meters. The results were then analysed. Pre-payment meters were mostly well-liked in spite of the poor reliability experienced with early models installed in Khayelitsha. Consumers with different cash-flow and income circumstances preferred different types of meters. This points towards the need for a flexible approach to the choice of meters for particular areas.

The majority of respondents surveyed preferred high-mast lights over standard street lights. This is primarily due to the fact that they create a brighter, safer night environment.

THE QUALITY OF THE ELECTRICITY SERVICE PROVIDED

It was found that the reliability of supply in the areas studied is poor. Black-outs occur frequently in some areas (up to 80% of households survey said 'often' in some areas). Poor reliability prevents full dependence on electricity for daily activities, such as, cooking.

Reliability is still perceived as a problem in Langa and Gugulethu, both of which are served by a well-established distribution authority. The survey found that residents interviewed felt that their areas were not effectively represented on the Cape Town City Council, and that they were thus unable to voice their protest at the quality of service provided.

KEY DETERMINANTS OF INCREASED ELECTRICITY CONSUMPTION LEVELS

The use of electric stoves for cooking is the most important factor leading to higher electricity consumption levels (see Figures 8a, 8b). In Khayelitsha, about half of the households surveyed cook on electric stoves. This group had consumption levels which were one-third higher than the average for the area. Those cooking with electric stoves had total monthly electricity consumption levels of 45% higher than those cooking with gas.

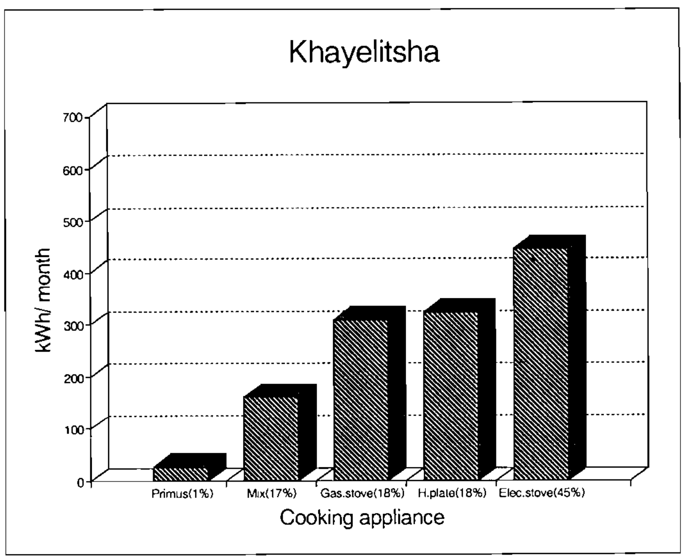

Figure 8a: *Total electricity consumption for households in Khayelitsdha using various cooking appliances*

Electric hotplates did not markedly increase electricity consumption because they were normally used with other fuels for cooking.

Geysers were also found to lead to higher electricity consumption. Households with geysers had consumption levels which were about 50% higher than those without electricity, in the areas surveyed (Figure 9).

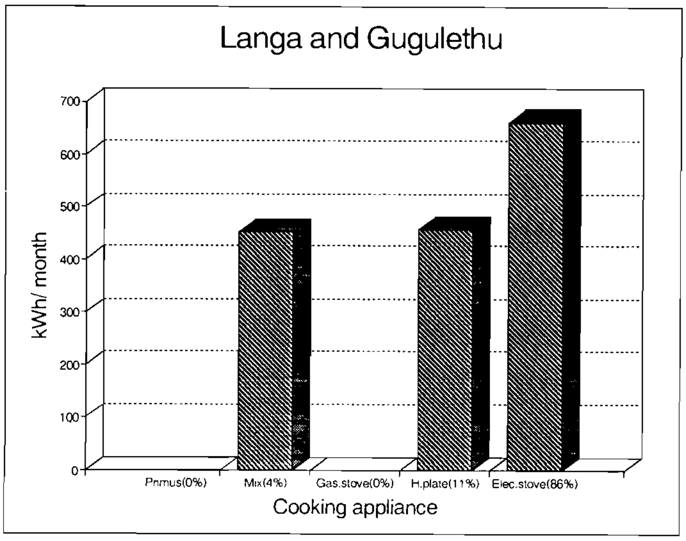

Figure 8b: *Total electricity consumption for households in Langa and Gugulethu using various appliances*

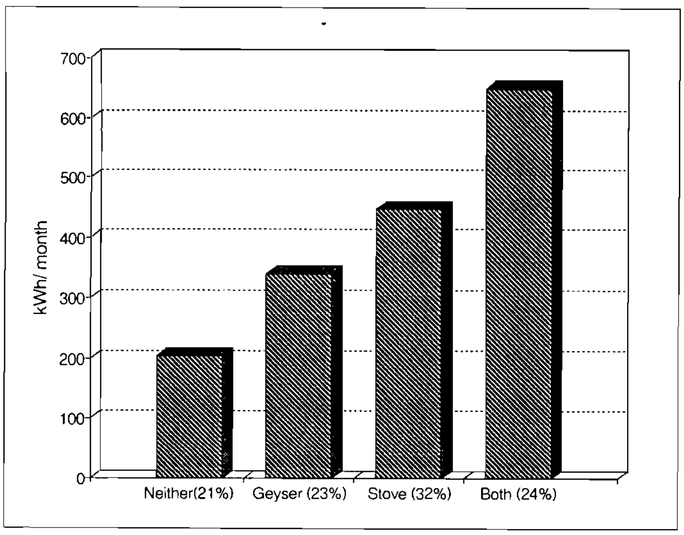

Figure 9: *Total electricity consumption for households using various stoves and/or geysers*

The period of access to electricity is another important determinant of growth in consumption levels (Figure 10a, b). It was found that electricity consumption levels in households connected for a year in one part of Khayelitsha were 60% higher than households recently connected to an electricity supply point (Figure 11).

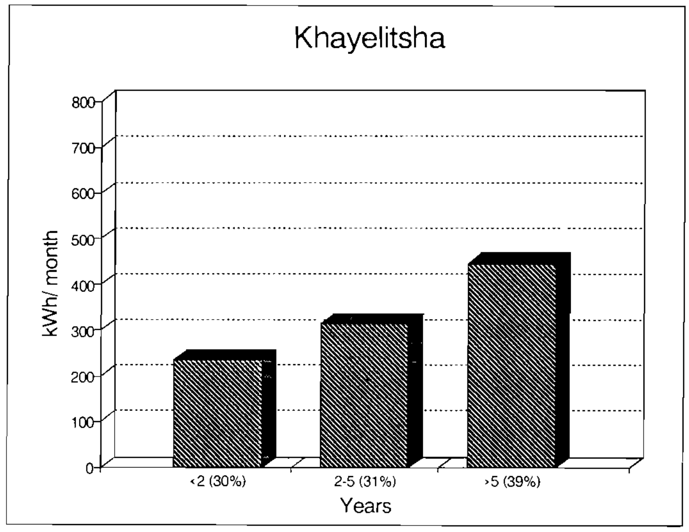

Figure 10a: *Years of access to electricity – Khayelitsha*

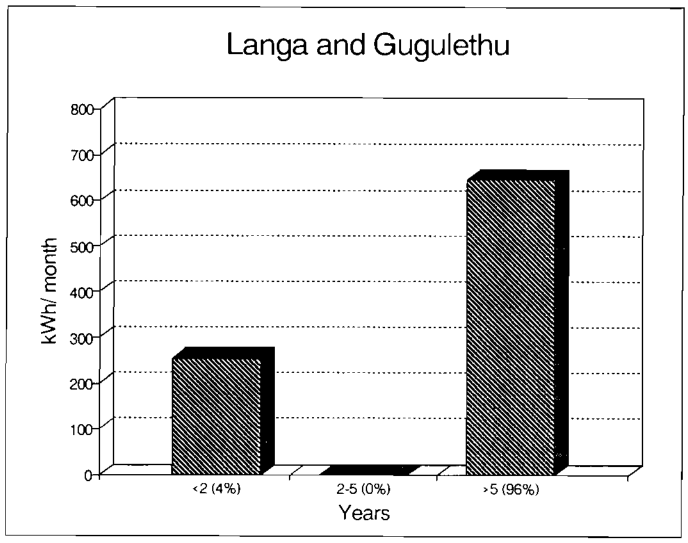

Figure 10b: *Years of access to electricity – Langa and Gugulethu*

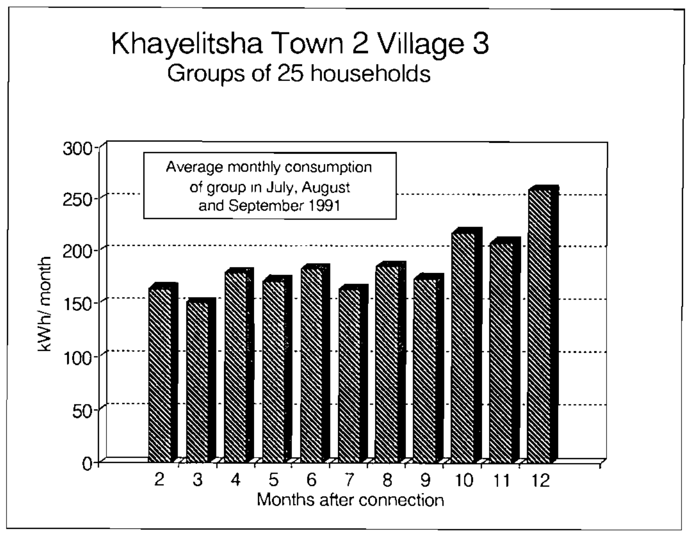

Figure 11: *Period of access to electricity*

Businesses run from home resulted in higher household electricity consumption (Figure 12a, b). About one-fifth of households in the sample ran businesses from home. The extent of the increase in consumption depended on the type of business being operated. Support, in the form of credit facilities, for the creation of home-based micro-enterprises in low-income areas would probably result in increased electricity consumption.

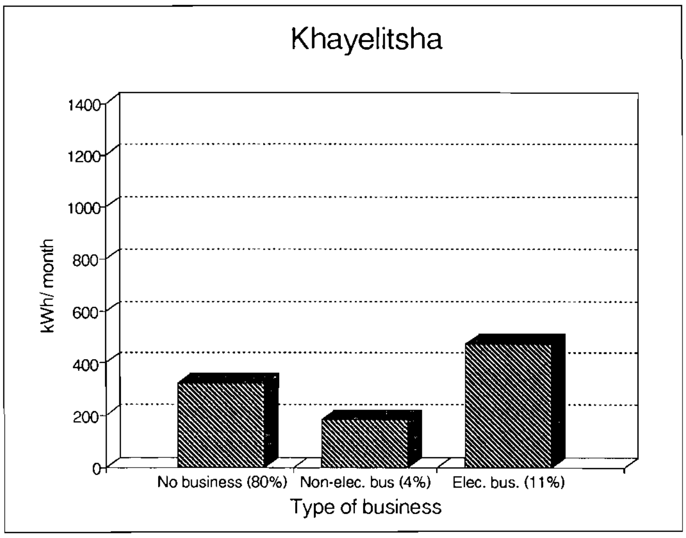

Figure 12a: Business activity – Khayelitsha

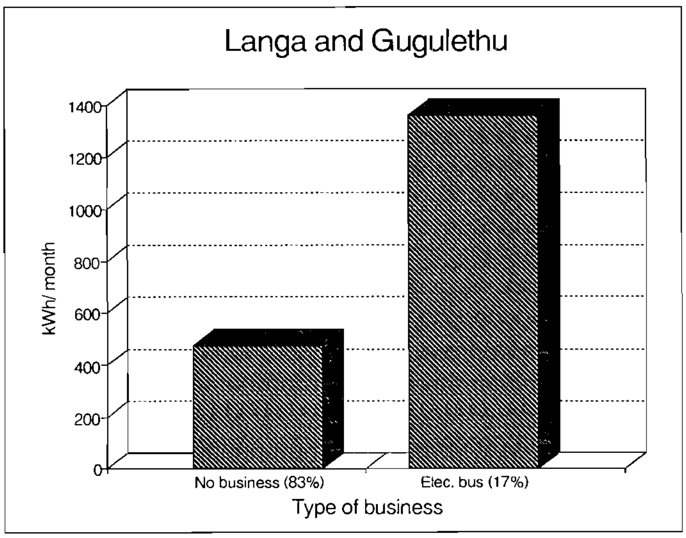

Figure 12b: Business activity – Langa and Gugulethu

Household size and reported household income are in general not good indicators of electricity consumption levels, although there was some evidence that very large households use significantly more electricity (Figures 13a, b and 14a, b).

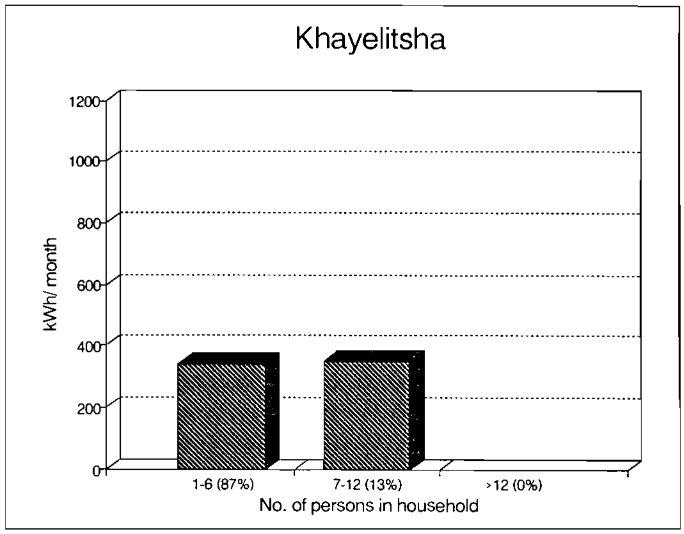

Figure 13a: Household size – Khayelitsha

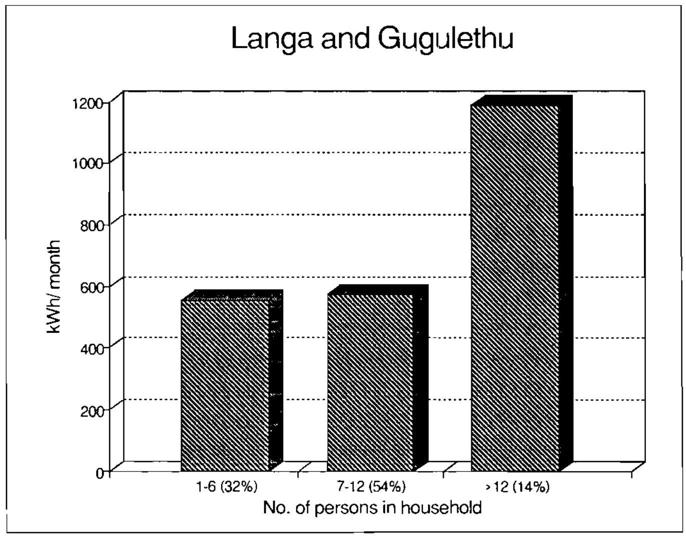

Figure 13b: Household size – Langa and Gugulethu

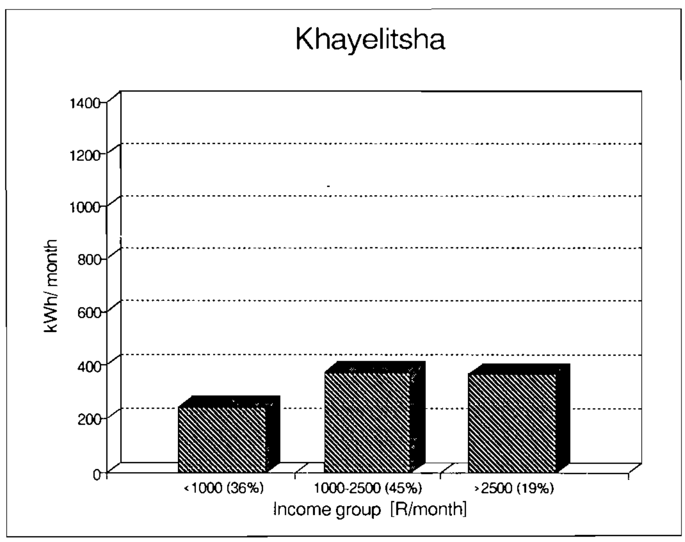

Figure 14a: Household income group – Khayelitsha

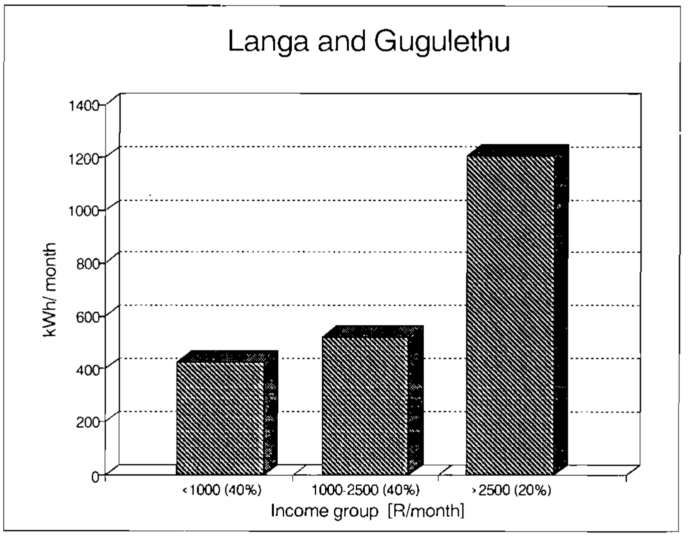

Figure 14b: Household income group – Langa and Gugulethu

ONGOING WORK IN THE ANALYSIS OF ELECTRICITY CONSUMPTION IN LOW-INCOME AREAS OF THE WESTERN CAPE

Aspects of the project described above are in the process of being repeated. The 108 households surveyed in the initial project are being revisited with an updated questionnaire. This will give further indications of trends in electricity use by extending data on average monthly electricity consumption by 12 months.

The initial findings of this exercise show that the amount of electricity used continues to increase. The increase in average consumption in some areas was found to be in the order of 80 units over the 12 months since the first survey.

The second phase of the project has been redesigned on the basis of wide consultation with outside parties. A range of individuals and organisations were invited to critique the methodology and scope of the initial project. It is hoped that the report produced at the end of the second phase will make a further contribution to the understanding of the electrification process.

RELEVANCE OF FINDINGS FOR THE ELECTRIFICATION OF LOW-INCOME AREAS

This study has revealed a number of important issues which have a general bearing on the electrification of low-income areas.

A central question affecting electrification planning relates to expected electricity consumption levels. The study has provided clear quantitative evidence that consumption levels in newly electrified areas have risen with time (Figures 10 and 11). Further tracking of this trend is necessary, but the much higher levels of consumption in Langa and Gugulethu suggest that it will continue. This evidence should encourage those planning electrification projects to count on higher consumption levels with time.

The key determinants of higher electricity consumption were found to be ownership and use of large electric appliances, particularly stoves and geysers. Higher consumption levels is likely to result from the acquisition of new appliances. This represents a "win-win" situation. Households will enjoy greater convenience and lower useful energy costs, and the distribution authority will enjoy a better return on its capital investment. On evidence given in this study, consumption levels after the installation of a stove or geyser could rise by up to 50%.

The purchase of new appliances may cause total household energy costs (including the cost of paying for the new electric appliances) to rise for a period. Yet the longer term benefits for the households are clear. The high levels of expenditure on HP payments for electric appliances in Khayelitsha are evidence that the purchase of appliances is already a priority for newly electrified households.

What steps can be taken to increase market penetration of large electric appliances? Both appliance manufacturers and electricity distribution authorities stand to gain from producing and marketing lower cost electric stoves. Non-profit schemes to market and distribute appliances have been used with much success all around the world (including in White municipal areas in the past) and need to be explored actively for use in low-income areas.

As evidenced by their low incidence in Langa and Gugulethu, geysers tend to be installed at the time of the construction of a new house, or not at all. Nonetheless, distribution authority schemes to assist households to install geysers may be feasible. Again, such schemes would be very much in the interest of manufacturers and distribution authorities to undertake. This is not to suggest that alternative methods of heating water in electrified houses, such as solar water-heaters, should not be considered.

Improving the reliability of the electricity service provided in low-income areas should be a priority. Besides being necessary for reasons of equity, consumption levels will probably rise if quality improves. Many households retain, and continue to use, non-electric appliances because of the frequency of black-outs. Dependence on electricity will rise if the service is dependable.

For similar reasons, the reliability of pre-payment meters installed in low-income areas needs to be improved. The results of the study in Khayelitsha indicate that, on the whole, these meters are liked, despite their dismal reliability record in the area.

Introducing innovative appliance marketing schemes and improving the quality of supply in low-income areas can only be undertaken by professionally run, service-oriented distribution authorities. Very few township areas, and certainly not Khayelitsha, Langa or Gugulethu, have such authorities. The distribution sector of the South African electricity supply industry has evolved within the paradigm of apartheid, and township areas are in most cases served by institutionally weak Black local authorities. The current structure of the electricity distribution sector and possible options for restructuring have been considered by Steyn and Theron(3). The formation of a National Electrification Forum, which would draw in all major parties to consider this issue, is currently under consideration.

CONCLUSIONS

Electrification in South Africa has reached a stage where it is seen as a necessary strategy for increasing living standards and promoting economic growth. Whilst further research is always useful, it is now no longer necessary to argue the positive contribution that electrification can make to households, communities and the national economy. With the growing commitment from Eskom and local authorities to the electrification of more than three million households in South Africa, it remains for researchers to attempt to analyse and understand ways in which the benefits of these actions can be maximised for all concerned. It is to be hoped that the information gained from micro-level studies, such as the one described in this paper, will prove to be useful in this way.

ACKNOWLEDGEMENTS

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REFERENCES

(1) BORCHERS M L and EBERHARD A A (1991). Household energy supply and price trends. Unpublished Draft Final Report for the Energy Branch, Department of Mineral and Energy Affairs. Project number NE/14/6/12.

(2) THERON P (1992). Electricity use in low-income areas of the Western Cape. Unpublished Draft Final Report for the Energy Branch, Department of Mineral and Energy Affairs. Project number NE/14/6/17.

(3) STEYN G and THERON P (1992). Policy proposals on electricity and local government in South Africa. Report submitted to Planact for the Bulk Services Study of the Local Government Policy and Planning Research Project (LOGOPOP).

THE COST-EFFECTIVENESS OF EXPLOITING LANDFILL GAS IN SOUTH AFRICA

* T M LETCHER and ** R SCHÜTTE

Landfill gas (LFG) contains over 50% methane and hence can be considered as an energy source. This paper investigates the cost-effectiveness of exploiting landfill gas in South Africa. Energy options for use in electricity production, water-heating, space-heating, clay drying and brickmaking are analysed in this paper. The results are compared to energy costs currently in force in South Africa. It is shown that electricity from landfill gas can be produced at a cost of 9c per kWh. This is comparable to current Eskom charges. Water-heating from the burning of LFG can be obtained for as little as 3c per kWh. This is very much cheaper than the costs involved in using paraffin, liquefied petroleum gas (LPG) or coal which costs about 20c, 42c and 12c per kWh respectively.

KEYWORDS: landfill gas; waste-derived fuels; cost-effectiveness

INTRODUCTION

The exploitation of methane from landfill has been well demonstrated overseas[1] and to a lesser extent in South Africa[2]. The cost-effectiveness of the exploitation in South Africa has unfortunately not been fully researched. The main reason for this is that the pumping of landfill sites for methane gas is a new concept, and up to the end of 1991, the gas was being pumped from only two sites in South Africa, namely, Grahamstown and Robinson Deep.

The reasons for the lack of interest in exploiting landfill gas in South Africa are, firstly, environmental issues do not appear to be as important to the common man in South Africa as they are in Europe or in the U.S.A. Secondly, the cost of energy and electricity has, until recently, been relatively low-priced in South Africa.

In order to make a decision on the cost-effectiveness of exploiting methane from landfill the following information must be accurately known:

(a) how much LFG, and hence methane gas, can be pumped from the landfill in question per hour?
(b) how much energy can be obtained from the LFG?
(c) what is the cost of
   (i) the drilling of the wells,
   (ii) the high-density polyethylene (HDPE) piping and fitting,
   (iii) the vacuum pump for extracting the gas, and
   (iv) the appliance (e.g. hot-water system or electricity generator etc.)?
(d) is it essential to use a gas storage system (gasometer)? If so, what would it cost?
(e) what is the life expectancy of each of the items in (c) and (d) above?
(f) how does the cost, taking (a), (b), (c), (d) and (e) into account, compare with alternative energy sources, e.g. paraffin, coal, LPG or electricity?

Each of these points will be discussed in turn.

* Head: Chemistry & Applied Chemistry, Department of Chemistry, University of Natal, King George V Avenue, Durban 4001, South Africa
** 208 York Street, Greytown 3500, South Africa

HOW MUCH METHANE GAS CAN BE PUMPED FROM A LANDFILL SITE?

This question can be answered by doing a sophisticated pumping trial with a variable speed pump and accurate pressure sensors surrounding the trial well.

Alternatively, the result can be obtained, theoretically, by using refuse survey data and kinetic models of anaerobic digestion[3]. The second method is used in this paper.

The results of a technical investigation with per capita refuse production are given below[4]:

INCOME STATUS OF COUNTRY	WASTE PRODUCTION ($kg.cap^{-1}.day^{-1}$)
low-income countries	0,4-0,6
middle-income countries	0,5-0,9
industrialised countries	0,7-1,8

A figure of 1 $kg.cap^{-1}$[5] is used in the following analysis. It is assumed that all of the refuse is landfilled.

The authors have shown previously[6] that each tonne of dry biodegradable waste produces 416 m^3 of methane over many years. If it is assumed that 50% of the landfill is biodegradable, a figure of 53% was obtained at the Grahamstown site[7]) and that the landfill has a moisture content of 30%, then every person will produce, each year

$$0,365 \times 0,70 \times 0,50 \text{ tonne}$$

of dry biodegradable waste. This material under anaerobic conditions will eventually be degraded into methane and the maximum possible volume of methane obtained from this over many years is:

$$0,365 \times 0,70 \times 0,50 \times 416 \text{ m}^3 = 53,1 \text{ m}^3$$

If the dumping of refuse continues at a constant rate for 5-10 years a steady state will be reached, and the maximum amount of methane extractable from the landfill each year will be 53,1 m^3. Assuming that half of the gas is lost by diffusion, then the amount produced per capita per year (assuming steady state conditions) is 26,6 m^3. In the U.K., a figure of 40,5 m^3 has been used[8].

HOW MUCH ENERGY CAN BE GOT FROM THE LFG?

The authors have found that a cubic metre of methane, at Standard Temperature and Pressure (STP), contains 36 MJ of energy[6] and hence, the energy production from 26,6 m^3 cap^{-1} yr^{-1} is:

$$26{,}6 \times 36 = 956 \text{ MJ cap}^{-1} \text{ yr}^{-1} \text{ or } 30 \text{ W cap}^{-1}$$

A town of 10 000 inhabitants could produce 300 kW of energy from its landfill site, assuming a 100% conversion of energy from burning methane. Realistically, the town could only produce 100 kW of electricity or, expressed in another way, 2,4 MWh or 2400 units from its landfill site, assuring a conversion efficiency of 33%. This amounts to only one or two percent of the domestic electricity needs of a small town with 10 000 inhabitants.

WHAT IS THE COST OF DRILLING WELLS?

The cost depends on the number of holes and the analysis is given in Table 1.

Number of holes	1	5	10	20
Area of landfill/m²	3 600	18 000	36 000	72 000
Depth of landfill/m	10	20	20	20
Population serviced by landfill	10 000	100 000	200 000	400 000
Cost per hole/R	15 000	3 800	2 400	1 700

Table 1: The cost of drilling a landfill as a function of the number of holes

It is assumed that the sites are being used for landfilling, are well-developed anaerobically, and are at least 5 years old. The cost of installing the drilling rig is assumed to be R14 000 and the cost of drilling each hole is R1 000 (this is based on a recent quotation - April 1992).

In the authors' experience, pile driving is very much more effective than drilling. The plastic and car tyres inhibits normal drilling procedures. It can be seen that the price per hole is very much dependent on the number of holes.

WHAT IS THE COST OF THE HDPE PIPING?

The current cost of 100 mm HDPE is about R55 m^{-1} (based on an April 1992 quotation). Polyvinyl chloride (PVC) is very much cheaper but it is brittle, and the weight of lorries over the trenches containing the PVC pipes could well result in the PVC cracking. The same problem arises with earth movements caused by increased compaction of the landfill following the decomposition of the biodegradable material.

Assuming the pump house is 100 m from the first well, that the wells are spaced 60 m apart and that the wells are 10 m or 20 m deep, then the cost structure is as given in Table 2.

Number of holes	1	5	10	20
Depth of holes/m	10	20	20	20
Length of piping/m	110	440	840	1 540
Cost per hole/R	6 050	4 840	4 620	4 510

Table 2: The cost of piping (HDPE, 100 mm)

The cost of piping per hole decreases only slightly as the number of pipes increase.

WHAT IS THE COST OF VACUUM PUMPS OR GAS BLOWERS FOR LANDFILL GAS EXTRACTION?

There are many vacuum pumps and blowers which are useful, some being specially designed with spark-proof motors for LFG.

The authors have used an air vacuum pump (40 m^3 h^{-1}) and a landfill gas blower (200 m^3 h^{-1}). The latter, being specially designed for methane containing LFG, was fitted with special spark-free switches.

The smaller pumps' (40-50 m^3 h^{-1}) current costs are between R12 000 and R20 000. The larger pumps (200-300 m^3 h^{-1}) cost in the region of R20 000 and R55 000.

IS A GAS STORAGE SYSTEM NECESSARY, AND IF SO, WHAT IS THE COST?

Gas storage facilities are necessary if the maximum use of the methane is required. An alternative procedure is to flare unwanted gas. This unfortunately results in a loss of energy.

The cost of gasometers is high and a recent quotation for a 500 m^3 storage vessel amounted to over R500 000. The cost of gas storage facilities would increase the cost of exploitation enormously.

THE OVERALL COST OF THE PUMP AND PIPING SYSTEM

Using the figure previously quoted, the cost of the piping and pump installation (including a pump house at R10 000) is summarised in Table 3.

Number of holes	1	5	10	20
Area of landfill/m²	3 600	18 000	36 000	72 000
Depth of landfill/m	10	20	20	20
Estimated flowrate per hole for CH_4 gas/m^3 h^{-1}	15	25	25	25
Number of pumps required	1 small	1 large	2 large	3 large
Total cost of installation/R	71 050	133 200	240 200	384 200

Table 3: The total cost of the "methane from landfill" infrastructure

The total cost includes a pump house (R10 000 or R20 000) and pumps (estimated price of R20 000 for the smaller one which pumps at 50 m^3 hr^{-1} and R40 000 for the larger pump which pumps at 200 m^3 hr^{-1}). All pumps have been duplicated. The cost does not include gas storage facilities.

COST OF APPLIANCES

There is a large range of applications to which the methane can be put. Some of these include electricity generation, household hot-water systems, space-heating, clay drying, lighting, cooking, brick-firing, hot-house warming, and baking. Other possibilities, such as vehicular use, have not been discussed.

The cost of each of these are very different as can be seen from Table 4.

	required CH_4 flow rate /m^3 hr^{-1} per unit	rated efficiency %	cost /10^3R per unit
Gas turbine (4 MW)	1 000	40	15 000
Diesel ADC (100 kW) (local)	25	40	150
Spark ignition 400 kW	100	401	500
Spark ignition (50 kW)	13	30	50
Hot-water system (20 kW)	5	40	6
Cooking (2 kW)	0.5	40	0.5
Brickmaking (80 kW per lance)	20	40	1.0
Lighting (200 W)	0.20	10	0.5

Table 4: The estimated cost of appliances and values for the exploitation of methane from landfill

LIFE EXPECTANCY FOR EACH OF THE APPLIANCES

It is very difficult to assess this and the authors have used a figure which covers only 5 years. The calculations were based on a five-year period redemption, borrowing the money at 20%.

CALCULATION OF COSTS

Tables 5, 6 and 7 give a breakdown of the costs involved for realistic landfill sites serving 10^4 or 10^5 or 2 x 10^5 or 4 x 10^5 people. The Tables relate to electricity production, hot-water generation and brickmaking. Other applications, such as, bitumen melting, space-heating, hot-house warming and clay drying, would involve costs similar to those in the brickmaking application.

Table 5 illustrates the costs involved in exploiting methane from landfill for electricity production. The figures are based on a realistic landfill site which is 5 years old. No gas storage facility has been included.

1.	Number of holes	1	5	10	20
2.	Area of landfill/m^2	3 600	18 000	36 000	72 000
3.	Depth of landfill/m	10	20	20	20
4.	Population served	10 000	100 000	200 000	400 000
5.	Flow rates per hole/m^3 h^{-1} (30% efficiently)	15	25	25	25
6.	Solid waste/ tonne yr^{-1}	3 600	36 000	72 000	144 000
7.	Total methane flow rate/m^3 h^{-1}	15	125	250	500
8.	Maximum possible energy (100% efficiency)/MJ h^{-1}	540	4 500	9 000	18 000
9.	Realistic electricity produc. (30% efficiency)/MJ h^{-1}	162	1 350	2 700	5 400
10.	Realistic energy produc. /10^6 kWh yr^{-1}	0,39	3,29	6,57	13,14
11.	Realistic rate of energy production/kW	45	375	750	1 500
12.	Engines installed (incl. replacement)/kW	2 x 50	2 x 400	2 x 750	2 x 1500
13.	Cost, engines and installation/10^3R	100	1 000	2 000	4 000
14.	Cost of infrastructure/10^3R	71	133	240	384
15.	Annual redemption (5 yrs @ 20%)	37	227	448	877
16.	Annual maintenance/10^3R	30	50	75	100
17.	Annual supervision part-time 10^3R	20	40	-	-
	full-time 10^3R			100	200
18.	Total annual costs/10^3R	87	317	623	1 177
19.	Electricity costs/ c(kWh)$^{-1}$	22,3	9,7	9,4	9,0

Table 5: The costs involved in exploiting methane from landfill for electricity production

In Table 6 it has been assumed that the houses are 50 m apart. Again no allowance has been made for gas storage. Row 22 does not include the cost of the gasometer.

1.	Number of holes	1	5	10	20
2.	Area of landfill/m^2	3 600	18 000	36 000	72 000
3.	Depth of landfill/m	10	20	20	20
4.	Population served	10 000	100 000	200 000	400 000
5.	Flow rates per hole/m^3 h^{-1} (30% efficiency)	15	25	25	25
6.	Solid waste/tonne yr^{-1}	3 600	36 000	72 000	144 000
7.	Total methane flow rate/m^3 h^{-1}	15	125	250	500
8.	Maximum possible energy (100% efficiency)/MJ h^{-1}	540	4 500	9 000	18 000
9.	Realistic energy production boiling water (40% efficiency)/MJ h^{-1}	216	1 800	3 600	7 200
10.	Realistic energy production/ 10^6 kWh year^{-1}	0,526	4,38	8,77	17,53
11.	Realistic energy production/kW	60	500	1 000	2 000
12.	Gasometer volume/m^3	100	1 000	2 x 1000	4 x 1000
13.	Gasometer cost/10^3R	20	100	200	400
14.	House units	3	25	50	100
15.	Cost of hot-water units and piping/10^3R	24	219	438	875
16.	Cost of infrastructure/10^3R	71	133	240	384
17.	Annual redemption (5 years @ 20%)/10^3R	24	95	186	352
18.	Annual maintenance/10^3R	20	30	60	80
19.	Annual supervision part-time/10^3R	10	20	40	-
	full-time/10^3R	-	-	-	100
20.	Total annual costs/10^3R	54	145	286	532
21.	Heating costs/c(kWh)$^{-1}$	10,3	3,63	3,2	3,0
22.	Heating costs/ c(kWh)$^{-1}$ (no gasometer)	9,4	2,9	2,8	2,6

Table 6: The costs involved in exploiting methane from landfill for household hot-water systems

1.	Number of holes	1	5	10	20
2.	Area of landfill/m^2	3 600	18 000	36 000	72 000
3.	Depth of landfill/m	10	20	20	20
4.	Population served	10 000	100 000	200 000	400 000
5.	Flow rates per hole/m^3 h^{-1} (30% efficiency)	15	25	25	25
6.	Solid waste/tonne yr-	3 60	36 00	72 000	144 000
7.	Total methane flow rate/m^3 h^{-1}	15	125	250	500
8.	Maximum possible energy (100% efficiency)/MJ h^{-1}	540	4 500	9 000	18 000
9.	Realistic energy production brickmaking (40% efficiency) /MJ h^{-1}	216	1 800	3 600	7 200
10.	Realistic energy production/ 10^6 kWh year^{-1}	0,526	4,38	8,77	17,53
11.	Realistic energy production/kW	60	500	1 000	2 000
12.	Alteration to existing gas burners/10^3R + blowers	50	50	100	200
13.	Cost of infrastructure	71	133	240	384
14.	Annual redemption (5 yrs at 20%)/10^3R	24	37	68	117
15.	Annual maintenance/10^3R	20	30	60	80
16.	Annual supervision, part-time/10^3R	10	20	40	-
	full-time/10^3R	-	-	-	100
17.	Total annual cost/10^3R	54	87	168	297
18.	Heating costs/c(kWh)$^{-1}$	10,2	2,0	1,9	1,7

Table 7: The costs involved in exploiting methane from landfill for brickmaking

The cost-effectiveness of LFG is seen when a comparison is made between the results found in Tables 5, 6 and 7 and the cost of other forms of energy which are tabled in Table 8.

Fuel	Cost of fuel to consumers (in Durban - March 1992) per unit	Cost c/MJ^{-1}	Cost c(kWh)$^{-1}$	Cost c(kWh)$^{-1}$ assuring 40% efficiency
Electricity	17c(kWh)$^{-1}$	4,72	17,0	
Paraffin	82c litre^{-1}	2,18	7,9	20
LPG [Afrox]	230c kg^{-1}	4,651	6,7	42
Coal	40c kg^{-1}	1,28	4,6	12

Table 8: A comparison of energy costs of alternate energy sources

CONCLUSIONS

The results from Table 5 show that LFG can be used to produce electricity at a cost of about 9c(kWh)$^{-1}$ for large installations (landfill sites servicing 100 000 and 400 000 people). This is slightly less than results obtained by Kolbe[5] who obtained 11,6c(kWh)$^{-1}$. This is comparable to the Eskom cost which ranges between 9c(kWh)$^{-1}$ (the cost to the Grahamstown Municipality) and 17c(kWh)$^{-1}$ (the cost to the consumer in Grahamstown).

LFG can be used to heat water at a low cost of 2-3c(kWh)$^{-1}$. This figure takes into account an efficiency of 40% for the LFG burners. Using a similar percentage efficiency the figures for paraffin, LPG and coal are 20c(kWh)$^{-1}$, 42c(kWh)$^{-1}$ and 12c(kWh)$^{-1}$ respectively.

Landfill gas is thus very much more cost-effective than using paraffin, LPG or coal or other alternative energy sources, and can be used to produce electricity at a price comparable to Eskom prices.

REFERENCES

(1) RICHARDS K (1989). All gas and garbage. *New Scientist,* 3 June, pp.38-41.

(2) LETCHER T M, ROSE P, LA TROBE B, TAYLOR S and THERON R (1988). Energy from landfill refuse sites. *ChemSA*, November, pp.333-337.

(3) LETCHER T M, SCHUTTE R and LA TROBE B (1991). Assessing the energy potential of a landfill site. *Journal of Energy R and D in Southern Africa,* Vol.2 No.1, February, pp.7-11.

(4) JOHNSON COINTREAU S, CUNNERSON C G, HULS J M and SELDMAN N N (1985). Recycling from municipal refuse. World Bank Technical Paper No. 30, World Bank.

(5) KOLBE F F (1991). Solid wastes as an energy source. *Imiesa,* March, pp.8-12.

(6) LETCHER T M (1990). Landfill gas properties. *Technology SA,* May, pp.15-17.

(7) SCHÜTTE R (1992). Methane from landfill. Unpublished Rhodes University MSc. thesis.

(8) UNITED KINGDOM. DEPARTMENT OF THE ENVIRONMENT (1990). National assessment of LFG production. Contractor's report.

OVERVIEW OF THE 15TH WORLD ENERGY CONGRESS

*** R K DUTKIEWICZ**

KEYWORDS: WEC; developing countries; developed countries; energy resources; renewable energy

INTRODUCTION

The 15th Congress of the World Energy Council was held in Madrid from the 20th to the 25th of September 1992. It attracted approximately 4 500 delegates from nearly 80 countries. There were also delegates from a number of international organisations. On offer were 240 technical papers presented in four parallel sessions and a number of working group, round-table and plenary sessions.

Many high-level delegates were present, with a sprinkling of Government Ministers and Deputies, the Secretary-General of OPEC, the Vice-Premier of China, and similar dignitaries. The technical papers varied from the excellent to the bearable, but the quantity on offer made digestion difficult and their true value will only become apparent after leisurely study subsequent to the Congress.

The ceremonial level of the Congress was made to match the diplomatic level of the delegates with a number of world prominent speakers, and the official opening on the first evening was made by the King of Spain. The first working day started with a plenary session addressed by invited speakers.

OPENING KEYNOTE ADDRESSES

During his opening keynote address the first speaker, Claudio Arazandi of the Spanish Ministry of Industry, pointed out that oil reserves have been increasing steadily over the last two or three decades and oil reserves now stand at 40 years of demand at the present consumption rate. It is anticipated that reserves will increase in the future. The reserves of gas have increased by a factor of 4 in the last five years and now stand at around 36 years of supply. It was considered that gas demand will increase at the expense of oil in relative terms. It is anticipated that oil prices will not increase in real terms over the next 8 years and thereafter will increase at a modest rate. Gas prices are expected to rise towards the price of oil.

David Simon, Deputy Chairman of BP, said that 40% of the oil which would be required by the year 2000 had not yet been discovered. He defended the oil industry's environmental position, and said that emissions from refineries had decreased by 40% over the last 10 years. In the U.S.A., refineries were spending 15-20 billion dollars per year on protecting the environment. In Europe, the figure was around 9 billion dollars. He warned against introducing a carbon tax unwisely and said that if such a tax was deemed necessary, then it should be applied to all energy sources equally.

Dr R K Pachauri, Director of the TATA Energy Institute in India, emphasised the plight of the developing countries, which would have to go through a phase of increasing energy intensity as they tried to improve their economies. Since the developing countries lacked the skills and finances for improving their energy efficiencies, it should be the role of the developed countries to assist the developing countries. He said that the main pollution problem in many developing countries was the exposure of mainly women and children to the emissions from the burning of traditional fuels in the indoor environment. He stressed that the present aid attitude to developing areas, whereby experts were "parachuted" into the region for a short time and then left, was not effective.

Dr Subroto, Secretary-General of OPEC, called for co-operation at the technical level between oil exporting countries and the oil majors. He pointed out that the role of the oil majors had changed dramatically over the last three decades, and that they had moved from being the only players on the petroleum front to being minor players. He pointed out that the new national oil companies, formed by many of the OPEC countries, were now amongst the largest oil producers in the world. He warned of the danger of a carbon tax, which would result in the net transfer of economic rent from the developing to the developed countries. It would lead to higher end-use energy costs, which would translate into increased costs of imports for the developing regions.

ENERGY HORIZONS IN A WORLD OF 9 BILLION INHABITANTS

A plenary session was devoted to the possible problems which will face the world when it reaches 9 billion inhabitants, estimated to be by the middle of the next century. Three speakers talked on this subject. The first speaker was Zou Jiahua, Vice-Premier of China. He discussed the problems which already beset China, a country with one-fifth of the world's population. China is placing significant emphasis on energy conservation, and energy intensity in China has fallen by 30% between 1980 and 1990. He saw oil consumption falling steadily in the next century, and that there would be a significant increase in the use of nuclear power. China is to increase its energy efficiency programme, and will also push for increased electrification in order to decrease pollution.

The next speaker was Mrs Maneka Gandhi, former Minister of Environment and Forests in India. She called for the world to relinquish its dependence on fossil fuels and said that renewable energy could be developed if the world gave up its insistence on developing armaments. There should be a move away from large centralised plant to decentralised small-scale renewable generation which must not be operated by governments. However, she said that the developed world uses 70% of the total world energy although they only have 15% of the population, and it was imperative for the developing countries to drastically reduce their energy intensity ratios. The developing

* Director, Energy Research Institute, P O Box 33, Plumstead 7800, South Africa

countries must be allowed to develop economically without any impositions on their energy situation. She claimed that energy prices in the developed countries were too low, leading to excessive energy consumption. She called for a halt to all nuclear energy development.

The final speaker was Mrs H Steeg, Executive Director of the International Energy Agency. She disagreed with many of the statements made by Mrs Gandhi, especially those on the subject of nuclear energy. She said that there was no easy solution in an uncertain world. She called for better collaboration on research and development amongst the developed countries, and said that the developing countries should be involved in this research. Prices should adequately reflect cost, especially in the developing world, and cross-subsidisation should not be allowed. Social subsidies should be kept separate from energy costs and should be seen for what they are. She suggested that transmission and distribution of electricity should be separated from the producers to allow for the development of competitive energy sources.

THE FUTURE OF LAND TRANSPORTATION

A round-table session was held on the subject of the future of land transport. Mr N Miura, Managing Director of Nissan Motors said that in Japan 50% of goods and 66% of passengers were moved by road. Of the total energy involved in road transport, 5,5% was utilised during the vehicle manufacturing phase, 10% in the production of materials for use in vehicle construction, and 84,5% was used for the actual transportation process. In a country such as Japan there was growing congestion on the road system and Tokyo was now considering putting 30% of the goods traffic underground.

Dr Roberta Nicholls said that in the U.S.A. rail transport was not cost-effective. However, increasing the efficiency of engines exacerbated the transport problem due to higher mileages. She did not think methanol would have a very large affect in the U.S.A. because people did not like to change to a new fuel source as they were happy with what they had. Electric vehicles would be an even further departure from that which people understood. In the U.S.A., electric vehicles had a higher capital cost than that of conventional vehicles, and also had higher operating costs. More work was required to be done on aspects such as car-pooling, and in the future more people might work from home.

Dr U Seiffert of Volkswagen in Germany said that 85% of transport in Europe was by road. In Europe, the diesel-engined passenger vehicle was increasing its share of the market. In Germany, it was found that in 1985 the total mileage increased significantly because of the decrease in the working week. He called for improvements in road systems to ensure a smoother flow, with a resulting decrease in energy usage and pollution production. If the CO2 problem was cause for concern then emphasis should be given to the use of diesel engines. He also said that it would be wrong for the developed world to export anything other than the most advanced engine systems to the developing world. He saw the use of hydrogen as still being a long way off.

ENERGY FOR TOMORROW'S WORLD

The World Energy Council has started a major project to investigate the problems and opportunities for world energy over the next quarter of a century. In order to carry out this work the world was divided into 8 regions, and committees were set up in each region to prepare energy status and scenario reports. These 8 separate reports will be integrated by a central organisation.

The Madrid Congress was the first opportunity for the various regional groups to report on their findings and to present their draft reports. It became clear from attendance at the various report-back sessions that the perceived problems and opportunities varied significantly from region to region. It will therefore be difficult to amalgamate the regional reports without generalising to such an extent that the summary becomes meaningless as a basis for action formulation.

An analysis was carried out by the central organisation on the findings to date, and they summarised the following key themes for the basis of an agenda for action:

(1) Achieving an adequate energy supply
(2) Energy technology development and supply prospects
(3) Containing the environmental impact of energy
(4) Energy efficiency and conservation
(5) Security of supply and interdependence

RENEWABLE ENERGY RESOURCES

One of the Standing Committees of the WEC is concerned with evaluating the resource base of renewable energy and the obstacles related to its utilisation. The preliminary results of this study were presented at a working group meeting. The energy forms studied include solar, geothermal, wind, hydro and ocean.

The findings of the committee are classified under two scenarios: the business-as-usual scenario and the ecologically-driven scenario. Under the business-as-usual scenario, and excluding the contribution of traditional biomass utilisation, it is estimated that by 2020 renewables will contribute 4% of total world energy demand. Under an ecologically-driven scenario the renewable energy contribution would be 14% of total world energy demand.

CONGRESS CONCLUSIONS

A summary and the conclusions of the Congress were produced and presented by John Baker from the U.K. He found that whilst there were many conflicting pressures on the world energy community, three coherent findings were apparent:

(1) The first priority must be to alleviate the poverty and suffering of the developing world. This could only be achieved through economic development and increasing use of energy resources.
(2) The use of energy, both in the developed and developing countries, must be associated with concern for the environment.
(3) There will not be any foreseeable shortage of energy for the next three decades.

GENERAL

The WEC has, for many years, organised large and impressive conferences, but the feeling after attending them was that no lasting benefit was derived from them. However, this now appears to be changing, mainly due to the number of projects being carried out outside the

Congress and which are being reported and discussed at the Congress. The most ambitious of these is the "Energy for Tomorrow's World" project. This project has already led to a large team effort in the different regions, and now allows an overall assessment of regional resources, opportunities and problems to be made.

Other major areas of work focus on the problems of developing countries, the role of renewable energy, waste handling, district heating, and thermal plant availability. Each of these is likely to make a significant input to our knowledge of the world's energy position and opportunities.

COMMENTS ON "ENERCONOMY '92"

***R K DUTKIEWICZ**

KEYWORDS: Enerconomy '92; energy economics; energy management; energy utilisation

INTRODUCTION

The Southern African Institute of Energy organised the "Enerconomy '92"Conference which ran from 8 to 9 June 1992 at the CSIR Conference Venue in Pretoria. The Conference focused on the effective use of energy in industry, mining, and commerce. It brought together 33 technical papers and two keynote speeches on the subject of the energy-economics relationship, and in particular, energy management and energy conservation. This paper covers some of the general impressions of the conference and of the field of energy management in South Africa gained by the author. The following comments on the conference highlight some of the main points made.

It was ably pointed out by a number of speakers that large amounts of money can be saved if energy is used wisely, most of the savings being made with very little expenditure. A figure of 10%-20% financial savings with no capital expenditure was quoted by a number of speakers. One of the guest speakers, Dr E.W. Lees, Head of the Energy Technology Support Unit in the U.K., estimated that in the U.K. the saving ratio on expenditure in this field was 7 to 1, i.e. an expenditure of R100 would result in a saving of R700. The second speaker, Dr Stiles from the SADCC Energy Group, explained that energy conservation has been recognised as being of prime importance in attacking the energy problems of the SADCC group of countries and that large amounts of money were being injected for this purpose. If these numbers are correct, then there is a potential saving of R1 500 million per annum in the South African economy.

The question may therefore be asked why it is that with such obvious financial gains to be made, there is no significant commitment to energy management and conservation in South Africa? There are possibly two main reasons for this apathy. In the first place, the cost of energy, and in particular electricity, in South Africa has been very low and any saving is overshadowed by the problems that manufacturers have experienced in terms of import dumping, labour unrest problems, sanctions, etc. The problems related to energy are thus seen as insignificant.

In the second place, energy conservation is not a highly visible process. It does not appear directly on the balance sheet, and there is nothing obvious to show for it. In fact, success is judged by the absence of something rather than by the presence of something. Industry understands budgets, tenders, construction programmes, and then the final cocktail party to mark the opening of the plant - but there is no culture of loss management in its wider context in South Africa.

BARRIERS TO EFFECTIVE ENERGY MANAGEMENT

There are, unfortunately, a number of barriers to the introduction of a cult of energy management. Most of these barriers are due to the lack of information available to determine the possible savings, a distortion of the energy market in South Africa, and a lack of accountability for energy matters in most companies.

One of the main barriers to energy information dissemination is the ubiquitous Petroleum Products Act which has cloaked in secrecy any data on oil matters. The Act itself has been largely useless, since it has been possible for people outside the country to estimate imports and demand with a reasonable degree of accuracy, whilst denying such information to research workers in the country. The only information that may have been of strategic value was the origin of the crude imported into the country, but this information is not required for carrying out any supply-demand analysis for the country. There is no need to maintain the secrecy any longer and the statement that there is still a United Nations ban on oil imports into South Africa, requiring the maintenance of secrecy, cannot be considered to be rational. It is estimated that the Petroleum Products Act has set back energy research in South Africa in this field by some five years.

Another barrier to the effective introduction of an energy management scheme in many companies is the present aversion to taking any risks and the siege mentality which requires a pay-back period of not more than six months for even small capital expenditure.

* Director, Energy Research Institute, P.O. Box 33, Plumstead 7800, South Africa

It is also true that the South African energy market is a distorted one, with the true cost of the supply of energy being hidden. No consideration is given to the externality costs of energy production. Whilst these externality costs may be insignificant when viewed against a background of high basic energy costs, as is the case in most of the world, they could well become significant when applied to very low energy costs. For instance, no consideration is given to the cost of depleting the country's coal resources.

A further problem with introducing an energy management system is the lack of accountability for energy costs in most companies. Energy costs are lumped together with water costs and rates and entrusted to an accountant to ensure that they are paid timeously. There is no analysis of energy costs, nor any desire to improve the situation. This is especially true in commercial buildings where any increase in energy costs is automatically passed on to tenants as increases in rent.

Within this rather bleak picture there are some signs that an awareness of energy management is occurring. It is encouraging that the developers of large commercial buildings are now looking at lifetime costs, with energy costs being a prominent part of these costs. A number of papers discussed work in this field, and it is evident that the consulting engineers are becoming proficient here and are providing a high-level service to their clients.

It is also encouraging to see from the papers presented at the Conference that the mining industry is beginning to develop energy management systems. At the moment there are only a small number of mines involved, but this should increase as the successes experienced by these mines become better known.

However, energy management systems have made very little impact on the other industrial sectors and especially in the manufacturing sector.

THE WAY AHEAD

What are the possible steps that can be taken to improve the situation in South Africa?

In the first place, the excellent papers of Dr Lees and Dr Stiles should be dissected to see what can be applied to South Africa with minimum changes. Both the U.K. and SADCC have gone further down the road to an adequate energy management system than South Africa. Their experiences should be analysed with a view to seeing what lessons South Africa can learn.

Secondly, there is significant scope for an awareness campaign to encourage industry to apply cost-saving methods. If the successes achieved by companies can be brought to the notice of others, showing the significant savings that can be achieved, then the normal economic force of "greed" should be sufficient to drive the dissemination of information.

For the reasons enumerated above, it is obvious that there is no industry-based method that can be used to introduce systems for the efficient management of energy. It is therefore imperative that Government introduce an imaginative and efficacious energy conservation programme. This should include an educational component, a publicity component, and also arrange for the provision of expertise.

CONCLUSIONS

Whilst there are some encouraging signs that energy management is being accepted in certain sectors of industry and commerce in South Africa, there is still a long way to go. The benefits to the country of introducing an effective energy management culture amount to an estimated R1 500 million. It is unlikely that even a small part of this will be realised without a firm commitment from Government to disseminate information and develop expertise. Much can be learnt from the work being carried out in both developed and developing countries, and there is a large scope for energy conservation in South Africa.

DETAILS OF AUTHORS

DALE A P

BSc (Rhodes), MIEE, MZweIE, CEng
Powerplan Consultants (Zim) (Pvt) Ltd,
32 Kingsmead Road, Borrowdale, Harare, Zimbabwe
Tel./Fax.: 263-4-882501

After graduating in Physics and Applied Mathematics, Peter Dale started his career in 1956 in the Meteorological Department of the Federation of Rhodesia and Nyasaland before training as an engineer with Associated Electrical Industries and at the Borough Polytechnic in London, England from 1959-61. Thereafter he worked as an electrical engineer with AEI, the Central African Power Corporation (Kariba System) and Anglo American Corporation in Zambia where he was appointed Chief Electrical Engineer in 1969. In 1973, he emigrated to Canada where he established his own consulting practice, providing project development, appraisal and management services principally to the Canadian International Development Agency and also to the World Bank. His work covered most parts of Sub-Saharan Africa, albeit specialising in hydroelectric developments and international power interconnectors in West, East and Southern Africa. After a contract in 1989/90 with the SADCC Energy Coordination Unit in Luanda, Angola, he returned to Zimbabwe in April 1991.

DE VILLIERS M G

BSc(Chem Eng) (Wits), MSc (UCT)
Research Engineer, Energy Research Institute, University of Cape Town, P O Box 33, Diep River 7800, South Africa
Tel.: (021) 705 0120; Fax.: (021) 705 6266

Mark de Villiers initially worked as a water treatment engineer following his undergraduate studies. He joined the Energy Research Institute in April 1992, after completing a Master's programme at the Institute. His half-thesis was on Energy Management in Industry, and included a case-study on the brewing industry. He is currently working on energy and environmental research projects.

DUTKIEWICZ R K

Pr Eng, PhD, FIMechE, Hon.F(SA)IMechE, MBIM, MIProdE, FInstE, CEng
Professor of Applied Energy and Director, Energy Research Institute, University of Cape Town, P O Box 33, Plumstead 7800, South Africa
Tel. : (021) 705 0120, Fax. : (021) 705 6266

Professor Dutkiewicz graduated with a BSc (Eng) and MSc (Eng) from the University of the Witwatersrand. He obtained a PhD at Cambridge University for research work in heat transfer in nuclear reactors.
He worked as a design engineer for the Atomic Energy Division for GEC in the United Kingdom. On his return to South Africa, he became Head of Research for Eskom. Thereafter he was promoted to Assistant Chief Engineer and later Manager (System Planning). Professor Dutkiewicz joined U.C.T. as Professor in Mechanical Engineering, and started the Energy Research Institute, of which he is currently the Director, in 1975.

LETCHER T M

PhD, BEd, MRSC, CCHEM, MSACI
Professor of Chemistry and Head of the Department of Chemistry and Applied Chemistry, University of Natal, King George Avenue, Durban 4001, South Africa
Tel.: (031) 816 3106; Fax.: (031) 816 3091

Professor Letcher's research interests include the optimum conditions for methane generation from landfill and the possible uses of landfill gas. He is also involved in research relating to the chemical thermodynamics of liquid mixtures and solutions.

FRASER D M

BSc(Chem Eng) (UCT), PhD (UCT)
Senior Lecturer, Department of Chemical Engineering, University of Cape Town, Private Bag, Rondebosch 7700, South Africa
Tel.: (021) 650 2518; Fax.: (021) 650 3775

Duncan Fraser matriculated from Centaurus High School, Windhoek in 1963. He obtained the degrees of BSc(Chem Eng) in 1967 and PhD in 1977 from the University of Cape Town.
From 1976 to 1979, he was a process engineer at the Caltex Refinery in Milnerton, Cape. Since 1979 he has been a Senior Lecturer in the Department of Chemical Engineering at the University of Cape Town.
His primary interest in the energy field is in the efficient utilisation of energy on chemical plants. His research in this area has focused on the application of pinch technology to existing plants, and the development of minimum flux as a heat exchanger network design parameter. He teaches pinch technology to U.C.T. students, and has also run a short course on pinch technology for those in industry.
Duncan's other interests are in the modelling of chemical engineering processes, such as leaching and olefin oligomerisation.

SCHÜTTE R

BSc (Hons), MSc (Chemistry) (Rhodes), MSACI, MIWMSA
208 York Street, Greytown 3500, South Africa
Tel.: (0334) 31 825

Miss Renate Schutte completed her MSc degree with the Chemistry Department at Rhodes University, Grahamstown. Her research concerned the exploitation of methane from landfill from the Grahamstown landfill site.

THERON P

BSc(Eng) (UCT), MSc(Eng) (UCT)
Energy for Development Research Centre, University of Cape Town, Private Bag, Rondebosch 7700, South Africa
Tel.: (021) 650 2833; Fax.: (021) 650 2830

Paul Theron joined the Energy for Development Research Centre (EDRC) in 1990. His work has focused on policy issues affecting electricity provision in South Africa, as well as detailed studies on the use of electricity and other fuels by low-income households. He completed a Masters thesis in 1991 on public and private sector roles in the provision of electricity in the urban areas of South Africa. He has recently been involved in the discussions around the formation of a national electrification forum. He is currently Project Manager of the South African Energy Policy Research and Training (EPRET) project.

THORNE S

BSc(Eng) (UCT)
Energy for Development Research Centre, University of Cape Town, Private Bag, Rondebosch 7700, South Africa
Tel.: (021) 650 3073; Fax.: (021) 650 2830

Steve Thorne started working on a contract basis for the EDRC Remote Area Power Supply (RAPS) team in mid-1991 on arriving back from exile. Steve has been interested and involved in energy and environmental issues and projects for some years. His background and formal training are in Chemistry and Chemical Engineering. Steve gained engineering experience in the paper industry, where he worked as a quality technician at the Sappi Ngodwana paper mill in the Eastern Transvaal over the commissioning period. His more recent work at the EDRC has been on electrification issues in urban areas in the Western Cape. His work within the South African Energy Policy Research and Training project includes the sectors on Energy Supply Options for Urban and Informal Settlements, and Energy Efficiency and Conservation.

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