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It is the policy of the Journal to publish, as far as possible, papers covering the technical, economic, political, environmental and social aspects of energy. Only previously unpublished work will be accepted. However, conference papers delivered but not published elsewhere are also welcomed. Short discussions, not exceeding 500 words, on articles published in the Journal are also invited. Items of general interest, news, technical notes, reviews and research results applicable to the Southern African context will also be included. Announcements of relevant publications, reviews, conferences, seminars and meetings will be included.

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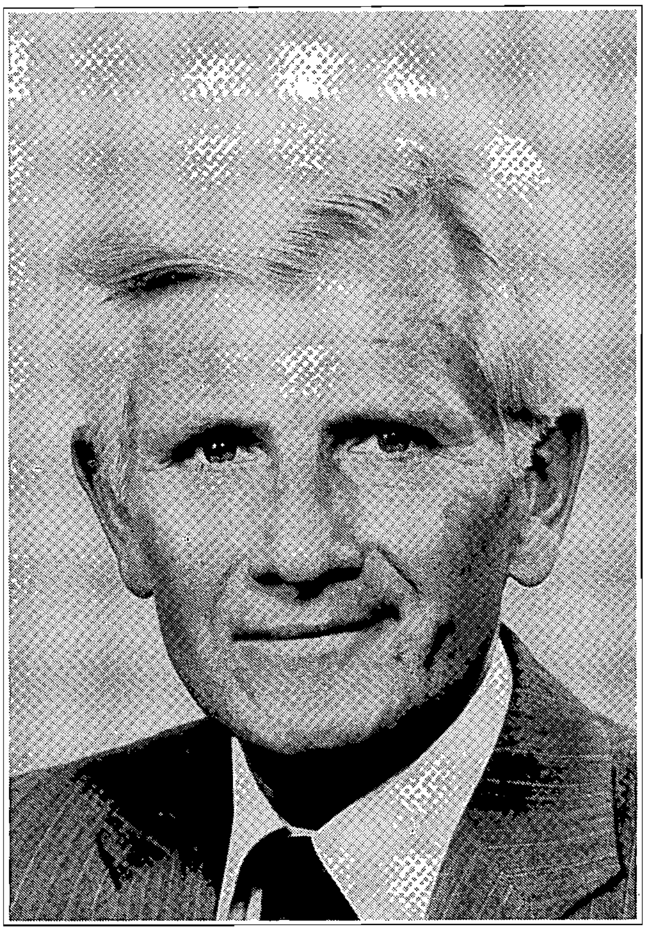
Profile: Allen Sealey

Chairman, Randcoal



Albert Allen Sealey rose to prominence in the South African (and international) coal industry in 1973 when he became head of the coal division of Rand Mines. Twenty years later, he is still at the helm, as chairman of Randcoal, the coal production house under which the coal interests of the companies fall. Allen is also chairman of two of the other new operations created by the restructuring of Rand Mines, namely, Randgold & Exploration (which manages four gold mines and has an exploration and services arm) and PGM Investments (a platinum investment holding company).

As one of the chief architects and key figures in the growth and expansion of Rand Mines' coal interests to the formation of Randcoal, Allen is a hard-core mining man who started at the work-face before rising to the boardroom. Matriculating in 1949, still too young to qualify for a blasting ticket, he started working at Crown Mines. After three years he was then awarded a bursary to study at the University of the Witwatersrand, graduating as a mining engineer in 1955.

He then returned to Crown Mines where he served as a shift boss, mine overseer and underground manager. He held various managerial positions on other gold mines in the Rand Mines Group, such as Blyvooruitzicht and EPRM. After working for a short time as a technical assistant to the consulting engineers at the Group's head office, he went to the United States where, after attending the Programme for Management Development at the Harvard Graduate School of Business Administration, he took the opportunity to visit various mining and tunnelling operations in the U.S.A.

On his return to South Africa he was appointed assistant technical manager of the gold division at the Group's head office.

Although Allen Sealey has served and continues to serve on the boards of various mining and other subsidiary and associated companies of the greater Barlow Rand Group, it is in the coal mining sector of South Africa that he has made his greatest contribution. In 1971 he was appointed as an assistant manager in the then fledgling Rand Mines coal division.

His role as a key planner of the South African coal industry, and in the growth and expansion of the Rand Mines coal division are underlined in a brief description of some of the major developments and projects in which he played a major role:

* the negotiation in the early 1970's of the huge low-ash coal contract with Japan, which moved South Africa into the international arena as a coal exporter of note;
* the construction of the Richards Bay railway line and coal terminal;
* the establishment, together with Shell and BP, of the Rietspruit and Middelburg export coal mines;
* successful negotiations with Eskom that led to the establishment by Rand Mines of Eskom-tied collieries like Duvha and Khutala;
* the raising of standards and levels of worker accommodation and other conditions of employment, as well as environmental care, protection and safety.

In addition, Allen has led and participated in critical ongoing negotiations between the coal industry and SATS/Spoornet on rail tariffs, mainly regarding coal exports. This in turn had an impact on the viability of the country's coal export trade.

Allen Sealey served three terms as chairman of the Transvaal Coal Owners' Association. He has also served as chairman of the Collieries Committee of the Chamber of Mines of South Africa, and Natal Associated Collieries since 1971. Furthermore, he served on the Council of the University of the Witwatersrand from 1984-1987, and was chairman of the Wits/CSIR Schonland Research Centre for Nuclear Sciences from 1985 to 1992.

A man widely known in international banking and trading circles, Allen was appointed chairman of the South Africa-Republic of China (Taiwan) Chamber of Economic Relations in 1985. Three years later, the Order of the Brilliant Star - Grand Cordon, was conferred on him by the Taiwanese government for his contribution to trade and economic relations between the two countries. He has served as a member of the Eskom Electricity Council since 1988, and has been chairman of the Richards Bay Coal Terminal Company since March 1991.

Allen Sealey is an active jogger, a dedicated fly-fisherman and a keen bird-watcher.

A socio-economic study of energy consumption patterns in the Eastern Cape

* A M M ROSSOUW AND * * D J L VENTER

This paper is a discussion of the results of completed research undertaken in some of the underdeveloped urban communities in the Eastern Cape and Border regions. The research includes a socio-economic profile of these communities, highlights trends found in their energy consumption patterns, showing where possible, inter-relationships. An important objective of the research was to produce a database which could be used for in-depth analyses to determine the impact of socio-economic factors on energy consumption patterns. A secondary objective was to ascertain whether a need exists in these communities for information centres which will be able to supply them with relevant information on energy and fuels.

The paper, firstly, describes the research process used in this project. This is followed by a discussion of the data derived from the research and its relevance to energy consumption and the communities' socio-economic conditions. In conclusion, an attempt is made, briefly, to integrate the main findings, highlighting their relevance to the energy consumption patterns found in these communities and their future development.

Keywords: socio-economics; energy consumption; Eastern Cape; underdeveloped areas; urban areas

Introduction

The provision of electricity to communities is at present a major political issue in South Africa and should therefore be approached with care[1]. It is thus necessary that a holistic picture of energy usage patterns be considered when planning any strategies or projects and for developing policy. The unavailability of data in this field regarding South Africa makes comparative studies virtually impossible. With this in mind, a database of information related to the Eastern Cape black urban communities' energy usage patterns was compiled. As the coverage of this database is extensive, it is not possible to discuss its contents in detail within the confines of this paper.

The focus of this paper will therefore fall on the status of some of the main socio-economic factors affecting energy consumption patterns among disadvan-taged communities in the Eastern Cape. As the research process is deemed of great importance in understanding and interpreting the data, this is also described in some detail. The discussions and evaluations of the data are restricted by the authors' fields of expertise. This paper is therefore presented as an information source for those who are authorities in the energy field, with the authors focusing on the socio-economic research and the statistical analyses. The study was undertaken by the Institute for Planning Research, University of Port Elizabeth[2] for the Chief Directorate: Energy, Department of Mineral and Energy Affairs. The Chief Directorate: Energy commissioned the project, while Eskom was a key recipient, being the major supplier of electricity in South Africa. The residential areas featured in this study were Duncan Village and Cambridge Township in the East London area, Lingelihle in the Cradock area, New Brighton, Kwazakhele, Zwide, Veeplaas/"Soweto By The Sea" and Walmer in the Port Elizabeth area and KwaNobuhle in the Uitenhage area. These residential areas will be referred to in terms of the area of location, e.g. Lingelihle will be referred to as Cradock.

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The objectives of the study

According to the brief received from the Chief Directorate: Energy, the broad objectives of the study were to obtain:

(1) qualitative data regarding fuel use and choice;

(2) accurate quantitative data on fuel use;

(3) data regarding other household expenditure items;

(4) contextual data relating to household function.

These were then translated into specific items to be researched, such as household size, population distribution, income by source, housing type and size, state of employment, educational levels, expenditure patterns, including fuels and quantities of fuels used. More subjective information was also deemed necessary, such as priorities of needs regarding fuels, attitudes towards existing fuels and perceptions of higher order fuels.

Thus more specifically, the survey objectives were:

(1) To conduct an empirical survey among a representative sample of households in the various areas to assess their:

— general socio-economic characteristics, i.e. demographic profiles, educational profiles and employment profiles
— income and expenditure characteristics
— residential characteristics, such as home ownership, size and composition of home, etc.
— energy usage patterns, such as types of fuels used, quantities used and expenditure on fuels
— attitudes and perceptions towards traditional fuels and electricity
— knowledge of the basic facts of electricity compared with other fuels.

(2) To analyse the results of the survey and to compile a written document of the findings.

(3) To attempt to identify any possible general trends from the data.

The principal objective of this survey therefore is to provide information to allow the Chief Directorate: Energy to analyse energy consumption patterns and related data, and to assess the need for energy information centres for the various areas.

As previously mentioned, it was impossible to examine all the data obtained through this study in this paper, thus only selected aspects are discussed.

Method of research

Questionnaires were administered by field-workers to a randomly selected, representative sample of respondents.

A structured questionnaire was prepared consisting of both pre-coded and open-ended questions to allow for free expression regarding the more subjective issues arising from the responses. The field-work was conducted by trained Xhosa-speaking persons who were thoroughly supervised by a qualified field-work co-ordinator.

Procedure of research

Sampling

In the sampling procedure, use was made of aerial photographs, street- and site maps, and on-site inspections. It is accepted that aerial photographs, in some cases, were out-dated, having been used for the 1990 census. For the formal residential areas maps were used, whereas for the informal residential areas sampling was done using aerial photographs and doing on-site inspections. On-site inspections also included discussions with local residents and community leaders. Allowance could therefore be made for any changes due to, for example, population growth, influx and physical or structural changes. A sample of residential sites within each of the areas mentioned was drawn. Sample sizes of between 300 and 500 are generally regarded as most appropriate in socio-economic research circles, especially when dealing with a well-defined topic such as the one proposed[3]. The sample was drawn as follows:

— In Port Elizabeth two distinct areas based on geographic location were selected. These included, (1) Walmer Township and (2) New Brighton, Kwazakhele, Zwide and "Soweto By The Sea" usually referred to as Ibhayi. In the East London area, Duncan Village (also known as Gompo Town) and Cambridge Township were chosen. KwaNobuhle was used to represent the Uitenhage black urban area, and Lingelihle the only black residential area at Cradock. These areas were selected for the purposes of the survey as they are regarded as representative sections of the disadvantaged population in the urban areas in a metropole, a city and a rural town.

— Systematic random samples were drawn for each of these areas as follows:

* Cradock – 200 respondents were identified, consisting of 150 formal residences and 50 shacks. Two cases were disregarded. The 200 households represented a sample fraction of 6,1%.

> "Two factors effecting the efficiency of energy consumption which have come out of the reasearch are ... that expenditure should be channelled to more effective but appropriate fuels, and that the materials from which dwellings are constructed and the design of housing should be improved with regard to thermal efficiency."

* Ibhayi – here there were 430 respondents consisting of 212 formal residences, 167 formal shacks, 26 informal shacks and 25 "silvertown" dwellings, the numbers being an approximate proportionate sample of each settlement type or shack area. Four cases were disregarded. The sample fraction in this case was 0,8%.

* Walmer – a sample size of 200 was drawn for this area, the sample fraction being 6,8%. Of this sample 53 cases were formal residences, 17 backyard shacks, and 130 formal and informal shacks. One case was disregarded.

* East London – a sample size of 400 was used, 200 each in Duncan Village and Cambridge. This sample comprised 131 formal residences, 133 formal and 71 informal shacks, and 65 backyard shacks. This constituted a sample fraction of 1,9%.

* Uitenhage – a sample of 400 was drawn, representing a sample fraction of 2,2%, of which 210 were formal dwellings and 190 were shacks. Of the formal dwellings, three cases had to be disregarded.

— As uncontrolled squatting occurs over a wide area, a cluster sampling technique was applied to draw samples from these settlements.

— Where questionnaires were not used or deemed faulty, they were disregarded rather than replaced. It is felt that replacement tends to introduce bias.

Field-work

* Training: Teams of field-workers, all of whom were local residents and matriculants, were selected by means of personal interviews. They then underwent a two-day training session. Aspects of training covered were the purpose of the survey, the role of the field-worker, and the need for accuracy and objectivity. Some basic principles and techniques of interviewing were also taught. Mock interviews were held between the field-workers to highlight any problems which may occur.

* Field-work operation: Each field-worker was provided with a map or aerial photograph of their appropriate area, with the sampled households to be visited marked thereon. The entire group met on a daily basis with the responsible researchers at a central point where the completed questionnaires were checked and day-to-day problems dealt with. No serious problems were encountered and the local community, local authorities, and the various civic organisations co-operated well.

* Control: Approximately five percent of the sample households were checked by the co-ordinator and it was apparent that in all cases the interviews had been conducted accurately and diligently. Any unclear or seemingly incorrect data were referred back

immediately, checked and corrected where necessary.

* General observations: Although the questionnaire was long (+16 pages) the respondents co-operated fully with the field-workers in answering the questions. This can be attributed to the holding of discussions with members of the various residents' associations prior to the survey.The result was that the residents were fully informed about the impending survey and the need to collect the data, which would be to their advantage.

Data analysis

The data was coded by the project researcher and analysed by the Chief Consultant at the UPE Computing Centre. It should be noted that in some cases (e.g. Table 8), small frequencies were recorded. The data in such cases could not be used for projections nor be awarded too high a value. Such figures should rather be viewed as indications only obtained through the sample of this study.

Socio-economic indicators

The socio-economic indicators selected for the purposes of this paper were population distribution, literacy level, employment status, income and expenditure, material with which dwellings are constructed, water availability, and sanitation[4]. All of these factors were seen to have a direct impact on energy consumption patterns in terms of the type and amount of fuel used.

Population distribution

Population distribution, in terms of age and gender, is a useful instrument for making projections. Considered together with other data, accurate projections can be made regarding other factors, such as the number of household heads, housewives and schoolgoing children. These figures would assist in planning pertaining to energy consumption and energy supply.

The population distribution for the communities involved in the survey can be seen in Table 1 and Figure 1.

From Table 1, it should be noted that 38% of the population are under 20 years of age and 38% are between the ages of 20 and 39 years. Another interesting feature is that the 0-9-year-old group is somewhat smaller than the 10-19- and the 20-29-year-old groups. This may indicate a reduction in natural population growth, or

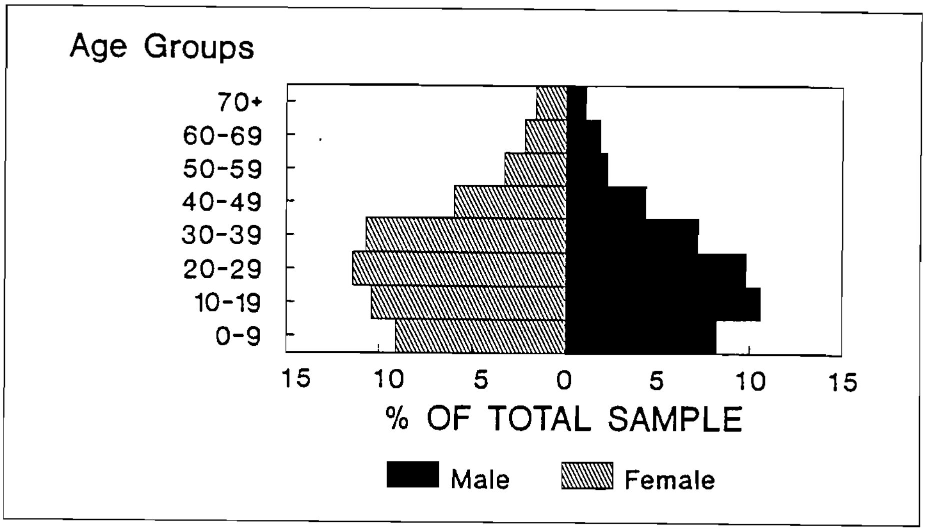

Figure 1: *Population distribution by age and gender*

AGE GROUP	MALE		FEMALE		TOTAL	
	N	%	N	%	N	%
0-9	668	8,2	734	9,1	1 402	17,3
10-19	856	10,6	845	10,4	1 701	21,0
20-29	790	9,8	919	11,4	1 709	21,2
30-39	584	7,2	863	10,7	1 447	17,9
40-49	358	4,4	488	6,0	846	10,4
50-59	183	2,3	266	3,3	449	5,6
60-69	152	1,9	177	2,2	329	4,1
70+	88	1,1	127	1,6	215	2,7
TOTAL	3 679	45,4	4 419	54,6	8 098	100,0

Table 1: *Population distribution by age and gender*

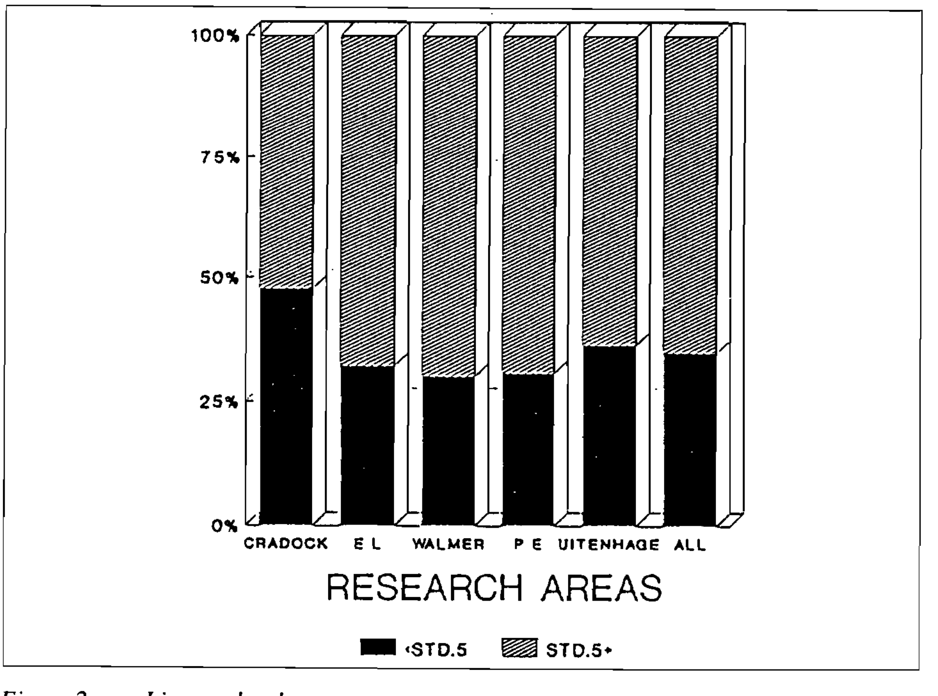

Figure 2: *Literacy level*

may be attributed to an influx of work seekers in the age group of 10-29 years. Whether the reduction in natural population growth is a trend remains to be seen[5,6].

Literacy level

The literacy level is a useful indicator of the socio-economic status of a community as it is directly related to other factors, such as employment, income generation and general standard of living. These factors in turn provide insight into questions such as affordability of commodities, which in turn, concerns fuels for household use. According to the UNESCO definition[7,8], the functional literacy level is measured by the number of people in the community who are 14 years of age and older, and who have at least the equivalent of a Standard Five qualification. The Standard Five qualification is used as the functional literacy level as it is usually achieved after at least seven years of schooling. The literacy level of the sample is depicted in Figure 2.

On average the literacy level differed slightly for males and females, namely, 44,9% and 55,1% respectively, the average being therefore 52,1%. This implies that the literacy level of 47,9% for those who are 14 years and older is below the acceptable level of functional literacy for survival in a modern society.

Employment status

The employment status of the region is estimated according to the level of employment of the potential work-force[9]. The potential work-force is obtained by taking the total population and deducting all the scholars and students, housewives, pensioners and the disabled.The remaining figure then reflects the potential work-force. Figure 3 indicates the rate of unemployment, which was found to be 46,5% for the research population. As casual and part-time labour can hardly be viewed as stable jobs, these categories were added to the unemployed category, which then increased to 54,9% of the potential work-force.

Income and expenditure per household

The total average household income for the research population was found to be approximately R854 per month. The average *per capita* income was calculated at approximately R220 per month. According to the household subsistence level (HSL)[10], the average household monthly income for a family of five in

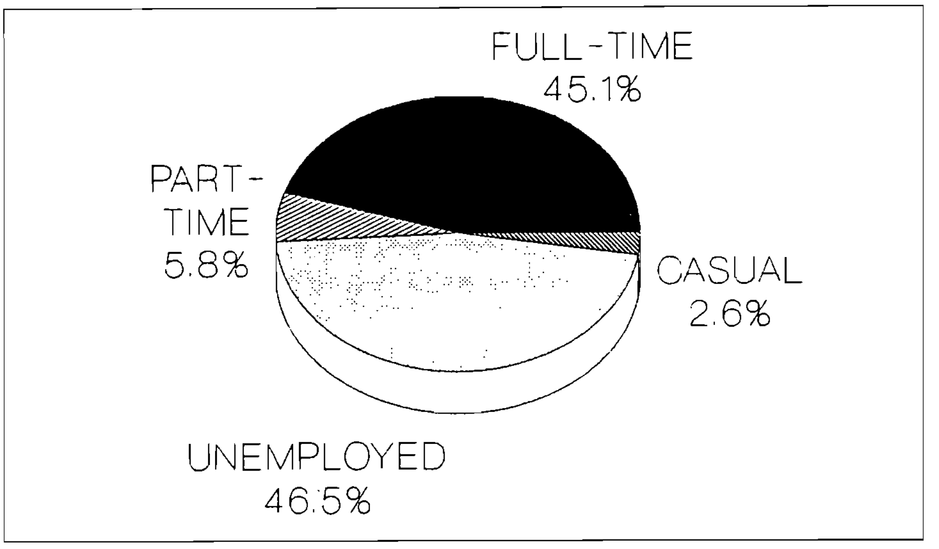

Figure 3: *Employment status of potential work-force*

HOUSEHOLD SIZE					
TOWN	NUMBER OF HOUSEHOLDS	MEAN	STANDARD DEVIATION	MINIMUM HOUSEHOLD SIZE	MAXIMUM HOUSEHOLD SIZE
CRADOCK	198	5,88	2,71	1	16
E.L.	400	4,19	2,48	1	16
P.E.	430	5,21	2,51	1	15
WALMER	199	4,52	2,46	1	13
UITENHAGE	397	4,77	2,51	1	15
TOTAL	1 624	4,85	2,58	1	16

Table 2: *Average household size*

RESEARCH AREA	MEAN TOTAL MONTHLY EXPENDITURE	MEAN MONTHLY EXPENDITURE ON ENERGY	ENERGY EXP. AS % OF TOTAL EXPENDITURE
CRADOCK	R492	R55,78	15,1
EAST LONDON	R616	R50,20	13,9
UITENHAGE	R643	R56,44	11,4
PORT ELIZABETH	R552	R46,47	10,5
WALMER	R691	R58,68	11,3

Table 3: *Ratio of monthly income spent on fuel for household purposes*

Port Elizabeth should not be less than R790. The data based on an average household size of five in the HSL was used as it is closest to the average household size found in the survey sample.

The average household size of the sample is depicted in Table 2. From this table, when considering the standard deviation, there appears to be a wide range of household sizes which does not strive towards the mean. The average income of households was therefore found to be marginally above this minimum figure. This means that, on average, households are barely managing to cope at a minimum level of subsistence.The household effective level (HEL) refers to what is needed in order to maintain health and decency in the long term and is calculated at 150% of the HSL. In the case of the research areas the HEL amounted to approximately R1 185. In comparing the HEL with the actual average household income it becomes clear that, on average, the households in the research area are well below the acceptable minimum income level.

The affordability factor concerning energy consumption patterns is of great importance and should be considered

HIERARCHY OF ORDER:	HIGHER ORDER (PRIMARY)			HIGHER ORDER (SEC.)		TRANSITIONAL		LOWER ORDER		COMBINED
	ELECTRICITY	LPG	GENERATOR	VEHICLE BATTERY	DRY BATTERY	COAL	PARAFFIN	WOOD	CANDLES	TOTAL
Cradock = 3 946* Total fuel cost of pop. % of Total fuel expend.	R39 263 17,8	R37 092 16,9	R4 420 2,0	R10 654 4,8	R16 652 7,6	R3 788 1,7	R78 683 35,8	R22 019 10,0	R7 497 3,4	R220 068 100,0
East London = 15 560* Total fuel cost of pop. % of Total fuel expend.	R112 188 14,4	R81 534 10,4	R5 446 0,7	R70 642 9,0	R77 489 9,9	R3 112 0,4	R390 867 50,0	R7 158 0,9	R32 676 4,2	R781 112 100,0
Uitenhage = 17 936* Total fuel cost of pop. % of Total fuel expend.	R201 601 19,9	R221 689 21,9	R19 730 1,9	R73 717 7,3	R68 157 6,7	R0,0 0,0	R409 479 40,5	R14 169 1,4	R3 767 0,4	R1 012 309 100,0
Port Elizabeth = 57 302* Total fuel cost of pop. % of Total fuel expend	R301 982 11,3	R445 237 16,7	R10 887 0,4	R222 332 8,3	R249 264 9,4	R2 865 0,1	R1 328 833 49,9	R50 999 1,9	R50 426 1,9	R2 662 825 100,0
Walmer = 2 266* Total fuel cost of pop. % of Total fuel expend.	R11 647 8,8	R28 892 21,7	R3 195 2,4	R11 103 8,4	R16 451 12,4	R0,0 0,0	R59 573 44,8	R113 0,1	R1 994 1,5	R132 968 100,0
TOTAL = 97 010* Total fuel cost of pop. % of Total fuel expend	R666 681 13,9	R814 444 16,9	R43 678 0,9	R388 448 8,1	R428 013 8,9	R9 765 0,2	R2 267 435 47,1	R94 458 2,0	R96 360 2,0	R4 809 282 100,0
* The figure refers to the total population of the area										

Table 4: Expenditure on fuel by fuel type per area

carefully. This factor includes both the cost of fuel types as well as the cost of relevant appliances. The percentage of expenditure which goes toward the purchasing of fuel would be a valuable indicator of the cost of fuels for household purposes. Table 3 depicts the total average household expenditure, the average household expenditure on fuel for household purposes, and the average expenditure on fuel as a percentage of the total average expenditure.

The percentages in Table 3 were calculated as the average of the percentages per household and not by simply calculating the mean fuel expenditure as a percentage of mean total expenditure. As expenditure patterns of households are not homogeneous, the calculation used is regarded as a more accurate measure of the average fuel expenditure per household.

Total expenditure per month by the research population on the major fuels for household purposes is as follows:

From this table it appears that expenditure on paraffin is the highest in all the areas. The general trend in all areas is that the level of use of electricity and liquefied petroleum gas (LPG) appears to be similar in extent and second to paraffin. The use of coal is almost non-existent, except in Cradock. When the fuel types are grouped for the total research area according to their hierarchy of order, the expenditure pattern is as follows:

(1) Paraffin (47% of total expenditure) and coal at 0,2% – transitional;

(2) Electricity, LPG and generators; (31,7% of total expenditure) – higher order (primary)

(3) Vehicle and dry batteries (17% of total expenditure) – higher order (secondary);

(4) Wood and candles (4% of total expenditure) – lower order.

It is clear that the largest expenditure is on paraffin, which is a transitional fuel.

The magnitude of the approximated monthly expenditure on fuel for household purposes (R4,8 M) for the research areas further confirms an urgent need for the formulation and implementation of a strategy to improve cost-efficiency. If, for example, the amount of kilojoules produced for this amount of money is considered in terms of types of fuel involved and appliances used, clear indications can be obtained as to what course of action regarding greater efficiency could be taken

Structure of dwellings

Physical indicators, such as the materials from which dwellings are constructed[11] and the state of rudimentary services, such as reticulation of water and sanitation, can assist with the planning of energy supply. The thermal performance of dwellings is affected by factors such as the design of the dwelling and the qualities of building materials, e.g. their insulation properties and the density of the material. These have a direct impact on the amount of fuel consumed specifically for space-heating[12].

If, for example, natural heat as well as the incidental heat produced by the use of other appliances could be effectively contained in winter, less fuel would need to be used directly for generating heat. The structure of the dwelling with regard to the ceiling is also an important aspect which affects thermal efficiency and therefore fuel consumption patterns[13]. Data pertaining to the above-mentioned factors are therefore discussed in the following paragraphs.

According to the data in Table 5, 47,6% of all dwellings are without ceilings. Those dwellings constructed of higher order materials tended mostly to have ceilings. The dwellings without ceilings are mainly those constructed of wood and corrugated iron, or mud and bricks. These are typically the structures found in the shack areas, which are also associated with the use of lower order or transitional fuels, such as wood and paraffin. In Figure 4 it is clearly shown that in the high- and middle class housing, electricity is most frequently used, whereas paraffin is mainly used in the low class and shack type of housing.

MATERIALS WALLS ARE BUILT OF	MATERIALS ROOFS ARE CONSTRUCTED OF													
	TILES				CORRUGATED IRON				ASBESTOS				TOTAL	
	WITH CEILING		WITHOUT CEILING		WITH CEILING		WITHOUT CEILING		WITH CEILING		WITHOUT CEILING			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
CARTON + PLASTIC	0	0,0	0	0,0	0	0,0	2	100,0	0	0,0	0	0,0	2	100,0
WOOD	0	0,0	0	0,0	39	22,0	127	71,8	1	0,6	10	5,6	177	100,0
CORRUG. IRON	0	0,0	0	0,0	222	31,8	455	65,1	5	0,7	17	2,4	699	100,0
MUD AND BRICKS	0	0,0	0	0,0	2	10,0	4	20,0	13	65,0	1	5,0	20	100,0
CEMENT BLOCKS AND MORTAR	9	2,1	0	0,0	38	8,8	6	1,4	291	67,4	88	20,4	432	100,0
BRICKS AND MORTAR	32	12,3	0	0,0	36	13,8	0	0,0	138	53,1	54	20,8	260	100,0
ASBESTOS	0	0,0	0	0,0	0	0,0	0	0,0	7	87,5	1	12,5	8	100,0
TOTAL	41	2,5	0	0,0	337	20,9	595	36,9	455	28,2	172	10,7	1 598	100,0

Table 5: Type of roof with/without ceilings by type of walls

Availability of rudimentary services

The rudimentary services referred to here include water reticulation and the sanitary system. Three basic categories of water availability were identified, *viz.* piped water to the house, piped water to the site, and street taps. In some cases no water was available, in which case water was fetched from various sources, such as other households, dams, rivers or streams. In this survey it was found that there was a marked difference among the various areas with regard to water availability. Table 6 shows the trends identified concerning water availability.

In total, a low percentage of households (2,6%) have no access to reticulated water. On the other hand, a relatively low percentage of households have access to reticulated water on site, either inside or outside the house, *viz.* 51,6%. The use of street taps is far from ideal, as such points usually seem to collect filth and easily become unhygienic. These "watering holes" are no substitute for the gathering place which water sources are regarded as in the rural areas, especially among the more traditional communities. It would seem that properly reticulated water systems are desirable for urban communities. As a basic need, the priority of reticulated water as opposed to electrification should be carefully considered[14].

Sanitary systems are important as they have a large impact on the health profile and should be seen as contributing to the satisfaction of basic needs. Effective sanitation would therefore have an impact on the level of satisfaction of the community and quality of life[15].

In total, 62,7% of the households surveyed had access to flush toilets of which most are either on the site or inside the dwelling occupied by the household. Of the households surveyed, 23,9% (that is, 294 of the 1 230 households) had access to communal toilets, of which 31,6% had to make use of the veld. The bucket and pit toilet systems appear to be in quite considerable use, *viz.* 27,9% of all households. It is important to note that in many instances the communal toilets were out of order or over-flowing. As a result, these toilets were unhygienic and virtually impossible to use, which has a strong impact on the health of the community and therefore the level of satisfaction and quality of life of these communities[14].

Energy consumption

Information pertaining to energy discussed in this paper relates to the availability of electricity, expenditure on fuels, fuels used for cooking, lighting and space-heating, and appliances used. Electricity is given special reference as electrification is a very contentious issue in South Africa and is regarded as a commodity to which all developing societies should aspire.

Availability of electricity

The availability of electricity was measured in terms of how many households had ready access to electricity by having the necessary conventional wiring already installed. In Table 7(a) this is depicted for the separate areas and for the research sample in total.

From the data depicted in this table it appears that the availability level of

TYPE OF WATER AVAILABILITY	RESEARCH AREAS											
	CRADOCK		EAST LONDON		UITENHAGE		PORT ELIZABETH		WALMER		HOUSEHOLDS COMBINED	
	N	%	N	%	N	%	N	%	N	%	N	%
Piped water to house	69	36,3	35	8,6	97	24,0	139	33,2	7	3,2	347	21,1
Tap on site	49	25,8	56	13,7	308	76,0	51	12,2	37	16,7	501	30,5
Street taps	55	29,0	304	74,5	—	—	227	54,3	166	75,1	752	45,8
Other sources	17	8,9	13	3,2	—	—	1	0,3	11	5,0	42	2,6
TOTAL	190	100,0	408	100,0	405	100,0	418	100,0	221	100,0	1 642	100,0

Table 6: Water availability

electricity is very low compared to the developed communities[16] and this disparity would seem to suggest action aimed at improving the situation. The percentages of households in formal dwellings seem to have a comparative level of access to electricity as do households in other black urban areas[17]. Any attempt to address this issue should include cognisance of various socio-economic factors, such as income levels and affordability of not only the fuel but also the relevant appliances. The structures of dwellings, and perceptions and attitudes of the communities concerned are also significant factors.

RESEARCH AREAS	HOUSEHOLDS WITH ELECTR. AVAILABLE		%-AGE FORMAL HOUSES	HOUSEHOLDS NO ELECTRICITY AVAILABLE		TOTAL	
	N	%	%	N	%	N	%
CRADOCK	32	16,2	25,6	166	83,8	198	100,0
EAST LONDON	38	9,5	28,2	361	90,5	399	100,0
UITENHAGE	73	18,5	33,5	322	81,5	395	100,0
PORT ELIZABETH	49	11,5	23,0	377	88,5	426	100,0
WALMER	33	16,7	60,4	165	83,3	198	100,0
TOTAL	225	13,9	28,9	1 391	86,1	616	100,0

Table 7(a): Availability of electricity

From Table 7(b) it is apparent that a far greater number of people do not have access to electricity than those who do. The worst case seems to be the East London survey area where 90,5% of households have no access to electricity, Port Elizabeth 88,5%, Cradock 83,8%, Walmer 82,8% and Uitenhage 81,5%. A small number of people do not have electrical wiring but have access to electricity. Closer enquiry revealed that these households actually tap electricity from neighbours by means of extension cords. The true incidence of this occurrence cannot be estimated as it is illegal and respondents fear possible prosecution.

Types of fuel used

The frequency of use of fuels for household purposes is shown in Figure 4. From this figure two factors become apparent, firstly, that a large number of households make use of paraffin. Secondly, paraffin is used to a significant extent in all types

HOUSEHOLDS IN EAST LONDON WITH ELECTRICAL WIRING AND ELECTRICITY OPERATIONAL

ELECTRICAL WIRING	ELECTRICITY OPERATIONAL					
	Yes		No		TOTAL	
	N	%	N	%	N	%
Yes	35	92,1	3	7,9	38	100,0
No	0	0,0	361	100,0	361	100,0
TOTAL	35	8,8	364	91,2	399	100,0

HOUSEHOLDS IN CRADOCK WITH ELECTRICAL WIRING AND ELECTRICITY OPERATIONAL

ELECTRICAL WIRING	ELECTRICITY OPERATIONAL					
	Yes		No		TOTAL	
	N	%	N	%	N	%
Yes	26	81,2	6	18,7	32	100,0
No	0	0,0	166	100,0	166	100,0
TOTAL	26	13,1	172	86,9	198	100,0

HOUSEHOLDS IN UITENHAGE WITH ELECTRICAL WIRING AND ELECTRICITY OPERATIONAL

ELECTRICAL WIRING	ELECTRICITY OPERATIONAL					
	Yes		No		TOTAL	
	N	%	N	%	N	%
Yes	68	94,4	4	5,6	72	100,0
No	1	0,3	321	99,7	322	100,0
TOTAL	69	17,5	325	82,5	394	100,0

HOUSEHOLDS IN PORT ELIZABETH WITH ELECTRICAL WIRING AND ELECTRICITY OPERATIONAL

ELECTRICAL WIRING	ELECTRICITY OPERATIONAL					
	Yes		No		TOTAL	
	N	%	N	%	N	%
Yes	47	95,9	2	4,1	49	100,0
No	0	0,0	377	100,0	377	100,0
TOTAL	47	11,0	379	89,0	426	100,0

HOUSEHOLDS IN WALMER WITH ELECTRICAL WIRING AND ELECTRICITY OPERATIONAL

ELECTRICAL WIRING	ELECTRICITY OPERATIONAL					
	Yes		No		TOTAL	
	N	%	N	%	N	%
Yes	33	100,0	0	0,0	33	100,0
No	1	0,6	164	99,4	165	100,0
TOTAL	34	17,2	164	82,8	198	100,0

HOUSEHOLDS COMBINED WITH ELECTRICAL WIRING AND ELECTRICITY OPERATIONAL

ELECTRICAL WIRING	ELECTRICITY OPERATIONAL					
	Yes		No		TOTAL	
	N	%	N	%	N	%
Yes	209	93,3	15	6,7	224	100,0
No	2	0,1	1 389	99,8	1 391	100,0
TOTAL	211	13,1	1 404	86,9	1 615	100,0

Table 7(b): Operationality of electricity of settlements and is not restricted to lower settlement areas.

In reality, households make use of a combination of fuel types. The fact that households had access to or were using electricity did not necessarily result in these households using electricity exclusively. The mix of fuel consumption in households is depicted in Table 8. In this table the average expenditure on fuel per household is also indicated. Only the most frequently used fuels or combinations are reflected in this table.

The most expensive fuel combinations consumed as reflected in this table are: LPG only (R132/mth), paraffin, LPG and generators (R112/mth), electricity and LPG (R99/mth), and electricity, paraffin and LPG (R98/mth). The cheapest combinations are paraffin only (R27/mth), paraffin and candles (R32/mth), and paraffin and wood (R37/mth). It is also significant that the average cost of using only electricity is R63,60 per month, approximately 2,4 times more expensive than using only paraffin, and even more so relative to combinations of paraffin and lower order fuels, such as wood and candles. The most prevalent patterns of fuel consumption are paraffin only (752 households), paraffin and LPG combined (211 households), paraffin and candles combined (185 households) and electricity only (124 households). It is interesting to note that the combination of electricity and paraffin is more expensive than electricity only, *viz.* R69,84 and R63,60 respectively.

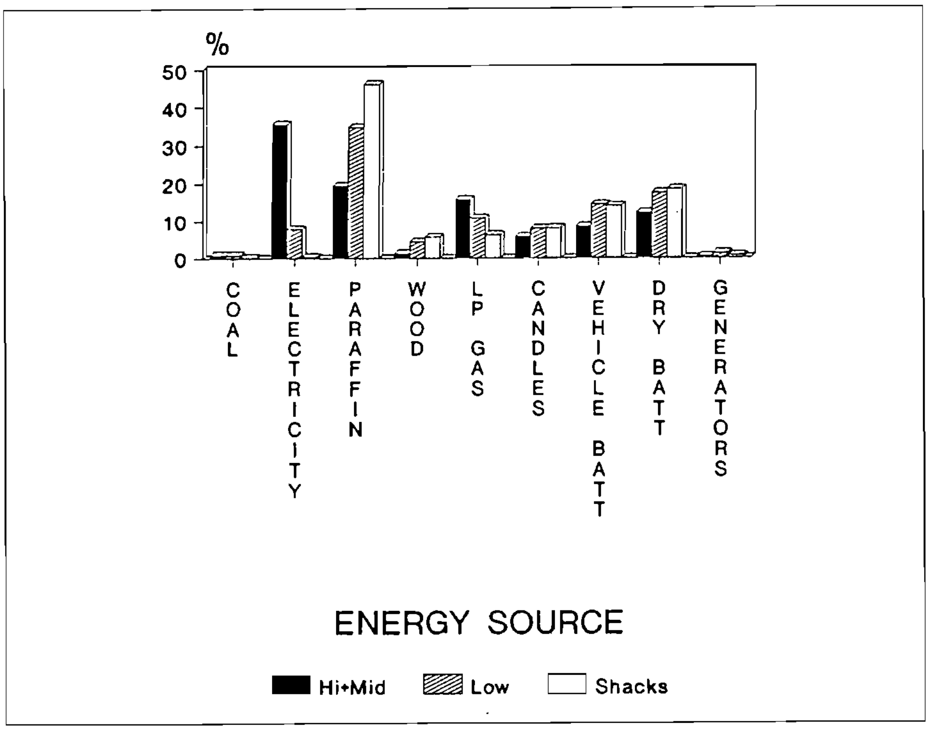

Figure 4: Frequency of usage of energy source by housing type

Purposes for which the various types of fuel are used

The major uses of fuels for household purposes are for cooking, lighting and space-heating. Using this stratification, Table 9 depicts to what extent various fuels are used for these major purposes.

It is clear from this table that paraffin is the most commonly used fuel, with electricity and LPG being the only other significant sources. With regard to lighting, it appears that other sources of any significance are candles and electricity. In the case of cooking,

COMBINATION OF USED BY HOUSEHOLDS	ALL CENTRES COMBINED		RESEARCH AREAS									
			UITENHAGE		WALMER		P E		EAST LONDON		CRADOCK	
	N	R/MTH	N	R/MTH	N	R/MTH	N	R/MTH	N	R/MTH	N	R/MTH
PARAFFIN ONLY	752	26,89	187	26,26	77	31,44	235	25,62	214	27,36	39	26,03
PAR/GAS	211	72,74	69	80,26	34	73,88	64	70,31	27	69,63	17	54,00
PAR/CANDLE	185	32,23	11	31,73	14	41,00	61	29,23	70	36,43	29	24,38
ELECTRICITY ONLY	124	63,60	43	81,47	29	32,97	32	54,00	10	93,90	10	76,10
PAR/WOOD	98	37,06	29	30,45	12	30,75	7	84,29	17	26,00	33	40,85
PAR/WOOD/CANDLE	67	40,43	3	23,67	9	52,22	3	32,33	18	44,72	34	37,24
ELEC/PAR	37	69,84	12	81,33	4	31,25	10	44,30	8	103,88	3	69,67
PAR/GAS/CANDLE	19	75,74	2	74,50	2	42,50	5	77,80	7	95,14	3	50,00
ELEC/PAR/GAS	15	98,93	6	75,50	—	—	2	61,50	1	62,00	6	141,00
PAR/GAS/GEN	15	112,07	8	130,38	1	171,00	1	63,00	—	—	5	80,80
PAR/GAS/WOOD	14	73,43	1	74,00	5	65,60	—	—	—	—	8	78,25
ELEC/GAS	13	99,69	6	99,17	1	52,00	3	112,00	2	91,50	1	130,00
PAR/GEN	13	61,54	5	39,40	3	105,33	2	68,00	3	50,33	—	—
GAS ONLY	7	132,57	1	61,00	4	191,75	—	—	2	50,00	—	—
NUMBER OF MENTIONS	1 620	43,59	394	48,89	199	46,51	430	38,19	399	40,58	198	47,90

Table 8: Combinations of fuel used and average monthly expenditure per household

electricity and LPG appear to be of some importance, and in the case of heating, electricity and wood are significant.

Appliances used

To complete the picture of consumption patterns which is partly addressed in the previous paragraph, it is necessary to include the ownership of appliances (Table 10). This also gives a perspective on the major uses of the various fuels.

Clearly most appliances used are powered by paraffin, specifically those appliances used for cooking, heating and lighting, as well as for boiling water and ironing. With regard to individual appliances the data could be summarised as follows:

* Standard stoves are mostly powered by either electricity (44,4%) or LPG (23,8%).
* Hotplates are used to a large extent and are primarily powered by paraffin (84,3%), i.e. the ordinary primus stove.
* Paraffin heaters are mostly used for space-heating, *viz.* 73,9%. To some extent electric heaters (21,9%) are also used.
* Fridges used are largely powered by electricity (59,8%) or LPG (28%).
* The major fuel used for lighting is paraffin at 82,7%.
* Kettles and irons are mostly powered by paraffin, *viz.* 77,8% and 76,7% respectively.

FUEL TYPE	PURPOSE					
	LIGHTING		COOKING		HEATING	
	N	%	N	%	N	%
ELECTRICITY	211	13,2	196	12,1	113	7,0
PARAFFIN	1 380	85,2	1 355	83,6	530	32,7
LPG	53	3,3	275	17,0	18	1,1
WOOD	0	—	80	4,9	118	7,3
COAL	0	—	17	1,0	14	0,9
GENERATOR	23	1,4	3	0,2	4	0,2
VEHICLE BATT.	18	1,1	0	—	0	—
DRY BATTERIES	34	2,1	0	—	0	—
CANDLES	297	18,3	0	—	0	—
PERCENTAGES ARE CALCULATED OUT OF 1 620, WHICH IS THE TOTAL NUMBER OF RESPONSES TO THIS QUESTION						

Table 9: Fuels used for major household purposes

* Understandably the appliances designated "OTHER" are mostly powered by electricity. It should be noted that these appliances constitute only a small fraction of the appliances used by households.

Conclusion

The data presented in this paper can be summarised as follows:

Socio-economic findings

— The survey communities are young, with the largest age grouping being that of 10-29 years. It could be speculated that this may be due to a reduction of natural population growth or that there is an influx of work seekers in this age group.

— The functional literacy level is 47,9%, the unemployment rate is 46,5%, the average household size is approximately 5 persons, although household sizes vary greatly and the average household income is well

APPLIANCES USED	FUEL TYPE																					
	NO RESPONSE		ELECTRIC		COAL		PARAFFIN		WOOD		LPG		CANDLES		VEHICLE BATTERIES		DRY BATTERIES		GENE-RATOR		TOTAL *	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
STOVE + OVEN	3	1,0	134	44,4	9	3,0	26	8.6	45	14,9	72	23,8	0	0,0	13	4,3	0	0,0	0	0,0	302	18,6
STOVE (PLATES)	5	0,4	54	4,4	3	0,2	1 044	84,3	5	0,4	117	9,5	0	0,0	10	0,8	0	0,0	0	0,0	1 238	76,4
HEATER	6	1,4	92	21,9	2	0,5	311	73,9	2	0,5	8	1,9	0	0,0	0	0,0	0	0,0	0	0,0	421	26,0
FRIDGE	2	0,7	162	59,8	0	0,0	21	7,7	0	0,0	76	28,0	0	0,0	8	3,0	0	0,0	2	0,7	271	16,7
LIGHTS	15	1,2	157	12,8	0	0,0	1 014	82,7	0	0,0	10	0,8	20	1,6	0	0,0	0	0,0	10	0,8	1 226	75,7
RADIO	7	0,8	148	17,0	0	0,0	30	3,4	0	0,0	3	0,3	0	0,0	191	21,9	490	56,3	2	0,2	871	53,8
TV	4	0,7	185	30,6	0	0,0	11	1.8	0	0,0	3	0,5	0	0,0	362	59,9	19	3,1	20	3,3	604	37,3
TAPE REC.	1	0,6	56	32,0	0	0,0	2	1,1	0	0,0	0	0,0	0	0,0	21	12,0	95	54,3	0	0,0	175	10,8
WASHM.	0	0,0	16	100,0	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	16	9,9
IRON	9	0,7	187	15,2	5	0,4	942	76,7	13	1,1	65	5,3	0	0,0	4	0,3	1	0,1	2	0,2	1 228	75,8
KETTLE	0	0,0	152	14,4	2	0,2	822	77,8	13	1,2	62	5,9	0	0,0	6	0,6	0	0,0	0	0,0	1 057	65,2
OTHER APPLIANCES	0	0,0	70	64,2	0	0,0	31	28,4	2	1,8	2	1,8	0	0,0	0	0,0	0	0,0	4	3,7	109	6,7
* PERCENTAGES FOR THE "TOTAL" COLUMN ARE CALCULATED OUT OF 1 620, WHICH IS THE TOTAL NUMBER OF RESPONSES TO THIS QUESTION. ALL OTHER PERCENTAGES ARE ROW PERCENTAGES.																						

Table 10 Appliances used by fuel type

below the HEL of approximately R1 185 per month.

Energy consumption findings

- Most of the capital expended on fuels is spent on transitional fuels, such as paraffin. Other expenditure tends to be more in favour of higher order fuels than lower order fuels.
- Two factors effecting the efficiency of energy consumption which have come out of the research are *viz.* that expenditure should be channelled to more effective but appropriate fuels, and that the materials from which dwellings are constructed and the design of housing should be improved with regard to thermal efficiency.

It is speculated that the standing of various socio-economic and energy consumption factors appear to coincide, *viz.*

(i) low income, inferior materials for the construction of dwellings, no ceiling, lack of (or access to) reticulated water and water-borne toilets, lack of access to electricity, and the significant use of transitional fuels; as opposed to:

(ii) higher income, higher quality material for dwellings, usually with a ceiling, access to reticulated water and water-borne toilets, and access to electricity.

Electrification

The need for electrification should be considered within the reality of the critical situation with regard to such basic needs as proper sanitation, water availability and shortage of acceptable housing (i.e. shelter). The lack of access to electricity or more cost-effective household fuels should, however, continue to be regarded as an important factor.

Fuel mix

The practice of fuel mixing appears to be a complex matter affecting energy consumption patterns. Access to or the use of electricity does not, for example, automatically imply that households cease to use other fuels or that they replace them entirely with electricity.

The most expensive fuel mixes involve combinations of paraffin and LPG, electricity and generators. The least costly combinations are those of paraffin with lower order fuels, such as wood and candles. The combination of paraffin with electricity was found to be more expensive than the use of electricity only. The most commonly found fuel consumption patterns were paraffin only, a combination of either paraffin and LPG, paraffin and candles, or electricity only.

The main appliances used were standard electric stoves, primus stoves, paraffin heaters, electric fridges and some LPG fridges, paraffin for lighting, and kettles and irons heated by paraffin-operated appliances.

The data which has become available through this research project has a wide field of application. It could be of value to a large number of professionals in the energy field, specifically those who are involved in planning, supplying, designing, or in associated fields, such as production and retail of appliances. Possibly its greatest relevance is for the consumers, in whose interest the data should be employed. The data presented in this paper possibly does not present the complete picture, but rather represents an overview of what is available.

It is hoped that such data will make a positive contribution towards a better understanding of the issues pertaining to energy supply and demand in South Africa. In combining socio-economic data with energy consumption patterns and the perceptions of communities, it may become possible to form a clearer and more complete picture of this most important field. The effective supply of appropriate energy will have a positive impact on the demands for development and the improvement of quality of life and standard of living. Considering the present demand for and emphasis on the need for development specifically in the so-called marginalised communities, the importance of making the proper use of this kind of data cannot be overemphasised.

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Energy usage in formal and informal black townships

*** A P GOLDING**

As part of a nation-wide data collection effort to determine the differing needs of urban energy users, 2 064 formal and informal households were interviewed about types of fuel used, appliances, consumption and expenditure, purchase and problems experienced. The survey was framed within the context of economic development and the socio-demographics of population growth, housing shortage and urbanisation on the one hand, and the "energy transition process" on the other. Eleven settlements mainly in Natal and the Transvaal, representing a cross-section of communities, were classified into four categories of formal and informal housing. Comparative results based on aggregated data suggested that geographical area and dwelling-type are major determinants of the mix of fuels used. Residential histories show that free-standing settlements are largely the result of overflow from the formal townships rather than the result of rural migration. Although there was some evidence to suggest people might obtain electricity the longer they were resident in an area, overall, the historic inequalities in service provision for blacks, the constraints on upward mobility, the shortage of formal housing and the lack of electricity in many areas means that the energy transition process is rendered somewhat obscure.

Keywords: townships; fuel use; urbanisation; energy transition; informal settlements; transitional fuels; traditional fuels; household energy

Introduction

In order to develop an energy policy that accommodates the differing needs of urban energy users in formal and informal areas, reliable data is required on fuel usage, consumption and expenditure. Although it is known that informal areas have energy patterns which are substantially different from those in formal areas, there is little data available. This paper outlines the results of a survey completed in 1992 as part of a contribution towards the construction of a comprehensive data bank on energy use in South Africa, regarded as a first step towards facilitating energy planning and policy-making.

The broad aim of the project was to obtain data on energy usage in formal and informal areas. Energy-related objectives were to determine:

* differences in patterns of fuel usage by area
* types of fuel used
* uses of each type of fuel
* types of appliances used
* consumption of and expenditure on each type of fuel
* where fuels were purchased, and
* problems encountered with various fuels.

Socio-econo-demographic objectives were to establish whether a relationship exists between period of urbanisation and energy use, whether informal settlements provide dwellers with opportunities to improve their standard of living or result in further impoverishment as a result of unemployment and the higher costs associated with urban living.

> "If energy use patterns are determined by the level of urbanisation, then the transition process will be expected to have major ramifications for consumption patterns."

As world economies develop towards industrialisation, so there is a move away from the use of traditional fuels, such as dung and wood, which are abundant in rural agrarian communities, towards commercial fuels necessary to power industry and service urban domestic consumers. The pattern will differ according to a country's access to fuel resources, so that for oil-rich countries, e.g. Nigeria, paraffin will be the most viable fuel for users, for the U.K., gas from the North Sea is the most cost-efficient fuel, and for many countries where transportation is a problem, electricity may be the cheapest fuel. This shift over time towards an optimal fuel has been called the "energy transition".

> ... which energy resources are to be used by a particular country depends in part on the energy transition process through which the population is passing [1].

Viljoen[1] has described the differing views on the energy transition process, finding that the literature reveals an underlying economic determinism and a tendency for model-building beloved of econometricians (as opposed to political economists, e.g. Adam Smith).

> Families attempt to move up the ladder of preferences for cooking and heating towards greater convenience, cleanliness, time-saving and "modernity"[2].

The above assertion seems intuitively plausible. Certainly families have always been attempting to advance their material conditions of existence. However, the "modernity" idea is somewhat vague and lacks extensive empirical support. The idea stems from the claim that "value systems" determine consumer choice of fuels and are the driving force behind the energy transition. The use of terms such as "value systems", hides a consensus political ideology of development; a view that all people in developing countries wish to be "westernised". This is either "soap powder" or remains to be proved.

It is the opinion of the author that care should be taken not to ascribe exclusive *powers of explanation* to "modernisation" (whatever it may mean). There are so many other constraints which enter into the equation of why people use certain fuels, for example, fuel price, availability, cost of appliances, type of food, cooking habits, how certain fuels impart preferred tastes to foods, taboos, etc.

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The energy transition process is a useful *description* of the shift towards higher technologies or more efficient fuels. The transition is quite apparent in comparisons between rural, peri-urban and urban fuel usage in South Africa. Wood accounts for over 75% of fuel consumed in the rural areas as against 49% in peri-urban areas[3]. In urban areas wood is used even less, mainly for kindling coal stoves. Correspondingly, energy use patterns appear to be influenced by the level of urbanisation. This issue was operationalised in the present study as the relationship between period of urbanisation and the fuel mix used. As the study was confined to urban households the analysis addressed the question indirectly by examining the urbanisation history of householders, since it was assumed that a proportion would have migrated from areas where traditional fuels are extensively used. If energy use patterns are determined by the level of urbanisation, then the transition process will be expected to have major ramifications for consumption patterns.

As one of the phenomena associated with increased rates of urbanisation is the growth in informal settlements, these areas should become increasingly important in national energy planning and investment decisions. Unfortunately the forces which create urban energy problems, namely, population growth and poverty, are beyond the control of planners. So a situation of crisis management often prevails. According to Soussan[4] the tendency to adopt generalised "blueprint" approaches as solutions based on one technology, such as electricity as a panacea, are not effective and waste enormous amounts of financial resources. Rather, an integrated energy management approach is required which takes cognisance of the existing fuel resources and the differing demands of the whole population.

Several authors have noted the striking disparity in the access to basic services and resources in South Africa and the planned emphasis on an energy-intensive industrial capitalist economy supporting a white minority at a high standard of living, while a black African majority existed in relative poverty (e.g. Eberhard[3], Christie[5]). Orlando Power Station stood for a number of years as the very symbol of this "plan", positioned precisely adjacent to those people denied access to electricity. The result is a *distorted energy profile* with many urban black settlements still without electricity, when in any other country of comparable wealth, they would have had this facility years ago. These factors have to be borne

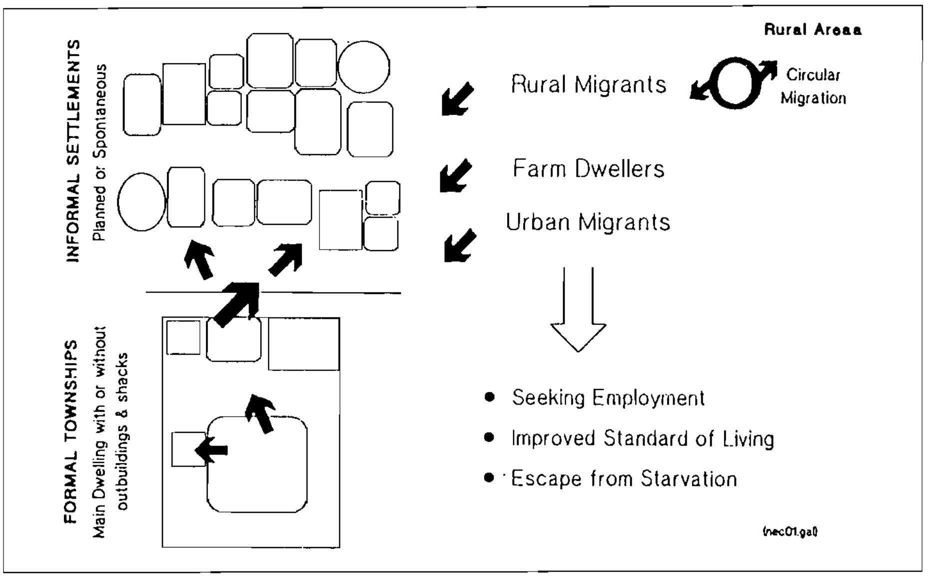

Figure 1: Formal townships and informal settlements: Growth through overflow and migration

in mind if the energy transition process is employed for forecasting purposes.

Two major trends to be considered when looking at energy demand are high black birth rates and the rate of urbanisation. The black population is expected to double between 1990 and 2020. Estimates do not take account of AIDS, the major impact of which will be in terms of human suffering and cost to the economy. The findings of the Urban Foundation and academics indicate that the repeal of the influx control laws had little impact on levels of migration from rural to urban areas. Rather, the growth in free-standing settlements is largely due to the overflow from the formal townships and the housing backlog (see Figure 1). On the other hand, there is clearly an element of migration from the increasingly impoverished rural areas.**

The increase in the number and size of informal settlements is seen as inevitable as a result of the present economic climate, the inability of homelands to be self-supporting and the unaffordability of conventional housing[6].

Authorities mistakenly assume that informal settlers are a transient population who will move elsewhere should they find better accommodation. The reality is that if their economic situation improves, residents of informal settlements are more inclined to upgrade their existing dwellings than to move to new dwellings - particularly when a settlement acquires legal recognition and hence, permanence.

Whether informal settlements provide people with opportunities to improve their standard of living is more of a rhetorical question which the present cross-sectional study was not adequately able to address. Economic planning and taxation in South Africa has resulted in capital- rather than labour-intensive processes in a country which strives for First World standards at the expense of its demographic realities[7]. The result is an inappropriate economic structure which has a limited basis for growth, depends on scarce skills, and has limited potential to offer employment to a large, rapidly growing, rapidly urbanised, relatively unskilled work-force. A growth rate of 5,4% is required to allow the annual increase in the labour force to be accommodated in the formal sector. As the Reserve Bank estimates the long-term growth potential of the economy at around 3,6%, the formal sector will only be able to offer employment to the minority of work seekers.

Contrary to the relationship between urbanisation and economic growth found in developed countries the urbanisation process in South Africa depends on the capacity of the informal sector to absorb new urbanites. This "backwash urbanisation"[8] paradigm suggests that urbanisation may not result in economic development - the opposite in fact[1].

Methodology

The samples were drawn by the Centre for Statistics of the Human Sciences Research Council, using Systematic Cluster Sampling[9], and based on the selection of a single complex sampling

** This is notable in such settlements as Tumahole in the Orange Free State, where as much as 34% of respondents had arrived directly from a rural area. However, the most recent arrivals had come from urban areas such as Parys.

	Total	Formal	Informal #	
			Planned	Unplanned
PWV:				
Alexandra	200	77	32	91
Orange Farm	123	0	94	29
Zonkesizwe	144	0	68	76
Mamelodi (Pretoria)	199	154	28	17
Jouberton (Klerksdorp)	321	182	22	117
OFS:				
Tumahole (Parys)	158	0	124	34
NATAL:				
Kwa Mashu	130	111	19	0
Newtown/Inanda/Ntuzuma	225	0	225	0
Umlazi (& Malukazi)	166	130	19	17
Sobantu (PMB)	145	145	0	0
CAPE:				
Galeshewe (Kimberley)	253	65	182	6
Total	2064	864	813	387

\# Informal Dwelling Categories: House or Shack

Figure 2: Details of sample

unit constituting each sample. A market research company administered questionnaires to 864 households in formal townships and 1 200 households in informal settlements (see Figure 2).

These settlements represent a cross-section of community types of differing age, size, mix of formal/informal housing, level of infrastructure, social-economic profile, and fuel sources.

The classification of settlements is somewhat complex. Formal townships consist of conventional houses in existing "proclaimed" townships. Informal settlement covers a much broader range of housing types, from tin shacks to orthodox brick houses, indistinguishable from houses in formal townships apart from the infrastructural context. Prior to the abolition of influx control the government regarded all (informal) "squatter" settlements as illegal. In 1985 the President's Council made an attempt to legitimise a situation which was seen to be getting out of control by sanctioning what it termed "orderly or planned urbanisation"(10).

This policy of ordered informal settlement envisages the growth of African urban settlement through the designation of new residential sites on metropolitan peripheries in which basic infrastructure and serviced sites will be provided by the State. This represents a form of controlled slum development and the strategy is rationalised in terms of an ideology of upgrading: it is argued that individuals will be able to upgrade their homes and communities as employment and incomes rise and thereby informal settlements will be transformed ultimately into fully serviced suburbs with high housing standards (11).

With this change in policy many hitherto spontaneous free-standing settlements formed by land invasions and termed "squatter camps" became planned site-and-service settlements. Orange Farm is an example. Typically there is always an unplanned area of closely clustered shacks housing new arrivals, who wait until a demarcated site is made available for them. This site is marked out and has access to basic amenities.

However, the informal settlements present a continuum in site-and-service facilities from refugee camp conditions to formal dwellings. An index of site-and-service was developed to distinguish between "Planned" Informal Settlement and "Unplanned" Informal Settlement. The two criteria used were access to running water and provision of permanent toilets for each dwelling. For "Planned" Informal Settlements the minimum standards which satisfy the criteria are street taps and pit latrines/chemical toilets (Figure 3).

The areas as a whole may be characterised in the following manner:

Zonkesizwe and Orange Farm – "Planned" Informal Settlement with a significant proportion of unplanned settlement;

Umlazi and Kwa Mashu – formal townships with a small informal component;

Inanda Newtown – site-and-service planned settlement with a preponderance of wattle-and-daub houses and shacks which are very difficult to distinguish between;

Sobantu – formal township with a negligible informal element;

Alexandra, Mamelodi and Jouberton – formal townships with substantial planned and unplanned settlement as well as backyard shacks and outbuildings;

Tumahole – planned and unplanned settlement;

Galeshewe – formal township with a large unplanned shack settlement.

The informal sample also consisted of some houses in Newtown, Zonkesizwe and Orange Farm. So there are four dwelling types: formal houses (in formal townships) and planned houses, planned shacks and unplanned shacks (in informal

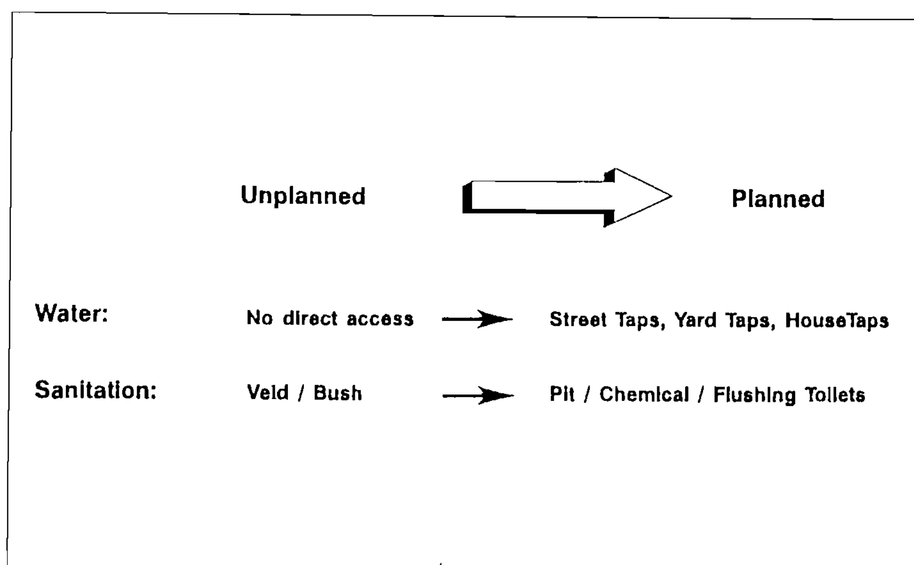

Figure 3: Classification of informal settlements

settlements). These four types provide the main categorisation for the analyses.

Results

The report[12] from which this paper is distilled comprises case-studies of eleven settlements with descriptive statistics. As the objective was to obtain data across a wide spectrum of settlement types, data cannot be easily compared. The reader should therefore bear in mind that the resulting heterogeneity imposes limits on the wider application of the results.

Fuels used: A cluster analysis performed on fuels used identified certain combinations. The groups were paraffin only (n=132); candles and paraffin (n=637); candles, paraffin, coal and wood (n=546); gas, candles and paraffin (n=153); electricity (n=460); electricity and candles (n=76); and electricity, coal and wood (n=60). Multiple fuel use is thus the norm.

Overall, 46% of informal households are dependent on candles and paraffin, whilst 34% use coal and wood in addition. Gas displaces coal and wood for 10%. Only 2% of informal households use electricity.

In formal households, 5% use paraffin only, which is similar to the informal sample (7%). However, only 10% of formal households use candles and paraffin, whereas 16% use candles, paraffin, coal and wood. Gas, candles and paraffin were used by 3% of formal households, while electricity remains the most widely used fuel in formal households (66%).

Geographical area: Geographical area is a major determinant of the mix of fuels used which are a function of local availability and cost as well as climatic factors. Figure 4 gives an overall comparison. There is a striking difference in the utilisation of coal, wood, candles and paraffin. For example, on the Highveld 43% of informal and 26% of formal households use this combination compared to 4% and 5% of the respective groups in Natal. Gas appears to be more widely used in Natal than on the Highveld.

Dwelling type: As would be expected, dwelling type is also a major determinant of fuel mix. This reflects the mainly formal nature of the Natal townships and the mainly informal nature of the Highveld townships. A Chi-square test on fuel clusters and dwelling type yielded a significant value with a Spearman rank correlation coefficient of $r=-0{,}63$ ($p<0{,}00001$).

Paraffin only users: In Galashewe, as many as 56 informal and 12 formal households only use paraffin. This is probably because of the high cost of wood in the area.

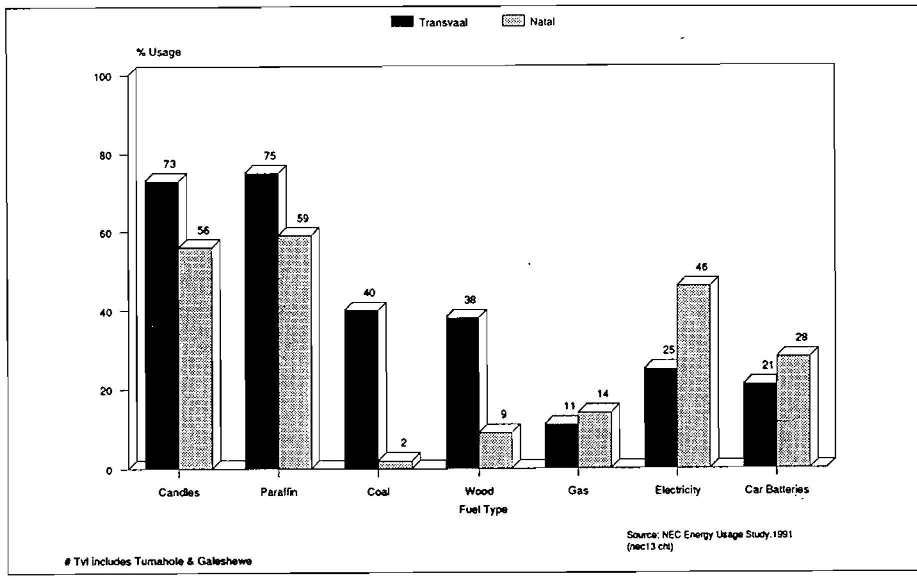

Figure 4: Fuel usage: Natal vs *Transvaal*

Candles and paraffin users: As much as 82% of unplanned shacks and 54% of planned shacks use candles and paraffin in Natal compared to 53% and 27% on the Highveld. This can be compared to the formal households – Natal 17% versus Highveld 3%.

Candles, paraffin, coal and wood users: Coal is used by few households in the Durban Functional Region. In the Transvaal, 83% of planned informal houses, 61% of planned shacks and 29% of unplanned shacks use coal and these other fuels, reflecting the total cost of this option and the ability of the different households to pay for it.

Gas, candles and paraffin users: In Natal, gas seems to replace coal and wood. As on the Highveld there is the same rise in the amount of users across the spectrum of dwelling types according to affordability.

Electricity users: Formal houses have been wired for electricity and are close to the grid. Comparatively few informal households have access to electricity, although the provision in Natal is better than on the Highveld.

Figure 5 indicates the usage of electricity among formal house dwellers who consequently make less use of other fuels. People living in informal shacks are the main users of candles and paraffin. Informal house dwellers are shown to be the main users of car batteries. Use of coal and wood is highest among planned shack dwellers, who may feel more secure in their tenure than unplanned shack dwellers and have thus purchased coal stoves.

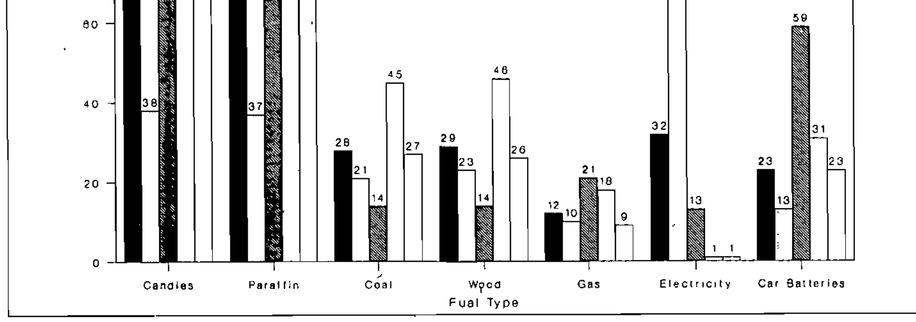

Figure 5: Fuel use by dwelling type

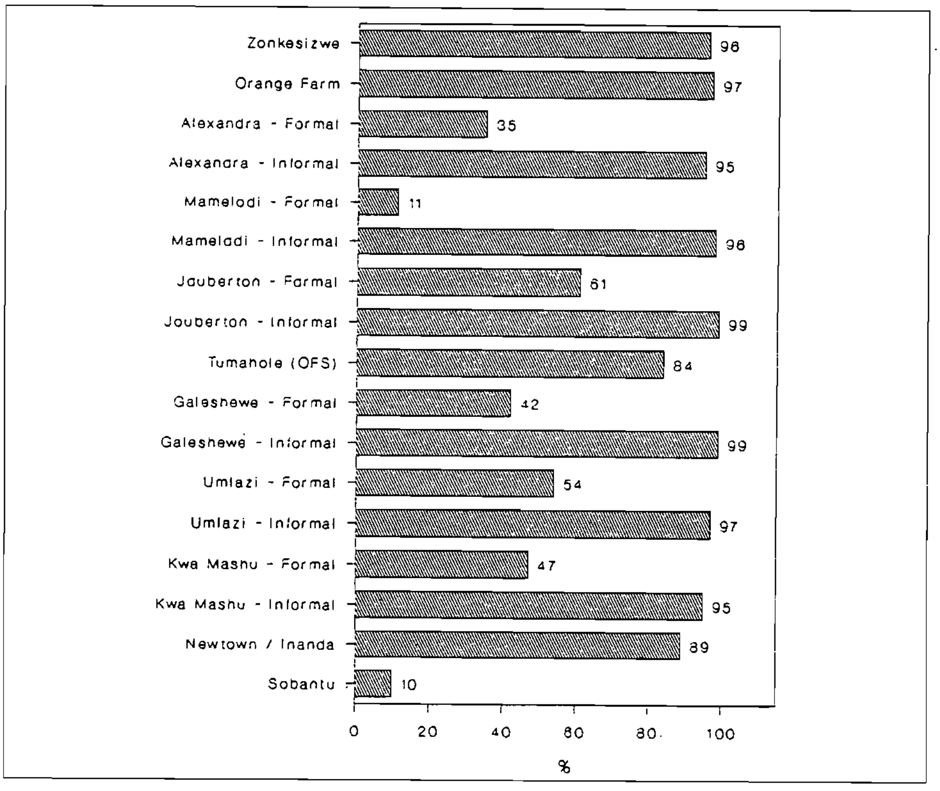

Figure 6 *Paraffin usage by township.*

The fuels least liked were frequently those most used. Overall, paraffin was least liked by most householders, being regarded as smoky, smelly, dirty, inconvenient and dangerous. But electricity was also least liked in Mamelodi, Sobantu and Kwa Mashu because of cost and inconvenience related to outages. Coal was perceived as versatile, and gas as fast. Figure 6 gives an impression of how dependent informal households are on paraffin.

The "Energy Burden": In the sample as a whole, energy expenditure accounted for 12,5% of the average household's income. Where the percentage is low it is generally as a result of

(i) higher incomes (energy expenditure is relatively income inelastic)

(ii) higher levels of electrification (e.g. Sobantu, Mamelodi)

(iii) non-payment of accounts (Alex-andra)

(iv) fewer fuels being purchased (duplication of fuels results in higher costs)

(v) climate (e.g. difference between Highveld and Durban Functional Region)

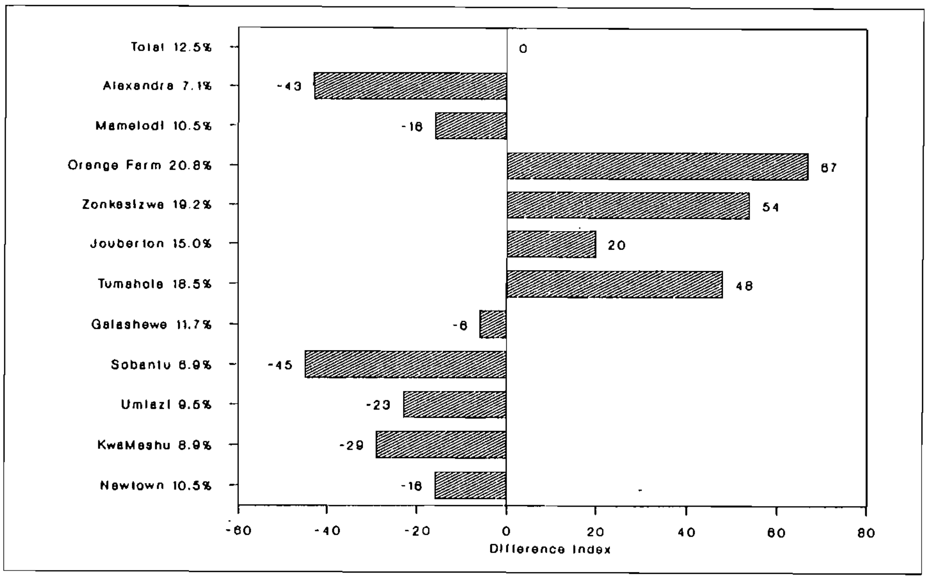

Figure 7: *"Energy Burden" : Energy expenditure as % of income.*

In this figure, the energy : income **index** is used to highlight the **differences** between the percentage of income spent on energy in the various townships compared to the sample as a whole. This reveals that Orange Farm residents appear to be spending the highest proportion of income on energy followed by Zonkeswizwe and Tumahole, as compared to Alexandra and Sobantu.

Urbanisation continuum: By examining residential histories at three points - birth-place, place moved to after leaving birth-place, and place lived at prior to present residence - it was possible to draw up a useful, if somewhat crude, picture of the temporal-spatial shifts in a household's past. The Rural-Urban Continuum differentiated between those with a rural background up until their move to the current township (RRR), those who were born and moved to another rural area (RRU), those merely born in a rural area (RUU), and those born in an urban area (UUU). The overall picture suggests that the vast majority (93%) have urban origins. For instance, in Orange Farm and Zonkesizwe (where one might guess there would be a fair proportion of migrants) in fact only 3% of householders are from rural areas. Figure 8 shows that Tumahole is the exception to this general pattern, where 34% had been residents for 2-3 years, having come directly from the rural OFS as a result of the drought.

This confirms other findings, that intra-urban rather than rural migration is the main contributor to the growth of informal urban settlements. Consequently, it was not surprising to find that the variable "time urbanised" was not a promising predictor of fuel use ($\underline{r}$=0,15).

Time resident: The most influential other variable to differentiate fuel types seems to be time resident at present household. In the Transvaal, a correlation of 0,42 and in Natal 0,32, suggest an association between increasing sophistication in fuels used and period of residence. Figure 9 suggests that newer residents will be mainly using candles and paraffin and to a lesser extent coal and wood. Over time it appears that other fuels are substituted until the household uses electricity. However, because the graph is a composite picture of both formal and informal townships, it is a rather crude description of reality. The formal townships' use of electricity dominates the picture. In informal townships there is a small but gradual trend for households to transfer from fuels of a lower calorific value.

No doubt the trend away from transitional fuels would be much more pronounced if households had access to electricity and

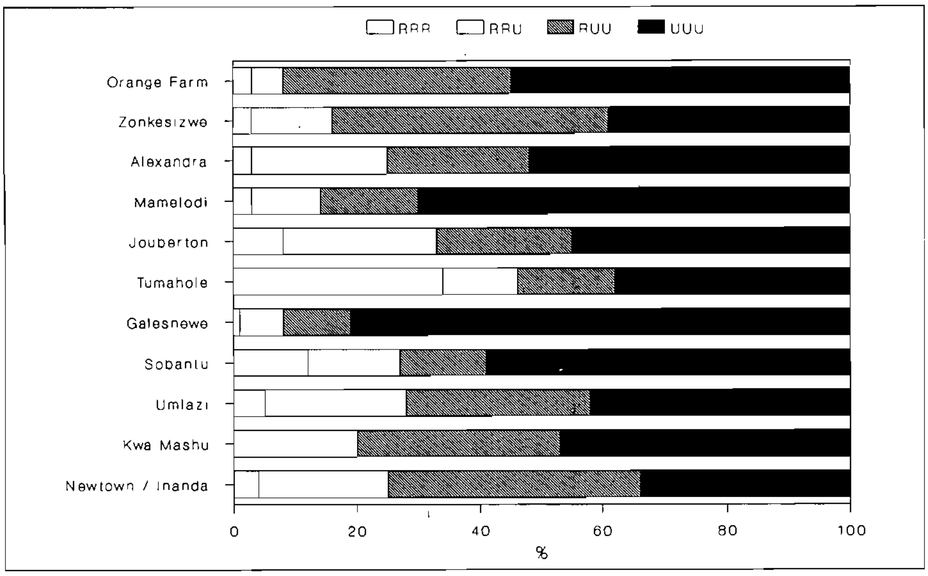

Figure 8: *Urbanisation continuum by township*

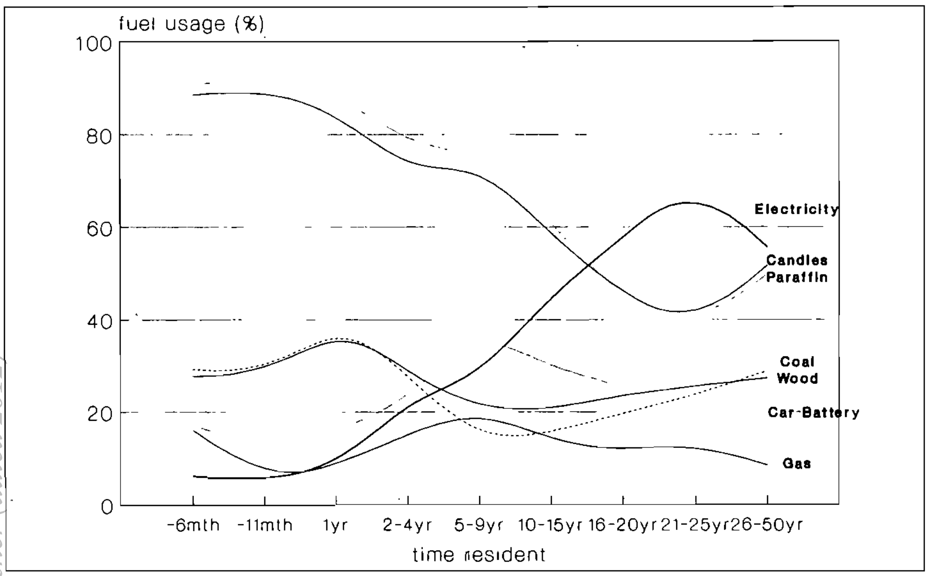

Figure 9 *Fuel usage by time resident*

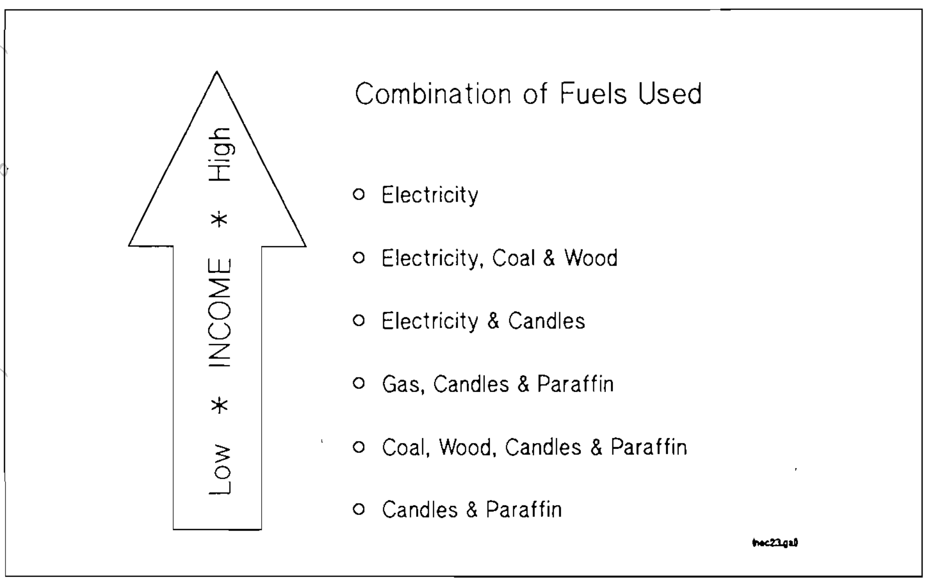

Figure 10: *The relationship between household income and the combination and number of fuels used*

could make a choice - there are people who despite having lived in an area for more than 25 years do not have electricity and are unlikely ever to acquire it. It is thus difficult to analyse the energy transition process in a situation where so little choice prevails. The most common response to the question of why people use certain fuels was that there is "no alternative".

Income: Income does predictably differentiate households according to dwelling type (r=0,37), time of residence (r=0,23) and type of settlement (r=0,37). Income is also related to fuels used in the following order: (i) lowest earners use candles and paraffin; (ii) the next use a combination of coal, wood, candles and paraffin; (iii) then gas, candles and paraffin; (iv) then electricity and candles; (v) electricity, coal and wood; (vi) and finally electricity only (see Figure 10).

Figure 11 shows a map based on correspondence analysis (a weighted principal components analysis of a contingency table). The result is a graphical summary of the relationships between the factors incorporated. There are several points to note:

* the relationship between electricity and those living in formal houses and their distance from the remainder of the sample,
* formal house dwellers tend to be those who have always lived in urban areas (UUU) and to have been urbanised for the longest period,
* those living in shacks are more recently urbanised - 1-10 years,
* unplanned shack dwellers are most dependent on candles and paraffin whereas those in planned shacks will also be using coal and wood, and
* the relationship between informal houses and car batteries suggests that residents of informal houses are attempting to emulate those in formal houses by using car batteries to power appliances that normally require electricity - an indication that these are prime candidates for electrification.

Conclusions

The variety of settlements required to be studied imposed limitations on the wider application of results, since each township was in effect a case-study. Time series data over a long period would provide the ideal information about the rate of fuel substitution but this is a costly procedure. The survey provided some clues into the hypothesis about "back-

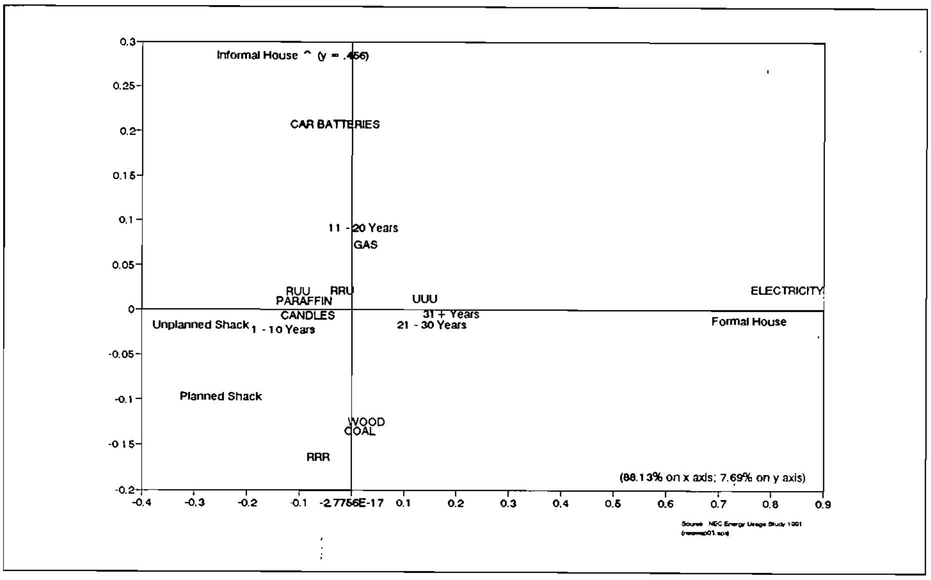

Figure 11 Fuel usage, dwelling type, years urbanised and rural-urban continuum

wash urbanisation'', but because of the limited nature of the questions about residential histories, it was not possible to determine whether the living conditions of those in informal areas had improved or deteriorated.

In the South African context the term "backwash" may be better rephrased as "urban backwash" and used to describe the overflow from formal townships of people whose standard of living will certainly have declined in terms of infrastructure. On the other hand, such households' quality of life may well be preferable to their previous domicile - having to pay rent for the dubious privilege of overcrowded conditions in backyard shacks.

There has been some evidence to suggest that there is a greater likelihood of people obtaining electricity the longer they have been resident in an area. However, the constraints on upward mobility that result from the shortage of formal housing and the non-availability of electricity in certain areas means that the natural transition process does not occur. The implications for the domestic energy transition process are therefore that time urbanised may be a less reliable predictor of fuel use than time resident. The study data do not allow firm conclusions to be drawn on this issue because of the relatively small number of respondents who had migrated from rural areas, where traditional fuel sources would have been used.

The survey demonstrated that there are considerable inter-regional differences in fuel use patterns which are a function of local fuel availability as well as climate. The type of dwelling is another key factor influencing the range of fuels employed. The backlog in both housing and electrification severely hampers the householder's choice of fuels, so that many informal shack dwellers are forced to continue using fuels which they find inconvenient, slow, unhealthy and expensive. In the context of the energy transition process it could well be argued that consumer's acts are based primarily on constraints - not upon choice.

In future it is likely that increasing numbers of people marginalised from the rural areas will augment these sorts of settlements as the polarisation of urban and rural wealth becomes more acute and is transferred to the urban areas. Although it has been acknowledged that energy systems and policy initiatives cannot be divorced from their developmental context, it seems likely that future policy will not be integrated - the urban areas will receive priority over the rural areas (subsistence sector) in the politics of energy planning, further exacerbating the economic imbalance.

This preliminary investigation posed some new issues. It has emerged that the key issue around which the supply and use of energy in the future revolves is the spatial distribution of domestic consumers rather than industrial consumers. This is a function of the dynamics of urbanisation and social change as they affect households. The historical process of black urbanisation initiated by one-sided economic growth in the industrialised sector has acquired a momentum of its own which has become disengaged from its economic underpinnings. As in other African countries urban growth may just as easily be accompanied by impoverishment as increasing wealth.

Acknowledgements

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Electrification in South Africa: A development perspective

* G STASSEN

This paper provides a development perspective of related issues and options which are central to the current electrification debate at national policy level. This perspective comprises an integrated approach dealing with the economic, institutional, technical and environmental aspects of electrification.

Keywords: electrification; development; integrated energy planning; urban areas; rural electrification; electricity distribution industry; environment; urbanisation

Introduction

Although detailed statistics on the extent of electrification** in South Africa do not exist, indications are that, by the end of 1992, approximately 44% of all dwellings in South Africa had access to electricity. There is thus an enormous challenge facing South Africa in ensuring that disadvantaged communities gain access to this enabling resource as rapidly as possible. For this reason the National Electrification Forum was launched in May 1993 to develop and promote the implementation of a strategy that will accelerate affordable and sustainable electrification. The purpose of this paper is to provide a development perspective of related issues and options which are pertinent to the electrification initiatives currently debated at national policy levels.

An integrated approach to electrification planning

Integrated energy planning in general denotes a detailed and disaggregated analysis of the energy sector, the linkage of the entire energy system with economic development and environmental issues covering all aspects relating to the institutional, financial and technical dimensions, and interaction between the various energy sub-sectors. It is being increasingly accepted that only through a comprehensive integrated approach can energy-related problems be effectively tackled. Therefore separate *ad hoc* planning for energy sub-sectors, such as electricity, in isolation is not appropriate against this background.

> "Less effort should thus be placed on accelerating electrification and more on ensuring that it effectively supports and promotes development in its broadest sense."

Traditionally, energy/electricity planning throughout the world has taken the supply side approach, that is, if energy resources were available, demand would follow, or meeting growing demand with more energy supply. Moreover, sub-sectors have been defined mainly according to the various energy sources. Subsequent analysis followed the path from the energy source through exploration, extraction, concentration, transportation, refining, storage, conversion, distribution to consumption by end-user.

An integrated approach to energy/electricity planning on the other hand, however, is end-use focused (on the consumer). It stresses the fulfilment of energy services working through the energy system towards supply. The end-use focus also offers better possibilities for including the environmental impacts related to the specific energy sources and technologies under consideration.

In developing an electrification strategy for South Africa it is therefore an imperative to adopt an integrated approach with the principal emphasis on three levels of analysis, *viz.:*

* the electricity sector and its interactions with the macro-economy. This includes assessing the economic, social, technological, environmental, institutional, political and resource linkages to electricity. The analysis of the first level assures that whatever the electrification strategy may be, it will be consistent with other priorities and will support the many interrelated, though often conflicting, national and regional objectives as effectively as possible;
* the linkages between the electricity sub-sector and the other energy sub-sectors. The second level deals with issues, such as the optimal mix between the different energy sub-sectors, diversification of supply, energy demand analysis, substitution and energy consumption by energy type and by sector;
* the management of the electricity sector, dealing with, amongst others, issues, such as pricing, end-use, supply options, financial viability, and capacity building.

Development impact of electrification

It is generally regarded that energy ranks amongst the basic human needs, such as food, shelter, water, sanitation and health. The need for energy to cook and to provide heat and lighting exists in all societies. Although the basic needs characteristic of energy are obvious, this does not *ipso facto* apply to electricity[1].

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** For the purpose of this paper, electrification denotes the provision of electricity from both the grid and stand-alone sources within the poorer and disadvantaged communities which have no access to electricity for domestic purposes.

Electricity is a convenient, safe, versatile and efficient form of energy which is widely perceived as the preferred energy carrier for social and economic development. Its availability could support growth and development in the broadest sense. It could furthermore reduce unproductive time spent collecting household fuels, and is widely perceived as creating employment opportunities (backward and forward linkages). According to several studies conducted locally the economic multiplier effect of electrification is estimated to vary between 1,0 and 3,0 although a more realistic figure would be closer to 1,5[(2)].

The job creation potential is estimated to be in the range of 1 job or every 4-20 electrical connections[(3)]. Moreover, according to Spies[(4)] "electricity is the only energy carrier which can provide an effective interface between the industrial and post-industrial (information) age."

Electricity is therefore an important but not sufficient pre-condition for development. Electricity provision alone does not promote growth or ensure that inputs other than electricity required for enhancing economic activity are mobilised on their own[(5)]. It is also apparent that none of the perceived developments associated with electrification will take place unless the basic economic and other necessary pre-conditions are already present[(6)].

From a development viewpoint it is important that electrification should not be considered an end in itself, but as a means to reach broader development goals and priorities. Less effort should thus be placed on *accelerating electrification* and more on ensuring that it *effectively supports and promotes development* in its broadest sense.

Although electrification is highly desirable to support development, it is not the most basic need nor highest development priority and therefore will have to compete with many other demands, such as housing, education, water provision and health services. In particular, electrification is likely to be closely linked to the housing process, which will be far more expensive and which will have to compete for funds with education – a very expensive social need[(7)]. The priority of electrification in the national context, relative to other socio-economic needs and consistency with broad development objectives, together with the development impact (perceived financial, economic and social costs and benefits of this programme, relative to those of alternative investments in other socio-economic programmes) of a national electrification programme, needs to be quantified carefully.

Focus and nature of a national electrification initiative

Nature and rate of the electrification process

Within the constraints of appropriate institutional structures and financial resources the rate and nature of the electrification process in South Africa will be determined by, amongst others:

* the rate and nature of urbanisation;
* the growth of black incomes;
* the cost of alternative energy sources;
* the desire for electricity by urban communities;
* political change which will bring the socio-economic issues to the forefront of political attention[(1)].

Urban focus

A characteristic of South Africa is the high rate of urbanisation. According to van den Berg and du Toit[(1)], the present black urban population could increase from 22 million in 1990 (57% urbanised) to 43 million in 2010 (72% urbanised). Electrification cannot be separated from urbanisation and the provision of housing that will have to be instituted. The impact of any electrification initiative will largely be dependent on progress made with the implementation of an urban development and housing strategy. Estimates of the housing backlog vary between 1,2 and 2 million dwellings, and at least 175 000 dwellings will have to be built per year to satisfy demand[(8)].

Urbanisation policy, including the provision of housing, urban infrastructure and amenities, and local government, is likely to figure prominently in any future development strategy. Like health, housing, education and other urban infrastructure, electricity is likely to be high priority.

It therefore appears that the focus of an electrification programme would be predominantly on the metropolitan, urban and peri-urban areas in South Africa. This focus is probably the most appropriate one in view of the fact that electricity is generally the least-cost option for urban households and the priority given to urban housing and other infrastructure provision.

Whilst electrification from the grid is considered to be the most cost-effective energy supply option in the urban and peri-urban environment, it should not be seen as the only desirable available energy source. Consideration should also be given to an integrated energy approach including supply packages, such as energy efficient housing design and solar water-heaters, as well as the introduction of energy conservation measures to use energy wisely and efficiently.

Rural electrification

The focus of policy formulation for rural development should be on integrated *rural energy planning* for *rural development*, rather than on *rural electrification per se*. Rural electrification is only one component of rural energy policy which is not independent of rural infrastructure policy in general. It should thus not be seen as a separate investment decision, unrelated to the broad spectrum of rural energy policy in general[(9)].

Rural electrification has a number of characteristics which should constantly be borne in mind. Briefly, these include:

* potential consumers are often widely dispersed, leading to high distribution costs relative to those incurred in urban areas;
* initial demand and consumption levels are low and associated with low load factors and seasonal variations.

As a result, few (if any) rural electrification programmes are financially self-sustaining within the first 5-10 years. In general, rural electrification programmes are primarily justified on social considerations with substantial capital subsidies being provided[(6)].

An integrated approach would imply looking much more closely at sustaining and improving the supply of traditional fuels (particularly wood) and other generation options to grid electricity, such as diesel and petrol generators, micro-hydro, gasifiers (biogas, etc.), wind turbines and solar energy.

The initial demands for electricity are extremely low in many rural electrification programmes. With such low demand levels it is difficult to justify the cost of grid extension or diesel/petrol generation. For average daily consumption below about 10 kWh and grid extensions of around 3 km or more, photovoltaic (PV) electricity at present compares favourably with grid electricity. Thus PV, as stand-alone or in hybrid systems with wind and diesel generators, is a cost-effective supply option to meet low electricity demands for the following applications:

* individual PV kits to provide power for domestic lighting and entertainment (TV/radio/hi-fi);

* water-pumping for both human and animal use and small-scale irrigation for subsistence farming activities;

* remote farms, schools (86% of black schools are non-electrified[10], businesses, clinics (e.g. vaccine refrigeration) and lighting of community centres.

The fact that the potential impact of rural electrification depends on the context in which it takes place, has obvious implications for the choice of area to be electrified. The World Bank[11] suggested that the following indicators will provide a guide to areas which are suitable for rural electrification projects. Rural electrification projects should be in those areas where reasonably strong and growing demands may be expected for electricity, and where the resulting benefits exceed the costs. Generally, this will be the case where:

* "the quality of infrastructure, particularly of roads, is reasonably good;

* there is evidence of growth of output from agriculture; and where, therefore,

* there is evidence of a growing number of productive uses in farms and agro-industries;

* there are a number of large villages, not too widely scattered;

* incomes and living standards are improving;

* there are plans for developing the region; and

* the region is reasonably close to the main grid (if the demand is particularly strong, remote regions may be considered too).[11]"

It is foreseen that pressure on competing scarce financial and skills resources will make rural electrification from the grid on any significant scale unlikely in the short to medium term.

There is therefore an urgent need for an integrated energy policy for rural areas that extends beyond grid electrification to demarginalise the rural population to enable them to take part fully in modern society at all levels.

Institutional aspects

Restructuring of the Electricity Distribution Industry (EDI)

The problems of the EDI and local government structures are widely recognised. The restructuring of the EDI and reformation of local government structures are therefore widely perceived as necessary to achieve affordable, adequate and sustainable electrification. Restructuring of the electricity distribution system should develop in an evolutionary manner in response to emerging social and political processes, broad development goals and priorities, as well as new approaches to local government and urban and rural development in South Africa.

"The impact of any electrification initiative will largely be dependent on progress made with the implementation of an urban development and housing strategy."

Capacity building

Indications are that Eskom has the institutional, financial and technical capacity to achieve their target of electrification in their area of supply through also making use of private sector contractors.

It is also apparent that the large municipal undertakings have the capacity to drive a major electrification programme within their existing supply areas. However, there is little capacity to tackle a proposed task of such magnitude in the black local authorities, smaller municipalities, and the homelands[12]. This aspect will require extensive capacity building, training, and the mobilisation of the private sector, e.g. small contractors, to ensure that the EDI as a whole can cope with the challenge. This capacity cannot be instantly created but has to be built up over as short a time as possible to ensure that a sustainable electrification process is established.

The capacity of the distribution materials industry and electric appliance industry seems to be sufficient to meet the requirements of a national electrification programme.

Financial considerations

There are limited financial resources within the South African financial system, and electrification options should therefore be considered in the context of sectoral balance, development impact and fiscal impact on the local, regional and national levels.

Various alternatives can be considered for recovering the costs of new electrical connections. The cost of repayment can be borne either directly by the consumer by way of a tariff that allows for repayment of the capital cost, or jointly by all the consumers in the service area of a particular electricity distributor. The latter would imply that a different redrawing of the boundaries of electricity distributors would lead to considerable readjustment of tariffs and a considerable degree of cross-subsidisation.

Other alternatives would be to extend loans which have to be repaid over a specific period to individual consumers (various payback periods and repayment structures are possible), or to include the cost of the connection with the purchasing price of all new housing. Alternately, various alternative forms of direct subsidisation or cross-subsidisation of connection costs are possible and would appear likely if electrification is given high priority by authorities on social or welfare grounds rather than on purely economic grounds. Should subsidisation be considered, the following criteria, amongst others, should apply:

* the fiscal extent and impact of both capital and recurrent subsidies on the local and national level should be quantified;

* subsidies should be consumer-orientated and not towards the electrification process;

* fairness in applying subsidies should be encouraged so as not to favour electricity consumers relative to consumers of other fuels in poorer communities;

* specific target groups (e.g. the poor section of communities) should be identified;

* a time-frame for subsidies should be established;
* the recovery of operating and maintenance costs should be an absolute minimum requirement.

Electrification cost recovery issues should also not be addressed in isolation but as part of the broader cost recovery framework of all services, taking due cognisance of long-term fiscal implications and possible distortions in development priorities.

Electrification technologies

The level of electrification should reflect distribution at the right cost to the right place. This approach is inextricably linked to affordability (both the consumer and the distributor of electricity), willingness to pay, and least-cost supply strategy applying the most appropriate mix of supply technologies without reducing quality, safety and service standards to unacceptable or long-term unfavourable levels.

It is thus desirable to improve the availability and affordability of electricity through more efficient use and introducing various innovative electrification options where appropriate. These include:

* single-wire earth return;
* single-phase lines;
* bundle low-voltage and high-voltage conductors;
* electricity lines erected midblock, thereby reducing service connection costs, car accident damage, etc.;
* low-voltage reticulation (1000 V) in more remote areas which allows transmission of smaller loads over relative long distances at reduced cost;
* pre-payment metering;
* readyboard house wiring at a cost of about R200 instead of R1 000 - R3 000 for conventional house wiring. Other wiring techniques, such as surface or under-plaster flat cord and pre-wired harness systems are also available;
* remote area power supply systems, such as PV, wind, micro-hydro, etc.

Pre-payment metering is still a source of controversy in many townships[13]. Problem areas revolve around the perception that pre-payment metering is aimed at simply alleviating non-payment in black communities. Furthermore, if it is such an appropriate tool for budgeting purposes and load management, why is it not applied in white households? The concept of pre-payment metering needs to be addressed in a holistic manner covering delivery, tariff, the supply authority, community involvement and many other issues of concern.

Electrification standards are in many instances still too high. Although much work has been done in this regard by successful co-operation between the major stakeholders, an ongoing effort is still required to further the rationalisation and standardisation of electrification.

Environmental considerations

A national electrification programme of about 2,6 million connections between 1992 and 1998 would add at least 5 000 MW to existing coal-fired stations. This could result in increased high-level SO_2 emissions, NO^x and particulate emissions in the Eastern Transvaal Highveld. In some townships SO_2 and particulate concentrations are respectively 2,6 and 6 times greater than in the Eastern Transvaal Highveld.

These effects could be offset by improvements in the severe levels of air pollution in the township areas from a partial substitution of coal which is used for space-heating in badly designed dwellings (from an energy efficiency point of view) necessitating the use of lower cost fuels, such as coal. It is foreseen that an electrification programme will not completely eliminate township emissions, largely as a result of the financial inability or unwillingness (social preference) by consumers to replace coal stoves with electric stoves. Turner et al.[14] argue that a 75% reduction in township emissions following electrification, would be a realistic target. However, this target appears to be too ambitious.

Any environmental assessment of the potential environmental impact of a sustainable electrification programme should clearly reflect the scientific and economic rationale behind the environmental considerations.

Conclusions

Several key issues have been identified from a development point of view which are central and pertinent to an envisaged electrification programme in South Africa. By establishing an integrated approach to the electrification process it can be ensured that electrification effectively supports and promotes development it its broadest sense in a sustainable manner.

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Overview of the Second World Coal Institute Conference on Coal for Development, held in London, England, 24-26 March 1993

* C W LOUW

This overview summarises the main views expressed at the conference regarding coal development, coal in the environment and coal investment. The author concludes with an assessment of these views in relation to South Africa's energy-, environmental-, and socio-economic situation.

Keywords: development; coal; environment; conferences; financing; energy policy

Introduction

Following the success of its first major international conference held in 1991, the World Coal Institute (WCI) decided to hold its second international conference during 24-26 March 1993 in London. The WCI is a non-profit, non-governmental organisation of coal-producing enterprises. Membership is open to coal producers from anywhere in the world. Present membership is drawn from thirteen countries spread across six continents, including South Africa.

The conference attracted world-wide attention, being attended by 336 delegates from fifty different countries. South Africa was represented by eight delegates from both the public and private sectors.

The main objective of this conference was to address the opportunities and problems associated with the greater reliance on coal throughout much of the world. The programme consisted of plenary sessions complemented by three parallel sessions on coal development, coal in the environment, and coal investment. There was also an exhibition which featured various aspects of coal technology, together with related marketing and financing services.

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Main viewpoints and trends

A number of important viewpoints and trends emanated from the presentations and discussions during the conference. A synthesis of these is presented below under the three above-mentioned topics.

Coal development

Prominence was given to the role of coal as an energy source in present and future economic development, and the importance and benefits of the future development of the coal industry.

Economic development will prove to be attainable on a world-wide basis only while secure and plentiful sources of energy are available. In this regard fossil fuels, particularly coal, which is the most widely available and most plentiful fossil fuel, will inevitably retain a predominant role for at least the greater part of the next century.

However, coal competes in a global market that is subject to strong political and economic pressures which, in many respects, affect it more than other energy resources. Therefore coal should be developed within a balanced mix of other energy resources, such as renewables.

The 1973/74 oil crisis clearly caused several countries to switch to coal for the generation of baseload electricity and also for industrial applications. Moreover, coal has played a vital role in the development of the economies of many countries, including those in the Asian-Pacific Rim, Eastern Europe and Russia, and will undoubtedly continue to do so. However, because of the growing concern about the environmental impacts associated with coal, there is no doubt that a prerequisite for its continued use will be the need for making the extraction and utilisation of coal as efficient and environmentally compatible as possible.

There is indeed a growing awareness amongst developing countries of the importance of using their coal resources wisely and responsibly to ensure the sustained development of their economies. Consequently, the principle of sustainable development has of late become the corner-stone in coal development projects launched in many of these countries. In this regard there is a need for close co-operation between coal producers, users and suppliers in order to stimulate the optimum development and utilisation of the vast coal resources in these countries.

On the whole, it seems that there is a promising future for the development of the coal industry despite uncertainties in the economic, political and environmental arenas. Besides the creation of job opportunities, the coal industry offers many benefits to world communities, such as the provision of infrastructures to move other cargo, the establishment of ports for other goods, etc.

With regard to coal's contribution to the development of the economies of Southern Africa, the medium-term prognosis for the expansion potential of the coal industry and related industries is not encouraging. In fact, some high cost collieries are facing closure. In South Africa, it is nevertheless anticipated that the country will meet the challenge ahead and maintain its position as an important player in the world scene for power generation mainly because of the resilience of the local coal industry. However, given current and projected economic circumstances, there is little prospect of significant, new greenfields coalfield development in South Africa, or, indeed, in the rest of the subcontinent during this decade.

Coal in the environment

This session dealt with the current environmental issues relating to the utilisation of energy, and coal in particular, as well as the development and application of new and cleaner coal technologies.

The world's environmental demands are growing because of the increasing realisation of the environmental degradation that can result from the inefficient and uncontrolled use of energy. Over time the control and pollution prevention requirements have become more restrictive, and this trend is likely to continue as long as environmental problems and cost-effective solutions are identified. Also, countries with developing and transitional economies, which in most cases lag far behind in environmental protection, are becoming acutely aware of the problems caused by environmental degradation and are beginning to address them.

Coal, which is the most prolific and low cost of macro-energy sources, is environmentally the most vulnerable. The challenge for the future is to develop and apply cleaner and more efficient coal-burning technologies as an element of price competitiveness in a market where the demand for energy will be greatly influenced by the impact of its use.

Considerable progress has been made in developing clean coal technologies, and several advanced techniques do exist in the market-place. For example, techniques such as advanced SO_2 scrubbers and fluidised-bed combustors, are in widespread commercial use throughout the world. Furthermore, a wide variety of more efficient and more economic coal-based technologies will be ready for commercial deployment by the year 2000, whilst also a variety of super-clean and super-efficient technologies which are now being researched will be ready for demonstration by the year 2000. However, adequate demonstration and timeous deployment of new technologies remain a *sina qua non* for securing coal's role as an environmentally compatible energy source.

More stringent environmental requirements and stiffer inter-fuel competition will require fundamental changes in the way electricity is produced from coal in the future. Current pulverised coal boilers, although effective, have limited performance capabilities that will most likely make them non-competitive in the future. This has resulted in a major emphasis being placed recently on the development of a new generation of coal-based electric power systems that inherently control air pollutants to a very low emission level without add-on pollution controls. They also produce marketable by-products, thus greatly minimising wastes, and are very efficient, further reducing pollution and improving system economics. Examples of these techniques are circulating fluidised-bed combustion, pressurised fluidised-bed combustion, advanced integrated gasification combined cycle systems, and integrated gasification fuel cell cycle systems, with plant system thermal efficiencies expected to approach 50-60%.

> "The challenge for the future is to develop and apply cleaner and more efficient coal-burning technologies as an element of price competitiveness in a market where the demand for energy will be greatly influenced by the impact of its use."

The single most important environmental challenge remains the effective curbing of emissions from fossil fuel combustion, in order to mitigate the effects of possible global warming. Several cost-effective options do exist to address the curbing of greenhouse gas-related emissions. In the short term, this would involve improvement in the end-use efficiency of coal-based electricity, improvement in the efficiency of coal-based electrical generation technology and other direct combustion processes using coal. In the longer term, a number of advanced coal technologies, as already mentioned above, will further assist in reducing greenhouse gas emissions. However, a key challenge will be to lower the cost of these options to enhance their viability as cost-effective measures for achieving these environmental objectives.

It is necessary to explore urgently every mechanism whereby new technologies for clean coal production and utilisation can be transferred to developing countries as quickly and effectively as possible. Herein the coal industries of developed countries have indeed a leading role to play in terms of:

- overcoming barriers, such as the securing of financing, the complexity of the technology, control in the quality of local content, unavailability of components, the availability of skilled labour, protection of intellectual property, and weak legal and institutional structures;
- assisting with mining reconstruction to allow the more efficient mining of coal;
- providing appropriate advice on coal utilisation technologies to arrive at an appropriate energy mix;
- setting of realistic standards for environmental management;
- promoting coal as a clean energy source by launching appropriate public awareness and educational campaigns.

Energy prices need to become more realistic in terms of reflecting true costs. Firstly, environmental costs should be identified in order to balance decisions to invest in new supply with decisions on end-use efficiency and conservation. The realistic estimation of external costs associated with emissions is currently still difficult but vitally important to coal development, to the extent that the coal industry should have an interest in supporting ongoing investigations which clarify the situation, particularly with regard to the problem of global warming. Secondly, coal subsidies in several countries, like the U.K. and Germany, which distort current prices on the world energy markets, should be removed in time.

It appears that despite the good progress already made by the coal industry in terms of improving its operational efficiency, coal still suffers from a poor environmental image. This emphasises the importance of campaigns being undertaken by the coal industry to inform and educate the general public concerning current technological developments and improvements related to the utilisation of coal.

Coal investment

This session focused on the financing of coal production, transport and power generation projects.

Investments in energy and in coal in particular, require large amounts of capital. A central issue is the mobilisation of capital resources. However, few governments have the regulatory and related infrastructures in place to mobilise the necessary capital. Moreover, foreign capital can provide only a limited complement to domestic sources. A parallel effort is therefore needed to develop domestic capital markets, and here the role of the government is critical in their establishment. Furthermore, subsidies and low rates of return on energy investments as a result of government policies are inimical to both the energy sector and capital markets. Mechanisms must exist in domestic markets to allow investors to withdraw so as to enable them to get a quick and reasonable return on their capital investments.

Changes in pricing policies and public ownership, as well as the establishment of appropriate environmental policies, are all considered to be part of a sound financial strategy.

There is currently an instability in the coal market due to the fact that the purchase of coal is being dominated by the electric power industries. A greater stability needs to be introduced into the marketplace by a vertical integration of the interests and activities of the coal industry and the electric power industry to stimulate demand to create new and larger markets for coal. Moreover, the fact that coal producers need to compete not only with one another for markets, but also to face competition from other energy sources and endure pressure to improve coal preparation and combustion technologies to meet higher environmental standards, highlights the need for them to form alliances with energy suppliers in order to meet these challenges.

Financial institutions, such as banks, are becoming more cautious of investing in energy and particularly, coal development projects because of the lessons of the past. Firstly, political risk is considered to be an important factor, and in this regard governments must have sound energy development policies to attract investment. Secondly, because of the growing awareness of the environmental impacts of energy generation and utilisation, these institutions place a high premium on protecting the environment, including related liabilities, when they consider investing in energy development projects.

Investors and lenders face many challenges in supporting developing countries to meet their rapidly increasing demand for electricity in a least-cost manner, both economically and environmentally. Besides assisting developing countries to increase their power production, in many cases from coal, they should also assist them to contribute to the world's collaborative efforts to save the environment and to intensify their efforts to achieve energy efficiency and conservation. In particular, in order to meet the enormous investments required for all forms of power expansion, developing countries should be assisted in moving rapidly towards the privatisation of power supply.

Future uncertainty can often be reduced by contractual agreements, and the probability of obtaining financing can thus be improved. In clarifying the course of future behaviour between the parties involved, contracts can and do play a very significant role in the development of coal mining projects.

> “It is necessary to explore urgently every mechanism whereby new technologies for clean coal production and utilisation can be transferred to developing countries as quickly and effectively as possible.”

Environmental legislation and related regulations, as well as directives propagating the sustainable development of energy sources, have thus far had a marked and significant impact on coal development and hence, on investments in the coal industry in countries such as Europe and the U.S.A., and will most probably continue to do so. The coal industry needs to view these developments as an opportunity rather than as a threat to preserve its markets, foster development, and further the goals of initiatives to ameliorate coal's anticipated environmental impacts.

Conclusions

The conclusions offered here are based upon the author's analysis and assessment of the views expressed by the conference's Conclusions Panel, taking into account the South African energy-, environmental- and socio-economic situation.

Coal's role in development

There is no question that, because of its abundance, coal will play an increasingly important role as an energy source in the development of world economies. However, there are indications that coal will be experiencing stiff competition, at least in the short term, from other environmentally cleaner energy sources, such as natural gas. Consequently, in order to secure coal's role in the future, the principle of sustainable development, which entails the wise and environmentally responsible utilisation of coal, has now been widely accepted, in developed and developing countries, for all new coal development projects.

In South Africa, where coal as a fuel is the backbone of the country's energy economy, it has become imperative that it needs to be used as efficiently and cleanly as possible in order to effectively contribute towards improving the quality of life in all sectors. Here the domestic sector is a case in point, where excessive air pollution arising from the poor combustion of coal has become a source of great concern. Because of practical realities every effort should be made through appropriate incentive measures to encourage initiatives aimed at the production of low-smoke fuels from coal at affordable prices in order to complement existing programmes concerning the provision of electrical energy to those townships which presently do not have access to electricity.

Coal's environmental image

Despite the considerable progress that has been made by the coal industry, particularly in the developed countries, in improving its efficiency in the mining, preparation, transportation and utilisation of coal (some of which have already been discussed in this paper), the commodity still suffers from a poor environmental image. As previously mentioned, some active campaigning for coal and its efficient use should be undertaken to inform the public, such as through the arrangement of a "Coal Day" or even a "Coal Week" as has already been done with considerable success in countries such as Australia and Japan.

Policy responses to global warming

Knowledge related to the phenomenon of global warming and its environmental implications is still clearly limited. Continued and well-focused R & D is needed to reduce current uncertainties and to allow the introduction of well-timed measures, as well as timeous adjustments to energy policies. This, *inter alia*, calls for a better assessment of the global impacts of the full life cycle of coal production and utilisation in order to develop appropriate technologies that will eliminate or mitigate the anticipated environmental impacts.

Despite the gaps in current knowledge regarding the problem of global warming, it is widely recognised that the implications of the evidence at hand are sufficient to warrant the taking of cost-effective measures. In this regard, improvement in energy efficiency in industrial processes and buildings are considered to yield the best results in the short term. In the longer term, incentives that will encourage the development and application of cleaner technologies for the utilisation of coal and other fossil fuels, as well as the exploration of economically promising alternatives to fossil fuels, need to be provided.

The recent draft White Paper prepared by the Interdepartmental Co-ordinating Committee for Global Environmental Change, which sets out policy on global environmental change for South Africa and indicates local actions required for the formulation of more specific strategies, also addresses those issues that are currently of global concern. The actions required to refine the proposed strategies need to be followed up in a co-ordinated fashion involving all the key role-players once the White Paper is approved and accepted.

Realistic pricing of energy

An increasingly compelling case is being made for the realistic pricing of energy to reflect true costs, including externalities such as environmental costs. This will ensure the development and application of alternative clean energy sources. In view of the increasing environmental pressures being exerted both locally and internationally, it may well be expected of South Africa in the future to adopt a similar approach in order to comply with international norms. In order to allow timeous adjustments to the country's energy policy, it would only seem expedient that a comprehensive investigation be made into an assessment of the socio-economic implications and feasibility of adopting such an approach in South Africa.

> "On the whole, it seems that there is a promising future for the development of the coal industry despite uncertainties in the economic, political and environmental arenas."

Improvement of energy efficiency

The improvement of energy efficiency, combined with a demand-side management approach, is still regarded as one of the most cost-effective measures in the short term to ameliorate the attendant environmental impacts of global warming. More specifically, the improvement of energy efficiency with regard to both power generation and end-use currently enjoys a high priority.

The role of the coal industry

The coal industry has indeed made considerable progress in improving the efficiency of its operations with regard to the mining, handling and transportation of coal as an energy source. In this regard the South African coal industry is to be commended for its efforts in improving its existing operations, as well as its contribution to the compilation and release of a new document, *An Aide-memoire for the Preparation of Environmental Management Programme Reports for Prospecting and Mining*, which should assist mine managements in complying with the array of environmental requirements for mining in South Africa.

However, there is no reason for complacency and always room for continued improvement. As has been previously mentioned, it is generally considered to be in the direct interest of the coal industry that it should be concerned not only with the marketing of coal as a commodity but also with promoting the more efficient use of coal as an energy source in close collaboration with users. Here the local coal industry, because of its wide experience and considerable expertise, is in an excellent position to play a leading role in Southern Africa.

Appropriateness of the present energy/environment policy for South Africa

The balanced yet pragmatic approach that is endorsed by the present energy/environment policy for South Africa is in essence reconcilable with current global thinking. However, in order to enhance the effective implementation of this policy, it is important that serious consideration be given to assessing the merits of introducing appropriate legislation whereby the Department of Mineral and Energy Affairs will be empowered to, *inter alia*, intervene in market mechanisms, where and when necessary, in order to facilitate the rational use of energy.

TECHNICAL NOTE

Estimation of the wind power performance of the Mabibi wind energy generator

* F F BRYUKHAN AND * * R D DIAB

This paper contains the first results of the wind energy demonstration project at Mabibi undertaken by Eskom, the National Energy Council (now the Chief Directorate: Energy, Department of Mineral and Energy Affairs), the University of Natal and Rotary. The results of the statistical and probability structure of the wind speed and wind generator power have been based on measured wind and electric power time series. These results show that the wind statistics and the calculated wind power generally do not depend upon the wind speed averaging period. A comparison of measured and estimated average power output based on a limited data set showed that there was a difference of only 27 W between the two methods, which implies that it is possible to estimate the average power output of the installed wind generator from the observed wind speed and the manufacturer's specifications with acceptable accuracy. There is, however, considerable dispersion between the two methods for individual wind speeds. More data are required before definitive conclusions on the accuracy of the power performance curve can be drawn.

Keywords: wind energy; power generation; wind statistics; Mabibi Wind Power Project

Introduction

Wind is a most promising renewable energy resource for the sparsely inhabited regions of South Africa, where there is no electric grid and loads are small, as has been highlighted by many authors[1,2]. To investigate different aspects of wind energy development in South Africa, a joint wind energy demonstration project between Eskom, the Chief Directorate: Energy of the Department of Mineral and Energy Affairs, the University of Natal and Rotary, was undertaken. It is located at a primary school in Mabibi, situated on the extreme northern Natal coast. The selection of the site was based on the results of formerly produced large-scale investigations of the wind energy resource of South Africa[3-8]. Methodological aspects of the project have been described in previous papers[9-11].

One of the most attractive aspects of the Mabibi Wind Energy Project is the simultaneous measurement of both wind and electric power. Mutual statistical analysis of the wind and wind generator power time series allows the definition of a relationship between different parameters of the wind and electrical power, which can be widely used for forecasting the usable energy at any place where there is reliable information about the wind climatology.

"One of the most interesting features of the Mabibi Wind Energy Project is the availability of simultaneous observations of wind speed and wind generator power output."

The purpose of this study was to determine the relationship between the electrical power and wind speed characteristics in order to estimate the power performance of installed wind energy generators using standard meteorological wind data.

The data

The following data, which were obtained during the observation period from 15 May-25 August 1992 at Mabibi, have been used in this investigation: the wind speed at a height 12,5 m above ground level and the electrical power output of the generator with a hub height of 12,5 m. In the project a 5 kW Whirlwind type HW4 turbine was installed. A full description of the experiment and technical characteristics of the electrical generator has been previously discussed[9-11].

Wind speed was measured by a MCS 117-2 anemometer and wind direction by an ESS wind vane erected at a height of 12,5 m. Five-minute averages were recorded onto a CR10 Ecologger which was powered by a 12 V battery. Data from the logger were downloaded onto audio cassette tapes, from where they were transferred to an IBM/PC compatible computer. The electric power generated by the wind turbine alternator was recorded as 30-minute averages onto an EPROM chip of a MCS-120 data logger. These data were then transferred to an IBM/PC compatible computer. The database file contained 29 664 5-minute values of wind speed (m/s) and 4 944 30-minute values of electrical power output (W).

Results and discussion

It is well known that the wind near ground level is characterised by considerable variability[12]. Furthermore, the averaging period of the measured wind characteristics, particularly, of the wind speed and wind direction, exceeds by far the time-scale of the process of the wind

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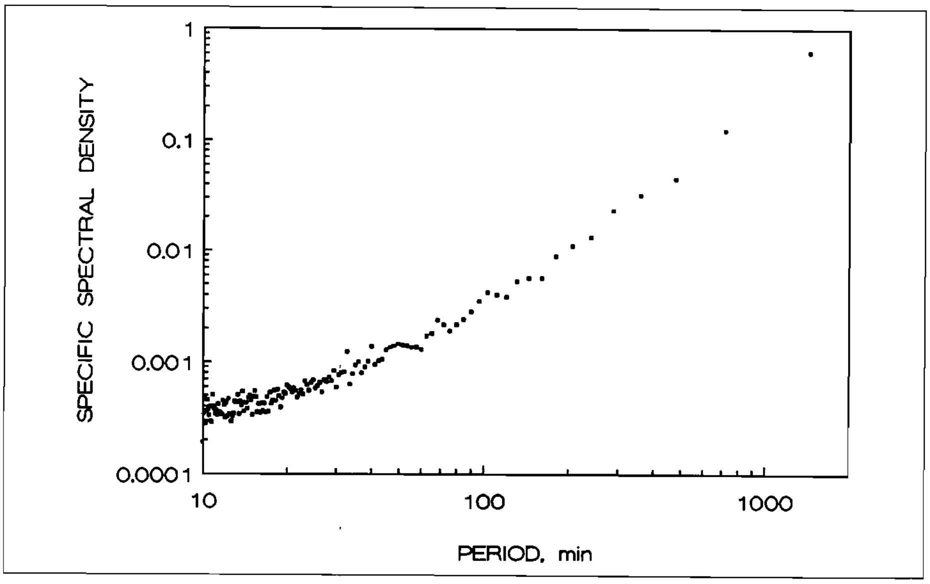

Figure 1: *Generalised wind speed spectrum at Mabibi, calculated as the average of daily normalised spectral densities for the period 15 May-25 August 1992.*

energy transformation into electricity, which is defined by the rotation period of the wind energy generator blades[13]. Nevertheless, the question of the suitability of using standard meteorological observations with, for example, an hourly averaging period, remains unresolved in many respects at present.

The variability in the wind measurements at Mabibi is illustrated by the generalised wind speed spectrum obtained by use of discrete spectral analysis of the 5-minute wind speeds (Figure 1).

The spectrum is a result of averaging the individual normalised spectral densities calculated over each of the 103 days of observations:

$$\bar{S}(k) = \frac{1}{103}\sum_{j=1}^{103} [a_j^2(k) + b_j^2(k)]2D_j \quad (k=1,\ldots 144)$$

(1)

where $a_j(k)$, $b_j(k)$ are the coefficients of the Fourier transformation for the j-th day of observations; D_j is the variance for the j-th day; and k is the harmonic index which defines periods and frequencies

$$T_k = 1440/k \text{ minute}, \quad V_k = k/1440 \text{ minute}^{-1}.$$

(2)

The value $\bar{S}_k$ is the contribution of the turbulent change of the wind with a period T_k to the total variance of the wind speed. It can be concluded from Figure 1 that the individual contributions of the harmonics with periods less than 1 hour to total variance are negligibly small and do not exceed 0,2%. The total contribution of these harmonics according to the calculation is

$$\bar{S}_f = \sum_{k=24}^{144} \bar{S}(k) = 7,1\ \%.$$

(3)

It can therefore be assumed that in view of the small contribution made by harmonics with a period less than 1 hour, that hourly averaged data are adequate for the purposes of estimating wind power.

Analysis of a longer time series (more than 10 days) reveals a strong diurnal harmonic (24 hours), which is to be expected as a result of considerable wind speed change from day to night. It is also possible to identify another spectral density maximum coinciding with the natural synoptic period of 2-3 days. (These results are not illustrated here.)

A second point in favour of the suitability of using hourly wind data in preference to more frequent sampling is given by the comparison between empirical probability densities which were calculated by using wind data of different averaging periods. The results of the

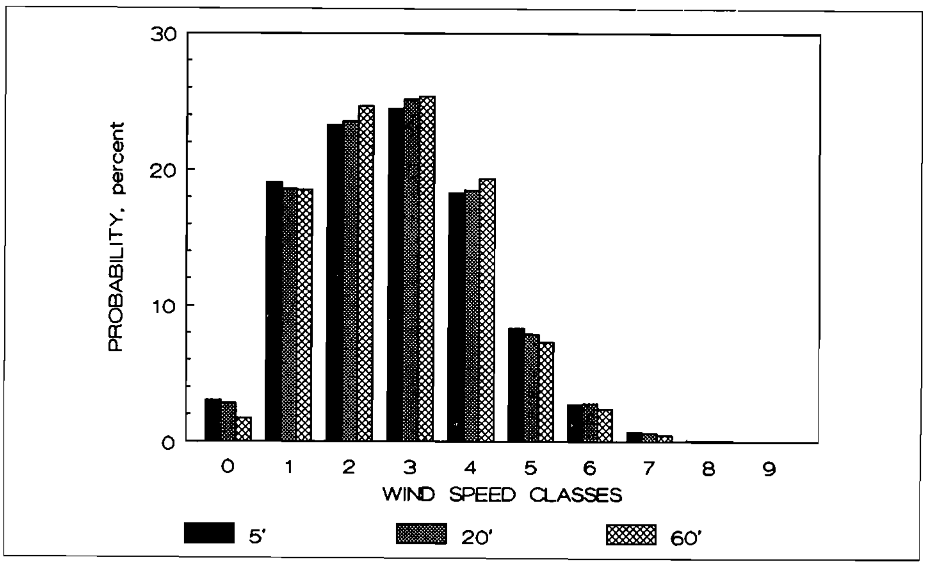

Figure 2: *Probability distributions of wind speed at Mabibi averaged over different time periods. Wind speed classes: 0: calms and v <2 m/s; 1: 2 ≤ v <3 m/s; ... k: k+1 ≤ v < k+2 m/s.*

Averaging period, minute	5	10	20	30	60
Mean wind speed value, m/s	2,91	2,91	2,91	2,91	2,91
Wind speed standard deviation, m/s	1,57	1,56	1,55	1,54	1,53
Mean cubed wind speed, m^3/s^3	47,7	47,2	46,9	46,7	46,4
Estimated mean wind power, P	357	351	353	349	345

Table 1: *Dependence of general wind statistics and estimated wind power output upon wind speed averaging periods*

calculation of the different wind speed class probabilities for the averaging periods 5, 20 and 60 minutes are presented in Figure 2. It is evident that there are small differences between the corresponding probabilities.

A third argument is provided by a comparison between wind statistics estimated from wind data averaged over the periods of 5, 10, 20, 30 and 60 minutes. The results are shown in Table 1, from where it is readily apparent that there is little difference between the estimates.

This is also true in the case of the wind power output which is estimated from

$$\bar{P} = \int_0^\infty W(v)f(v)dv \qquad (4)$$

where f(v) represents the probability density of the wind speed and W(v) the power performance curve. The power curve of the Mabibi wind generator which was constructed from information given by the manufacturer[14] was used in this calculation. The differences between the power estimates are small and do not exceed 12 W.

One of the most interesting features of the Mabibi Wind Energy Project is the availability of simultaneous observations of wind speed and wind generator power output. Regretfully, however, at this stage of the experiment many data errors and omissions in the power output data file have occurred. The most reliable power output data were obtained over only 4-5 days of the experiment. Nevertheless, the availability of about 200 successful power output measurements averaged over each 30-minute period allows the checking of the accuracy of the indirect wind generator power estimation by using only observed wind data. In order to achieve data compatibility the wind speeds were also averaged over 30-minute intervals. The average measured power output over this 4-5 day period was 462 W compared with an estimated value of 435 W. A difference of only 27 W implies that it is possible to estimate the average power output of the installed wind generator from the observed wind speed and the manufacturer's specifications with acceptable accuracy.

The results of both methods of calculation are further presented as probability distributions in Figure 3. In the first case, the probabilities of different power output classes were produced based on the measured power output data and, secondly, on the wind data and manufacturer's power performance curve. Figure 3 shows reasonably good quantitative and qualitative accordance between the results based on the two methods of calculation.

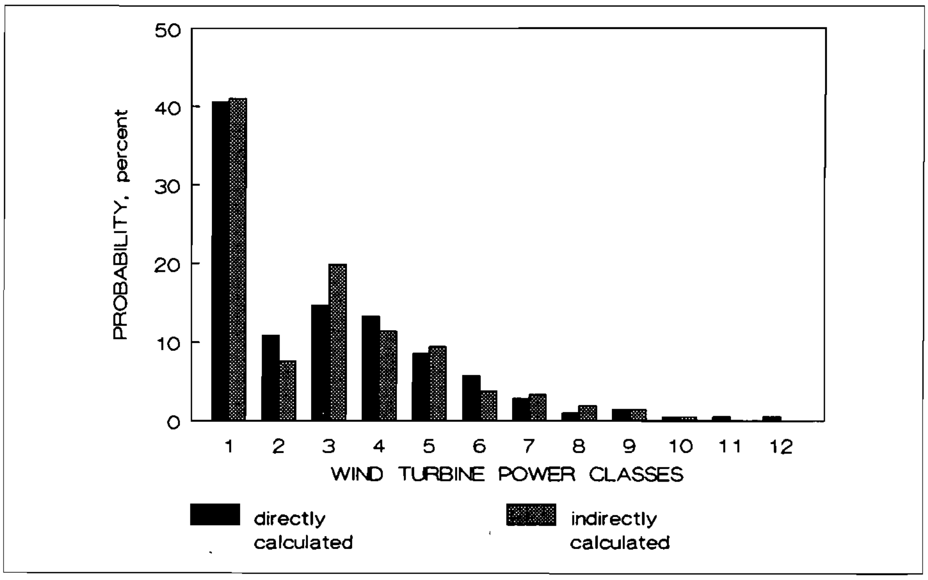

Figure 3: Comparison between directly and indirectly calculated wind turbine power distributions at Mabibi. Power classes: 1: 0 ≤ P <200 W; 2: 200 ≤ P <400 W; ... k: 200 x (k-1) ≤ P , 200 xk W.

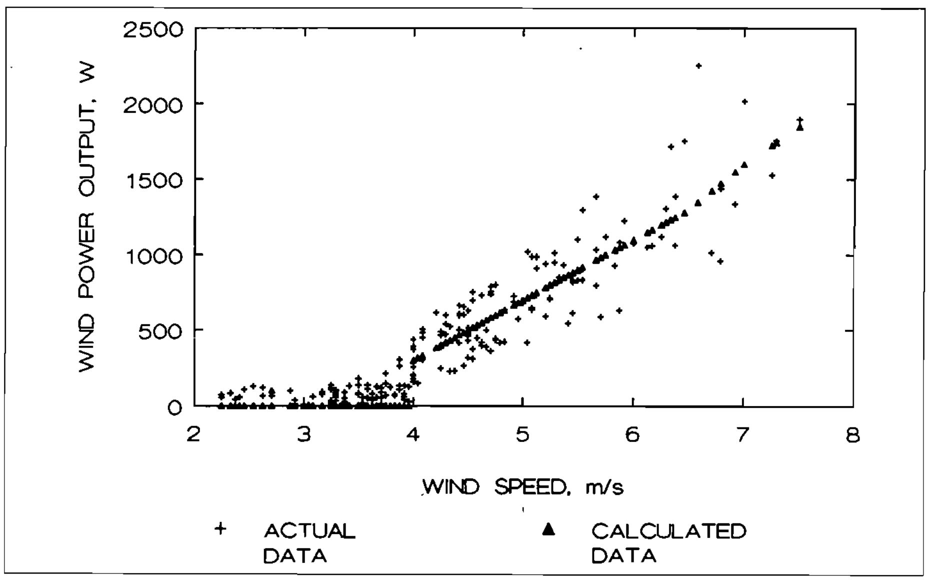

Figure 4: Comparison between measured power output at Mabibi and power output calculated from wind turbine specification.

Further comparison between measured and estimated power output as a function of wind speed is presented in Figure 4. Quite considerable dispersion about the power performance curve is evident. This is not atypical for installed wind generators(15-16), but could also be a function of the very small data set. It is not advisable to draw any definitive conclusions from these comparisons at this stage.

The results obtained in this work, in particular the comparison between predicted and actual power output, will be complemented by further results which make use of additional observational data to be gathered at Mabibi.

Conclusions

The first results obtained from the measurement of wind and wind turbine power output at Mabibi have enabled us to draw the following preliminary conclusions:

(1) The contribution of high frequency turbulent fluctuations, with periods less than 1 hour, to the total wind variance is of the order of 7% and can be regarded as negligible.

(2) Wind statistics used for wind energy resource estimates and indirect calculation of wind power output can be computed with sufficient accuracy from the regular standard, that is, hourly, meteorological wind observation data.

(3) Comparison of the results of the wind power output calculation from wind data, the power performance curve and actual measured data suggest that it is possible to satisfactorily estimate average power output. However, there is considerable dispersion between the two methods at individual wind speeds. Since these findings are based on a very limited data set, it is important that future monitoring of wind speed and wind power output be undertaken.

Acknowledgements

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COMMENT

Some thoughts on attendance at the Enerconomy '93 Seminar in Pretoria, October 1993

* R K DUTKIEWICZ

Keywords: Enerconomy '93; energy management

The Enerconomy '93 seminar was the second in a series on energy management and was aimed at industry and commerce. Seventeen papers were presented, including a keynote address by Dr C Bjork of the Linkoping Institute for Technology in Sweden, who described Sweden's experience on demand-side management and its role in national integrated energy planning.

There was a high standard of papers presented and the evidence was that there is a growing awareness of the need for energy management. Work in this field appears to be expanding, but it is still at a very low level compared with what is being done in the industrialised world, and even when compared with some of the countries in the Southern Africa region. Whilst the enthusiasm was evident, it was a case of preaching to the converted and, though the work appears to be expanding, there does not appear to be a wide enough understanding of the need for energy management nor of the potential savings from the application of demand-side management techniques. Moreover, there does not appear to be sufficient interest from government in this field. It was estimated that a 10% saving in energy, a figure which previous energy audits have shown to be easily attainable, would result in a saving of some R3 000 million, or around 1% of the country's GDP.

Concern was expressed at the seminar that the tertiary educational institutions were not including enough matter in their syllabi to prepare technologists for this field. However, I feel that it is not a reflection so much on the institutions but on the lack of demand from industry - the educational material is available, or could easily be made available, but it requires a commitment from industry to set the educational process going.

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It is a reflection of the lack of interest from the industrial and commercial sectors that a seminar such as this one is held only every two years, whilst what is required is a series of regular seminars targeted at different sectors of the economy.

The complaint raised in the seminar, and often raised elsewhere, as to why not enough attention is paid to demand-side management was that the price of energy was too low in South Africa. Speakers implied that if the price could be raised somehow, more enthusiasm would be generated. However, it is unrealistic, and undesirable, to wish for some price increasing mechanism, such as a tax on energy. The economic development of the country has been grounded on inexpensive energy and it is more desirable that energy management should be encouraged by means other than an artificial rise in cost.

A number of speakers felt that regulations were required to force industry to adopt energy-efficient methods. Again, I feel that this is a legacy of our upbringing where in the past "they", meaning the government, were responsible for our ills and "they" had to fix it. To me the role of government in the field of energy management appears clear. It should adopt the minimum of regulations but should carry out a vigorous campaign to encourage industry and commerce to save energy. The potential savings to the country are enormous - between 1% and 3% of GDP, but industry is largely unaware of the potential savings to them. Encouragement cannot be left to normal market forces since these are not strong enough at the individual company level to make significant contributions on a reasonable time-scale. A campaign to make industry aware of the benefits of energy management, and assistance to industry to start energy analyses, is required, and only government is in a position to do this.

It would appear that there is a core of enthusiasm and expertise in the country to carry out demand-side management which needs to be worked in order to obtain the required national benefits. Prescriptive regulation would not be the correct method of encouraging energy conservation. Encouragement should be given to industry and commerce to carry out appraisals of energy usage. In order for this to be effective, a significant educational campaign needs to be instituted.

There are various potential players in this exercise. Foremost is government, who must provide the incentives to overcome the inertia of companies and to educate them. In this, government should be assisted by the main energy industries. Thus Eskom should be more involved in teaching the customers about the wise use of electricity, the motor industry should be more active in promoting efficient driving, and coal suppliers should be more involved in their customers' operation (much in the way that the TCOA was involved before its break-up). However, there are areas where the energy industry cannot be expected to assist its customers. For instance, the motor industry could not be expected to encourage the development and sales of more efficient motor cars; this is the role of government.

There appears to be a need for a governmental agency, such as those in other countries, to be in charge of a campaign for the more efficient use of energy. Such an agency could adopt the measures of such groups as the Energy Technology Support Unit in the U.K. in order to stimulate action in South Africa. The potential benefits to industry and commerce, and by implication to the country's economic well-being, are enormous but only a commitment by government can set it in motion.

Energy news in Africa

Coal

A methane gas industry could be set up in Zimbabwe if the results of a planned programme to determine production rates on a special grant area in the north-east of the country prove favourable. Shangani Energy Exploration, in which Union Carbide Zimbabwe has an 80% shareholding, has become the first company exploring for coal-bed methane in Zimbabwe to be given the go-ahead to actually produce the gas.

The company has requested funds to test production rates with a R9 M, nine-well drilling programme near Lupane in Matabeleland North province. It has been confirmed that there is a large resource of methane but production rates will depend on the permeability of the coals and their capacity to yield the gas.

Provisional production rates based on comparisons with producing wells in the U.S.A. have been used to test the economics of various end-uses including power generation, flame stabilisation and ammonia production.

Other possible uses, such as, the production of liquefied methane, the manufacture of diesel fuel and methanol, and the potential for industrial or domestic heating have not yet been evaluated.

All the methane produced will be taken up by the local industry but an export market for the downstream industries which would be established in Zimbabwe is possible.

(Source: Engineering News, 23/7/93)

Electricity

Zesco, the Zambian national electricity utility, has announced that it is to use technology developed by Eskom for its electrification programme of the townships. This was recently announced by Zesco MD, Robinson Mwansa. Zesco is particularly interested in the readyboard, which eliminates the need for wiring low-income homes, and high-mast lighting of townships.

Both utilities subscribe to the concept of a future interconnected electricity grid on the subcontinent. This would combine South Africa's coal-fired power stations with the hydroelectricity of the region. A more balanced generation mix would supply the cheapest. most reliable power required for economic growth.

(Source: Eskom News Release, 4/8/93)

The prospect of an interconnected electricity grid in Africa took a further step forward when Eskom signed an agreement with the Egyptian Electricity Authority (EEA). Eskom's chief executive, Dr Ian McRae, held talks with Egypt's minister of Electricity and Energy which centered on technical co-operation between the two utilities, with special reference to electrical interconnections across Africa.

In terms of the agreement, co-operation would focus mainly on the planning of generation and transmission systems, unit costs and tariffs, the operation and maintenance of power systems, manpower training, regional interconnection, information technology, local manufacture, financing and electrification.

Also emphasised in the talks was co- operation in a giant hydroelectricity project at Inga on the Zaire river. The project has a potential capacity of more than 60 000 MW.

(Source: Eskom News Release, 11/10/93)

Two Canadian firms are to execute a World Bank-funded project to develop an estimated 32,77 billion cm^3 of natural gas on the island of Sonosongo, 250 km south of Dar es salaam. It has been estimated that these gas fields would produce 200 MW of electricity for domestic use and export to Kenya.

The project is expected to cost $300 M, and this will require the construction of a 300 km pipeline from Songosongo to Dar es salaam where gas turbines will produce electricity from the gas. There will also be a gas treatment plant at Songosongo and an electricity generating plant at Dar es salaam.

The country is expected to earn $50 M/year from the venture which will be well underway by 1995. The project will augment electricity produced by the state-run Tanzania Electricity Supply Company (TANESCO). Tanzania currently produces 400 MW of electricity, which is 50 MW below its power demand.

(Source: Development Dialogue, July/August 1993)

Oil

A joint loan agreement between the Industrial Development Corporation (IDC) and Angola's state oil company, Sonangol, has been signed to finance the construction and installation of two offshore oil production platforms, worth a total of R340 M for the Cabinda oil field. Once final financing arrangements are completed the platforms will be constructed in Durban by Intershore, a joint venture between the U.K.'s Amec and local companies Dorbyl Marine and Murray & Roberts Engineering. The venture was formed in 1992 to capitalise on experience gained on the Mossgas project and to pursue offshore oil contracts on the African coast.

(Source: Engineering News, 8/10/93)

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Initially Dr Louw was concerned with air pollution and other environmental-related research, playing a leading role in the Air Pollution Research Group of the Council for Scientific and Industrial Research (CSIR). Subsequently, he managed the National Programmes of Weather, Climate and Atmosphere Research and Remote Sensing within the Foundation for Research Development of the CSIR.

Besides publishing and presenting numerous research papers at local and overseas conferences, mainly in the field of air pollution and other environmental-related matters, he served on several national expert scientific committees and councils. In 1989, the National Association for Clear Air Individual Award was presented to him in recognition for his key role in the management and development of air pollution research in South Africa.

When he joined the National Energy Council, (now the Chief Directorate: Energy, Department of Mineral and Energy Affairs) he became involved in managing coal R & D as well as the energy/environment interface.

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Anton Rossouw has been with the Institute for Planning Research since June 1991. He was previously employed in the civil service in various departments working as a social worker. He gained wide experience in this field, specialising in community development and research for initiating community development projects. Anton has initiated numerous community development projects including research and evaluation in this regard. He currently works as senior researcher and is involved in managing a wide variety of research projects. His special interest in research is community involvement, dissemination of information and the direct application of research results.

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13-14

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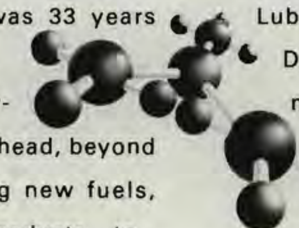

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