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EDITORIAL

INAUGURATION OF THE SOUTHERN AFRICAN INSTITUTE OF ENERGY

S VAN RENSBURG, President, Southern African Institute of Energy

On 1 July 1990, the Southern African Institute of Energy was officially formed. As such, it is the successor to the S.A. branch of the Institute of Energy in the U.K.

In order to maintain a viable Institute it became necessary to form a local body and yet preserve its association with the London-based Institute of Energy. The Institute is a member of the Associated Scientific and Technical Societies of South Africa, is in association with the U.K. Institute of Energy and is also a member of the South African National Committee of the World Energy Council. The Institute's motto is *Ad Africae Vim Tractandum*, which means *Energy for Africa*.

On 22 May 1991, an inaugural conference was held in Johannesburg to formally launch the local Institute. About 100 delegates attended the conference which had as its theme "Energy: Southern African Options". This tied in well with the Institute's motto. The conference was officially opened by Dr Louw Alberts, Chairman of the CSIR and a leading figure in energy matters in South Africa. The Keynote Address, which dealt with energy strategies for Southern Africa, was delivered by Mr R P Viljoen of the National Energy Council who, with only a few days warning, agreed to replace Dr D Neethling, Chief Executive of the National Energy Council who could not perform this task because of ill-health.

Mr Doug Willis, Immediate Past President of the Institute of Energy, U.K., spoke on the international coal scene. High-profile speakers, all leaders in the energy field presented papers on: The role of research (Mr D W L Krueger, Director, ENERTEK), Alternative energy options (Prof. R K Dutkiewicz, Director, Energy Research Institute, U.C.T.), Environmental matters (Dr G P N Venter, NEC). Other papers presented covered the options or solutions available to Southern Africa, namely, Nuclear (Dr J W L de Villiers, Director, AEC), Hydro (Mr S C du Plessis, ESKOM), Oil (Mr N A Deudney, MD, Southern Africa Energy Company Limited), Synfuels (Dr A Geertsema, GM, Sastech R&D) and Coal (Mr A B Cook, Deputy Chairman, Coal Division, Rand Mines).

The conference ended with a panel discussion chaired by Dr N Boegman, Director, ENPRO. Judging from the feedback obtained during and after the conference and from the lively discussion during the panel discussion session, it was concluded that the conference was a great success.

Anyone interested in obtaining copies of the Conference Proceedings, or wishing to apply for membership of the Institute, should contact the Institute Administrator, Mrs Ellen Francis, Tel.: (011) 800 3954, or write to her at P O Box 93480, Yeoville 2143, South Africa.

INDUSTRIAL STEAM BOILER STOCK IN SOUTH AFRICA

*R K DUTKIEWICZ

This report describes the results of a survey of industrial boilers in South Africa. The source of the data was the records of the Department of Manpower who keep details of operating boilers as part of the boiler registration procedure.

Of the 6 101 boilers analysed, 46% are situated in the Transvaal, 27% in the Cape, 20% in Natal, and 7% in the OFS. Of the total capacity, 75% is based on coal, 21% on oil, and electricity, gas, and other fuels make up the remaining 4%.

Most of the boilers analysed were less than 30 years old, but five boilers were constructed in the last century and the oldest boiler was manufactured in 1843.

KEYWORDS: boilers; surveys

INTRODUCTION

A survey has been carried out of the stock of boilers in operation in South Africa. The survey was carried out by analysing the records of the Department of Manpower who keep account of the specifications of all boilers under the Machinery and Works Act. The records are kept in each of eleven centres and reflect the boilers operating in that region. The regions are:

Benoni	Bellville	Bloemfontein
Germiston	Cape Town	Durban
Johannesburg	East London	
Pretoria	Port Elizabeth	
Vereeniging		

The records include details of the boiler manufacturer, physical characteristics of the boiler, the use to which it is put, and the address of the operator. Time did not permit individual visits to the boilers, and the results reflect the information available only in the offices of the Department of Manpower.

A total of 6101 boilers were identified, although not all the required information was available for each boiler and a number of the records had therefore to be discarded. In certain cases information was missing in one or other area and therefore the information could be used in part of the analysis but not for all of it.

The boilers were categorized by a number of parameters such as:

- Type of boiler, e.g. water-tube, shell, or electrode
- Fuel used: coal, gas, oil, electricity, or other
- Capacity of boiler
- Operating pressure
- Dimensions of boiler

In addition, the location of the boiler, the type of industry in which it is operated, its manufacturer's and Government numbers, and the registering Manpower office are also included. Details of the information which was captured are given in Appendix A. The information is stored in a database and any of the parameters can be accessed[1].

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ANALYSIS

Number

Altogether 6 101 boiler details were obtained from the records of the Department of Manpower. These boilers did not include utility boilers. The survey also included only boilers producing steam at capacities between 2 kg/hr and 300 000 kg/hr (from and at 100 °C). It therefore did not include hot water producers, boilers of the chemical complexes such as that of Sasol and AECI, the bagasse boilers of the sugar mills, nor the boilers of the large pulp and paper mills. The survey also did not include the boilers under the control of the Department of Mineral and Energy Affairs, which includes boilers situated at mines, nor of boilers operated by ISCOR and the Railways. These latter groups represent some 10% of boilers and would not significantly alter the analysis of boiler population. It is estimated that the boilers covered by the survey use approximately one-third of the coal sold for final consumption and approximately one-third of the oil consumed for non-transport applications. A number of the bagasse boilers excluded from the study are dual-fuel boilers which also burn coal.

The geographical disposition of the boilers is shown in Table 1.

Table 1: Geographical distribution of boilers

Area	Percentage (%) of boilers
Eastern Cape	10,4
Natal	20,7
Orange Free State	7,1
Transvaal	46,4
Western Cape	15,4

Type of boiler

The boilers have been divided into four types:

- Water-tube boilers
- Shell boilers (horizontal)
- Shell boilers (vertical)
- Electric boilers

Water-tube boilers are more expensive than shell boilers in the low pressure market and become competitive only in applications where high pressure process steam is required or where very large quantities are required. In the U.S.A. and in the U.K. the split between water-tube and shell boilers occurs at a size of between 5 MW and 10 MW[2].

Shell boilers are normally limited to pressures below 20 bar and to capacities up to 20 MW (31 900 kg/hr) for oil and gas firing, and up to 12,5 MW (19 940 kg/hr) for coal firing.

The percentage of boilers in each of the type categories is given in Table 2.

Table 2: Distribution of boilers by type (percentages)

Type	By numbers	By capacity
Water-tube	8,8	36,1
Shell	77,1	60,4
Vertical (shell)	10,0	2,9
Electric	4,1	0,7

Age of boilers

Some of the boilers registered are very old, with one being registered in 1843 and a total of five being registered in the last century. The age spread is shown in Figure 1. Most of the boilers are however less than 30 years old. Boiler sales peaked in the early 1970's, with a steady decline in the number of boilers installed since then. From a peak of 234 boilers registered in 1971, it fell to 100 registrations in 1985, the last year for which complete records were available to the survey. If a histogram is plotted of boiler ages in ten-year bands (see Fig. 2), the decrease in boilers constructed over the last decade is evident.

If the boiler statistics are plotted on a capacity basis rather than on a number basis, then the total capacity of boilers by age is as given in Figure 3. Again the decrease over the last decade is evident.

Capacity

Most of the boilers are small, with 35% being below 1 000 kg/hr capacity, 20% being in the range 1 000 to 2 000 kg/hr, and only 3% being above 20 000 kg/hr. The total capacity of all the boilers in the survey is estimated at 29 000 tons of steam per hour (from and at 100 °C).

Although there is a wide spread in the average boiler capacity from year to year, there is nevertheless a significant increase, as shown in Figure 4, where the 7-year moving average line shows an increase from around 3 000 kg/hr in the 1930's to the present 6 000 kg/yr.

Fuel

The fuel inputs into the boilers have been divided into five categories: coal, oil, gas, electricity, and other.

The category "other" includes mainly fuel from within an industry and most of the boilers reported as using "other" fuel are at refineries or in chemical plant producing essential oils, resins, plastics, and similar products. A number of the boilers using "other" fuel are at dry-cleaning works.

In areas away from the Cape the cost of coal is far lower than that of oil and it would be expected that most boilers would be coal-fired. However, oil is the fuel of convenience since the smaller operators are unable to cope with the handling of coal even if it was cheaper. Therefore it may be expected that more of the smaller users would use oil. The analysis has shown that more shell boilers (40,0%) use oil than coal (35,4%). If however this is translated into boiler capacity, then much more coal is used. The table below shows details of capacity and boiler numbers, in terms of the type of boiler and the type of fuel used.

Table 3: Details of fuel and boiler type (percentages)

Boiler Type	Coal	Oil	Gas	Elec.	Other	Total
Numbers						
W/Tube	7,3	1,1	0,1	0,0	0,3	8,8
Shell	35,4	40,0	0,9	0,0	0,7	77,0
Vertical	6,2	3,7	0,1	0,0	0,1	10,1
Electric	0,0	0,0	0,0	4,1	0,0	4,1
Total	48,9	44,8	1,1	4,1	1,1	100,0
Capacity						
W/Tube	30,0	4,6	0,1	0,0	1,3	36,0
Shell	42,3	16,5	0,4	0,0	1,2	60,4
Vertical	2,5	0,3	0,0	0,0	0,0	2,9
Electric	0,0	0,0	0,0	0,7	0,0	0,7
Total	74,8	21,5	0,5	0,7	2,5	100,0

Usage

An analysis was made of the usage of boilers by economic activity. The results, on a broad category basis, are shown in Table 4. The basis of the division was the Industrial Classification as given in reference (3).

Table 4: Boiler usage, by number, by economic activity

Economic Category	Percent of total boilers
Agriculture, forestry, fishing	2,2
Mining, quarrying	0,2
Manufacture	60,7
Electricity, gas, water	1,6
Construction	0,1
Wholesale & retail, accommodation	2,2
Transport, storage, communication	0,4
Business	0,3
Community, social, personal services	32,2

DISCUSSION

In view of the old age of a significant portion of the boiler stock in South Africa, it was decided to compare this distribution with other countries. One such comparison is shown in Figure 5 where the values are compared with the age distribution of industrial boilers in France[3] in 1975. The South African boiler data have been truncated to be able to compare the data to the same period as the French data. It is seen that the age distribution is similar to that in France. The trend in other European countries also appears to be similar.

As is to be expected, coal is the main fuel, with some 75% of the market in terms of capacity (and energy input). However, a large number of boilers, especially those of the smaller size, use oil. It has been calculated that the oil boilers covered by this survey use 1,2 million tons of oil per year. In 1986 the consumption of residual oil in South Africa amounted to an estimated[3] 900 000 tons. The figure of 1,2 million tons is based on the boilers steaming at full load, although at a load factor commensurate with the size of the boiler. It is to be expected therefore that the actual consumption would be less than the calculated one since boilers rarely steam at full load, and it is known that certain of the boilers are normally kept as back-up and are used only for a few months per year. The coal-fired boilers of the survey use an estimated 6,7 million tons per year, or 30% of the reported total industrial use.

The largest proportion of oil boilers is in the Western Cape where 52% are oil-fired compared to a national average of 39%.

There is a relationship between the installation of boilers and the country's economic activity. This is illustrated in Figure 6 which is a graph of the capacity of boilers installed in successive years plotted against the economic activity of the country as reflected in its Gross Domestic Product (GDP). Since economic activity could rise in the primary sector where little steam would be used, or in agriculture where again little steam is used, the boiler capacity has also been plotted against the manufacturing component of the GDP. It is obvious however that the manufacturing component of GDP has grown at the same rate as total GDP since both curves in Figure 6 show similar trends.

DATABASE

The boiler database has been produced as a database for use on a PC computer. It is available on a series of disks, each for a different part of the country. The database has been set up in "DBase III+" and can be accessed by anyone with DBase capability. The database and explanatory report are available from the National Energy Council[1].

ACKNOWLEDGEMENTS

The work of analysing the boiler data was carried out initially by Dr A Pouris and Mr G Vicatos, and completed by Mr P C Botha. Their work is gratefully acknowledged. The project was made possible with financial support from the National Energy Council whose support is appreciated.

The project could not have been carried out without the excellent co-operation of the Regional Offices of the Department of Manpower in the various centres. Their assistance and forbearance are also greatly appreciated.

The author would also like to thank Mr N. Magaziner and Dr D P Naude for helpful comments on the contents of the report.

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APPENDIX

The following are the data obtained from the Department of Manpower records. This information has been set up in a database from which the analysis was carried out. Details of the database are available from the National Energy Council.

FIELD	DEFINITION
Maker	Boiler manufacturer
Type	Water-tube, shell, vertical, electrode
Fuel	Coal, oil, gas, electricity, other
Year	Of boiler manufacture
Work	Boiler works number
Capacity	Steam capacity (kg/hr)
Pressure	Design pressure (kPa)
Grates	Number of grates (coal-fired)
Shape	Shape of grate
Area	Grate area (m²)
Surface	Boiler heating surface (m²)
Government	Government boiler number
Industry	SIC* code for industry
Place	Place of boiler installation
Division	Government registering office
Address	Address of company owning the boiler
Usage	Nature of industry using the boiler
Status	Whether the boiler was new or used

* Standard Industrial Classification Code

FIGURE 1. BOILERS REGISTERED IN EACH YEAR, OPERATING IN 1986.

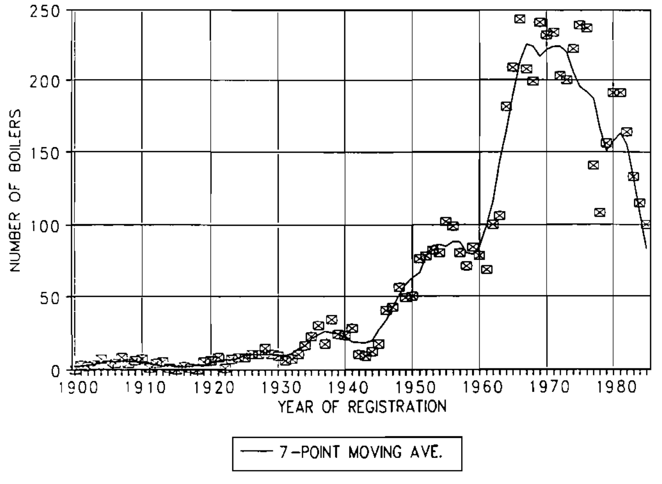


FIGURE 4. AVERAGE CAPACITY OF BOILERS BY YEAR OF REGISTRATION

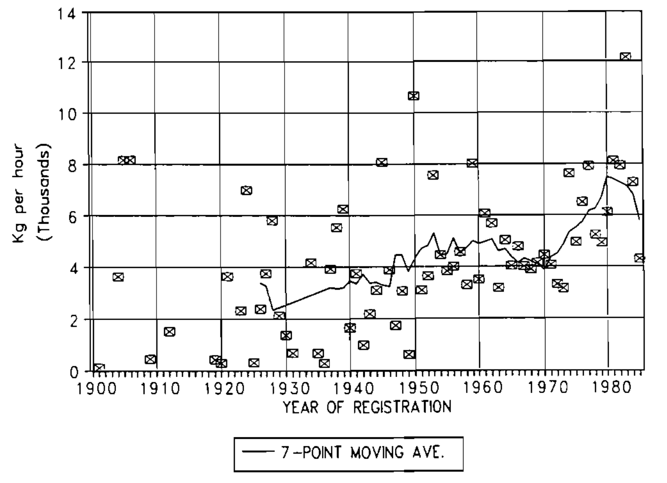


FIGURE 2. CAPACITY OF BOILERS IN FIVE YEAR BANDS

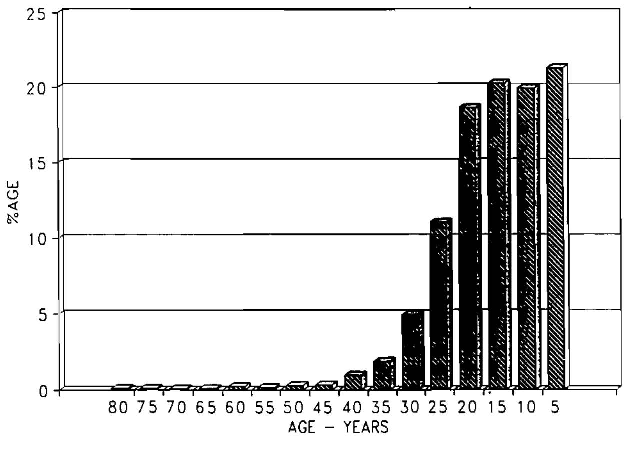


FIGURE 5. AGE OF BOILERS BY CAPACITY FOR SOUTH AFRICA AND FRANCE IN 1975

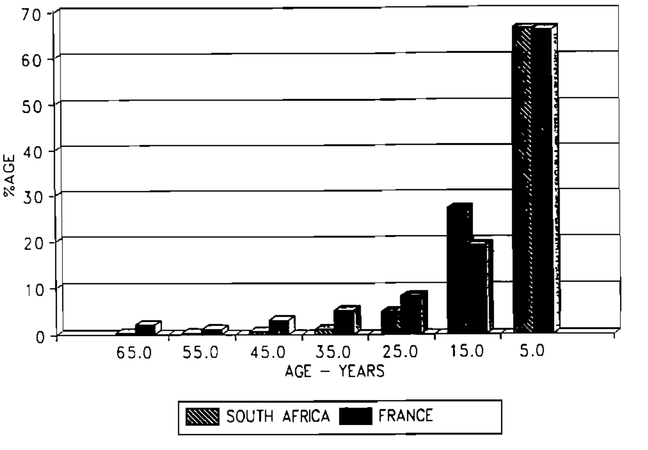


FIGURE 3. TOTAL CAPACITY OF BOILERS IN 1986, BY YEAR OF REGISTRATION

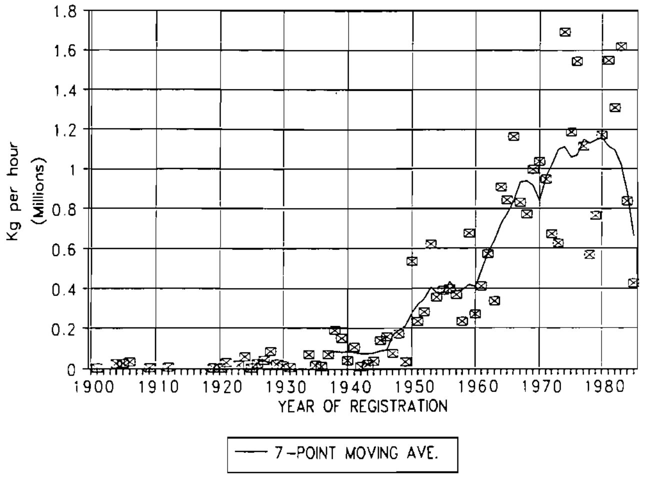
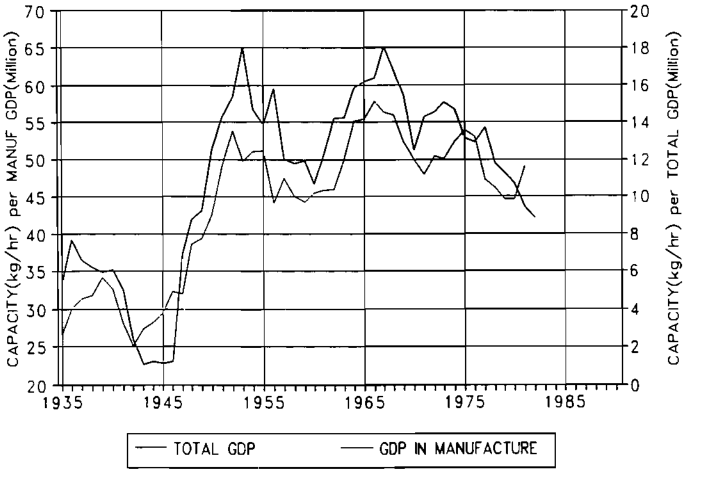


FIGURE 6. BOILER CAPACITY PER MILLION RAND OF GDP - 7-POINT MOVING AVERAGE



ECONOMIC DEVELOPMENT, ENERGY AND THE ROLE OF ELECTRICITY IN THE SOUTH AFRICAN ECONOMY

*P H SPIES

This paper provides a contextual overview of likely future patterns of economic development in South Africa, and of the implications of these patterns for energy demand in general and electricity demand in particular. The pattern of economic development in South Africa is expected to change direction over the coming decade. This change is expected to affect, *inter alia*, investment decisions, patterns of industrialisation and as a consequence the pattern and level of energy demand in South Africa. It is therefore a moot question whether energy forecasting models can provide sufficient insight for effective long-term electricity planning in a developing country such as South Africa. It is argued that the electricity industry can make an important contribution to South African development. As a consequence, electricity development in South Africa should be development-based rather than forecast-based.

KEYWORDS: energy efficiency; economics; electricity

INTRODUCTION

An objective of this paper is to provide some general comments on the relation between energy and economic development. The more specific objectives are to apply these insights to the South African situation, to study some of the important relationships between economic development in South Africa and energy, and to provide some suggestions regarding the potential developmental role of electricity as one of the country's most important energy carriers.

The paper follows a contextual line of inquiry. The relationship between energy and development is first discussed within a global context, and a few causal factors and indicators which could be useful in the evaluation of the South African energy economy are introduced. Economic development patterns in South Africa are then discussed within the context of this global overview. Past economic trends and future prospects for the South African economy are examined within the context of socio-political change and changing development imperatives in the country. The implications of these for the energy economy in general and electricity in particular are reviewed, and the socio-economic factors which could impact most on the (normative) development of the South African electricity industry over the coming decades, are identified.

ECONOMIC DEVELOPMENT AND ENERGY

Development defined

Economic development is a process of qualitative and quantitative improvement in the state of a nation's economy. What is considered to be an improvement in the economy may differ at more advanced stages of the developmental process, depending on value and cultural structures in a society. For example, during earlier stages of economic development, communities generally tend to be more concerned with problems relating to their basic needs, such as housing, food, clothing, and energy for household purposes.

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Qualitative changes during economic development may consist of:

- Improvements in the distribution of income.
- Relative shifts in the size of primary, secondary and tertiary (e.g. services) sectors of the economy.
- Changes in the production structure of an economy, e.g. changes in the technology of production and the quality of manpower.
- Changes in physical infrastructure, such as changes in transport, communication and energy networks.
- Changes in the institutional structure of a country, such as the decentralisation of economic management and privatisation.
- Shifts in societal values (associated with, *inter alia*, rapid urbanisation) and political power, which can affect market patterns and policy decisions over the longer term.

Quantitative economic changes are generally expressed as growth rates in the size of the economy (e.g. gross domestic product [GDP] growth), average disposable income, investment, trade, and foreign exchange holdings.

The rate of economic (GDP) growth is often used as an indicator of economic improvement, and the GDP per capita as a broad indicator of the general level of economic development of a nation. The level of a nation's development is, however, a function of its ability to serve the needs and legitimate aspirations of its population over the long term. Development is therefore a complex systemic concept which emphasises the importance of mutual interdependencies between social, economic, institutional, political, technological, and resource factors in a society. It is possible for a country to experience rapid economic growth while simultaneously retrogressing in a developmental sense. Such countries are vulnerable to commodity price fluctuations, international technological progress (producing a shift in international competitiveness) and socio-political instability, amongst others.

It is therefore of utmost importance for energy planners to take heed of the developmental challenges facing a nation, and not to focus only on economic growth as the main precursor for energy demand.

Patterns of economic change during development

The importance attached to economic growth as an indicator of economic development is understandable because industrialised free market societies are generally egalitarian, which diminishes the need for them to be overly concerned with changes in the structure of their economies. Moreover, a typical development pattern during industrialisation is noted by relatively high rates of economic growth and an initial increase in the inequality in the distribution of income, whereafter a systematic broadening of participation in the economy is experienced[1]. Typically, the development process is initiated with an increased socio-economic dichotomy between urban and rural areas, followed by rapid urbanisation, the mobilisation of the urban working class in the industrial process, and the incorporation of this newly industrialised class into the modern society by means of socio-political reforms.

It is, however, a moot question whether South Africans could expect to experience such smooth transformations. The rate of social and political transformation in the country increased significantly during the past few years. For example, in South Africa the largest section of its population, the Blacks, remained relatively underurbanised until approximately 1980. Rapid rates of urbanisation during the 1980's changed this situation. The black urbanised population increased from 33% of the black population in 1980, to a current figure of more than 50% of a much larger black population[2]. It is therefore to be expected that fundamentally different socio-political imperatives will direct development patterns in the country. These imperatives could produce important discontinuities in South African socio-economic trends within the next decade.

Patterns of change during industrialisation and economic development can be studied from the perspectives of the particular processes which are initiating development, as well as from changes in the socio-economic structure of a developing society. Development studies are concerned with both these perspectives. In the first instance the interest is normative, in that general indicators for development design are required. In the last instance the interest is positive/deductive as it provides an understanding of the process and structure of societal transformation during development. It is not the objective to provide an exhaustive overview of these. Only two patterns with direct relevance to energy studies are reviewed, namely the MEI (matter-energy information) transition, and the relation between structural change during development and the quantitative and qualitative characteristics of energy consumption.

THE MEI-TECHNOLOGICAL EVOLUTION AND ENERGY INTENSITY

The most important reason why the late 20th century world differs so much from the 17th century world is the impact of the scientific revolution of the 17th and 18th centuries and the consequential scientific-industrial culture produced by it. A characteristic of this industrialisation process was its dependence on the availability of sufficient and relatively cheap energy sources.

Studies in technological evolution indicate a typical MEI-transformation pattern of development[3]. During the first phase of technological evolution only matter (which is measured in mass or volume) is embodied in technological artifacts. Energy and information are supplied by man. The artifact is therefore essentially an implement. During the second phase of the technological evolution, energy (measured in abilities to perform work) is added to matter, while information is supplied by man. The artifact becomes a machine. In the third phase, information (measured in structured signals) is added to matter and energy, and the artifact becomes an automat.

The industrial era is often called 'the machine-age'[4,5]. It was an era which progressed economically on capital formation and the harnessing of increasing amounts of energy by means of the use of machines in industrial processes. Technological and economic developments in recent years seem to emphasise information and services as the main economic driving forces in highly developed societies. This new post-industrial society[6] is also called 'the information society' by authors such as Masuda[7] and Toffler[8].

Extrapolating from this pattern of technological innovation, one should expect the energy intensity of developing economies to increase during earlier stages of industrial development. In contrast, one should also expect the energy intensities of the economy to decrease incrementally at advanced stages of development.

International statistics on the energy intensities of countries seem to support this observation. However, the pattern of technological evolution is not the only explanation for differences in energy intensities among countries. Differences in the structure of the economies of countries may also impact significantly on energy intensities.

THE STRUCTURE OF THE ECONOMY AND ENERGY INTENSITY

Apart from the pattern of technological innovation, the structure of a country's economy is influenced by various institutional, social, resource, and economic factors. A country may, for example, be richly endowed with agricultural and mineral resources, which could in turn influence the pattern of industrial development in that country and thus the energy intensity of the economy at a particular stage. It will be pointed out later that long-term trends in the energy intensity of various sectors of the South African economy differ significantly.

There also exists a direct relation between economic growth and the structure of the economy. One useful indicator of a country's economic structure is the industrial classification based on type of end-product. Generally speaking, the economic structure of a country can be defined in terms of primary (i.e. production of food, raw materials and minerals), secondary (i.e. processing of primary products into manufactured products) and tertiary sectors (i.e. the production of services). Analyses of long-term data indicate general trends regarding the relative contribution of the various sectors during development[9]. The proportionate economic contribution of the primary sector (especially agriculture) tends to decline during economic development, while the share of the secondary sector, in particular manufacturing, tends to increase with time. Available statistics regarding trends in the tertiary sector are less clear.

Results of an analysis in industrialised countries of global trends indicate both increases and decreases in energy intensity. Industrialised countries are presently in a state of transition, i.e. between an industrial and post-industrial (information) age. It seems likely that energy intensities in highly industrialised economies will continue to decrease incrementally over the longer term, concurrently with incremental increases in the economic product. This is due to a systematic increase in the importance of services and information as the new products of industrial enterprise. (It is important to note that the sectoral classification of official statistics cannot effectively reflect these changes, because the changes are not only inter-sectoral but also intra-sectoral. The information and service facets of modern industrial processes are increasing.)

Another important structural change over the long term, which also is not explicitly reflected in national statistics, is the increase in energy efficiencies which is associated with economic development and technological progress[10,11]. Especially increases in the capabilities of information handling and control mechanisms may significantly increase the energy efficiency of production processes over coming decades.

A development which holds vast implications for both producers and consumers of energy carriers, especially electricity, is the possible commercial availability of superconductors within the next decade or two. The direct impact of superconductors in the various technological fields is in improved handling of energy and information. The final impact will be on the improved transmission of electricity, very powerful magnets, compact and efficient motors, high performance computers and the improved transmission of information[12]. However, in the case of electricity, the early application of superconductors is not expected because of, *inter alia*, strong vested interests in present technologies[13]. An application which could have a shorter implementation lag is the storage of energy. The energy storage density of superconducting ceramics is, for example, approximately 100 times larger than that of alkaline cell type batteries[14].

Other examples can be noted, but suffice it to say that these new technological developments require a relatively sophisticated techno-industrial structure in order to be effective. It is therefore clear that relatively underdeveloped and technologically backward societies could increasingly be faced by comparative disadvantages in energy efficiencies over coming decades.

GLOBAL PATTERNS IN ENERGY INTENSITY AND ENERGY ELASTICITY

So far the concept 'energy intensity' has been used in this paper as a broad indicator of the energy efficiency of a country's economy. It is now necessary to define this concept more precisely, and to provide some supporting evidence regarding global and South African efficiency changes.

The energy intensity (E_{INT}) of an economy is the relationship:

$$E_{INT} = \frac{\text{Energy consumption}}{\text{Gross Domestic Product}}$$

Another associated relationship is the energy income elasticity (E_e) of an economy, which is expressed as:

$$E_e = \frac{\text{\% change in energy consumption}}{\text{\% change in Gross Domestic Product}}$$

Energy intensity (E_{INT}) is a measure of the average energy efficiency of an economy. Changes in E_{INT} of a particular economy are primarily produced by structural changes in an economy. It is important to be cautious when cross-sectionally comparing the E_{INT} of different countries. Different values for E_{INT} could be the result of factors such as pricing policies, import dependence, product/sectoral mix, differences in national accounting practices, and exchange rate conversion problems, amongst others. It is nevertheless possible to utilise E_{INT}-data of different countries in order to identify general trends.

Energy income elasticity (E_e) is a relatively unstable indicator of the marginal energy intensity of a country's economy since it is influenced by the rate of change of energy consumption as well as changes in the GDP growth rate. It is nevertheless useful in short- to medium-term energy demand forecasts as a derivative of anticipated economic growth.

Data on long-term energy intensities in the U.S.A. and the U.K. (see Figs 1 and 2) indicate an increase up to a point in time (1920 for the U.S.A. and 1880 for the U.K.) whereafter it shows a clear downward trend. Trends in energy intensities in the less developed and developed OECD-countries (see Fig. 3) support the hypothesis (as discussed in the overview of the impact of structural changes) that early stages of economic development produce increased energy intensities, and later (more advanced) stages, decreased energy intensities. Moreover, less developed countries tend to have higher energy intensities than more developed regions.

What understanding of the local energy scene can be gained from these trends? South Africa is often described as a microcosm of the world — a country where underdeveloped and developed socio-economic characteristics intermingle. In recent years a number of commentators emphasised that South Africa is increasingly displaying underdeveloped ('Third World') characteristics; also stating that in future national planning should take note of recent fundamental changes in the national condition. This new national condition can be seen in various social, economic and political processes in the country.

The energy intensity and energy income elasticity of the South African economy were reviewed in two editions of the publication *Energy projections for South Africa* by Kotze & Cooper[15], Cooper & Kotze[16] and by Cloete[17] in a newsletter: *The economic environment: The long-term economic growth and energy demand*. The changes which took place in these two net energy coefficients in South Africa, using deduced values for liquid fuels, are presented in Figs 4 and 5. An important factor to note is the rather inconsistent pattern of the South African energy intensities during the 1950's and early 1960's, the decline in energy intensity during the 1960's until 1973, the increase in energy intensity between 1975 and 1980, and the stabilisation of the energy intensity during the 1980's at a level more or less equal to that of the early 1960's.

Bitsakes[18] ascribes the pattern of energy intensities in South Africa during the latter half of the 1970's and the 1980's to increased mechanisation (*inter alia*, in response to increasing labour costs) and the establishment in South Africa of energy-intensive industries. This is partially confirmed by the trends in the capital intensities of the South African economy[19], which indicated

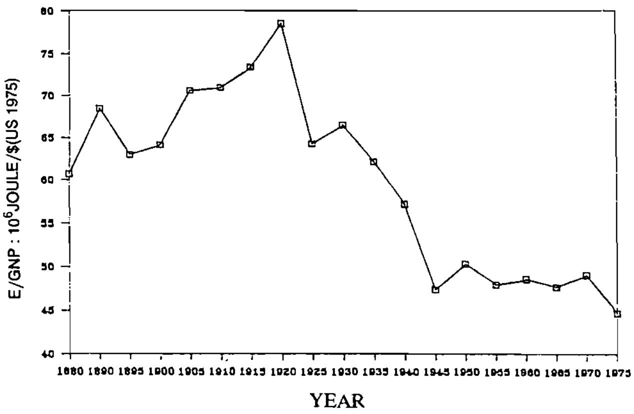

FIGURE 1: NET ENERGY: GNP IN THE USA, 1880–1975

Source: Based on data in Edmonds, J & Reilly, J M. (1985). *Global energy: Assessing the future.* Oxford University Press. p. 50.

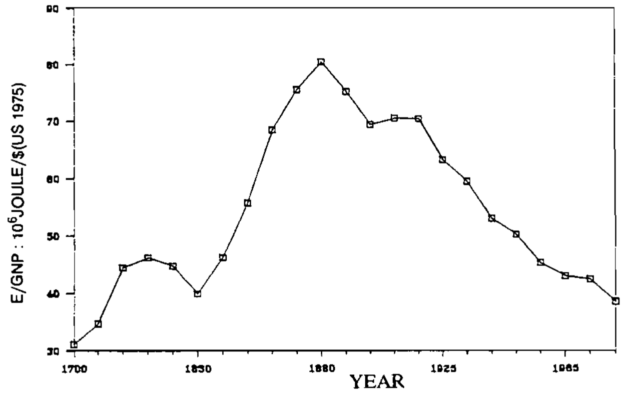

FIGURE 2: NET ENERGY: GNP RATIOS IN THE UK, 1700–1975

Source: Based on data in Edmonds, J & Reilly, J M. (1985). *Global energy: Assessing the future.* Oxford University Press. p. 49.

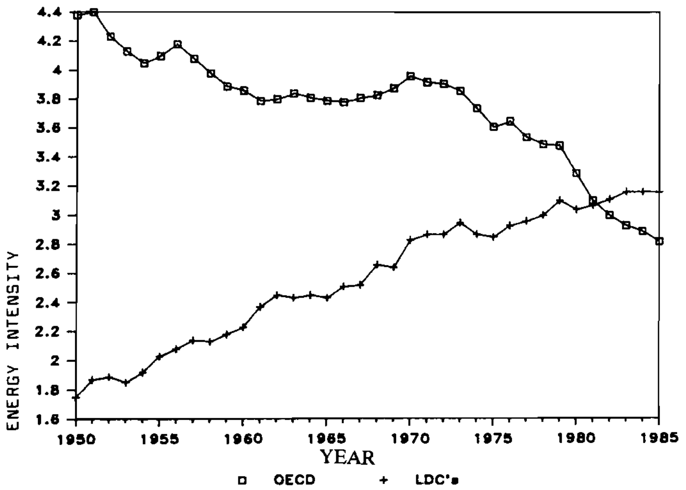

FIGURE 3: NET ENERGY INTENSITIES IN THE LESS DEVELOPED AND OECD COUNTRIES, 1950–1985

Source: Based on data in Tabti, M T & Mandl, W. (1986). Energy indicators. *OPEC Review*, Winter. pp. 444, 447.

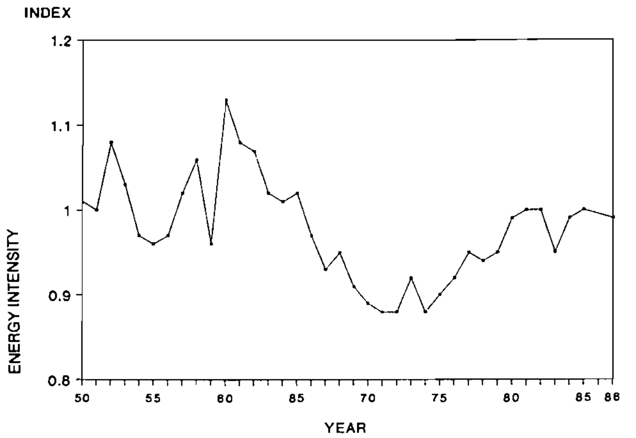

FIGURE 4: NET AGGREGATE ENERGY INTENSITIES OF THE SOUTH ECONOMY, 1950–1986 (1985 = 100)

Source: Doppegieter, J J, Du Toit, J & Wessels A. (1990). *Energy Futures 1990.* Institute for Futures Research, University of Stellenbosch p. 214.

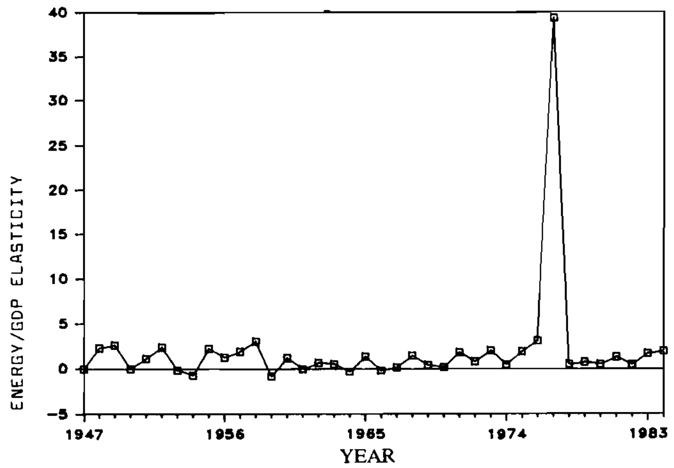

FIGURE 5: NET ENERGY: GDP ELASTICITIES IN SOUTH AFRICA, 1947–1984 (NET ENERGY DEMAND AND 1980 GDP)

Sources: Kotze, D J & Cooper, C J. (1984). *Energy projections for South Africa.* Rand Afrikaans University.

Central Statistical Service. (1987). *South African Statistics 1986.* Government Printer.

an 83% increase in capital intensity between 1973 and 1987. However, another important factor is the poor performance of the South African economy since the early 1970's[20]. It is possible that the higher capital intensity of the economy led to an increase in the demand for energy relative to GDP growth.

These explanations suggest that there is not sufficient evidence to accept recent increases in energy intensities as being a product of a permanent structural shift in the South African economy, i.e. presenting a new trend for the future. At least it cannot be argued that these changes were produced by shifts in proportionate sectoral contributions to the GDP in the South African economy. The proportionate contribution to the GDP of agricultural (approx. 7%), mining (approx. 14%), manufacturing (approx. 23%), trade (approx. 13%) and all the other officially classified sectors of the South African economy have remained largely constant over the last 20 years[2]. However, changes in sectoral energy intensities do indicate shifts in the pattern of energy utilisation within sectors. For example, in the two decades between 1966 and 1986 the energy intensity of the household sector decreased by 24%, the transport sector's intensity decreased by 50%, the mining sector's intensity increased by 100%, and the industrial sector's intensity increased by 32%[19].

The energy income elasticity coefficient of the South African economy over the period 1947 to 1984 averaged at 1,02, if the outlier value for 1977 is ignored. As can be expected, this coefficient is relatively volatile, but fluctuates around a value significantly lower than the average energy income elasticity-value of less developed countries of 1,88%, as calculated from statistics provided in Tabti and Mandl[21]. This could suggest that South Africa's energy consumption patterns were nearer to that of the developed 'First World' in the past, rather than that of the developing world. This concurs with the classification of Chant & Hickling-Partners Inc.[22] who grouped South Africa with Western Europe, Japan, New Zealand and Israel as 'highly developed market economies with relatively low energy resources'.

SOCIO-ECONOMIC CHANGE IN SOUTH AFRICA AND ENERGY CONSUMPTION

As was pointed out earlier in the global overview of the interrelation between economic development and energy, structural (including technological) changes can influence energy demand through inter- and intra-sectoral shifts, and through changing practices and efficiencies in the economy. Important underlying factors which were identified include different trends in sectoral energy intensities, changes in industrial technology, and changes in socio-economic determinants such as urbanisation, social values, and income distribution. Economic development was defined as a complex multi-faceted concept; noted by continuous changes in the social, economic and political fabric of society.

It is nevertheless generally accepted that a problem in economic development exists when a country is faced by a secular (long-term) downturn in economic growth, a downturn which, for example, depresses the average gross domestic product over the longer term even when the best fiscal and monetary policies are used to prime the economic pump. South Africa's economic situation of the last 15 years suggests the possibility that the country is now faced with such a developmental challenge — a challenge which holds important implications for long-term energy planning in this country.

Economic growth in South Africa expressed in terms of growth in real GDP, averaged at 4,8% per annum between 1946 and 1973, with average growth figures of approximately 5,8% per annum during the 1960's. After the so-called 'oil crisis' of 1973 the industrial economies of the world entered a period of lower economic growth. In South Africa the economic growth rate decreased to 3,3% in the period 1973-1980 and to 1,1% in the period 1981-1989. The impact of this downturn in economic activity on living standards is clear when one considers that in order to maintain a constant per capita income, South Africa's GDP would have to grow at 3,6%. This is higher than the 2,3% population growth rate, and is due to the declining fraction of GDP spent by private consumers and the large foreign debt repayments since 1985. Moreover, a growth rate of 5,4% is needed in order to provide for the annual increase in the South African labour force[2].

The performance of the South African economy over the last 15 years indicates that there has, on average, been a decline in living standards. If allowed to continue, this could produce serious social and political instability in the country over the long term. As a consequence, any national planning process in South Africa should seriously contemplate the nature and potential impact of future discontinuities which could flow from these trends.

The malaise of the South African economy can neither be understood nor cured by focusing on any one aspect of the economy, but must be seen in the context of low labour productivity, population growth, urbanisation, national and global politics, human values and perception changes, shifts in international trading patterns, and technological change amongst others. All of these factors operate together and interactively, to produce a complex non-deterministic economic environment.

The economy is faced with a relatively stagnant domestic market due to growing unemployment, a decline in per capita income, cost-push (often politically induced) inflation, a decline in the Rand exchange rate, and sanctions (including oil sanctions) which, *inter alia*, decrease the price received for exports and increase the import prices of selected goods and commodities (such as oil) due to middleman margins. It is also faced with severe capital constraints with, in the recent past, an annual foreign claim on its economy of R4 000 million a year in order to service interest on foreign debt alone, i.e. apart from the withdrawal of foreign credit facilities in August 1985, and the scheduled repayment of foreign debt since then. These constraints should be seen against an annual investment requirement of R36 000 million for job creation, i.e. investment being approximately 20% of GDP[2].

There are various ways to interpret the factors which will influence future growth patterns of the South African economy. The most obvious is the 'normalisation' of the South African political situation, the removal of sanctions and the possibility of foreign investment capital again becoming available to South Africa. However, these factors are only marginal to the deeper social and economic transformations South Africa is currently experiencing. The population of the country's urban centres is growing at a rate equal to twice that of the population growth rate. The labour force is increasing by 400 000 a year, but during the 1980's only approximately 450 000 jobs were created in the formal economy. The country is experiencing a shortage of capital while simultaneously being confronted by a growing surplus of low-skilled manpower, and a shortage of skilled manpower[2]. Moreover, the capital intensity of the South African economy is increasing at a real compound rate of 3,5% per year[23].

Current patterns of socio-economic change in South Africa therefore suggest that we are becoming more urbanised, the economy more capital-intensive, the population on average poorer with a high likelihood that the income distribution could worsen in line with the growing un- and underemployment in the country. What does this entail for planning in the energy field? From a developmental perspective the most important message is that we should not plan for long-term GDP growth rates of, for example, 2 to 3% per year. Such rates of economic growth are inherently unstable and therefore unsustainable over the long term, given the growing social and political pressures in the country. Energy planning should therefore take note of the need to contribute to developmental strategies which can improve the socio-economic prospects of South Africa.

THE POTENTIAL ROLE OF ELECTRICITY IN THE DEVELOPMENT OF SOUTH AFRICA

It is now necessary to focus more closely on the past and potential contribution of electricity in the energy economy of South Africa.

The share of electricity in the net energy market increased from 11% in 1960 to 28% in 1987[16]. Other important energy carriers are oil, with an increased share of the net energy market from 20% in 1960 to approximately 33% in 1987, and coal, with a decreased share from 55% in 1960 to approximately 27% in 1987. Between 1960 and 1980 electricity demand increased by an annual growth rate of 7,8% per year, and by 4,9% per year between 1980 and 1987[24]. These growth rates are a reflection of the general impact of economic growth on energy demand, and of the systematic increase of electricity's share in the net energy market over the past few decades.

Approximately 88% of the installed electricity capacity in South Africa is coal-fired, and electricity generation consumed approximately 42% of the total coal sales (including exports) in 1988. Electricity generation is therefore highly dependent on one non-renewable resource which could become supply-stressed by the second or third decade of the next century[25]. Moreover, current trends in the world and in South Africa suggest growing pressure from environmentalists, with associated cost implications for coal mining and electricity generation in the future.

The capital constraint on the South African economy was discussed earlier. The electricity and water sectors are the most capital-intensive sectors of the South African economy. For example, in 1987 electricity and water required 3,4 times more fixed investment for every million Rand sectoral contribution to South Africa's GDP than the average for the economy as a whole[2]. In terms of job creation, the electricity and water sector required R360 000 (1985 Rand) capital stock for every employee in this sector in 1985, compared to the national average of R46 900 for the same year[2] Given the existing capital constraints and the previously discussed threat of growing unemployment in the country, it is clear that South Africans will by necessity have to be very careful in future in the formulation of their investment strategies.

It is not the objective to discuss the future growth of electricity demand as a function of economic growth trends. Other researchers such as Van der Dussen[26], Cooper and Kotze[16] and Davison[24] have covered this topic extensively. Some general conclusions which can be drawn from their research as well as the previous analysis in this paper are:

- If we expect historical energy income elasticities of the South African economy to continue in the future, then the average long-term rate of increase in energy demand should match the average long-term rate of GDP growth.
- Since 1960 the share of electricity in total energy demand increased by 0,6% per year on average, which suggests a possibility that the rates of growth in electricity consumption could be slightly higher than the rates of GDP growth over the longer term, i.e. if past trends are to continue.
- The long-term pattern of energy demand in general and of electricity demand in particular is influenced by two major socio-economic developments in South Africa, namely, first, by the rapid rate of black urbanisation and, second, by the possibility that the future development of energy-intensive industries may be constrained by the growing political emphasis on socio-economic policies which emphasise increased fiscal expenditure on human and community development (this trend could also be amplified by the current financial pressures experienced in especially the gold mining industry).

As was mentioned before, it is not prudent to derive long-term patterns in energy consumption simply from economic growth forecasts when a country is faced with serious developmental problems. Normative planning scenarios could serve a better purpose under these circumstances because they focus on potential growth rather than forecast growth. For example, if we argue along the lines of full employment, long-term average rates of GDP growth of 5,0% and more are necessary for socio-political stability. It is most unlikely that the present economic structure and the current patterns of economic development in South Africa can support such a level of economic growth on average over the long term[2]. A major socio-economic restructuring which, *inter alia*, emphasises human development, vast housing schemes and inward industrialisation is necessary. It seems highly likely that this could be the pattern of the 1990's. The following comments therefore focus on electricity's potential contribution to the restructuring and development of the South African society.

The most dominating developmental challenge faced by South Africans is to design strategies which can help the country to cope with its population's high propensity to urbanise, and the high rates of urbanisation. High rates of urbanisation have important energy implications. These were discussed more comprehensively by Cloete and Du Toit[27] and Van der Berg[28]. Urbanisation represents a shift away from informal self-help systems of food, water, housing, energy, transport, and water disposal, to new integrated and formal (payment-based) systems. These systems require finance for integrated infrastructure development which can support these services over long distances. Employment for the population is also necessary because it is only through the earnings of individuals that communities can attain an autonomous development ability — and of course an ability to pay for services such as electricity provision.

Urbanisation and rising incomes promote the use of commercial fuels. In this respect Cloete and Du Toit[29] refer to the so-called 'energy-ladder' by which households tend to proceed from 'lower' forms of energy carriers to 'more sophisticated' forms, depending on their economic status. Electricity is at the top of this ladder, coal and paraffin in the middle, and wood, dung and harvest residuals at the bottom. Experience in Pakistan also seems to confirm this trend[30].

Access to electricity is of course an important factor in electricity penetration in South Africa. Such access can be limited due to:

- infrastructural problems (mostly in rural areas);
- lack of suitable housing or lack of suitable electricity supply schemes for informal housing settlements such as in squatter areas;
- unemployment and insufficient income which will, *inter alia*, affect the ability to pay for electricity installation in houses, which costs approximately R2 000 per housing unit[2]; and
- the cost of electrical appliances which could be an important inhibiting factor in expanding the types of uses of electricity within poorer households.

The problems relating to access to electricity are therefore compounded by growing unemployment and uncontrolled squatting. Regarding the provision of electricity to shacks, it is important to note that in Brazil, where electricity is provided to shack settlements, household demand for electricity increased more than eightfold in 25 years[31]. It may be useful for South African planners to research the Brazilian experience, because it is most likely that informal housing settlements could be the dominant urbanisation pattern in South Africa for the next two decades. The need for low-income housing is increasing at a rate of 140 000 per year, and current housing backlogs in South Africa amount to approximately 1,3 million[2].

Energy is generally considered to be a basic need of a poor community. Electricity is a relatively cheap, safe and efficient form of energy. Moreover, given the current South African socio-economic status (compared for example to other African countries), electricity seems to be the most appropriate energy carrier for the exploding urban population of South Africa. Its availability could affect small business development, educational development, and upward mobility in the consumer market. The other relatively cheap alternatives of coal and fuelwood, although perhaps currently more affordable for the poorer section of the population, could represent a serious environmental threat for the country in the longer term.

The socio-political and modernisation implications of electricity provision in South Africa should therefore not be underestimated. It is a moot question whether the longer term socio-economic prospects of South Africa can improve significantly if a growing proportion of the urban population does not have access to electricity in their homes. Moreover, electricity is the interface for the industrial/post-industrial (information) transformation process.

This paper did not discuss any of the various decentralised forms of electricity provision. Suffice it to say that the pattern of electricity provision is another aspect of an integrated national electricity provision strategy which also warrants extensive analysis.

The main theme of the argument in this paper was that electricity provision should be a central facet of an inclusive national developmental strategy. Such a strategy should consider not only the finances, technologies and structures that are needed for comprehensive electricity provision, but also the fiscal and monetary policies necessary for the strategy to be effective. Comprehensive cost-benefit studies which evaluate the expected long-term (20 to 30 year) social benefits and costs for the South African nation could conceivably produce recommendations for electricity subsidies under certain circumstances. Pricing strategies for appliances and electricity, and tariff strategies should also be part of such an inclusive developmental design. The important point is that the electricity industry, together with the government, should not base their strategies on long-term forecasts, but on integrated development designs.

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ELECTRICITY PREPAYMENT METERING SYSTEMS USING ENCODED TOKENS

*C E DINGLEY

The South African electricity supply industry is embarking on a programme to take supply to several million households. The widespread acceptance of the benefits of encoded-token prepayment metering systems, and the relatively high cost of imported units, has stimulated what has become a vigorous industry in South Africa. This paper provides an outline of the available systems, and considers the questions of token distribution, possible theft and fraud, and tariffing implications. The conclusion is reached that there are no serious obstacles to the use of these systems, and that this form of metering will become the norm, despite its higher initial cost.

KEYWORDS: prepayment metering; electricity tariffs

INTRODUCTION

Prepayment metering of public utility services to the domestic consumer offers advantages to both the utility and the consumer. To the utility it means a reduction in the administrative load and the elimination of bad debt, while to the consumer it provides a means of controlling expenditure. The scope of the problems arising from the use of conventional metering and billing systems is illustrated by statistics from the City of Cape Town[1]. In the 1988/1989 financial year the City Treasurer issued 142 000 disconnection orders for overdue electricity accounts. Of this number some 30 000 consumers were actually disconnected and subsequently reconnected.

Prepayment systems for gas and electricity based on coin-operated meters have been in use for decades. These systems do however have associated with them the problems of theft, coin collection and the high cost of maintenance[2]. The use of physical tokens, made perhaps of plastic, eliminates some of the problems related to coin-operated meters, but in turn gives rise to others, notably the possibility of fraud[3]. The development of micro-processor technology has made possible the use of encoded tokens, and it is on these devices and their application that this paper will concentrate.

Encoded-token prepayment meters became available, mainly from European countries, during the mid-1980's, but were too expensive in Rand terms to be considered for use in South Africa. Devices of this type were, however, seen as offering considerable benefits, and this stimulated what has become a vigorous industry in South Africa. This paper provides an outline of the available systems and operational experience to date.

The paper starts with descriptions of the meters and of the token distribution systems. Then follows a discussion of theft and fraud prevention and detection, and a consideration of tariffing implications.

ENCODED-TOKEN METERING DEVICES

The metering devices are normally wall-mounted in a convenient position inside the house. The service connector is taken directly to the meter, without the need, as shall be seen, for a separate incoming miniature circuit-breaker or for a meter box. The meters are relatively expensive, at around R400 per unit as compared to about R100 for a conventional meter, but this difference is partially offset by the elimination of the circuit-breaker and meter box.

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The meters have five main functional components:

(i) The measuring circuitry.
This measures energy consumption with either an assumed or a measured power factor.

(ii) The incoming miniature circuit-breaker (MCB).
This disconnects the supply when the user's credit is exhausted, or in the event of an overcurrent fault. The breaker may also be manually operated by the user from the front of the meter (when modifying the house-wiring for example). Note that this MCB takes the place of the normal incoming MCB required in each house.

(iii) The micro-processor.
This interfaces with all the other major components and provides the logic to drive the meter. The fact that the design is based on micro-processors means that specific supply authority requirements can relatively easily be incorporated.

Provision must be made for data retention in the event of a power failure. This is usually done by means of non-volatile computer memory.

(iv) The token reader.
Various media are being used for data encoding. The most common is the credit-card type token (with data encoded on the magnetic strip), while other systems on offer use bar codes or optically read data. One system does not use a machine-readable token at all; the consumer is instead issued with a number which is then entered via a keypad on the front of the meter. The issued number is an encrypted 12-digit code made up of the consumer's meter number, the number of units purchased, and a transaction number, which is one of a set of several thousand numbers allocated to that consumer. In view of the established position of the credit-card type token, this paper will concentrate on that system.

Tokens may be disposable (costing around 15 cents) or re-usable. They need to be entered into the reader at a steady speed compatible with the rate at which that device operates, but users quickly master the technique. A small LED indicator lights up when the card has been successfully read, and the encoded data is wiped clean. Some metering devices are also designed to mark the card to show that it has been spent.

Tokens are usually valued in terms of electrical units rather than money. This obviously facilitates the changing of tariffs.

(v) User interface.
The following front panel indications are typical for credit-card type token systems[4]:

- Card accepted light (card valid and read successfully).
- Card rejected light (card invalid or not successfully read).
- Credit "gauge": 8 LED's to show various levels of remaining credit. (For an extra cost of approximately R40 the meters can be fitted with a liquid crystal display showing the exact number of units left at any time. This greatly enhances the consumer's ability to budget and is therefore increasingly the preferred option.)
- Low credit remaining: flashes when credit falls below a certain value.
- Insert new card: lights up when credit has expired. (This and the low credit indication are incorporated in the same light.)
- Rate of consumption indicator: a LED with a flash-rate proportional to rate of consumption (a very valuable educational tool).

TOKEN DISTRIBUTION SYSTEMS

The token distribution system used will depend on the desired level of security and hence on the back-up accounting procedures used.

The first (low security) approach is for the utility to pre-code tokens of various denominations and to distribute them via retail outlets, post offices, and the like. This approach has the advantages of a low administrative overhead, and a high level of convenience to the customer. Tokens (and meters) could carry an area code to limit the use of tokens to certain areas. Check metering installed on the feeder to a particular area would measure the total energy entering the area, and this could be compared with units sold in the form of tokens. There would obviously be a mismatch of a few percent because of electrical losses, but as long as this mismatch remained more or less constant, the utility could feel confident that fraud was not a problem.

The second (high security) approach is to store a unique number in each meter, which then accepts tokens coded only with that number. Consumers requiring a new token then visit a utility office, give their details, and wait while a token is encoded. Details of token sales are then recorded in a database so that consumer token purchasing habits may be monitored on an individual basis. The supply authority would be alerted to possible criminal activity by any significant and sustained reduction in token purchases by a particular consumer.

The disadvantages of this individual monitoring approach are the inconvenience to the consumer (who is restricted as to where and when he or she may purchase tokens), and the cost to the utility. Experience to date has shown that a clerk in a secure office, with up to R20 000 worth of computer and encoding equipment, is required for every 1 000 consumers.

The most common approach adopted in South Africa since prepayment meters were introduced a couple of years ago has been that of high security individual control. It would seem, however, that it would be feasible and preferable to start with the low security area monitoring approach, and move to the high security approach only if really necessary. It is noteworthy that to date there have been no reports of the fraudulent production of tokens, and only a small number of reports of attempted bridging around the meter. (Because of various tamper-proof design features, these attempts were quickly discovered).

THEFT AND FRAUD PREVENTION AND DETECTION

There are two aspects of concern: the fraudulent production of tokens, and the by-passing of meters.

Suppliers have taken various steps in the way in which data are physically encoded, and in the coding system used, to make unauthorised production of tokens as difficult as possible. (Proprietary details of the encoding systems used are, for obvious reasons, not published.) Despite these steps, however, it would be prudent to work on the assumption that fraudulent production is possible.

For such a form of fraud to have attractive financial returns, the operation would need to be on a large scale, which in turn means that it would require the collusion of large numbers of consumers. It is therefore unlikely that such an operation could be sustained for long without being reported. Moreover, if token distribution were done using unique consumer identification numbers, then fraudulent production of tokens would be extremely cumbersome and probably not worthwhile. But even with only a low level of security, using zone coding, detection of large-scale fraud would be easy, and it could no doubt be rooted out by the police and the supply authority.

Thus in general it appears that fraud is not a serious threat, and certainly not nearly serious enough to deter utilities from using systems such as these.

The second problem to be addressed is that of the by-passing of meters. This is obviously also a potential problem with conventional metering systems, but in the latter case regular visits from the meter reader are a reasonable deterrent.

By-passing will tend to be an isolated and not very widespread practice, firstly because people are generally not criminal by nature, and secondly because of the physical dangers involved and the risk of being caught. Suppliers have nevertheless taken some trouble to design tamper-proof meters. The general idea is that the connecting wires should be built into the wall and should come into the meter from behind, so that the meter would need to be removed from its mounting for the by-passing to be carried out.

One design approach is to have the meter and its base as completely separate units. The meter is fitted only when the supply is connected to the house, and it can be removed only by a technician using a specially designed tool. Access to the power terminals can then be gained only by the breaking of seals.

The suppliers' anti-tamper features, backed up by occasional checks by the utility, and meaningful penalties for those found cheating (probably including the temporary suspension of supply), should be sufficient to keep this type of activity to a minimum.

TARIFFING IMPLICATIONS

The simplest form of tariff structure to implement with this type of meter is of course a flat rate per unit consumed regardless of how much is used or when it is used. This could be problematic where it is desirable to use lifeline (or rising-block) tariffs, or where the utility wishes to extend time-of-use pricing to domestic consumers.

The features needed to implement these more complex tariffs are a 24-hour clock with battery back-up, a calendar built into the software, and programs to provide the appropriate logic. Indications are that these features will increase the cost of the meter by some R50.

Thus, although prepayment meters in their simplest form are very limiting in terms of the tariff structure that may be used, they do, with some additional features, offer the possibility for the first time of extending time-of-use pricing to the domestic consumer. They will be able to do this in a far more flexible and, if necessary, complex manner than could ever be done with multiple electromechanical registers or meters (such as the "white meter" available in the U.K. for off-peak consumption).

CONCLUSIONS AND DISCUSSION

Taking a lead from European utilities and meter suppliers, the electricity supply and equipment industries in South Africa have over the past few years successfully developed and implemented an electricity prepayment metering system suitable for conditions in the developing world. There is in South Africa now an almost total commitment to the use of this type of meter for new electrification projects. Prepayment metering based on encoded tokens offers considerable advantages to both utility and consumer, advantages which in the long run will probably outweigh the additional initial cost.

Reasonable steps must obviously be taken to make fraud and tampering as difficult as possible. It is not likely that these will prove to be serious problems.

Detection and prevention of such activities is of course made much easier by the installation of computer-based token distribution systems, so that each individual consumer's token purchases can be monitored. But this approach is cumbersome and expensive, and the cause of much inconvenience to consumers. It also raises the question of whether the correct operation of the sophisticated computer systems and networks required for this level of security can be sustained in the long term in countries with severe shortages of skills (such as South Africa). The implementation of prepayment metering should therefore be planned on the basis of area control, with occasional "sweeps" by utility personnel in areas where losses appear to be increasing.

An important question is whether the householder's improved ability to monitor the consumption of individual appliances, as well as total household consumption, will lead to the more careful use, and hence saving, of electricity. Intuitively this would seem likely, and suggestions have been made that consumption in areas using prepayment meters is turning out to be lower than normal, but no firm evidence is as yet available.

Prepayment domestic electricity metering using encoded tokens could well become the norm over the next few decades, not only in South Africa, but throughout the world. It is in line with the universal transition from electro-mechanics to digital electronics in control and measuring devices. The cost of the meters will come down in real terms as volumes increase and as designs and production techniques improve, so that the considerable advantages of this type of metering will become available for not much more than the cost of conventional metering systems.

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A REVIEW AND ANALYSIS OF ELECTRICAL LOAD RESEARCH: METHODOLOGIES FOR USE IN SOUTH AFRICA

*J J ANDERSSEN

The relevance of information on the hourly end-uses of electricity is discussed. This information is important for purposes of planning and operation of an electricity undertaking. The paper describes the positive role which reliable information can play in providing the motivation for and in the advancement of programmes aimed at improving planning and electricity efficiencies. Some of the methods which have been utilized overseas to obtain this information are reviewed for their possible direct application in South Africa, or to be used as a basis for the development of an own-set of methodologies.

Collecting and preparing this information is, however, a difficult, long-term and costly undertaking, and therefore there is a need for the availability of stable long-term funding for this purpose. The relative roles the State and the electricity distributors should play in the process of collecting this information, seen as ingredients for success, are highlighted.

KEYWORDS: electricity load research; electrical energy efficiency; electricity conservation; data

INTRODUCTION

The ultimate objective of electrical load research is to improve planning, the efficiency of electricity utilization, and to advance conservationist actions. Whilst large efficiency improvements are strived for, small reductions in growth rates are significant, particularly in the long term. Even reductions in electricity growth rates of the order of 0,5% per annum will give rise to large savings in future capital expenditures. Several authors[1] have already pointed out that expenditures towards improved efficiencies in electricity end-use can realise more and better 'negative' kWh (lower cost, less polluting, more reliable) than similar expenditures on the creation of new generation capacities.

Convincing supply-side planners of the benefits of negative growth rates in electricity consumption is very difficult. What is even more difficult is to convince utility managements that the reduction in growth rates is directly correlated with electricity efficiency programmes, that these can be sustained, and that the construction of new generation capacity can be postponed. The momentum of supply-side thinking coupled with the difficulty of detecting the small changes in growth rates due to electricity efficiency programmes make this task even more problematical. The South African problem is compounded by the lack of knowledge concerning the inter-connected loads and when the maximum individual demands occur.

To improve efficiencies in general requires considerable management effort. This applies to all sectors and also to electricity utilization. How does one recruit and retain the motivation of individual consumers to participate in programmes to improve electricity efficiencies? If the immediate benefits are apparent and significant monetarily, the task would be easy. However, if the benefits are claimed to be long-term, without being able to substantiate such claims with reliable and tested information, the task of recruiting participants will be very difficult.

For many years in South Africa the practice has been to add supply, and nothing was done to optimize the demand-side. This has lead to the low levels of motivation with electricity planners, manufacturers of electrical equipment and the ordinary consumer to improve end-use efficiencies. An important contributor to this has been the tariff signal of ESKOM's Tariff A, which for many years encouraged consumers to reduce demand. It did nothing to stimulate electricity efficiency improvements or conservation actions. The most important reason for this is the fact that this tariff is not cost-reflective and is inherently cross-subsidizational. Fortunately this is about to change when the time-of-use tariffs planned by ESKOM (Tariffs T1 and T2) come into effect from March 1992.

To better appreciate the task of developing reliable hourly end-use information, it should be remembered that one is dealing with stochastic processes which occur over a wide front and can only be estimated. To detect small changes in the probability density functions of the load patterns due to conservation measures, requires carefully controlled experiments performed with the whole population of consumers.

Minimum ways to extract reliable planning information must be found to satisfy the information requirements. Different techniques have been developed to minimize the effort and cost to acquire this information. Some of these techniques will be reviewed in the paper and their application in South Africa will be considered. Very little has been done in the RSA to develop its own methodologies. There is a great need for this as the cost of direct implementation of the load analysis and estimation techniques described below will be very high, and unique solutions for South Africa will have to be found. The current research project underway in the Cape

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Metropolitan area** is aiming at improving our knowledge of the commercial sector's hourly end-use loads.

ELECTRICITY STATISTICS IN SOUTH AFRICA

Available data

According to Van Deventer et al.[2], 90% of the electricity generated in South Africa flows through the national grid. Sixty percent of this is supplied to end-users by ESKOM directly, and 40% reaches the market via redistributors, mainly municipalities. The ESKOM database covers the 60% it supplies directly. It contains data for individual consumers and also for SIC code class groups to the second level.

These data are based on monthly accumulated energy consumption and demand, and do not contain information on hourly load shapes or end-uses by type of load. Work on consumer level hourly load shape data has started at the Engineering Investigations Department of ESKOM, for the purposes of tariff design. ESKOM's pilot time-of-use tariff project, underway at present, will also provide similar information.

Municipal sales are a problem area. The Municipal Yearbook contains some information about sales of electricity to consumers. These statistics are based on tariff groups and not end-use sectors, making the extraction of end-use planning information from this source impossible. Individual municipalities do from time to time extract hourly load shape information which is required for the operation of their systems. This information is seldom published and is normally used for internal purposes only.

Confidence levels

The confidence levels in the individual consumption data extracted by ESKOM are high. Anderssen and Du Toit[3] pointed out, however, that the usefulness of SIC coding in the extraction of load profile statistics is low, and that it has virtually no place in the study of end-use loads.

The confidence levels in the electricity statistics of the Municipal Yearbook are low. Only certain municipalities provide information to the editors and this is in summarized form.

Lane et al.[4] in a recent study for ESKOM used all available information in an attempt to dissect the hourly system load curve into the following end-user class categories: developing townships; established residential and agriculture; commerce; manufacturing; coal, gold and other mining; transportation; non-metallic production; base metal production; and chemical. Lane describes the confidence levels in the breakdown which was done as low and states that improved confidence would be forthcoming only as more data become available.

The low confidence levels of available electricity statistics on the sectoral use of electricity limit its usefulness as a planning tool. The present level of information probably only serves as an overall indicator of electricity consumption and how the consumption changes over the long term. It is hardly usable to measure small changes and cannot be used in any way to determine causal relationships for the purposes of econometric studies.

Whilst the level of information collected in the past served the needs of the supply-side planners, the emergence of demand-side options to solve the many problems facing the electricity industry placed new demands on the levels of and confidence requirements for electricity statistics.

Generating these statistics for South Africa is particularly challenging for a number of reasons, such as: the low budgets allocated for this work; the fact that the diverse loads of the industrial and mining sectors consume some 72% of the total amount of electricity[2], the large Third World component and a general lack of knowledge of these consumers' electricity needs; and the very low level of knowledge on end-uses.

WHAT USE CAN BE MADE OF END-USE LOAD INFORMATION?

Provides motivation

The availability of independent and reliable information on what can actually be achieved with programmes directed at improving energy efficiency can play a very important role in motivating the participation of utility decision-makers and consumers. It is intuitively felt and supported by overseas experience[5] that the availability of consistent and reliable information on the energy efficiency of products, technologies and conservation methods, which can be applied, can play an important role in further improving efficiencies.

The methods described in this paper can, when applied, improve the level of available information for improved decision-making, and encourage management and planners to devote the time and effort demanded by efficiency improvement projects.

Planning tool

There is a need in the electrical supply industry, worldwide, to be able to forecast the effects efficiency improvement programmes will have. The ability to accurately evaluate their potential impact will provide electricity decision-makers with valuable planning information. The ability to measure the effect of conservation and other measures is needed to reach a conclusion on the achieved results, whether on a system- or consumer-level.

Planning financial incentives

Direct and indirect financial incentives are normally part of such programmes. To assess the level of, and which incentives to allow, requires advance knowledge of the impact these measures are likely to have. In a conservation project directed at encouraging consumers to switch to more efficient lighting, some form of financial incentive would normally be essential to ensure success. Typically, the utility would offer to subsidize the replacement light fitting by a predetermined amount. Without advance knowledge of the conservation potential of this measure, it will not be possible to assess the level of this incentive.

** 'Cape Town Electrical Load Study and End Use Segmentation for the Commercial Sector'. Research assignment allocated to Anderssen & Partners by the National Energy Council 1989.

Planning the creation of new generation capacity

Econometric methods are used worldwide to estimate the probable growth in electricity consumption. These models require information on the correlation of electricity consumption with a wide variety of economic and human behavioural patterns. Whilst supply-side planners can accurately estimate the marginal cost of adding generation capacity to their system, they experience great difficulty in estimating electricity growth rates. The extent of their problem is illustrated by the fact that in their 1989 annual report, ESKOM's management estimated a growth rate of 4% for 1990, whilst the actual growth rate achieved was only 1,4% (ESKOM 1990 Annual Report).

According to Van Deventer et al.[2], ESKOM uses two modelling programmes to forecast the likely long-term growth rates in electricity use. They do recognize that the adequacy of historical and current energy statistics is of cardinal importance to improve modelling.

Unlike the situation on the supply-side, where positive capacity is created, it is extremely difficult to analyze the marginal cost of creating negative capacity. Reliable information on how consumption patterns are influenced by economic, temperature and seasonal changes is equally important in both supply-side and demand-side planning. The number of unknowns on the demand-side, however, is such that the determination of the causal relationship between investment and capacity is not directly or accurately known. This can be improved as more is learnt about the effectiveness of measures introduced to improve efficiencies.

Cost benefit studies

Cost benefit studies aim at calculating in advance what the overall financial benefit will be of a set of measures to influence consumers, prior to the implementation thereof. The accuracy of these calculations can be enhanced by having available data of consumers based on end-use recordings and, in particular, the real responses to measures.

Technical applications

Apart from the usefulness of load data to improve energy efficiency programmes, the information can also be used to enhance network design planning and power flow calculations. The accuracy of power flow simulations are limited by the general lack of knowledge on the actual load conditions prevailing in the network at any time. This limitation can to a large extent be overcome by the results of load data analysis work.

Cost of service studies

Consumer load profile information is needed in cost of service studies for good tariff design, a subject which is current in South Africa. Also, in this instance methodologies for low cost and effective collection of this data are not yet available in the RSA are examined.

With the needs for load data established and after discussion of the possible uses to which the information can be put, we now turn to the load data analysis methodologies which have been applied overseas and which could be used as a basis for the development of South African methodologies.

ANALYSIS METHODS

Overview

Essentially, information regarding electricity end-uses may be obtained in four ways: engineering models, statistical models, direct metering of end-use components, or the transfer of end-use data collected by others. The latter assumes that reliable data are available from another centre. In the South African case this is not yet the position. However in time, as more information becomes available, one can expect that the transfer of such data will become possible.

Engineering models

Under this method, end-use modelling is performed based on engineering estimates of the installed energy-consuming equipment, for example, the projected number of hot water cylinders or air conditioning capacity installed. Multiplying this with the projected utilization patterns yields a forecast of the electricity used by hot water cylinders or air conditioners per time of day. This figure could then be added to similarly derived figures for other major devices used by consumers, to arrive at an aggregated forecast of electricity use for the residential or commercial sector as a whole.

Commercial load simulations

In the commercial sector, building simulation has been used by a number of U.S.A. companies to develop end-use load profiles. Their use today is widespread and includes programs such as COMMEND, LOADSIM, DOE-2 and others. They are used to develop hourly load profiles for variations in temperature, building occupancy, types of buildings etc. Building simulation computer models can estimate the end-use load profiles of an individual building from information about its characteristics and operating schedules. The aggregate end-use profiles of the commercial sector can be estimated by simulating the average building or each individual building in an audit sample.

Residential sector

In the residential sector engineering estimates and modelling are also possible. They require surveys of domestic appliance use, which are used as basic inputs to residential energy simulation models, to simulate the end-use profiles of residential consumers. Models of this nature (REEPS) have been developed in the U.S.A. However, these require a large amount of data, and in order to set the estimation parameters, they require a very sound knowledge of the behaviour patterns of consumers, which can differ significantly if, for instance, TV programme schedules change. According to Wright[6], these models have been successfully employed in simulating the total energy consumption for new development areas.

Advantages and disadvantages

The simulation approach is especially useful for estimating the impact of changes in commercial building characteristics. In particular, simulation can be used to design efficiency enhancement programmes and to predict their impacts. Unfortunately, detailed simulations are expensive. The cost of simulating an individual building can approach the cost of end-use monitoring the building.

Moreover, profiles from buildings are often biased. The extent of the bias can be demonstrated and corrected by comparing the simulated total load with the actual total from load research monitoring.

Engineering modelling of loads suffers from a serious shortcoming in that it ignores consumer behaviour. Its use in the industrial sector is also very limited due to the large variety in end-uses and usage patterns. The computer models referred to above are also virtually useless in estimating the load-shape changes after a significant increase in the price of electricity or a change in tariff structure.

The effectiveness of engineering estimates can be improved by bench-marking or calibrating the model with a series of known data. This is typically one of the uses that end-use monitored load data can be put to under this methodology. Schôn[7] demonstrated the surprising accuracies which can be achieved with the prediction of load shapes by the calibration of these models.

Application of engineering estimation in South Africa

Engineering estimations of end-use loads have not yet found formal application in South Africa. Methods aligned to it have been used to predict the likely outcome of the direct control of hot water cylinders. None of the computer models mentioned above are in use in this country. According to Basson[10], DOE-2 was purchased by the National Buildings Research Institute of the CSIR, but was never used to its full capacity due to a lack of resources and data. It is unlikely that these models will render the correct results in South Africa, given the changed circumstances. The possibility of adapting them for the local situation has not been investigated and should be undertaken before their effectiveness for South Africa can be ruled out. The models mentioned do require significant amounts of input data to run, information which is not yet at hand in South Africa. It will also be necessary to calibrate the computer model mentioned above with actual monitored end-use data.

Statistical models

Basic model

These models make the assumption that the demand for energy can be analysed by relating energy consumed by a particular appliance in a given time period to time, weather, type of consumer and other strategies (cycling of air conditioners or the switching off of hot water cylinders).

$E_t = (a)t + (b)Ti + (c)Ci + (d)F$

where: E_t = energy used at time t,
Ti = temperature and humidity index,
Ci = index to indicate the type of consumer,
F = factor for other strategies such as direct control.

(a), (b), (c), (d) are coefficients which are estimated statistically.

These models are useful for short-term forecasting, for instance, in their ability to be able to predict the potential contribution of direct control equipment at various times. They have the disadvantage that they need to be re-estimated often, for instance, every time significant changes in consumption patterns occur. They can also not be used to predict the precise load shape changes which will result from the addition of new consumers of varying demographics in a particular area.

To construct these models requires significantly more data of the existing patterns of use than is available in South Africa today. They are, as for engineering modelling, not suitable for use in the industrial environment. Direct end-use load monitoring can, as was the case before, be used to provide bench-mark data to calibrate the statistical coefficients. Under stable known conditions these models give accurate results. They also should be studied in greater depth for possible use in South Africa.

Statistically adjusted engineering estimation (SAE)

Gellings[8] describes several methods which have been developed in the USA for integrating conventional load research information with building simulation. This was necessary in order to reduce the bias of results from building simulations. In SAE analysis a building simulation is used to develop end-use energy shares or profiles, and a statistical method is used to adjust the simulated end-use estimates to match the monitored total building load profile. Depending on the data available, the simulation and reconciliation can be carried out on a sample of individual buildings, or at the sectorial level. The SAE approach retains some of the disadvantages of building simulation. Relatively complex building characteristic information is usually required for the underlying engineering model.

Econometric modelling

A further trend is to integrate into end-use modelling the behavioural element characteristic of what is known as the econometric approach. A behavioural or econometric model of electricity demand forecasts consumption in terms of consumer response to economic variables such as price and income. It is assumed that all consumer behaviour can be represented by an econometric model. A wide choice of variables can be included in such a model, from local unemployment figures to GNP.

This type of modelling finds more application in the long-term forecasting of demand and energy consumption. Added as a refinement to the statistical modelling discussed before, it has the potential for being used as a technique in demand-side planning. It has so far, in this role, seen little application even in the U.S.A.

Conditional demand analysis (CDA)

In these models, the physical factors found in end-use engineering models and the behavioural factors found in econometric models are brought together in a single hybrid model (Wright[6]) which allows for a more comprehensive grasp of the many diverse influences that shape the demand for electrical energy. The technique for doing this is commonly called Conditional Demand Analysis.

In its most common application, CDA is used to combine usage and account information with data from an all-residential appliance saturation survey. In practice, the technique relates the customer to customer variation in use to the presence or absence of various appliances or other household characteristics.

CDA produces a statistical regression model that can be used to predict total use as a function of household characteristics, by examining the coefficients of the model, or more generally, by comparing the predicted use under varying assumptions. If, for instance, a large residential load research sample is available, with appliance stock and demographic information, CDA can sometimes yield end-use profiles, especially if used in conjunction with some end-use metered information.

CDA has several important advantages. It is relatively inexpensive since it does not require metering. Moreover, CDA develops end-use metering information on actual account data so that the results reflect the actual effect of customer behaviour. Since large samples are affordable, CDA can be used to study market-segment comparisons and price effects.

The effectiveness of CDA is limited by the information content of the available data. Most of the limitations of CDA are associated with the problem of multi-colinearity. Multi-colinearity occurs, for example, if two or more appliances or end-uses tend to be present or absent in the same households. In this case, the separate use or demand of the individual end-uses cannot be determined reliably from variation in total household use or demand. In particular, one end-use can be overstated, i.e. offset by understating the other end-use.

Conditional demand analysis has not yet been applied in South Africa. It is a method, though, which can be applied in this country. Application thereof will enhance the knowledge base on loads in South Africa.

Load research based end-use estimation (LRB)

A method which is gaining in popularity in the U.S.A., is load research based end-use estimation (LRB) developed by Dr R Wright. In this method the hard monitored end-use data, with carefully selected samples, are extrapolated to the population as a whole, by using other population statistics such as total rented area, total energy consumption or any other as bench-marks. It uses the bench-mark data to calculate confidence intervals and can predict the adjustments required in the sample size, where recording is done, to improve these.

Wright[6] argues that the previous methods fail to take full advantage of the extensive information available in the U.S.A. on total building load data. Instead of starting with a complex engineering model, LRB is grounded on the rich information provided by total building load data collected in the U.S.A. due to PURPA legislation since 1978. Although some simple building characteristic information is still required, LRB eliminates the need for operating hours, types of heating ventilation and air conditioning equipment, envelope characteristics and other detailed audit information required by conventional simulation models and SAE methods. Like CDA, LRB results will reflect actual conditions and behaviour. LRB is especially useful for determining after-the-fact impact measures of, say, efficiency enhancement projects.

The approach is centered on the statistical disaggregation of the total load profile into the underlying temperature-dependent and temperature-independent or base load profiles. End-use metering has shown that air conditioning and space heating are the dominant temperature-dependent end-uses in the various commercial sectors. This suggests that the air conditioning and space heating loads can be estimated by analyzing the temperature response of the total building load. This is expected to give an unbiased estimate of these loads without relying on detailed audit information. Moreover, the temperature-independent or base load profile of a commercial building provides accurate hour-to-hour information about the building's actual occupancy and use. LRB provides a simple method with which to combine the base load profile with some straightforward audit information to reliably estimate the end-use load profiles of lighting, air conditioning and other major end-uses.

END-USE LOAD DATA MONITORING

All of the more theoretical approaches above require calibration from actual recorded data to improve their reliability. End-use data monitoring can provide this data and will significantly enhance the value of these techniques. However, it cannot stand on its own. The cost of this work is high and requires the processing of a large amount of data; so much so that there is a danger of being flooded with meaningless data.

End-use monitoring finds good application in the commercial and residential consumer classes. In the U.S.A., Australia, France and elsewhere where it is applied, good results have been obtained with end-use monitoring, particularly where it was used in combination with one of the other statistical and engineering estimation methods. These projects are beginning to yield information about air conditioning and lighting loads in the commercial and residential sectors, and also electricity end-use by plug loads, computers and other miscellaneous loads.

Recorded end-use information can play an important role in developing after-the-fact evaluation of the impact of conservation and load management programmes. However, on its own it cannot be used to reliably estimate the disaggregation of the total load curve. The challenge is to buttress a comparatively small and restricted end-use metered sample with a larger and broader conventional load research sample in order to develop reliable end-use load profiles for commercial market segments. The LRB methodology above can accomplish this important task.

SUMMARY

The collecting of end-use load statistics is a time-consuming and costly undertaking. The use of electricity is so diverse that reliable information can be extracted only if the requirements for and objectives with the information are clearly stated. A specific method or a combination of the methods described above will normally be required to extract the information needed. It would therefore be wrong to rule out any of the methods above as not being suitable for application in South Africa.

Whilst these methods can produce reliable results where end-uses are fairly homogeneous, they cannot be applied in the industrial sector due to the large variety of equipment, processes and patterns of utilization of electricity. The diverse usage patterns of the industrial sector and their dominant position make the problem in South Africa particularly difficult. For the industrial sector, treatment of individual concerns provide the only reliable method for collecting actual electricity load information.

Load research based (LRB) statistical analysis has demonstrated its worth in a number of applications. The work reported by Seeto and Keene[9] shows the remarkable accuracies which can be achieved where loads are of a homogeneous nature. However, whilst it is one of the most promising methods, it cannot come to its rightful place in South Africa due to the absence of the requisite population statistics, appliance saturation and other data, to give it its accuracy. The emphasis is to have reliable data collected over prolonged periods of time, to which strict statistical rules are applied with bench-mark information to validate the work.

APPLICATION OF ANALYSIS TOOLS IN SOUTH AFRICA

In order for South Africa to be able to use any of the techniques described above, it will be necessary to obtain substantial amounts of new data, not hitherto available in the country. These include: appliance saturation studies; end-user behaviour studies; load profile studies from samples of consumer groups; stratification of consumer populations; specific energy consumption/conservation studies; statistical analyses; econometric studies, and many more.

Data from these studies should make it possible to apply many of the methodologies developed overseas, such as those described above. However, for South Africa to progress towards improving its knowledge base, it will have to develop its own unique methodologies. The experience in France, the United Kingdom and the United States confirms that the best results can be achieved only if maximum use is made of all existing data in the context of the circumstances prevailing in the particular country. This also impacts on the basic manner in which data on electrical energy consumption is kept in the R.S.A., which will have to be amended to allow the availability of this information for load research purposes. In most cases, electrical energy consumption data are kept by the Treasury Departments of municipalities, structured for accounting purposes. It is often very difficult, if not practically impossible, to extract historical consumption data from these records for load research purposes.

It also implies that local authorities should collect load research data in an ongoing and systematic manner. The basic methods as to how this could be done are often lacking with the local authorities, and an educational process would probably be required to establish the basic techniques.

Clear statements from planners about their information needs are further necessary ingredients to develop an own set of methodologies. Hitherto planners, particularly at municipalities, have not yet come forward with their needs.

ENERGY EFFICIENCY IMPROVEMENTS: INGREDIENTS FOR SUCCESS

Long-term nature

The development of an own-set of methodologies, and the motivation of the large number of electrical distributors involved in South Africa to undertake the most basic work to collect the required data and to develop the planning information, will take several years to accomplish. Moreover, channels of communication will have to be established and procedures developed for the whole electrical supply industry to ensure that data are collected and collated on a common basis.

Furthermore, improvement in electricity end-use efficiency is a slow and long-term process, and there is a need to monitor the progress made in an ongoing manner. This will ensure the availability of reliable information, which was pointed out to be an important motivator, and to stimulate participation. Previous reference was made to a recent survey of industry leaders in the USA, which identified the need for Federally-supported demonstrations of energy-efficient technologies. Information regarding what can in fact be achieved, and the technical and economic viability under actual usage conditions were stated as requirements. The absence of such data leads to greater perceived risks and a reluctance on the part of decision-makers to participate. Other studies concluded that information feedback can play a significant role in reducing electricity consumption. Figures of between 5% and 20% have been quoted[5].

Stable funding required

As the work to collect and prepare this information is of a long-term nature, it requires stable funding. The initial set-up costs of end-use metering, for instance, are high, and therefore it is important that the maximum use is made of the instrumentation installations and the data which are extracted. This would imply that once installed the equipment should be left at the location for as long as the co-operation of the consumer can be retained and typically the conservation measure being applied is to be tested for its benefits.

The longer the recording equipment is left collecting reliable data, the more the end results can be refined. It therefore provides the possibility to improve the confidence levels in the results.

The roles of the State and electricity distributors

To ensure that progress to improved electricity efficiencies is maintained, the State and the electricity distributors will each have to make its own contribution towards funding of the work.

The State

The State should act as the independent controller with its eye on the long-term energy horizon, creating an awareness with the electricity distributors and consumers of undesirable trends, making funds available to study these trends, and to act in order to ensure the reversal of negative trends. For this it will need electricity end-use statistics based on data obtained from carefully planned and ongoing projects designed to detect long-term trends and to support its decision-making processes.

The State should use the instruments at its disposal: budget, information dissemination, and legislation to achieve its objectives.

The electricity distributors

A great responsibility rests on the shoulders of the electricity distributors. They will normally act if there is a clearly perceived short-term need. Pressure groups play an important role overseas in bringing long-term adverse trends to the notice of utilities. South Africa does not yet have effective lobbies and pressure groups operating in the energy and environmental fields, and a considerable amount of self-discipline is therefore required from the electricity distributors.

Funds for load research should be internally generated in the industry. It should not be incumbent upon the State to tax the distributors to fund research on its behalf. South African distributors do not stand alone as regards their reluctance to fund R&D, let alone R&D aimed at the reduction of its own sales. In the USA, load research is enforced by regulation, a practice which is strongly resisted in South Africa. In France the work is motivated by the realisation of its importance for Electricite de France.

The work represents a new expense for electrical distributors, and for this reason it requires a very specific commitment from them and careful planning of their needs.

CONCLUSION

Whilst not all of the methods described can be applied successfully in South Africa, a number of methodologies are available for the collection and preparation of end-use load planning information which could be used in a variety of ways to improve planning and the utilization of electricity. Accurate information can be used to predict the potential for electrical energy efficiency programmes, and technologies, and to measure their effects. South Africa will, however, have to develop its own solutions to the problem of preparing planning information, taking cognizance of the resources at its disposal.

The availability of the resulting information will enhance participation and improvements in energy efficiency. For these methods to be successfully developed and applied in South Africa, however, a stable source of funding must be established, as the work is of a long-term nature and particularly the initial work is very costly. It is also most important for municipalities to build and to maintain customer database files, from which information is easy to extract for load research purposes.

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