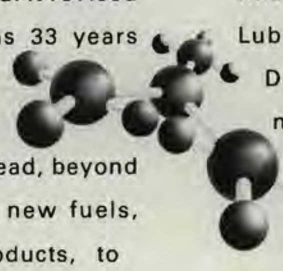
JOURNAL OF ENERGY IN SOUTHERN AFRICA

Vol.5 No.4 November 1994



Journal of Energy in Southern Africa

Vol.5 No.4 November 1994

A quarterly publication

Supported by Chief Directorate: Energy, Department of Mineral and Energy Affairs

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Contents

Subscriptions (1995)

Individuals (Southern Africa) R99,75/year or R34,20/single copy	Individuals (Foreign) US$75/year or US$25/ single copy
Corporate (Southern Africa) R199,50/year or R68,40/single copy	Corporate (Foreign) US$150/year or US$50/ single copy

Includes VAT, postage and packing in Southern Africa. Elsewhere, the subscription includes airmail postage and packing. All cheques to be made payable to the **University of Cape Town** and to be sent to the address below.

Enquiries may be directed to:
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Tel.: (021) 705 0120 Fax.: (021) 705 6266

ISSN 1021-447X

EDITORIAL

Y Blomkamp

Regional Energy Forum for Southern & East African countries held at the Good Hope Centre, Cape Town, South Africa, 13-14 October 1994

This was the second Forum of the Southern and East African region, which was held under the auspices of the World Energy Council (WEC), and organised by the South African National Committee of the World Energy Council (SANCWEC). The official welcome to all delegates attending the Forum was given by Dr I C McRae, Chairman of SANCWEC. After being entertained by a group of Zulu dancers (employees from Eskom's Duhva Power Station), the opening address was given by the Minister of Mineral and Energy Affairs, the Hon. Mr R F (Pik) Botha, who stood in for President Nelson Mandela, who was unfortunately indisposed. Papers were then presented on the global and regional energy scene respectively by Dr G Ott (Chairman of the WEC Executive Assembly), Mr I D Lindsay (Secretary-General of the WEC), and Dr Z S Gata (Regional Co-ordinator of the WEC Commission).

Sixty-three countries were represented at the Forum, of which 24 were African countries. The main purpose of the Forum was to discuss how development should occur in Southern and East Africa, as reflected in the theme, "Mobilising energy for growth". It was emphasised that economic growth in the region will depend on the effective use of energy, while the role of the WEC in the process would be that of facilitator.

Several key issues were raised. The first was one which had been discussed at the Executive Assembly held just prior to the Regional Forum, namely, that the region should incorporate Africa as a whole and not only Southern and East Africa. It was argued that the problems of the Southern and East African region were in fact those of Africa, for example, poverty, hunger, lack of infrastructure, political instability, etc. Similarly, the energy problems of the Southern and East African region were the energy problems of Africa.

Ian Lindsay, in his opening address, highlighted several important issues, while referring specifically to the findings of the WEC Commission on the Sub-Saharan African region (which includes South Africa). These were

(i) that 9% of the world's population is to be found in this region,

(ii) that it is responsible for 2,5% of world economic activity (measured by volume), and

(iii) that it consumes 2,7% of world primary energy[1].

However, its *per capita* commercial energy use is among the lowest in the world, approximately 16 GJ per annum. The region also possesses extensive primary energy resources (oil, gas and coal), has a huge hydropower potential, extensive uranium deposits, and a high level of solar irradiation[1]. As the region with the fastest growing population (i.e. more than 3% per annum), the main energy issue confronting it is how to ensure adequate, reliable, environmentally acceptable and economically sustainable energy supplies to its people[1].

Despite possessing adequate energy resources, there were other issues to be considered regarding the utilisation of these resources. For example, it was important to create (i) a suitable energy base or infrastructure to combat poverty, and (ii) a suitable economic climate to enable these resources to be developed and utilised. Also, many African countries with vast energy resources were perceived as politically unstable. For example, Zaire has vast hydropower resources, but its political unrest could result in many potential investors viewing the country as an unacceptable economic risk.

The importance of creating long-term energy projects in Africa was stressed. However, these energy projects need long lead times, and there is also the ever-present problem of obtaining finance for these projects. Minister Botha, in his address earlier, had suggested that industrialised countries that were looking for a practical way to become successfully involved in African development could possibly buy the Cahora Bassa hydro-electric scheme, rehabilitate it, and then place it at the region's disposal. This would be a most welcome energy investment with far-reaching development potential for the entire region.

Of the 24 African countries represented at the Forum, only a third of them have undertaken any long-term project planning. The Minister of Energy & Water Development of Zambia, the Hon. Edith Nawakwi, emphasised that Africa also lacked technology and advanced human resources.

Several of these issues were discussed at a press conference held with Dr McRae and Mr Lindsay. Dr McRae stated that if Africa was going to be successful in attracting investment for energy projects, it was necessary to get certain political structures to

(1) clearly identify their role or mission;

(2) open membership to all;

(3) look at how they are structured;

(4) inject new players into these structures, for example, South Africa could play a bigger role in SADC and the Organisation of African Unity (OAU).

Furthermore, if African countries want to be regarded as serious about attracting energy investment, it is vital for them to change their image, and to become efficient. At present the energy infrastructures of many African countries were seen by the industrialised countries to be very inefficient because of a lack of maintenance, finance and adequate management. For example, some African countries save as much as 20% of their income, yet this money does not go into energy. Mr Lindsay emphasised that it would not take much money to make these infrastructures more efficient.

Mr Lindsay stressed that on the whole, government intervention in the energy infrastructures should be minimal. For example, there should be minimum State interference in the day-to-day management of energy institutions, such as electric utilities. Deregulation and privatisation were important to attract international investment. However, some energy projects are not and were unlikely to be viable, for example, rural electrification. But these projects also require substantial funding and in this case subsidisation by government was vital. It was also important to develop interaction between the various energy structures, such as, the utilities, the various players in the transport sector, etc.

On a bigger scale of interaction, regional co-operation in Africa was emphasised as extremely important for the development of energy resources. Judy Koncz, in her Rapporteur's Report of papers on this subject, stressed the importance of interdependence as a means of promoting co-operation in the region, and that "political will" was the most important pre-condition for any such meaningful co-operation. Some examples of co-operative energy projects, present and future, are the common electricity grid in the region (the Southern African Power Pool), the Batoka Gorge project (South Africa and Zimbabwe), the Inga scheme (Zaire), and a speculative proposal for the interconnection of electricity grids from the Arab States in North Africa, Southern Africa, through the Straits of Gibraltar to Spain, to mention but a few.

In summary, looking at the issues raised at the Forum as a whole, it was very interesting to note that *electricity* was seen as the main energy source for Africa. Possibly the reason for this is, as Dr Mbuende, the Executive Secretary of SADC stated, that electricity offers the most suitable form of energy utilisation for the Southern African region. (Or else, the electricity sector has a better marketing strategy than those related to the other forms of energy?!) Dr R Vedavalli, Senior Economist at the World Bank, in her Keynote Paper, used electricity as an energy form to illustrate that in order for Africa to move from darkness to light, not just electricity was necessary but a *change in mind set or attitude*. In other words, real development could only come from within. There were comparatively few papers which concentrated on the other primary energy resources in Africa, such as, oil and coal, and the alternative energy sources, such as, nuclear and renewable energy.

In retrospect, one could ponder on a proposed slogan given by Edith Nawakwi, Zambia's Minister of Energy & Water Development: Energy is a right and not a privilege. But then one is entitled to ask, if this is so, who is going to pay for it? This was the refrain that rang through the Forum time and time again and to which there seemed to be no definite answer.

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Profile: John Theo

Managing Director, Mossgas

John Theo was born in Johannesburg on 14 November 1941. He grew up in Parkview, Johannesburg, and matriculated from Parktown Boys High School in 1959. He graduated as a chemical engineer from the University of the Witwatersrand in 1963 and was registered as a Professional Engineer in 1975.

He was employed for twelve years in the oil refining industry, having commenced his career as a Process Engineer at the Shell & BP Petroleum Refineries (Sapref) in Durban in 1964. He then worked for Sasol as a Process Engineer, mainly on the Natref Refinery Project. During this time he spent twelve months at the offices of UOP in Chicago in the U.S.A. and eighteen months divided between the offices of Fluor Haarlem in Holland and Lurgi Oil in Frankfurt, Germany. In 1970, he joined the Mobil Refinery (Genref) as a Principal Process Engineer. He was then later promoted to Chief Chemical Engineer.

After leaving Mobil in 1974, John entered the contracting field. He worked as a Senior Chemical Engineer for Foster Wheeler in the United Kingdom where he was involved in the design of the Sullem Voe Onshore Crude Stabilisation facilities in Norway, as well as the front end design of the Topside facilities for the Bombay High Offshore Production Platform, India.

On returning to South Africa in 1976, he joined Bateman Engineering where he worked for eight years in various senior positions, including a two-year involvement as Project Manager of the multimillion Rand Dwangwa Sugar factory project in Malawi. This involved international supply and financing arrangements, and was successfully completed on time and within budget. During his last four years with Bateman's, he served as Managing Director of various subsidiary companies.

In 1984, John Theo started up his own project management company called TJT (Pty) Limited, which he ran successfully for five years. The company handled various projects in the oil, petrochemical, chemical, sugar and food industries for major clients such as, Sapref, Mobil, CPC, Lonrho Sugar, S.A. Tioxide, to name a few.

In 1989, he sold this company and joined Mossgas as General Manager (Operations) at the company's corporate head office in Sandton, Johannesburg. In this capacity, he was charged with the responsibility of building up an operating company virtually from scratch. The company gradually relocated its activities to the onshore plant, which was then under construction at Mossel Bay, where he took up office in 1991. The commissioning of the onshore plant in just under seven months under his management is generally regarded as a world-class achievement. The plant was also brought into production two months ahead of schedule.

In June 1993, John was promoted to the position of Chief Executive Officer. He joined the Board of Mossgas in January 1994 and was appointed to his present position as Managing Director in March 1994.

John is married to June Wheeler. They have two children, a son studying for an LL.B. degree at the University of Cape Town and a daughter at boarding school, also in Cape Town. He is a member of the George Bridge Club in George, where he lives, and is still an avid supporter of both rugby and athletics, sports in which he took an active part in his youth.

The combustion of South African coals: A utility perspective from theory to practice

*M VAN DER RIET

For both developed and developing countries coal is an important source of primary energy, and its clean and efficient utilisation remain a priority. Methods now exist to simulate process conditions, hence enabling diagnostic and investigative research of the combustion process as it occurs in modern utility boilers to be undertaken. This has offered greater resolution to basic analyses which, by themselves, have been shown to be inadequate for predicting or diagnosing process performance. Opportunities now exist at the local level for increased collaboration between coal producers, users and researchers, to jointly promote an improved understanding of the combustion of South Africa's coal reserves.

Keywords: coal; combustion; pilot-scale testing; power generation; boilers

Introduction

Coal remains one of the world's most important energy sources, and this is especially so in the South African context. International figures indicate that coal provides more than 26% of primary energy requirements (1991), with the balance derived from sources such as, nuclear, gas, oil, hydro-electric, geothermal, biomass, solar, wind, etc. In South Africa the energy mix is different to international patterns, with coal providing 87% of our primary energy needs (excluding liquid fuels, (1989)). This mix is as a result of the relative abundance of cheap coal and the corresponding scarcity of suitable and economic alternatives. While there is significant opposition to the use of coal as an energy source based on its effect on the environment, it is anticipated that coal will remain an important energy source for the foreseeable future.

As coal reserves have been depleted or discovered, so the sourcing of coal has changed over the years. Whereas Poland was the leading steam coal exporter in the 1970s, Australia, South Africa and the United States now dominate this market. Domestically mined coal powered the industrial growth of many of the now developed countries such as, the United States, United Kingdom, and Japan. The use of domestic coal continues to be the trend with developing nations such as, China and India. In areas where domestic coal no longer meets demands, a reliance has developed on internationally traded coal.

"However, commercially competitive Permian coals from countries in the Southern Hemisphere now dominate the steam coal supply market, and this has meant that some of the old concepts governing combustion need to be refined or changed. This has had a significant impact on the South African power utility industry."

In 1992, 3 530 million tons (Mt) of hard coal was produced by the world's principal coal producing nations of which 404 Mt was traded over borders. The traded tonnage (of predominantly hard coal) is expected to exceed 500 million tons per annum (Mtpa) by the year 2000. South Africa's contribution to this scenario is fairly significant, totalling 4,8% of the total production and 12,4% of the traded tonnages respectively[1]. The efficient utilisation of South African coal is therefore not only of interest to the South African industry but also to many other users.

Of the hard coal traded, there is an approximately equal split between steam coal and coking coal. However, this is likely to change, with forecasts indicating a levelling off of demand in coking coal and a potential doubling of steam coal requirements in the forthcoming decade[2]. The predominant user of traded steam coal is the power utility industry (68% in 1991), and this usage will increase with power stations predicted to be consuming three-quarters of traded steam coal by the year 2000[1]. It is noted that half of the world's total coal production (domestic and traded) is used for power generation, and that just under half of the world's electricity is derived from coal[3]. Utility coal combustion will therefore form the basis of this discussion.

Many utility boiler plant manufacturers and operators have accumulated extensive experience with the combustion of Laurasian Carboniferous coals from the industrially developed countries in the Northern Hemisphere, as this was their predominant feedstock in previous decades. However, commercially competitive Permian coals from countries in the Southern Hemisphere now dominate the steam coal supply market, and this has meant that some of the old concepts governing combustion need to be refined or changed.

This has had a significant impact on the South African power utility industry. Eskom's present boiler stock has historically been designed and manufactured by European- or United States-based contractors, and in many cases the coal feedstocks encountered in South Africa differ from those upon which these companies have based their major

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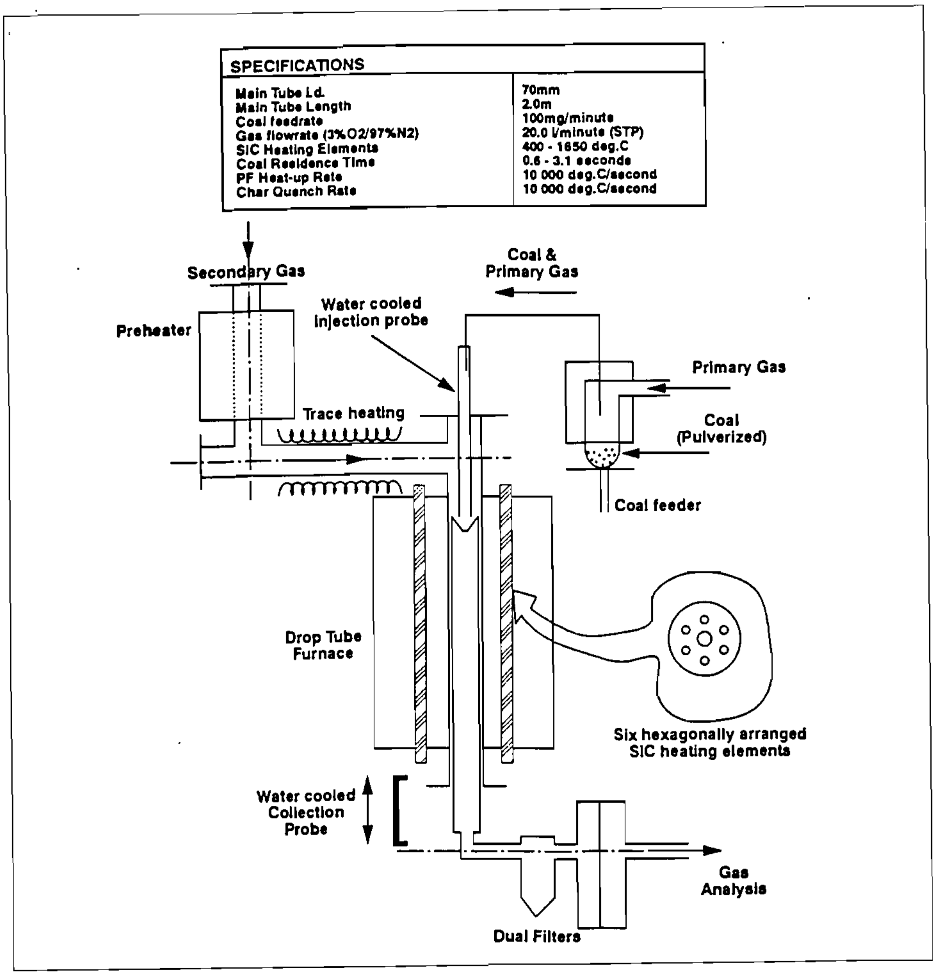

Figure 1: Eskom's drop tube furnace

business and experience. This has required that Eskom and their boiler manufacturers and suppliers also refine or change old concepts, as has been the case with many other utilities internationally.

Combustion

Eskom relies on pulverised coal technologies to combust its widely varying coal feedstocks, with a diverse range of boiler configurations and boiler sizes. The combustion of pulverised coal is an extremely rapid and at the same time complex process, despite the fact that the simplistic goal is merely to liberate as much of the coal's chemically bound energy as heat in a controlled manner and with the minimum of problematic by-products. An understanding of the composition and structure of coal assists in appreciating these complexities.

Coal consists of two major component groups, these being the macerals and the minerals. The macerals constitute the organic matrix, being derived from plant material following the peatification and coalification processes. The minerals constitute the inorganic components, and are either inherent in the plant material or deposited with the plant material after it has died. Both macerals and minerals play an important role in the combustion process.

A simple chemical analysis will show that the organic matrix in coal is typically composed of carbon, hydrogen, nitrogen, oxygen and sulphur. These elements rarely participate in the combustion process according to their simple and known chemical reactions with oxygen. A microscopic examination of the coal structure reveals that these chemical elements are combined in a multitude of complex structures. These structures can be categorised into different maceral groupings, with the three major maceral groups being vitrinite, exinite and inertinite. This composition determines the *type* of the coal. The *rank* of the coal can also be determined microscopically, and is related to the age or maturity of the coal. The degree of contamination by mineral matter will determine the *grade* of the coal.

Such simple analyses as described above confirm the composition of the coal, and can in many cases be used to infer the combustion behaviour of coal in a utility boiler. This inference is, however, challenged in many instances, particularly with the Southern Hemisphere coals[4-9]. The reason is that in order to be able to infer combustion behaviour one relies on extensive prior experience with similar coals, and as already stated, Southern Hemisphere coals are dissimilar in many respects to their Northern Hemisphere counterparts upon which most of the current experience has been accumulated.

The derivation of a refined understanding of the combustion behaviour of Southern Hemisphere coals is receiving attention, notably by the major users of these coals, such as Eskom and other international utilities. The Australian coal producers, as the principal hard coal exporters, are also well advanced in this area[4-6,8-9].

Essentially the understanding is derived by using pilot- or sub-scale test facilities which can reproduce the combustion conditions of a full-scale boiler while allowing diagnosis and accurate control of the process. One such facility is the drop tube furnace (DTF), which has been applied extensively in diagnostic and investigative research of the combustion process. The DTF successfully simulates some of the more important conditions in a boiler, such as heat-up rate, final temperature, and gaseous environment. The DTF allows the derivation of the fundamentals of the combustion process, as well as providing the basis for the diagnosis or prediction of full-scale combustion behaviour.

Case-studies

The combustion behaviour of a wide range of coals can be evaluated under controlled and reproducible conditions in a DTF. A comparison of their behaviour allows qualitative comparisons, while a mathematical manipulation of the results can be combined with a model of the boiler that the coal is fired in, to provide a quantitative evaluation.

The Eskom DTF (Figure 1) is essentially a vertical heated tube with an inner diameter of 70 mm and a total length of 2 m. The coal is pulverised to less than 150 microns in size, devolatilised in nitrogen to release volatile constituents, and then combusted at a range of temperatures for various times. The combustion residues are drawn from the combustion process and rapidly quenched, with the gaseous components being analysed on-line to report O_2, CO, CO_2, NO, NO_2 and

SO_2. The solid components are analysed with a range of techniques to determine the extent of combustion, which components have combusted and what structural changes have occurred.

The combustion efficiency relates to the temperatures and times of the combustion process, and can be resolved with Arrhenius theory to produce kinetic parameters. By assuming a shrinking core model, spherical coal particles and the primary combustion product being CO, the combustion efficiency data can be used to derive the rate of removal of carbon per unit external surface area (q) by integrating the following equation[10,11]

$$du/dt = -Sq$$

where
- u = unburnt carbon fraction
- S = geometric surface area
- t = combustion time
- q = rate of removal of carbon per unit external surface area

and

$$q = P_g/(1/K_o + 1/K_s)$$

where
- P_g = the gas stream oxygen partial pressure
- K_o = diffusonial reaction rate coefficient
- K_s = surface reaction rate coefficient

The first order Arrhenius kinetic equation can then be applied to the data as follows:

$$K_s = A\exp^{(-E/RT)}$$

where
- A = frequency factor
- E = apparent activation energy
- R = universal gas constant
- T = coal particle temperature

A range of coals has been assessed with a DTF to qualitatively compare ignition and combustion characteristics. A selection of Eskom feedstocks, another Southern African coal and international benchmark coals are compared in Figure 2.

The chemical and basic maceral compositions are listed in Table 1.

The coals were chosen to represent a range of grades and types, but falling within a fairly narrow range of rank. In terms of an initial assessment of combustion it is important to note parameters such as, volatile matter, moisture content, fixed carbon/ash and calorific content.

The volatile matter and moisture contents indicate potential for heat release or heat absorption respectively during the crucial ignition phase. This has to be combined with the actual energy required to ignite the volatile matter and the remaining solid residue. This energy is measurable, but cannot be deduced from the basic chemical analyses. The volatile matter activation energy is insignificant compared to that of the solid residue (the latter measurement will be discussed later).

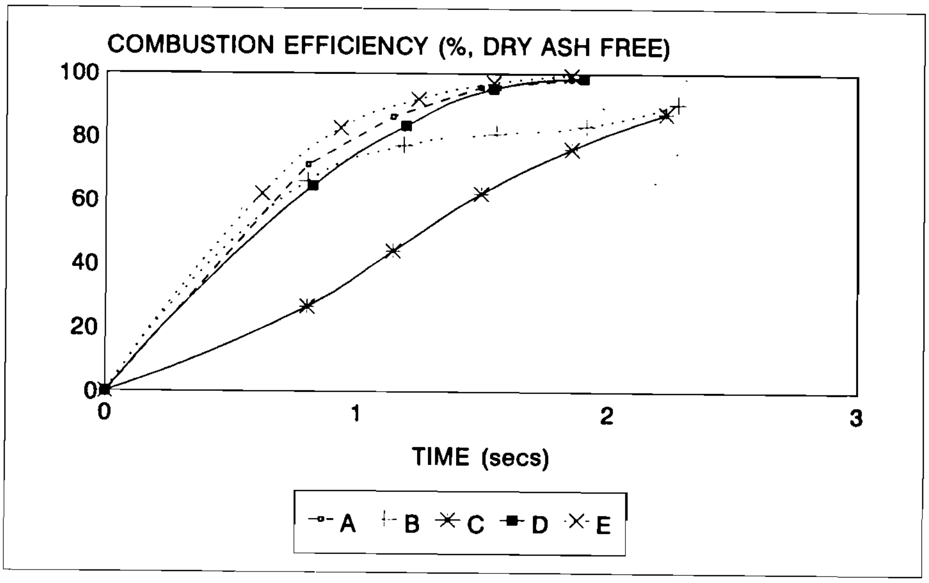

Figure 2: Combustion efficiency vs time (1 400 deg.C, 3% O_2)

	A Australia	B Germany	C RSA (Witbank)	D RSA (Eskom)	E RSA(Eskom)
PROXIMATE ANALYSES (% m/m, air dried basis)					
Inherent moisture	2,8	1,1	1,0	1,3	5,7
Ash	10,5	5,4	14,4	35,7	39,9
Volatile matter (VMdaf)	35,1 (40,5)	38,4 (41,1)	24,9 (29,4)	28,2 (44,8)	19,4 (35,7)
Fixed carbon	51,6	55,1	59,7	34,8	35,0
Fuel ratio (FC/VM)	1,5	1,4	2,4	1,2	1,8
ULTIMATE ANALYSES (% m/m, air dried basis)					
Carbon	71,82	80,22	70,16	48,65	40,97
Hydrogen	4,83	5,57	4,14	3,69	2,38
Nitrogen	1,70	1,17	1,44	1,02	1,07
Sulphur	0,50	0,86	0,59	1,12	0,36
Carbonates (as CO_2)	0,84	0,43	0,93	2,02	1,06
Oxygen	7,01	5,25	7,34	6,50	8,56
Calorific content (MJ/kg)	29,12	32,99	28,05	19,49	14,98
PETROGRAPHIC ANALYSES (% v/v)					
Vitrinite	83,0	92,0	27,5	62,4	17,5
Exinite	4,0	2,5	4,6	5,2	2,0
Inertinite	13,0	5,5	68,0	32,4	80,5
Mean random vitrinite reflectance (RoV)	0,62	0,61	0,67	0,42	0,54
Rank	Low rank bituminous	Low rank bituminous	Low rank bituminous	Sub bituminous	Sub bituminous

Table 1: Basic chemical and petrographic analyses

The volatile matter contents of the coals (Table 1) vary from 19,4% to 38,4%, while the dry ash-free (daf) volatile matters range from 29,4% to 44,8%. The fuel ratio (FC/VM) varies from 1,2 to 2,4 (low fuel ratios are preferred, but burners can be designed to accommodate high fuel ratios greater than 2,0). There are therefore, three different methods for evaluating the same results. The daf volatile matter and the fuel ratio (the preferred methods of evaluation) predict that coals D,B and A would release more energy from volatile matter combustion compared to coals C and E. As such this can imply ignition behaviour, bearing in mind that the activation energies must still be incorporated. Carbonates can affect the ignition process by releasing CO_2 at relatively low temperatures of 800-900°C. However, the carbonates are not significantly high for the coals under examination.

It is not possible to assess combustion behaviour on the basis of any of the chemical analyses. The calorific content determines the energy available in each kilogram of coal, but this does not determine how the energy is released in a boiler. Coals D and E are noted as having low calorific contents. The ash content also affects the combustion process by absorbing energy during the ignition and combustion phases which has to be released later prior to the ash exiting the convective heat exchangers. This absorption of energy can slow down the ignition and combustion of the coal, and may be significant for coals D and E which have high ash contents.

The basic maceral composition of a coal can provide an indication of ignition and combustion behaviour[12] but caution is advised in the interpretation. It is accepted that exinite and vitrinite contain more aliphatic (relative to aromatic) constituents than inertinite, implying a higher volatile matter which is linked to improved ignition behaviour.

The exinite and vitrinite macerals were generally regarded as more plastic and fluid than inertinite at high temperatures, with the implication being that plasticity would allow pores to develop during devolatilisation. This translates to a higher available specific surface area and hence potentially better combustion. However, recent studies show that just three maceral categories do not offer sufficient resolution, and that certain macerals reporting as inertinite are more plastic at high temperatures than certain other macerals reporting as vitrinite[7]. Further, the condition of the coal (e.g. oxidised or weathered) can also play a significant role in the transformations of the individual macerals.

Coals C and E have significantly lower content of vitrinite and exinite than the other coals on the basis of basic maceral analyses, and bearing in mind the limitations noted above this could imply a retardation in ignition and combustion. The rank of a coal affects its porosity, moisture and volatile matter, fluidity and swelling capacity, which in turn affects combustion[12]. However, the coals examined in this comparison were chosen to fall in a fairly narrow rank range so as to minimise the influence of rank variations.

In summary, the chemical and basic maceral analyses indicate that coals C, D and E from South Africa could potentially exhibit retarded ignition and combustion behaviour compared to the international benchmark coals in this study. Evaluation to this level is the norm but can unfortunately provide a biased and incorrect assessment. Increased levels of characterisation have now been developed, as discussed below.

Evaluation in a pilot-scale combustion simulator (DTF) provides a different view, as illustrated in Figure 2. The combustion efficiency (dry ash-free basis) of the coal chars shows that the five samples combust at different rates with distinctly different burnout times. It is convenient to consider the burnout time as the time taken for the pulverised char to combust to 98% completion, and the extrapolated results (at 1400°C, 300-600% excess oxygen) are summarised in Table 2 for comparison. These show that coals A and E combust the most rapidly, compared to the average combustion of coal D, and the relatively sluggish combustion of coals B and C. The test conditions are idealised and not representative of the variability encountered in a boiler. It nevertheless remains apparent that in a relative comparison the reactivity of the coals in no way relates to their chemical and basic maceral composition. The latter analyses indicated that coals C, D and E would be disadvantaged in terms of combustion, but this is proven incorrect in the case of coals D and E. Conversely, coal B was predicted to combust well, which again is disproved in practice.

An indication of ignition behaviour can be drawn from the energy derived from volatile matter combustion versus the activation energy for the char combustion (i.e. an energy ratio), as represented in Table 2. It is noted that the volatile matter content of the coals is generally greater under the higher temperatures and more rapid heating conditions of the DTF compared to the conventional proximate analysis.

The energy ratio is derived as follows:

$$E^{1}\ (\text{MJ/kg}) = E\ (\text{kJ/mol}) \div 12{,}01\ (\text{kg/Kmol.C})$$

$$\text{Energy ratio} = \frac{CVvm}{E^{1}} \times \frac{DTFvm}{100-IM-Ash-DTFvm}$$

where
- E = activation energy (kJ/mol)
- E^1 = activation energy (MJ/kg)
- CVvm = volatile matter calorific content (MJ/kg ad)
- DTFvm = drop tube furnace volatile matter (% m/m ad)
- IM = inherent moisture of coal (% m/m ad)
- Ash = ash of coal (% m/m ad)
- ad = air dried basis

The energy ratio shows coals C and E to be similarly low, and coals A, B and D to be similarly high in terms of energy available for the ignition process. A fairly wide range of energy ratios can be tolerated by modern pulverised fuel boilers, provided they have been accommodated in the boiler/burner design. Problems arise when fuels are switched or blended, and the energy ratio deviates from that of the design fuel(s).

It is noted that the fuel ratio (FC/VM) roughly correlates with the energy ratio of the five coals examined, providing thus a first order approximation of ignition behaviour on the basis of basic chemical analyses.

	A Australia	B Germany	C RSA (Witbank)	D RSA (Eskom)	E RSA (Eskom)
Burnout time (s)	1,8	2,7	2,5	2,0	1,7
Activation energy (kJ/mol)	98,0	69,3	148,9	107,4	94,5
Frequency factor (kg/m^2/s/atm)	804	92	12 390	1 084	259
DTFvm (%,ad)	42,9	37,3	33,2	34,8	23,9
VMprox (%,ad)	35,1	38,4	24,9	28,2	19,4
HIV (%)	49,2	42,5	37,7	52,5	33,9
CVvm (MJ/kg)	33,4	37,3	31,6	29,4	21,2
Energy ratio	4,0	4,3	1,7	4,1	2,1

Table 2: Combustion characteristics

Conclusion

Utilities rely on the efficient combustion of their feedstocks, which depends on the successful matching of the boilers, their operating conditions and the fuels themselves. The ignition and combustion of coal is a combination of physical and chemical processes, the interpretation of which often goes beyond the conventional chemical and basic maceral analyses.

Empirical evaluations in pilot- or sub-scale test facilities can provide a basic quantification of the combustion performance under simulated process conditions. Examples discussed above illustrate the sometimes poor correlation between ignition and combustion behaviour, and chemical and basic maceral analyses. While this may be true, the basic analyses still form a crucial role in quality control by providing an indication of gross variations. Further, detailed petrography to supplement the basic maceral analyses provides the key to interpreting the mechanism of combustion and hence exploring the difference between process behaviour and basic predictions. This, however, depends on experience and the accumulation of an extensive database on the coals typically sourced by the utility.

This is providing a new basis of understanding of the world's coal supplies, with utilities, coal suppliers, boiler manufacturers and research organisations developing new methods of analysis and testing. It will ultimately assist in not only optimising the efficient utilisation of the world's coal reserves, but also ensuring that this utilisation has as little negative environmental impact as possible. South Africa remains a major player in the world context, and an improved understanding of our coal reserves and their combustion behaviour will assist in their correct and ultimately most efficient utilisation.

Acknowledgements

The author gratefully acknowledges Eskom's permission to publish this paper, the assistance of colleagues in the Energy Technologies and Chemistry Sections, and specifically Dr Rosemary Falcon of Falcon Research Laboratories.

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Proposed strategy for improved industrial energy effectiveness in South Africa

* M G DE VILLIERS

An industrial energy effectiveness strategy is proposed for government to facilitate the more effective use of energy in South African industry. Potential benefits include reduced consumer costs, increased competitiveness of South African goods, reduced expenditure on energy services and reduced environmental impact of energy use. Annual industrial energy costs could be reduced by about 9-12% in 2005 and 14-16% in 2015 through improved energy effectiveness.

With the current resource constraints of South Africa, the strategy focuses on programmes that can be implemented at low cost with potentially high returns. Energy effectiveness activities can be classified as information provision, financial incentives, regulations and standards. Information provision should be seen as the cornerstone of the strategy, and the programmes can include an awareness campaign, publication of an energy management handbook, a training programme, a boiler testing scheme, a plant energy audit scheme, a sectorial energy audit scheme and a demonstration scheme. The estimated medium-term energy cost saving of the proposed measures is R483 million/annum, compared with a public expenditure of R9,4 million/annum.

Keywords: energy effectiveness; industry; energy effectiveness programmes; energy management; energy efficiency; energy audits; energy conservation

Introduction

In the past the South African government has involved itself with energy supply and has left energy effectiveness to market forces. However, a careful examination of the situation in South Africa, supported by numerous past studies in other countries, has shown that there are a number of barriers in the market preventing the optimum allocation of resources. Through the two oil crises of the 'Seventies, a growing awareness of the environmental effects of energy use, the need to reduce investment in additional energy supply and a desire for increased economic growth, governments in most countries have identified these barriers and implemented strategies to remove them. The South African government has in recent years shown increasing concern for the more effective use of energy and has begun investigating the means to facilitate this process.

South African industry

In South Africa, industry (mining and manufacturing) is responsible for about half of the total national energy consumption[1] and contributes about 60% towards the electricity demand peak[2]. Energy intensities in mining and manufacturing have been steadily increasing over the past 20 years, and South Africa's industrial energy intensity is at least double that of most developed countries[3]. The fraction of value added attributable to energy costs rose by 63% on average in industry between 1970 and 1985[4], and this fraction is considerably higher in South Africa compared with most developed countries. Also of concern is the fact that South African industry spends about 11% of its GDP on energy compared with 5-9% for most other developed countries[3].

South Africa's high industrial energy intensity can be attributed to a number of factors[5]:

(1) South Africa's industrial structure is weighted towards energy-intensive products such as, basic metals. South Africa's industrial energy intensity would be 26% lower if its industrial structure were adjusted to that of a typical developed country.

(2) The relative costs of energy, labour, and capital favour greater use of energy and labour, and less capital expenditure than in most developed countries.

(3) A number of external factors, beyond the control of industry, favour increased specific energy consumption in South Africa. Examples are quality of raw materials, quality and mix of products, fuels mix, age of plants, utilisation of production capacity, and size of production units.

(4) The likelihood exists that energy is not used effectively in South Africa. For example, (a) energy losses are sometimes higher than necessary; (b) waste energy is not always recovered when cost-effective, and maintenance and operating procedures are often inadequate; (c) there is insufficient accountability for energy use; and (d) insufficient attention is given to energy in the design stage.

The purpose here is to address the last factor.

Potential benefits of industrial energy effectiveness

Important benefits to South Africa regarding improved industrial energy effectiveness include:

(1) Greater international competitiveness of South African goods through reduced manufacturing costs and compliance with international energy efficiency standards.

(2) Reduced local consumer costs.

(3) Reduced expenditure on energy, thus freeing finance for more pressing investment.

(4) Reduced environmental impact of energy use, including atmospheric pollutants and greenhouse gases.

The potential for improved energy effectiveness was examined by developing a frozen efficiency scenario, a business-as-usual scenario and an energy effective scenario for South African industry between 1990 and 2015[5]. Figures 1a and 1b graphically illustrate the developed scenarios.

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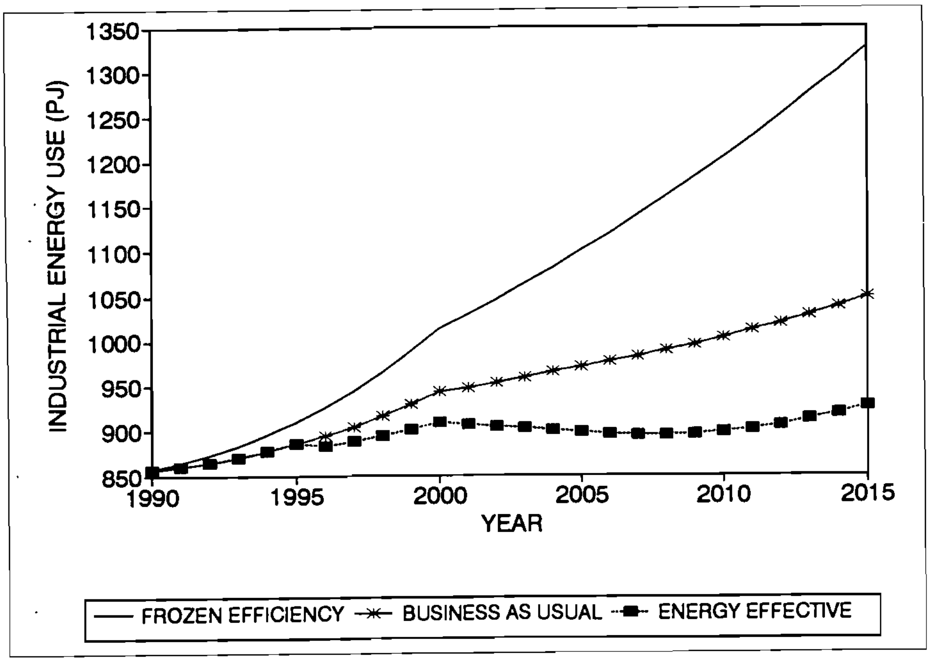

Figure 1a: Industrial net energy consumption scenarios for low growth

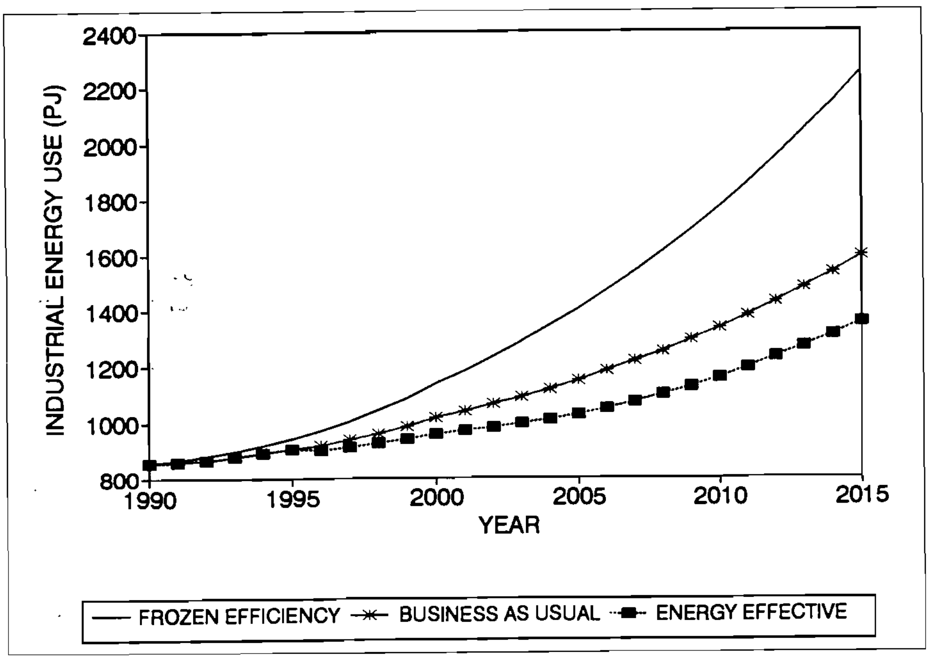

Figure 1b: Industrial net energy consumption scenarios for high growth

	2005		2015	
Scenarios	**Low Growth**	**High Growth**	**Low Growth**	**High Growth**
Business-as-usual	12 998	15 445	13 676	20 752
Energy effective	11 846	13 651	11 830	17 479
Potential saving	1 152	1 794	1 847	3 273

Table 1: Annual cost of energy to industry in 2005 and 2015 (Rmillion, 1993 prices) [5]

Estimated energy costs, calculated from two of the energy scenarios, are shown in Table 1. Annual energy costs could be reduced by about 9-12% in 2005 and 14-16% in 2015 through improved energy effectiveness. Based on the definition of energy effectiveness only cost-effective changes were considered. The average pay-back period to achieve these savings is estimated at 1,5 years.

Proposed industrial energy effectiveness strategy

In the past government resources for energy effectiveness have been minimal and activities have focussed mainly on research. A National Committee for the Effective Use of Energy was set up to draft an energy efficiency strategy in 1989 but progress has been slow due to insufficient staff and funds[6]. With the limited government resources and urgent development needs of South Africa, few government resources will be available for energy effectiveness. This reality must be borne in mind when developing an industrial energy effectiveness strategy for South Africa. It is generally accepted that a mix of energy effectiveness measures is best mainly because energy is consumed in so many different ways by so many different types of consumers[10]. The most successful strategies to promote industrial energy effectiveness appear to be those that are integrated into the overall economic policy environment of the country[7].

The overriding motive for improved industrial energy effectiveness in South Africa appears to be increased profitability[8], which can be accomplished through reduced operating costs, higher than average return on investment, improved product quality, improved production reliability and improved public image. It is essential to focus on these issues when promoting energy effectiveness and not merely on saving energy. In addition, most executives in South Africa believe that the user is responsible for energy effectiveness[8] and thus the government should give the impression of being a facilitator rather than a regulator.

Policy issues

In order for the above potential to be realised, it is widely accepted that government, energy suppliers, energy equipment manufacturers/suppliers, educational organisations, energy contractors, consulting engineers, and consumers all have a role to play[9]. However, a number of barriers have prevented the necessary participation of each of these players in energy effectiveness. Barriers include lack of awareness, knowledge, information, human resources, capital, the high perceived risk and low visibility of energy effectiveness measures, lack of technology and technological innovation, and a lack of competition between energy suppliers[3].

In order to achieve improved energy effectiveness, an appropriate institutional structure should be established to plan, implement and evaluate policies and programmes. It is therefore proposed that a strong central energy effectiveness group be established. Such a group can be expanded from the Energy Directorate of the Department of Mineral and Energy Affairs. It is imperative that the energy effectiveness group has sufficient influence in government to be able to implement its ideas. In addition, such a group should have close ties with all major players and relevant government departments to ensure that an holistic approach is taken[10].

Listed below are some of the areas of immediate interest to the energy effectiveness group[9].

(1) Little competition exists on the energy supply side and promotion is heavily weighted towards electricity. If greater competition between energy suppliers could be stimulated, then the provision of energy services, including assistance with the more effective use of energy, can be expected to expand.

(2) Little effective regulation or profit incentives exist for utilities to apply integrated resource planning (IRP), and two options to address this problem are proposed. Either regulation is required to ensure that utilities adhere to the principles of IRP, or a government agency implements non-pricing, demand-side management measures and utilities concern themselves only with the supply and pricing of demand-side measures. It is necessary that a working group be appointed to further investigate IRP in the South African context.

(3) General pricing policy is beyond the scope of this study, but externality costs which could be significant in South Africa require attention. Externality costs include (i) damage to human health, (ii) damage to forests, crops, and flora, (iii) contamination of water systems, and (iv) increased corrosion. Although externality costs are a reality, a major problem is their complexity of calculation and the involvement of subjective considerations. However, this does not justify a dismissal of externality costs. It has been estimated in the U.S.A. that externality costs are about the same as electricity prices for conventional coal-fired power stations and about half the electricity price for coal-fired power stations with flue gas desulphurisation[13]. Meetings with relevant organisations are required to decide on how externalities are to be dealt with in South Africa in the future.

(4) The inclusion of energy awareness in primary, secondary and tertiary education would serve to ingrain energy awareness in the next generation. Key educators should be brought together to discuss a means for including energy effectiveness in curricula at all levels.

Database

Essential to any programme is a comprehensive energy database which includes energy use statistics, details of energy users, energy manufacturers, energy suppliers, consultants and auditors, details of energy effectiveness activities, data on energy equipment, and energy prices and tariffs. The database is essential for[10]:

— Targeting information dissemination to consumers, equipment manufacturers/suppliers, and energy consultants. Information to be disseminated can include notification of workshops, seminars, or training courses; successful demonstration schemes and new technologies; sectorial energy guides; details about energy audits; financial assistance programmes; and the latest energy prices and tariffs with projections for the near future.

— Assessment of energy effectiveness potential and the consequent setting of practical goals.

— Planning of energy effectiveness measures.

— Monitoring the success of energy effectiveness measures.

An energy use database has been initiated in South Africa (the 'Cooper' database)[1] which can form the basis of a more comprehensive database.

Information

Provision of information can be used to complement other policy instruments and is invaluable in ensuring the success of other types of policy measures. Even company executives in South Africa, who generally would like as little government intervention as possible, believe that the government should provide information on energy effectiveness[8]. Information programmes are not designed to save energy directly and therefore their effectiveness cannot be measured. They should be ongoing, as awareness is not static and needs to be reinforced periodically.

To make any programme successful the information on the programme and its mode of communication is crucial. This has led to programmes becoming more group-specific[11,12]. Target groups should include technicians, engineers, managers, and managing directors. Direct links should be established with companies, their representatives, and industrial associations.

Facets of an awareness campaign can include publications and advertisements in journals/newspapers, energy management awards, and seminars. In general, an industrial energy awareness campaign should be well-targeted, eye-catching, concise, and should make use of opinion leaders[8]. In addition, persons involved with energy effectiveness schemes should be encouraged to partake in general industrial seminars, and journals and newspapers should be contacted about having features and adverts on energy effectiveness.

A handbook on energy management is a useful source-book for energy managers, engineers, and technicians. Such a handbook, dealing specifically with South Africa, would be useful for industry since handbooks from other countries are often based on different fuel prices, regulations, and equipment costs. The handbook could be followed up later with a series of handbooks dealing with more specific subjects.

Specialised short training courses are often recognised as being of prime importance to the development of improved energy effectiveness[7]. They can vary in length from a few days to a month. Topics of importance include energy management, energy audits, power factor improvement, operation of motors, and combustion efficiency. These activities can be organised and promoted by government, although costs can be partially recovered through course fees. Courses can be conducted by equipment manufacturers, energy consultants or auditors, energy suppliers, and specialists in education. Periodically experts from other countries can be used to give talks or courses.

Industrial boiler testing is a type of specialised audit that can be considered for subsidisation. Measures to improve boiler efficiency are generally low cost and thus boiler test recommendations are usually implemented[12]. Such audits can be carried out by boiler experts. Information regarding the operation of boilers can be disseminated in this manner.

There are three levels of measures of which companies can be made aware: (i) common industrial equipment and process changes, (ii) specific process changes, and (iii) implementation of new technologies. Each of these levels has been addressed by different programmes in many countries[3]. Generally, plant energy audits can identify those related to common industrial equipment and processes, sectorial audits can identify specific process changes, and demonstration projects can increase the penetration of new technologies. Each of these schemes should be partially subsidised to ensure that they are utilised adequately by industry.

Plant audits can be classified as quick audits, requiring one to three days, and detailed audits which usually require a number of days or weeks. Generally, quick audits in other countries are at least part-subsidised by the government. Often the cost of a detailed audit is fully or partially reimbursed if it is followed by investment. The objectives of subsidised audits are[7, 10]:

- To increase awareness and provide industries with basic information on plant energy usage and areas where energy can be used more effectively with minimum cost.
- To motivate industries to conduct detailed audits.
- To collect energy use data and information on potential energy effectiveness improvements.
- To determine which audit recommendations were not implemented and the barriers to their implementation.

Subsidised plant energy audits will be invaluable in South Africa as a means of informing managers of opportunities for improved energy effectiveness, and as a vehicle for the dissemination of general information on energy effectiveness. Audits will be especially useful to small and medium-sized businesses which cannot afford to have in-house energy managers. On the basis of experiences in other countries it is suggested that 50% of the audit cost be subsidised. This subsidy level is sufficient to attract attention to having an energy audit, yet low enough to ensure that the audit is taken seriously and its findings implemented. Because of the lack of energy awareness in South Africa, it is recommended that audits are well-marketed to ensure the greatest possible penetration[11]. To ensure that sufficient qualified energy auditors are available in South Africa, it may be necessary to hold periodic workshops on energy auditing.

Sectorial energy audits are common in many countries and involve the compilation of energy consumption guidelines for a specific industrial sector and the provision of information on good practices in that sector with regard to energy effectiveness[3]. An analysis of practices is often included in other countries and their applicability locally. These studies also highlight energy-intensive and energy-wasteful areas, and areas where energy could be used more effectively. Literature surveys, plant energy audits, and general surveys need to be conducted.

Demonstration schemes increase the market penetration of new technologies by marketing the success of a project. They involve an agreement with a company whereby, in return for a grant, the company will allow its energy consumption to be analysed before and after implementation of the technology. If successful, the technology can be marketed. Marketing is the key to the success of a demonstration project[11].

Financial incentives

Financial incentives include the provision of grants, low interest loans, and tax incentives. Considering the financial constraints of public funding at present, it is unlikely that sufficient funds will be available for financial incentives. Even modest financial incentives would require R10-R40 million/annum public funding[9]. Only import duty relief on energy-efficient equipment should be given consideration at present.

Regulations and standards

South Africa does not have the necessary skills available for industry to impose regulations such as, the appointment of energy managers, or submission of energy effectiveness plans. The only regulation which may be appropriate is the submission of energy use statistics for the energy database.

Standards for electric motors and boilers could yield large benefits[5]. Some countries have found that negotiating voluntary standards with manufacturers is an effective means of introducing standards[3]. In return for establishing voluntary standards manufacturers could receive assistance from government for research and development requirements.

Summary of proposed programmes

In summary the following programmes are proposed:

National energy database
Awareness campaign
Energy management handbook
Energy effectiveness training programme
Subsidised boiler testing scheme
Subsidised industrial energy auditing scheme
Sectorial energy audit scheme
Demonstration scheme

Implementation of the strategy

The strategy should be implemented in three phases:

(1) ***Initial phase:*** This involves the government's commitment to energy effectiveness, the development of the skills and infrastructure necessary for implementation of the strategy, and the establishment of an energy effectiveness group. This phase has already begun in South Africa.

(2) ***Development phase:*** Development should take place on two fronts, namely, policy and implementation. Policy development entails the examination of those organisations which can become involved in the implementation of the strategy and how they should be stimulated to become involved. Implementation development involves conducting a number of projects to develop methodologies for the implementation of each of the schemes. Projects for a database, an information campaign, a plant energy audit scheme, and a sectorial energy audit scheme have already begun in South Africa.

(3) ***Continuous phase:*** Once methodologies have been established it is necessary that the strategy be implemented in such a manner that it can evolve with increased feedback and as the needs of energy consumers change. Information from each project should be entered into the database so that each scheme can be evaluated and further refined. Feedback from projects is therefore

essential. In addition, it is imperative that realistic targets are set based on a bottom-up analysis[7].

Costs and savings

Including the cost of the development phase projects, the energy effectiveness group and research assistance, the total cost of the strategy to government over the development phase (the next two years) is estimated at R2,4 million/annum. In the medium term the total cost of the strategy to government is estimated at R9,4 million/annum. It is estimated that the medium-term saving of this strategy, excluding savings from research and development and the stimulation of energy effectiveness activity by bodies such as energy suppliers, will be R483 million/annum.

Conclusions

It is clear that energy effectiveness is a largely untapped energy resource that exists in South African industry. By 2015 energy use could be reduced by 14-16% through improved energy effectiveness. Government can act as a catalyst in mobilising this resource. In order to achieve this, an energy effectiveness group should be established which can then decide on policy issues and how each player can become involved in the energy effectiveness process.

Measures that appear to be appropriate are those involving the creation of an awareness of energy effectiveness, providing the relevant information, and education and training. Inappropriate measures for South Africa at present are mostly financial incentive schemes which have been introduced in other countries, and many regulations which are usually only applicable under conditions where there are energy shortages or high energy imports. The potential medium-term energy cost saving based on the proposed measures is R483 million/annum, compared with a public expenditure of R9,4 million/annum. Improved industrial energy effectiveness can therefore be of significant economic benefit to the country.

Acknowledgements

This study was made possible by funding provided by the Department of Mineral and Energy Affairs. The pro-active involvement of Dr P Rossouw and Mr J Basson of the Chief Directorate: Energy, Department of Mineral and Energy Affairs is gratefully acknowledged. In addition, four workshops were held during the course of the study to discuss issues related to an industrial energy effectiveness strategy. The time and input of those persons involved is appreciated. Delegates to the workshops were Mr J Basson of the Department of Mineral and Energy Affairs, Mr B Berwyn-Taylor the Cape Town City Electrical Engineer, Mr R Carvalho from BP, Mr G de la Hunt of Joostenberg Bricks, Mr A Dykes an energy consultant, Mr L Hauptfleisch from Anglo American Corporation, Mr D Kruger of the Chamber of Mines, Professor I Lane of the Department of Electronic Engineering of the University of Pretoria, Dr S Lennon of Eskom, Dr P Rossouw of the Department of Mineral and Energy Affairs, Professor T Ryan of the School of Engineering Management of the University of Cape Town, Mr A Snow of Eskom, Mr C Snyman of Eskom, Professor N Tully of the School of Mechanical Engineering of the University of the Witwatersrand, and Mr L Wallis of National Chemical Products.

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Energy efficiency in brickmaking: Implications for housing in the Western Cape

* H W G DE LA HUNT AND * *R K DUTKIEWICZ

The pressing need for affordable houses to be built in the Western Cape has highlighted the need to reduce the costs of building material. Clay bricks have been steadily losing ground to cement bricks due to cost factors. It is shown that the costs of clay products could be significantly decreased by reducing the energy use in brickmaking. Such reductions could be achieved by using tunnel kilns and dryers. In addition to the reduction of energy on a per kilogram basis, it is shown that the use of a maxi brick's larger hollow blocks would reduce the amount of material per square metre of a finished wall surface.

Keywords: bricks; clay products; energy efficiency; energy utilisation; housing; costs

Introduction

It has been shown by Bennett[1] and Huggett[2] that the heavy clay industry is a large user of energy and that brickmaking has a record of inefficient energy usage. The European brickmaking industry's specific energy consumption in 1985 was 3 080 kJ/kg, whilst in South Africa a manufacturer producing some 40% of the country's bricks has a consumption of 4 400 kJ/kg. However, the European figure was an average figure for the EEC countries, whilst the figure for new plant is claimed to be 1 500 kJ/kg.

The figures quoted were for plants using heat for drying and firing. In South Africa, some 60% of manufacture is carried out with open air drying of bricks with no commercial energy utilisation. For such plant it has been estimated that the energy consumption in firing alone is of the order of 1 700-3 800 kJ/kg. Open air drying suffers from the disadvantage of a limited season, since drying cannot be carried out during the rainy season.

Thus, there appears to be great scope for decreasing the energy use in the industry.

Firing

Much of common brick production in this country, and virtually all common brick production in the Western Cape region, is carried out using clamp kilns for firing. The clamp is a long-established and rather primitive method of burning or firing bricks. A general description of the process follows. Combustibles are mixed with the clay during the manufacturing of the "green" or undried brick. The dried brick is densely stacked, some 30 bricks high, above the hearth of the clamp which consists, in its simplest form, of two or more layers of open set staggered rows of bricks with coal placed in all the openings between the bricks. The size of the clamp will be governed by the factory's output and usually varies from 300 000 to 6 000 000 bricks, in an extreme case. The outer shell of the clamp is covered with one or two layers of burnt bricks and, depending on the brickmakers preference, might or might not be plastered or "scoved" with a water/clay mixture. Fireboxes are set around the base of the clamp at the level of the hearth and are used to ignite the clamp. The burning process takes between 4 to 6 weeks from cold to cold and is, to a very large extent, uncontrolled. Huiras[3] states that a total waste of 14% for the open air drying and clamp-firing process would be regarded as very good. Besides the problem of a limited manufacturing season, the clamp-firing system produces an excessive level of air pollution.

In comparison with the low capital but high labour component clamp kiln, the tunnel kiln, which is a continuous firing system, is not limited by adverse weather conditions. However, it does have a high capital cost. In the developed world tunnel kilns are virtually universally used and produce bricks after a firing time of between 36–72 hours. The new tunnel kilns being developed have firing times of the order of a few hours.

Some thirty years ago a large number of non-facing plaster (NFP), common building or "stock" bricks, were fired in kilns. Examples of these are:

* the tunnel kiln of the Hare brothers, Mowbray,
* Blake's tunnel kiln at Killarney, near Milnerton,
* the Buhrer of Brick & Clay at Bellville,
* the Hoffmann kilns of Hume Pipe Ltd; Genboig, Rochester, and Blakes at Table Mountain, Koelenhof and Stellenbosch.

None of these kilns are in operation today. Instead, in 1994 there are 23 factories in the Western Cape manufacturing the total common plaster brick production, (at present some 300 million bricks per annum) and all are fired in clamps.

Drying

Compared with air drying, which is commonly practiced in the Western Cape, drying in developed countries is carried out in chamber or tunnel dryers. Chamber dryers use a batch drying approach with bricks packed loosely in a chamber into which heat is applied. A tunnel dryer is a continuous dryer where the clay-ware passes through zones of increasing temperature. Problems may be experienced in tunnel drying with the uneven drying of bricks due to their being stacked fairly high, thus limiting air to the inside of the stack.

With a tunnel kiln and a tunnel dryer it is possible to integrate the two, with the waste heat of the kiln being used as input heat to the dryer. There are limitations to this, however, due to the pollutants present in the waste kiln gas, since components such as sulphur dioxide could adversely affect the quality of facing bricks.

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Brick size

There is a pressing need in the Western Cape for affordable housing built with quality products. The cost of these products should be, ideally, less than or at least the same as those available at present. Energy saving, as a goal, is desirable and laudable, but to find ready acceptance it will have to offer an economic advantage. Due to the relatively high cost of energy in the Western Cape an energy saving of at least 40% by making hollow-ware instead of solid clay bricks immediately becomes, economically, very attractive. Considering all its other advantages, the potential exists for the introduction of fired clay hollow blocks as a substitute for solid clay bricks, cement bricks and blocks.

A clay hollow block should not be confused with solid bricks which are perforated. While the term *hollow block* does apply to the conventional brick size and the *maxi brick*, when they have up to 40% voids, this discussion, while including these units, favours the larger unit comparable with the cement blocks currently used in the Western Cape. The perforation of bricks is common practice among South African facing brickmakers. The idea of perforating bricks is finding favour in the United Kingdom. A brick is considered perforated if it has holes passing through it regardless of their size or number. However, this is not strictly in accordance with the British Standard BS 3921:1974, where a brick is considered perforated when the holes passing through it exceed 25% of its volume. If there is below 25% perforation, the standard considers the brick to be "solid" for structural purposes[4]. The same criterion applies at present in South Africa. MacDonald[5] states that it has been established that perforated bricks with voids up to 40% have acceptable mechanical properties, and negotiations are underway to unify European brick standards which will open up the possibility of a higher percentage of voids. He says that each 5% increase in voids implies an energy saving of 330 TJ, worth about R5 million per annum in U.K. fuel costs. The trend towards hollow bricks is clearly indicated in the figures[6] for five EEC countries from 1951 to 1981. Units with less than 15% perforations decreased proportionally from 65,7% to 22,2%; units with 15-40% perforations increased in proportion from 5,7% to 35,6%, as did those with greater than 40% perforations from 28,6-42,2% over the 30-year period.

Generally speaking, there are two types of hollow blocks. On the one hand, those favoured by the southern European countries such as, Italy, Spain and Portugal, as well as the South American countries. These blocks have holes parallel to the mortar bed. The other type of block is favoured by the Germans and Austrians in particular, where the holes are normal to the mortar bed. These latter blocks have the advantage of a greater vertical crushing strength.

The energy advantages of using a clay hollow block, with 40% voids, over solid bricks are numerous and obvious. Hollow block is lighter than the solid brick, and this saves physical energy in production, loading and building. The relatively lighter product saves cartage costs and energy. In the manufacturing process the amount of clay raw material, which is a non-renewable resource, is reduced and less crushing and processing energy is required. It could be assumed that there is a directly proportional energy saving in the drying and firing processes of the hollow product. However, this is not necessarily so, as considerable additional energy advantage is gained in both processes due to the thinner wall thickness of the hollow block which allows better heat transfer with faster drying and firing times. This in turn implies more efficient drying and firing, and because of faster cycles, lower specific energy cost, as well as a saving in capital costs, because consequently the dryers and kilns can be relatively smaller than those required for the conventional process times. Energy, labour and mortar savings can be achieved if large blocks are used rather than the equivalent of the solid clay brick or maxi. Larger blocks also require less skill in laying than conventional bricks. Hollow fired clay blocks of the same size as cement blocks presently on the market are lighter and have a greater crushing strength, as well as being gentler on the builder's hands than their cement equivalent. Perhaps of greatest significance in the Western Cape is the observation by Searle[7], namely that, "The penetrability to rain is low, but the blocks do not cause condensation on the interior walls of buildings, as does concrete." It is not the purpose here to consider the relative merits of clay as opposed to cement but rather to find an energy-effective way of producing an alternative to solid clay bricks. While insulation costs are not likely to be significant in affordable housing, there is considerable merit in building houses that are warmer in winter and cooler in summer.

Performance characteristics of perforated brick masonry compared with solid brick equivalents are reported in the *Building Research Establishment Digest*[4] already referred to in this text. Tests on Western Cape hollow fired clay maxis have been done by Cattell and Ramsay[8].

Building projects using the recently available hollow maxis have raised problems, from the mason's point of view, with regard to the difficulty of cutting the block, and perforated headers and returns with the lateral holed units. Chasing is also perceived as a problem. These and other issues have been resolved in Europe and the main challenge will be to overcome a natural resistance to change rather than any real difficulty with the product.

While a large range of sizes of hollow-ware is made overseas and the merits of the two major types can be debated, for this discussion no decision has to be taken on these scores. The process and principles apply equally to both types, and more than likely sizes will be agreed upon which best suit door- and window-frames, as well as other relevant criteria.

Production of hollow-ware

In recent months, Claytile, at Koelenhof in the Cape, has developed a method of firing hollow-ware, up to the size of maxis, in clamps. They have also established that it is not feasible to burn larger hollow blocks in this way. Clamp firing requires little capital but is labour-intensive, has high product wastage, is weather dependent when combined with open air drying and is not energy efficient, particularly as no heat is recoverable for drying. The weather dependence is a major factor in that factories that dry in the open air and fire in clamps often produce for only seven months in the year. This is a poor use of capital assets. The issue of not employing or under-utilising staff for five months of the year is an unacceptable practice which raises ethical and labour questions, as well as productivity problems, with employees. Clamp firing is also frowned on by the air pollution control authorities. Hollow blocks, with holes parallel to the mortar bed, were made and fired in Hoffmann kilns at the Road Afric factory in Somerset West (Cape) and the Table Mountain factory at Koelenhof in the Cape. Both factories manufacture a full range of sizes. A popular unit was the "WB2" which is a block with the same dimensions as the conventional building brick but with two lateral holes. The WB2 was cheaper ex-factory and for cartage than the conventional brick. Both factories ceased production in the 1970s.

If the hollow block is to be promoted, possibly to the detriment of the solid clay brick, it would be most reasonable for the present producers of solid clay bricks to convert to hollow block production. The 23 factories in the Western Cape already have the infrastructure, raw materials, crushing and preparation plant which, with little modification, could produce the unburned product. Only five of these factories have dryers and not all use their dryers throughout the year. As has been stated above, the clamp method which they use is not appropriate for large hollow blocks and is wasteful of energy and materials. Therefore, to achieve the proposed goal, namely to provide inexpensive and yet high quality building material, and to make it possible for the present clay brick factories to produce it at low capital cost and energy efficiently, dryer and kiln must be made available.

It is extremely difficult, if not impossible, to justify the investment in any overseas kiln to a clamp brickmaker. What is required is a different approach to the drying and firing process. In most modern plants bricks are stacked on cars in stacks of four bricks deep and perhaps 10-15 layers high. They are then dried in tunnel dryers and pass into tunnel kilns, still on the same car, where they are fired. Often, particularly in the case of hollow-ware, the product is dried in a separate dryer, after which it is set onto kiln cars for firing in a tunnel kiln. In these cases the drying and firing cycle is determined by the unit in the stack which is the last to be dried and the last to be satisfactorily fired. The result of this type of thinking, as well as uneven heat transfer, is that bricks are dried over a period of up to 36 or even 72 hours, with firing cycles of similar length. There is absolutely no justification for this when under laboratory conditions bricks can be dried in one or two hours and fired in a similar length of time. Therefore, if it is possible to achieve such drying and firing times with one brick it means that dryers and kilns should be designed in such a way as to treat each brick in exactly the same way. If this is done then the drying and firing cycle will be that achievable with one brick. This defines the concept as applied here as "fast drying and fast firing". To treat each brick in the same way, they should be stacked independently or *one-high* and the air flow passing around and through them should be uniform in velocity so that uniform heat transfer can take place. This can be achieved quite easily with hollow-ware if the voids are designed so that the web thicknesses are equal and the holes are distributed so that the air flow in and around the block is the same.

Discussion

Energy efficiency is a priority. The most energy-efficient way of drying and firing ware is to apply the fast drying and firing techniques. Short drying and firing times mean short retention times in the dryer and kiln, and this implies smaller units in less covered space, at lower capital costs. The smaller unit also implies lower surface heat losses. Further energy saving can be achieved if the ware is allowed to pass directly from the drying into the firing process, and this suggests an integrated dryer and kiln.

A concomitant advantage of one-high setting is the simplicity of the setting machines, with low maintenance and replacement costs, for both the loading and unloading processes. In comparison to the clamp method, where bricks are usually hand set onto a pallet for drying, transported by a forklift to a yard to wait for some weeks where they will dry, and are then removed by forklift to the clamp area for hand stacking into the clamp, the one-high offers a dramatic saving in labour. A further saving is that of pallets and forklifts. Clamp yards have considerable capital investment in pallets and forklifts. These items also have maintenance costs, and in the case of the forklifts, there is a running cost and the use of energy, both of which are saved with the simply set, integrated, one-high dryer and kiln.

Were a clamp yard to decide to operate on a two- or three-shift basis, this would imply a dramatic increase in labour with the possible responsibility of additional housing. Drying and clamping areas would have to be increased and the greater travelling distances across the yard might necessitate the purchase of additional forklifts. The proposed integrated unit is, in effect, an extension of the extruder and, ideally, should be operated continuously or at least for a six-day period with a holding break on the seventh day. Such an operation would allow better use of capital equipment in that the plant can operate on a twenty-four hour day and throughout the year. This would result in a dramatic increase in productivity from the same production unit and, of course, better use of plant. Full employment all year round would be another advantage. Although the specific labour requirement is considerably reduced for the production process, with increased production and the economic advantage of better packaging and sorting processes, no retrenchment need take place. The concept of fast drying and fast firing is fundamental to this type of plant. It is common knowledge that clays react differently to both of these processes and Sladek[9] points out that for fast firing, it is ideal to have clays with a low, free quartz content in combination with an appropriate coefficient of thermal expansion, low in organics and a preponderance of kaolinitic clay. Heckroodt[10] classifies brickmaking clays in the Western Cape into three groups all of which are predominantly kaolinitic. His A and B groups are both Malmesbury shales and weathered phyllites, consisting mainly of kaolinite, hydrous mica and quartz. The Energy Research Institute at the University of Cape Town has carried out tests on drying and firing hollow-ware and concluded that hollow-ware made from these clays can be dried and fired satisfactorily in less than 10 hours (i.e. ten hours from extrusion to packaging). According to Heckroodt these clays are abundant in this region.

The Fuchs ITO system of Messrs Vogel & Noot Industrie Anlagenbau of Graz, Austria, has found favour in Eastern Europe and, in fact, satisfies the principles and requirements set out above. Eustacchio[11] has argued for the ITO system of Fuchs, where a combination dryer and kiln dries and fires a range of ware one-high. The throughput, depending on the raw material and type of product, is between 4 and 16 hours. The system uses simple setting mechanisms to load and off-load the product. ITO systems operate at an economical energy consumption in the order of 1 880 kJ/kg for drying and firing. This is considerably below the energy consumption of clamps, according to the paper on South African clamp kilns by Huiras[3], where he quotes a range of between 1 870 kJ/kg and 3 730 kJ/kg for firing, without the possibility of any heat recovery for drying. The ITO plant has operated successfully for a number of years in Furstenfeld near Graz in Austria. It requires only two operators per shift to produce 2 400 000 common building bricks per month in two parallel units. Each unit operates with the dryer below the kiln, thus saving space and building area. An additional advantage of this system is its versatility. The unit is able to dry and fire a wide range of product sizes. Shrinkage is of particular concern for large hollow blocks and because the firing profile is accurately controlled, shrinkage is standardised.

In spite of the fact that the raw material is freely obtainable in the Western Cape, that the rationale behind the production and use of hollow blocks is convincing, and further, that the required technology and equipment is readily available from overseas, the heavy clay industry seems reluctant to take any steps in this direction mainly because of the high capital cost of overseas equipment. It can justifiably be suggested that to persist with the present open air drying/clamp method to produce solid bricks is an extremely short-sighted policy which will lead to the demise of this particular section of the industry.

The opinion expressed is that the capital expenditure required to purchase any dryer and kiln from overseas cannot be justified compared against the processes used in the clamp yard. Assuming this to be the case the challenge which has to be met is to produce an integrated fast drying and firing unit in South Africa with South African technology and materials to compete economically with the open air drying and clamp system or even the conventional dryer/clamp system. A brief look at a clamp yard making 12,5 x 10^6 (or 12 500 000) bricks per annum, over the seven-month period, reveals the following additional costs as compared to the proposed integrated dryer/kiln. Figures are gleaned from typical factories and reports within the heavy clay industry.

Labour and waste differences would amount to an annual saving of R590 000. Add to this figure the running costs of the forklifts and the maintenance of pallets and forklifts, as well as the additional cost of labour and materials to cover bricks to prevent rain damage. Finally, estimate the additional profit due to five extra months production of a fully equipped factory, this could provide the annual installment that would justify the purchase price of an integrated dryer/kiln as proposed above. Conservatively, the total amount is in excess of R800 000. On present interest rates this would allow a capital investment of R2 800 000. Add to this the fact that the clamp has a capital expenditure on forklifts and pallets of about R350 000, excluding hardcoring and sheds. This gives a justifiable capital expenditure on the proposed dryer/kiln of some R3 150 000, repayable over five years.

Initial investigations indicate that for this amount, an integrated fast dryer/kiln, either in-line or in the form of an annular disk, could be constructed in modular form with locally made ceramic blanket and hot-face refractories. This would include a complete heat source and an automated temperature and air control system.

Having justified the concept and the investment economically, it remains only to consider the energy saving advantages of the proposal. In the first instance, there is the saving in energy which is lost in the high waste figure in clamps and the diesel saved by not operating the forklifts. If a comparison is made between drying in the open air plus the best Huiras clamp figure (this figure might well have been achieved with a carbonaceous clay) and the Fuchs kiln, no energy saving can be claimed.

The most significant single factor is the fact that this proposal permits the manufacture of large fired clay hollow blocks with all their advantages for housing. Assuming that there will be 40% voids, in excess of 40% of the present process energy will be saved. If three assumptions are made, namely, (i) that 60% of the Western Cape NFP production will be converted to hollow block equivalents, (ii) that only 40% of the production energy will be saved due to voids and that further, (iii) all the present NFP production is open air dried and fired at the best quoted clamp energy figure, then, using the proposed dryer/kiln, there will be an annual saving of 430 TJ in process energy. At present coal prices this would amount to an figure in excess of R3 200 000 per annum.

Conclusion

It has been shown that the brickmaking industry is inefficient in its use of energy. Improvements can be made, especially by moving away from the clamp kiln systems used in the Western Cape to a continuous type of operation using tunnel dryers and kilns. Besides the improvement in the use of energy it would also lead to improvements in plant utilisation. It has also been shown that in spite of the cost of tunnel kilns being much higher than that of clamp kilns there is an overall financial benefit to the brickmaker if it can be proved that a kiln and dryer can be built in South Africa at the costs quoted above.

Besides the improved energy utilisation by improving the manufacturing process there are savings to be made in the energy usage per square metre of wall laid by moving from the common brick to a maxi brick or larger block. This development leads not only to an energy savings per kilogram of brick but also to a reduction in kilograms per square metre of wall area.

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*Biogas as a rural domestic energy source: A pilot study

****C THOM AND ***D I BANKS**

A household biogas plant was installed at the homestead of a rural family as part of a project funded by the Chief Directorate: Energy of the Department of Mineral and Energy Affairs. The Mathabela family operated the plant and utilised the gas for domestic purposes. During the first 18 months of operation limited monitoring of the system was undertaken, while the impact on the family was assessed over a period of two and a half years. The problems that were encountered related mainly to shortages of manure and water, as well as the maintenance and overall management of the biogas plant. This experience has indicated that the availability of sufficient quantities of manure and water from reliable sources presents greater constraints to the utilisation of the technology by smallholders than anticipated. In addition, it was recognised that the skills and resources of the users are as critical to the successful implementation of the technology as the availability of the necessary inputs.

Keywords: biogas; household energy; biogas plants; rural energy; costs

Introduction

Household biogas plants are widely used in some Asian countries, notably India and China[3], while the number of units installed in African countries was of the order of 1 500 in 1990[4]. In Southern Africa there have been efforts to develop the technology in Zimbabwe, Botswana and Lesotho[5]. However, these have occurred on a relatively small scale, and the number of household plants which have been installed in the region is probably of the order of one hundred.

By the middle of 1990 the only operative household plant in South Africa known to the authors was that of Professor D Holm, which is located on a smallholding outside Pretoria[6]. A few other units had been built on a one-off basis, and some literature-based assessments of the potential of biogas technology in South Africa had been undertaken[7,8]. However, very little field testing of the technology had been carried out in the rural areas of South Africa.

A biogas research project, funded by the then Energy Branch of the Department of Mineral and Energy Affairs, was subsequently undertaken by the Appropriate Technology Group of the CSIR's Division of Water Technology[9]. A number of demonstration biogas plants were built during this project's lifetime to study the technical, social and economic feasibility of the technology in South Africa. The first of these was a household biogas plant constructed to demonstrate and test the technology, and to undertake a preliminary assessment of the feasibility of biogas as a domestic energy source for low-income rural households in the former homelands. This part of the project was a joint effort between the Appropriate Technology Group and the Wits Rural Facility (WRF) of the University of the Witwatersrand. This paper summarises the findings of this project which have been discussed elsewhere in greater depth by Thom[9].

* Parts of this paper have previously been included in presentations to the Electricity "Beyond the Grid" Conderence[1] and the Anaerobic Digestion Symposium[2]

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The Mathabela family

The biogas plant was built at the homestead of the Mathabela family in the village of Timbavati, which forms part of a sprawling semi-rural conglomerate adjacent to Acornhoek in the Eastern Transvaal lowveld. The structure of the household underwent some changes during the period under consideration (i.e. October 1990-February 1993). However, the core of the household consisted of Mr and Mrs Mathabela, an adult son, Freddy, two teenage sons and a young teenage daughter. Freddy's wife, Marie Antoinette, and their small child joined the household during 1992.

At the time that the biogas plant was installed, the family's only formal income was R200 per month[10], which was earned by Mr Mathabela. Subsequently Freddy started working regularly for the WRF, and by mid-1992 their combined income was about R1 000 per month. However, in October 1992 it was established that Mr Mathabela, who earned R500 per month at the time, was still the only regular contributor to the combined household income.

The number of full-grown cattle owned by the family varied between eight and nine during the first 30 months of the project. The cattle graze on communal land during the day and usually return to the kraal at the homestead for the night. The family seemed ideal for the purposes of the project, as the number of cattle was seen as sufficient for the operation of a biogas plant, while water was available from a stand-pipe approximately 100 m from the homestead. Because the family had a low income, this provided an opportunity to investigate the possible utilisation of the technology by people in a fairly poor socio-economic grouping.

Freddy Mathabela, whose interest in biogas technology had led to his family's involvement in the project, was the principal contact between the project team and the family. The family appeared to be willing to participate in the project more from a sense of trust in the people who had approached them rather than from a personal understanding of the technology.

Design and installation of the biogas plant

It was decided to build an "Indian" type floating-drum plant at the Mathabela homestead as it was reputedly easier to build successfully than the "Chinese" fixed-dome type[3], which was the alternative. As the main purpose of the project was to demonstrate the technology to potential users, it was regarded as essential to reduce the risks of failure which could result in a negative attitude to the technology from the outset. The biogas plant that was built at the Mathabela homestead is shown in Figure 1. It

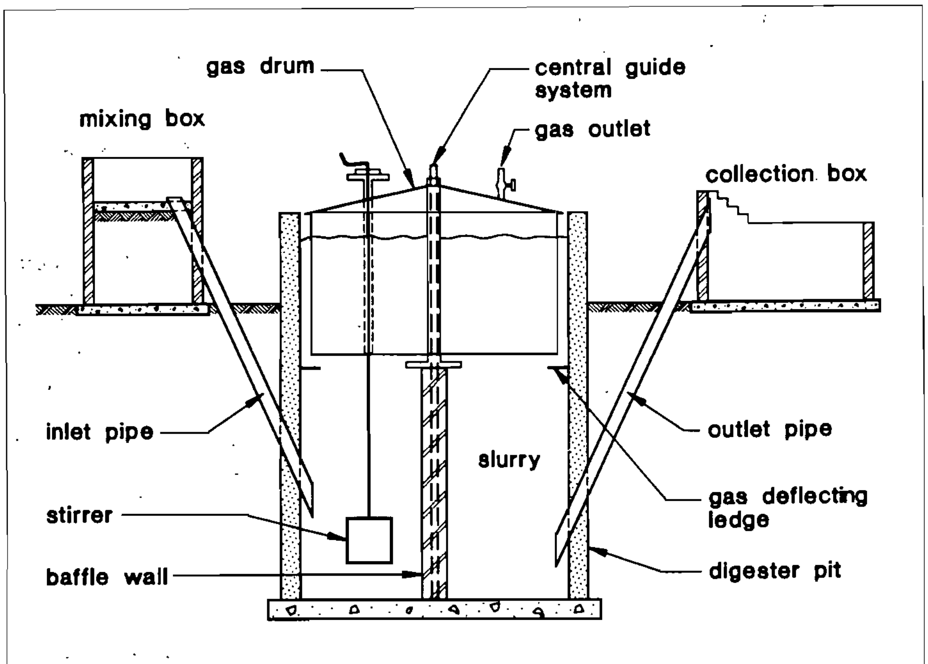

Figure 1: Sketch of the biogas plant installed at the Mathabela homestead

	Skilled labour (1990 Rands)	Materials (1990 Rands)	Total cost (1990 Rands)
Digester: mixing and collection boxes	R350	R1 270	R1 620
Gas drum	R480	R 990	R1 470
Piping and accessories	R 30	R 160	R 190
TOTAL	R860	R2 420	R3 280

Table 1: Construction costs of the biogas plant

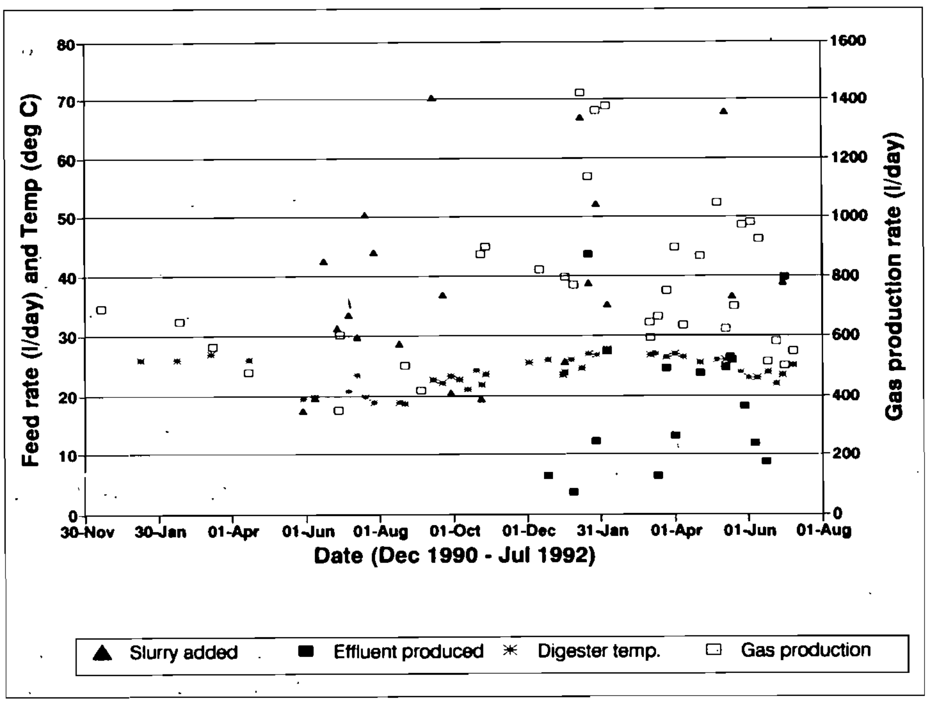

Figure 2: Recorded feeding rate, digester temperature and gas production rate

comprises a ferrocement digester pit and a painted mild steel gas drum.

The Mathabela family undertook to dig the hole for the digester as part of their contribution to the project. The final depth was 0,8 m shallower than required because a hard subsurface layer of semi-weathered rock was encountered, causing the digester to be built higher above ground level than intended. The 9 000-litre ferrocement digester was built using a four-part galvanised iron mould, while the slurry mixing and collection boxes were built of bricks. The mild steel gas drum was built in a metal workshop at Acornhoek and was painted to reduce corrosion. The drum weighed about 200 kg, requiring eight people to place it in position on the digester after the latter had been filled. Although this type of gas drum is used commonly, e.g. in India[3], its construction requires equipment and skills that are not generally available in rural areas. Also, it is fairly expensive, requires regular maintenance, and may require replacement after about eight years. High density polyethylene, which has been used successfully on other demonstration units[9], seemed to be more suitable.

The initial filling of the digester proved to be difficult. As water was not available at the stand-pipe close to the homestead, it had to be transported from another stand-pipe approximately 2 km away. Dung was collected from the nearby cattle kraals of friends and relatives of the Mathabela family. As only small quantities of dung could be obtained from each of these kraals, insufficient dung was collected to provide the optimum concentration of solids in the digester (8-12% total solids[3]).

Gas production started within three weeks of filling the digester, and gas burners were installed once the safety of using the gas had been ascertained. The gas was piped overhead for about 10 m through a reinforced nylon garden hose to a small rondavel which was used as a kitchen. A metal gauze flame arrester and a water trap in the form of a manometer were provided in the pipeline. The gas was utilised in two low-pressure, cast-iron gas burners with a flame diameter of approximately 11 cm, which were obtained locally. The burner jets were enlarged to 2 mm to allow for the low gas pressure (i.e. 75 mm water gauge at the plant). The Mathabela family erected a notice which informed passers-by of the biogas plant, and "no smoking" signs were painted on the digester.

The construction costs of the biogas plant are given in Table 1. The useful energy cost of the biogas produced in this type of plant when used for cooking purposes has been estimated as 7,3-8,4 c/MJ[9], including installation and maintenance costs, compared to 7,5-8,4 c/MJ in the case of paraffin and 7,9-10,4 c/MJ for liquefied petroleum gas (LPG), based on the costs of these fuels in the area[11].

Monitoring of the biogas plant

Limited monitoring of the biogas plant was undertaken during the first 18 months of the project to assess the utilisation of the plant by the family and to relate the measured gas production rate to other system parameters. These results have been briefly summarised. Measured values of the digester temperature, average feeding rate, and gas production rate are given in Figure 2.

The feeding of the plant involves the mixing of fresh dung from the kraal close to the plant with water before it is added to the digester. A reliable record of inputs to the digester could not be obtained as the feeding of the plant was not always recorded by family members and the quantities which were recorded were not always accurate. Attempts were made to establish practices that would ensure greater accuracy, such as, the use of particular containers to collect the dung and water, but these were difficult to enforce. As one of the main purposes of the project had been to assess the response of the family to the technology, monitoring was conducted with as little interference from the outside as possible to enable the members of the family to integrate the operation of the plant into their everyday lives.

During the latter part of the monitoring period the effluent displaced from the plant was also measured in an attempt to obtain a more accurate assessment of the feeding rate. The reliability of the effluent measurements appeared to be somewhat greater than those of the recorded inputs to the plant. Average feeding rates for every period during which fairly reliable measurements of either the slurry input or the displaced effluent could be obtained are presented in Figure 2. The average feeding rate for the entire monitoring period was estimated as 30 litres of slurry per day, at approximately 11% total solids (TS). However, it is likely that the actual feeding rate was lower than this, as the calculations were based on the records which were available, while feeding may have been less regular during times when no records were kept. This feeding rate corresponds to a retention time of 300 days, which is considered excessive when compared to the recommended retention times for simple biogas plants of 60-80 days[12]. The biogas plant was therefore significantly under-utilised.

The main reason for the low feeding rate appeared to be the small quantities of cattle dung available to the Mathabela family. While the available dung from cattle kept overnight in an unpaved enclosure is generally between 5-8 kg/head/day[12], the quantity of dung which could be collected from the kraal of the Mathabela family was equivalent to 3 kg/head/day (both at a TS content of 16%). The dung yield from these cattle seems to be exceptionally low, possibly because of the communal land's poor grazing conditions, particularly during the dry winter period. As a result, a minimum of 17 head of cattle may be required under circumstances similar to those of the Mathabela family to enable the utilisation of a household biogas plant.

The digester's temperature was measured using a thermometer attached to the end of a pole that was pushed into the digester through the outlet pipe. A general trend was evident in the recorded temperatures, which corresponded to seasonal changes. Maximum temperatures were recorded early in 1991 as well as 1992, while minimum temperatures were recorded in the winter months. As 20°C is the threshold temperature above which satisfactory rates of digestion and gas production can be achieved[9], the climate in the area is clearly well-suited to the production of biogas.

Gas production was measured by closing the gas valve on the gas drum and noting the rise in the height of the gas drum relative to the level of the slurry in the digester, usually for a period in excess of ten hours. During this period the family could not use the biogas. The low gas production at the outset was attributed mainly to the low total solids content of the slurry (less than 1%) at this time. The lower gas production rates recorded during the winter of 1991 could be attributed to low digester temperature. By the beginning of 1992 the slurry concentration had increased to approximately 5% TS due to the consistent feeding at relatively high slurry concentrations. Gas production was highest during the summer and autumn of 1992, but seemed to decrease once more as winter approached. The average gas production rate for the entire monitoring period was estimated at approximately 770 litres/day. This can be compared with the estimated 2 000 litres/day that would be required by the family to meet their basic domestic energy requirements[9].

Utilisation of the biogas plant

The circumstances of the Mathabela family have undergone some changes during the time that the biogas plant has been in operation. Together with the natural dynamics within the family, there was a lot of variation in the way that the biogas plant has been utilised. The severe drought in the area during the project also had a significant impact on the utilisation if the biogas plant.

Feeding of the plant

Feeding practices have varied considerably throughout the project. For example, at times teenage boys were employed by the family to herd the cattle and to feed the plant, while it was apparent at other times that no fixed allocation of feeding tasks were assigned within the family. Although men were predominantly involved in the feeding of the plant, Mrs Mathabela also did this on occasion. According to family members the biogas plant was fed every day, except when their cattle did not return to the kraal at night or when water was unavailable. Observations during the project have indicated that this occurred fairly regularly. The stand-pipe close to the homestead was frequently dry, in which case water had to be fetched from other sources, such as, a communal stand-pipe approximately 1 km away.

As discussed above, the quantities of dung added to the biogas plant were very small. Some measures on how to improve the situation were considered, such as, providing the kraal with a concrete floor to ensure that all the dung, as well as some of the urine, could be collected. At first the family seemed positive about this idea, but at a later stage they expressed concern that the cattle might experience discomfort as a result. Another possibility that was discussed was the collection of dung from other cattle kraals, namely those belonging to relatives and friends. This was done on occasions, but family members indicated that attempts at more regular collection would be met with resistance.

In October 1992, it became apparent that the plant had not been fed for about two months, mainly as a result of water shortages because of the drought, as well as the malfunctioning of the gas burners (see below). The family's eight head of cattle were also in very poor condition at the time. Feeding started again in January 1993 after the situation had improved, but virtually no gas was produced as the digester contained mainly spent slurry. The family was subsequently assisted with the emptying and restarting of the plant.

Utilisation of biogas

The use of biogas should be seen in the context of the total energy use of the family, which underwent a considerable change. Prior to the installation of the plant, firewood had been the only fuel used by the family for cooking and heating purposes[10]. It has been estimated that the family used 400 kg of wood per month, which would have cost R24/month if all of it had been purchased. After its installation, biogas was used for some cooking purposes, particularly by Marie Antoinette who preferred it to wood, while Mrs Mathabela appeared reluctant to move away from a woodfire. Marie Antoinette pointed out that Mrs Mathabela would often make a fire in the kitchen rondavel during winter, even when the former was preparing food on a woodstove in another part of the home.

The family cooked a large meal of pap (a type of porridge made from mealie meal) and meat/gravy every day, of which the latter was cooked on biogas, while a woodfire was generally used to cook the pap in a large three-legged pot. Apparently the family had found that the pap took a longer time to cook on biogas. As pap formed the bulk of the food consumed by the family, biogas had clearly not been adopted as the main cooking fuel. However, biogas played a significant role as a supplementary fuel in the household, as it was used by most family members, including the males, for purposes such as heating water for tea and bathing, as well as ironing. Family members indicated that they valued the gas for its convenience when performing these tasks. The heating of water apparently enjoyed priority when the quantity of gas was insufficient. The status of biogas as supplementary fuel was compounded by the fact that biogas production was too low to meet all the cooking needs of the family. As each of the gas burners consumed between 250 litres and 300 litres of gas/hour, a single burner could be used for approximately three hours per day on average. It is doubtful that the use of biogas significantly reduced the family's fuelwood usage, despite their claims to the contrary.

In October 1992, gas production was found to be very low because feeding had ceased (see above). The gas burners were also in a poor condition, with only a single one operative and burning with a low, weak flame. Wood was still used as the main cooking fuel, all of which was purchased from a local merchant. In addition, a LPG stove which had been obtained during 1992, was used for a variety of purposes. However, this seemed to be used only by Freddy and Marie Antoinette, while the rest of the family were again mainly dependent on firewood for tasks such as ironing and water heating. Marie Antoinette indicated that the LPG-fuelled stove cooked faster than biogas, although this perception may have resulted largely from the problems that were experienced with the biogas burners at the time.

Use of digested slurry

The Mathabela family grew mealies and vegetables at the homestead for their own use and during 1991, digested slurry was used as fertiliser in a small patch of vegetables next to the biogas plant. Mr and Mrs Mathabela were both very positive about the use of the slurry and felt that it benefitted the growth of the vegetables. However, no crops were grown during the dry winter season nor during the severe drought which affected the area particularly in 1992. At times the digested slurry was used as fertiliser by some of the neighbours of the Mathabela family. For example, a man was once observed collecting slurry in a bucket which was strapped onto the back of his bicycle.

Maintenance of the plant

Some one-off maintenance tasks related to the biogas plant were carried out by members of the family. For example, Mr Mathabela covered the exposed part of the PVC inlet pipe with plaster to protect it against UV radiation. Maintenance tasks which had to be performed regularly included the repair and cleaning of the gas burners, and the clearing of condensate from the part of the gas pipe between the water trap and the gas burners. Some of these tasks were performed a number of times by members of the family. In October 1992, the burners were found to be in a poor condition, mainly as a result of damage to the control valves where leaks had occurred. These were subsequently replaced, and the maintenance of the burners was again discussed with family members.

Major maintenance tasks that need to be undertaken include the repainting of the gas drum every second year, and the gas pipeline needs to be replaced when leaks develop. Early in 1993 the gas pipeline was replaced with the assistance of family members who were shown how the pipeline should be checked for leaks. The gas drum was also removed from the digester, cleaned and repainted. The family was provided with two metal shields which fitted around the gas burners. These were intended to improve the efficiency of the burners, and could also be used to protect the burners when they were not in use.

Responsibility for the plant

The family had not been asked to contribute financially to the biogas plant when it was installed because it was the first biogas plant that had been constructed by the project team, and it had been expected that the design would need some improvement. This clearly influenced the response of the family to the technology, as it provided them with a free source of energy in monetary terms. It also seemed to have resulted in some confusion about the ownership of and therefore the responsibility for the plant.

During the first 18 months of operation, the WRF had kept regular contact with the family as some monitoring of the system was undertaken. In the latter part of 1992, the family were left more to their own devices and it was in this period that the feeding of the plant ceased and the gas burners broke down. Of major concern was the fact that the family did not approach the WRF about the state of the gas burners. The main reasons for this were the confusion of responsibility within the family, as well as the fact that most family members seemed to have expected the WRF to detect the problem. It was subsequently agreed that the family would make a small payment (about R30) towards the cost of repairing the gas burners and the gas drum. Although they had been discouraged somewhat by the problems with the gas burners, they valued the biogas sufficiently to pay something towards the repair of the system.

Recent observations

The Mathabela family lost most of their cattle during the drought. In February 1994, the family indicated that the dung from the three remaining cattle had been supplemented by some dung from a neighbour's kraal to feed the plant. Gas production was very low at the time but the family indicated that they were using all the available gas. The biogas plant, the gas pipeline and the gas burners were all in good condition, although a minor blockage in one of the burners had to be removed.

During a visit to the family in May 1994, it was found that both gas burners were in working condition and were clearly being used by the family. It was subsequently established that a total of eleven head of cattle were being housed in the family's kraal at night, of which eight belonged to other people. This arrangement had apparently been made by the family to increase the quantity of dung available to feed the biogas plant, which was once more being utilised on a regular basis.

Conclusions

It can be concluded that the Mathabela family has found biogas to be a useful and desirable addition to their domestic energy mix. However, this has to be seen within the wider context, particularly seeing that the biogas plant had been provided to them at no monetary. Because of the high capital cost of a biogas plant and the unfamiliar nature of the technology, it is unlikely that the family would have been able or willing to acquire the technology of their own accord.

A number of problems have been encountered by the family regarding the utilisation of the biogas plant. These were related mainly to shortages of manure and water, as well as the maintenance and overall management of the biogas plant. Insufficient dung was available in spite of the relatively large number of cattle owned by the family, which can be attributed mainly to the poor grazing conditions in the area. Water availability also proved to be a problem, even in this area where water is generally available from communal stand-pipes. It became a particularly severe problem during the drought. While some maintenance of the biogas plant had been undertaken by family members, it is unlikely that they would be able to keep the plant in running condition without outside assistance. There is clearly a need to train and support users of the technology with regard to maintenance aspects.

Also, the biogas system had not been managed as effectively as it could have been, even prior to the period of severe drought. For example, provision could have been made for the storing of fresh dung which would not be utilised immediately. The digested slurry was also not fully utilised as fertiliser, while responsibility for the feeding and maintenance of the plant was generally not clearly allocated. This can be attributed to the limited skills and resources within the family, and an inadequate understanding on the part of the project team of the extent of management training and skills that were required. In general, the experience with the Mathabela family has indicated that the skills and resources of the users are as important to the successful utilisation of a biogas plant as the availability of sufficient quantities of manure and water.

This experience has therefore given some indication of the requirements for the successful utilisation of the technology by smallholders in South Africa, a matter which has been discussed elsewhere in greater depth by Thom[9]. Smallholders with an established ability to do repair work of a mechanical or structural nature would be in a better position to handle the maintenance requirements of a biogas plant. In addition, smallholders who are actively involved in farming and who achieve some degree of success as farmers are more likely to have the necessary management skills to optimally utilise a biogas system. However, it is not possible to draw any final conclusions based on a single installation. The four household biogas plants which have been installed in rural areas as part of the Biomass Initiative, an inter-departmental initiative co-ordinated by the Department of Mineral and Energy Affairs, should provide such an opportunity in the future.

In addition to aspects concerning the utilisation of biogas plants, it is necessary to consider obstacles to the adoption of the technology by smallholders. Very little can be deduced from the experience with the Mathabela family in this regard. However, the high capital cost of a biogas plant is likely to present a serious obstacle to the adoption of the technology by smallholders who lack access to resources, and this also includes most of the smallholders in the former homelands. Some form of financial assistance, possibly in the form of low-interest loans, or revolving credit schemes, would therefore be necessary to enable the installation of household biogas plants on a wider scale in rural areas.

Acknowledgements

The authors would like to acknowledge the financial assistance provided by the Chief Directorate: Energy, Department of Mineral and Energy Affairs. Sincere appreciation is also extended to the Mathabela family for their invaluable contribution to the project. Finally, the assistance rendered by staff of the CSIR, the Wits Rural Facility and the Mapulaneng Technical College, as well as by friends and relatives of the Mathabela family is gratefully acknowledged.

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COMPARATIVE ENERGY COSTS IN SOUTH AFRICAN CITIES RELATED TO HEATING VALUE

NOVEMBER 1994											
Energy source	Consumer prices			Cost of energy (c/MJ)			*Relative heating costs			Heating value	
	Coast	Inland	Units	C.T.	Jhb	Dbn	C.T.	Jhb	Dbn		
Coal A (Peas)	245,20	68,40	R/Ton	0,88	0,24	0,56	3,41	1,00	2,30	28,0	MJ/Kg
Elect.	20,01	21,92	c/kWh	5,56	6,09	4,84	22,75	24,92	19,81	3,6	MJ/kWh
Heavy Furnace Oil	53,06	67,36	c/litre	1,29	1,64	1,29	5,30	6,73	5,30	41,0	MJ/litre
Illum. Paraffin	89,63	101,53	c/litre	2,42	2,74	2,31	9,92	11,23	9,92	37,0	MJ/litre
Petrol (Premium)	166,00	176,00	c/litre	4,78	5,07	4,99	19,58	20,76	19,58	34,7	MJ/litre
Diesel	140,90	150,90	c/litre	3,94	4,20	3,94	16,14	17,20	16,14	38,8	MJ/litre
Power Paraffin	90,00	102,30	c/litre	2,40	2,73	2,40	9,82	11,17	9,82	37,5	MJ/litre
LPG	102,00	115,80	c/litre	3,72	4,23	3,72	15,24	17,30	15,24	27,4	MJ/litre
Gas											
Cape Gas	45,60	–	R/GJ	4,56	–	–	18,67	–	–	–	–
Gaskor	–	16,50	R/GJ	–	1,65	–	–	6,75	–	–	–

This table shows comparative energy costs (in SA cents/MJ) in selected South African cities (coastal and inland) based on a range of energy sources. The following criteria were taken into consideration in the calculation of the cost of energy:

(1) Transport costs for coal were obtained from Spoornet. Railage of coal was calculated from Saaiwater to Cape Town and from Saaiwater to Durban respectively.

(2) The energy cost has been calculated on the bulk delivered price for consumers, i.e. includes 14% VAT and other charges.

(3) All figures for electricity have been based on energy requirements for large commercial users.

(4) Electricity prices have been based on typical monthly accounts for large users (see Table 5 in the Energy Price List in *Selected Energy Statistics: South Africa*).

(5) A 75% load factor has been used in the calculation of the Gaskor prices.

(6) The relative heating costs are shown in relation to the cheapest source, i.e. coal in Johannesburg.

(Source: *Selected Energy Statistics: South Africa*, No. 31, November 1994)

Energy news in Africa

Electricity

Gabon

The government has yet again decided to postpone the privatisation of Gabon's electricity company, SEEG. Privatisation was initially postponed because of imminent presidential elections, and a management contract was signed in July 1993 with Electricite de France (EdF), Ufiner-Cofreth (Lyonnaise des Eaux) and Hydro Quebec. The management contract, which was valid for one year, has been extended for a further six months. Further privatisation has encountered stiff resistance from the unions and from government opposition parties.

(Source: Africa Energy & Mining, 14 September 1994)

Ghana

A previous exporter of electricity to the Ivory Coast, Ghana's Volta River Authority (VRA) purchased electricity from the Ivory Coast earlier this year to offset low water levels in the Volta basin. The interconnection with Ivory Coast enabled Ghana until June to import up to 30 MW to supplement peak period consumption. However, that supply is no longer available to the Electricity Corporation of Ghana resulting in power shedding of a similar amount in selective cuts in Accra.

According to the VRA, peak consumption in Accra is 160 MW, 65 MW at Kumasi, 40 MW at Sekondi-Takoradi, 60 MW at Tema and 30 MW in the northern sector. Ghana's consumption has risen by between 10-20% over the past five years.

In early September the VRA decided to cut all electricity supplies to the Volta Aluminium Company (Valco). The company then warned that it would sue for damages as it would have to shut down its operation, resulting in a loss of jobs to about 1 600 workers, and because sufficient warning had not been given to allow the shutdown to be done under "technically acceptable conditions".

After facing the prospect of having to pay out about $20 million in compensation the VRA withdrew its plan to cut electricity supplies to Valco. As a compromise it was decided that Valco would continue to operate two-and-half electrolysis lines out of three-and-a-half, and then two if a further reduction was required. Elsewhere, the VRA announced that it had conveyed "proposals" concerning a substantial but non- specified increase in electricity rates to the government in order to start or step up production projects, particularly the thermic power station planned for Takoradi.

It is claimed that political factors are compounding the problems of the Akosombo dam to an increasing extent. These factors reflect opposition to the deregulation of the electricity sector that is being carried out under pressure from international institutions. The pros and cons of privatisation are being discussed, particularly in relation to the planning of power stations based on the Tano gas development project and the Takoradi project. A commission has been set up under the auspices of the Energy and Mines minister to study a "rate system" for power stations financed and built by private companies.

(Source: Africa Energy & Mining, 27 July 1994, 14 September 1994, 28 September 1994)

Ivory Coast

Successful negotiations have been undertaken between the Compagnie des Energies Nouvelles de Cote d'Ivoire (CENCI) and the Ivory Coast government for the Vridi power station with a 165 MW capacity (5 x 33 MW). The first three gas turbines (Phase 1) are to be installed by March 1995 at an estimated cost of Ffr400 million.

The World Bank has offered the Ivory Coast government technical and legal advice for the project, but funding has also been requested. This funding will be used not only for the turbines in Phase 2 of the project but for the construction of the high voltage network in the Abidjan region, conversion of existing gas units at Vridi and new studies, particularly on the Ivory Coast's gas potential.

An increase in installed electricity capacity is regarded as a pre-requisite for any interconnection with Mali and Burkina Faso, even if the amounts involved are small, and for an eventual resumption of exports to Ghana.

(Source: Africa Energy & Mining, 13 July 1994, 27 July 1994)

Morocco

The first two sections of the Jorf Lasfar power station near El Jadida, Morocco, each with a 330 MW capacity have been built by an international consortium. One has gone fully into production while the other will be hooked up to the grid in early 1995. This reinforces the fact that the Office National de l'Electricite (ONE), the local utility, no longer has a production monopoly. The government's aim is to see private producers accounting for 50% of the country's capacity by the end of the decade. With regard to the third and fourth sections of Jorf Lasfar and the operation of the power station, several international consortia are bidding for the contract.

Taken together, the two units will boost the country's electricity production by 30%. Installed capacity was 2 700 MW at the end of 1992, of which 2 360 MW was generated by ONE and 360 MW by industrial self-producers. Morocco's electricity production has been projected to reach 11,1 billion kWh this year and sales 9,5 billion kWh, representing an increase of 6,3%.

The African Development Bank (ADB) is expected shortly to approve a $60 million loan to ONE for a new investment programme that essentially involves upgrading and extending its transmission-distribution network. The utility's main function in future will lie in distribution, although it will also work to extend its rural electrification programme and push schemes which promote the rational use of energy.

(Source: African Energy & Mining, 14 September 1994)

Mozambique

The ADB has initially agreed to provide Mozambique with loans worth $30 million for studies and equipment needed to supply secondary towns with electricity and for training personnel. The programme will include renovating and extending the technical training centre that Electricide de Mocambique (EDM) runs at Songo, where the station that serves as starting point for Cahora Bassa's existing and future high voltage lines is situated.

With regards to distribution, the various projects scheduled to get underway include the rehabilitation of the existing network at Catembe near Maputo, as well as at Namacha. New networks are to be created in five towns mainly in the south of the country. In addition, there are plans to install a 110 kV line some 45 km in length, as well as 64 km of 66 kV lines, 340 km of 33 kV lines, transformers of varying categories and, initially, around 100 km of low voltage distribution lines. A consultancy will be chosen to prepare the invitations to tender and a second one to handle training at Cahora Bassa.

The ADB has promised $25 million out of $120 million needed for electrical-mechanical equipment for the existing dam at Massingir on the Limpopo River. The Arab Bank for Economic Development in Africa has also pledged money for projects for local networks which will be used for lines, transformers and street lighting.

(Source: Africa Energy & Mining, 28 September 1994)

South Africa

A consortium formed by Eskom, Electricité de France (EdF) and the East Midlands Electricity (EME) to carry out the electrification of Khayelitsha and named Phambili Nombane ("Onward with Electricity" in Xhosa) has asked Cegelec (GEC-Alsthom) to act as prime contractor for the first phase of work costing Ffr10 million (R6,7 million). The contract was disclosed when the French president, Francois Mitterand, inaugurated the project alongside President Nelson Mandela on 4 July during his visit to South Africa.

Cegelec has already operated in South Africa, having helped in the connection of 100 000 to the electricity grid. The new contract calls for 5 000 connections. The 50 000 connections planned over three years in Khayelitsha is expected to cost R160 million. Local sub-contractors are also expected to be brought into the project.

The Caisse Francaise de Developpment (CFD) is also part of the scheme. Part of the loan of Ffr200 million to South Africa is to go towards the Phambili Nombane Training Centre.

The Khayelitsha joint venture is headed by Alain Roucole (EdF) and the operations manager is Ian Barge (EME). EdF is also planning to open a permanent office shortly in Johannesburg.

(Source: Africa Energy & Mining, 13 July 1994)

Southern Africa

Malawi recently announced an accord with Mozambique which provides for an interconnection with the line linking Cahora Bassa to South Africa. A build-up in capacity is planned for two or three of the state-owned ESCOM's dams on the Shire river. The recent drought conditions have resulted in low water levels and thus power shedding, lending impetus to the Malawi-Mozambique accord. The accord has given a further boost to Eskom's plans for the interconnection of the Southern African region, providing it with a market for its surplus coal-based electricity in the short and medium term, and to benefit from the region's hydro potential.

Since Eskom's projects extend as far as Zaire, it would see the advantage of countries belonging to the region's Preferential Trade Agreement (PTA) linking up with SADC. Up to now SADC has been opposed to any merger of the groups, a move that eleven countries set into motion last year with an agreement on COMESA (Common Market for Eastern and Southern Africa). Ethiopia in particular favours such a merger.

During President Mugabe's recent visit, Zimbabwe signed a pact with South Africa for commercial and technical co-operation on energy, which was seen as a prelude to the creation of an "Energy Fund" for Southern Africa.

Contracts have also been signed for the Zimbabwe lines, one of them running from Cahora Bassa (capacity to be sold by Eskom) and the other from Matimba via Botswana. Funding has been approved for the Cahora Bassa project. With regards to the rebuilding of the Cahora Bassa-South African line, an agreement was signed at Songo which confirmed that the European Investment Bank had agreed to take over Italy's cancelled $50 million commitment towards the project with approval from the Cahora Bassa Standing Joint Committee. Costs are expected to be higher than the initial $125 million envisaged and work is not expected to begin before March 1995 because of the rains. The line is likely to go into service in late 1997.

(Source: Africa Energy & Mining, 14 September 1994)

Uganda

The EdF has proposed a pilot programme for the commercial management of distribution in one of the districts of Kampala to the Uganda Electricity Board (UEB). The EdF is hoping for a broader partnership with the UEB when country-wide distribution is privatised. The EdF plan will involve a preliminary six month study by a team of international experts to gather basic data and examine the UEB's current situation. The distribution network in the proposed district will be mapped and an updated list of subscribers established. Thereafter a short-term programme will be drawn up with the UEB to improve the management of the subscriber service, including meter reading, billing and collection.

If the EdF is given the contract, it will go together with the creation of a commercial unit to be organised with the UEB. As for the privatisation of management in the electricity sector, the government has agreed to it in principle, although UEB is reluctant to agree to it.

(Source: Africa Energy & Mining, 14 September 1994)

Fuel alternatives

In Ghana, the absence of regulations concerning the use of liquefied petroleum gas (LPG) as a fuel for cars has complicated the government's policy which was aimed at getting households to substitute fuelwood for butane as a domestic fuel.

There has been a recent and sudden shift from gasoline to LPG as a fuel. Present LPG consumption in Ghana has jumped to 20 000 t/year compared with 5 300 t/year in 1989, a year before the campaign to promote the domestic use of LPG was launched. The use of LPG in cars now accounts for 42% of total LPG consumption. It also means that LPG drivers do not need to pay the tax levied on gasoline.

(Source: Africa Energy & Mining, 31 August 1994)

Mining

The Zambian government is studying a report by a German consultancy firm, Kienbaum, on ways and means to privatise Zambia Consolidated Copper Mines (ZCCM). The study recommended that the ZCCM be broken up into five units which correspond to the project for an underground mine at Konkola and four current mine sites (Mufulira, Chambeshi, Nchanga and Luanshya). The units would, however, continue to be controlled by a holding company in which the government would retain an interest. The premise of the report is that privatising the

ZCCM in one block could give a single foreign investment group too much influence over the country's economy and possibly even over the government. Zambian president, Frederick Chiluba, has insisted that 10-15% of ZCCM's capital would be floated on the Lusaka stock exchange.

The German report's implications are far-reaching, especially for Anglo American which presently holds 27,6% of ZCCM and is considered as the leading candidate in the privatisation. Gencor and RTZ are also interested. Anglo American has presented its case to the Zambian government in which the ZCCM would be taken over by a consortium, of which Anglo American would be a member. The State, which currently holds 60,3% through the Zambia Industrial & Mining Corporation (ZIMCO) would retain a minority holding. Management would revert to private hands. Anglo American claims that the breakup of the ZCCM into five units will be "long, difficult and expensive". If the company is sold as a single unit it would be better managed as it would be able to optimise on returns of investment.

Anglo American has also proposed that it raise the finance and manage a new mine at Konkola Deep. This proposition is an economically attractive one for the ZCCM which is short of cash. Development of the new mine is expected to be an expensive and difficult operation as the copper ore is deep. Also, the Zambian government may be faced with the closure, within a decade, of the Nchanga open pit mine which currently supplies 30% of Zambia's copper.

(Source: Africa Energy & Mining, 13 July 1994
SA Mining Coal Gold & Base Minerals, September 1994)

Zambia's Northern Metals Refiners is reported to have signed an agreement with Finland's Outokumpu and British, American and/or South African firms to build a plant at Kabwe to re-process mining waste from a number of Zambian mines to obtain gold, copper, zinc and lead.

(Source: African Energy & Mining, 27 July 1994)

Nuclear

The Atomic Energy Corporation of South Africa recently announced a pilot project for a plant to enrich uranium for non-military use with a new laser-based technology together with a Western partner. This partner is to invest $10 million in the project between now and when the plant comes on line in 1996-97. The development of the technology had already cost R200 million.

It has been estimated that the export value of the enriched uranium using the new technology could be worth $170-200 million. This means that the new process is seen to be competitive on the world market.

(Source: Africa Energy & Mining, 14 September 1994)

Petroleum

Sasol has short-listed three floating drilling rigs for the well it plans in early 1995 and subsequent options. The company is also still looking for ways to share costs for its Block 2012 project off the Namibian coast. This marks Sasol's debut in exploration, and two-thirds of the 11 000 km2 permit involves depths of between 200 m and 2 000 m.

(Source: Africa Energy & Mining, 28 September 1994)

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Douglas left the Wits Rural Facility in 1992, moving to the Cape where he concentrated on his Ph.D. research. His thesis was on free-cylinder Stirling engines. Douglas is presently using the resultant breathing space in his life to practice the craft of pottery, while considering future options.

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For the past twenty years he has been self-employed. Initially he established Joostenberg Brick Trust and has continued to be its Managing Director. Eight years ago, together with his son, he established Claytile (Pty) Ltd, and more recently, Clayblock C.C.

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Following his undergraduate studies Mark de Villiers worked initially as a water treatment engineer. He joined the Energy Research Institute in April 1992 after completing a Master's programme at the Institute. His half-thesis was on energy management in industry, and included a case-study on the brewing industry. He is currently working on energy and environmental research projects. Major projects include a study of the brown haze in Cape Town, development of an industrial energy efficiency strategy for South Africa, energy efficiency collaboration with countries in the region, and energy audits in industry.

DUTKIEWICZ R K

B.Sc.(Eng.)(Wits), M.Sc.(Eng.)(Wits), Ph.D.(Cambridge), Pr.Eng., FIMechE, Hon.F(SA)IMechE, MBIM, FInstE, C.Eng.
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Professor Dutkiewicz was born in Poland and obtained his schooling in the United Kingdom and South Africa. He received his B.Sc. and M.Sc. degrees from the University of the Witwatersrand in South Africa, and his Ph.D. degree from Cambridge University in the U.K. His Ph.D. degree was on heat transfer in nuclear engineering. He joined the General Electric Company in the U.K. as a nuclear engineer and worked on the design of the Hunterston Nuclear Power Station in Scotland and the Tokai Mura Nuclear Power Station in Japan.

He returned to South Africa to the Electricity Supply Commission, and was appointed Head of the newly formed Research Laboratory. Promotion saw him in the position of Deputy Chief Mechanical Engineer (Construction) and later as Manager of System Planning.

He joined the University of Cape Town in 1975 as Professor of Mechanical Engineering. Whilst in the Department of Mechanical Engineering he started the Energy Research Institute, which is now a separate entity within the Faculty of Engineering. He is currently Professor of Applied Energy and Director of the Energy Research Institute.

Professor Dutkiewicz served as President of the South African Institution of Mechanical Engineers in 1978/1979. He presently serves on a number of international committees dealing with alcohol fuels, energy demand-side management, environmental matters, etc.

THOM C

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Fax.: (012) 841 3954

Cecile Thom is a researcher and project leader in the Development Services and Technology Programme at the CSIR. She has been involved in the development and implementation of low-cost biogas technology in South Africa over a period of four years. During 1993/1994 she completed a research paper on rural energy policy in South Africa (Energy for rural development) as part of the Energy Policy Research and Training Project that was conducted at the Energy for Development Research Centre (EDRC) at the University of Cape Town.

She hold a Master's degree in Energy for Developing Areas, and is currently involved in energy planning in rural areas, with particular emphasis on local participation.

VAN DER RIET M

B.Sc.(Appl.Chem.)(Wits), B.Sc.(Hons.) (Appl.Chem.) (Wits), Ph.D.(Wits), Pr.Sci.Nat., MSACI
Chief Consultant (Fuels Combustion), Technology Research and Investigations, Eskom, Private Bag 40175, Cleveland 2022, South Africa
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Mark van der Riet studied at the University of the Witwatersrand, where he completed his doctorate on catalysts for coal synthesis gas conversion in 1988. He then joined Eskom's Engineering Investigations to initiate their coal combustion research facility. This facility now provides Eskom and outside industry with an applied coal research and investigative service, and encompasses a broad range of activities.

Mark's current responsibility is to coordinate these activities in the role of Chief Consultant, to which he was appointed in 1993. His areas of special interest include the study of the region's fossil fuel reserves, an the appropriate technologies for maximising their efficient and effective utilisation.

Forthcoming energy and energy-related conferences: 1995

1995

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26-26

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Email:louise@frd.ac.za
bettie@frd.ac.za

SEPTEMBER 1995

9-16

ISES 1995: IN SEARCH OF THE SUN Harare, Zimbabwe

Enquiries: In Search of the Sun, P O Box 2851, Harare, Zimbabwe

Tel.: (263) (4) 730 707
Fax.: (263) (4) 730 700

Email: xcarelse@zimbix.uz.zw

Recent energy publications

ERENS P J and DREYER A A

Cooling tower packing material characterization and optimization. Sep-1994. 246p.
Report No. ED9202

The main aim of this project was to a develop a computer program which can be used to optimise the design of effective splash-packs incorporating basic information, such as drop dynamics, drop formation processes in a tower and the given water and air inlet conditions without employing empirical data obtained from other splash-pack tests. The outputs required to achieve the above result included an extensive literature survey, a compilation of a database of fill characteristics, the development of the required theory to model the process and experimental studies to generate basic empirical data as well as test cases for comparison purposes.

GAUNT C T

Analysis of overhead distribution line outages. Aug-1994. 46p.
Report No. EL 9001

A survey was undertaken of 200 medium-voltage distribution lines operated by different electricity supply authorities. Most line were operated at 11 kV. The frequency, duration and causes of outages and the related damage were analysed. The design and construction of the lines were also analysed and relationships between the outage data and the line characteristics investigated. The perception of the performance of the line was compared with performance indices.

*MEARNS A J

The effect of barometric pressure on spark ignition engine operating characteristics. Apr-1994. 76p.
ERI Report No. GEN 165
R34,20

The primary objective of the project was the design and construction of a test cell capable of simulating a high altitude environment for engine testing. The secondary objective was the determination of the change in knock response and other operating characteristics of a range of high volume engines in use in South Africa.

SCHOLES R J *et al.*

Synthesis study: Energy and environment policy. Aug-1994. 60p.

Aims to identify the key issues in the interaction of the energy sector and the environment in South Africa, discusses the manner in which they are addressed by current policy, and suggests policy options for the next two decades. The key characteristics of the energy sector in South Africa are briefly summarised in Section 2, as are the country's physical and biological environments in Section 3. Section 4 points out some of the constraints the South African environment imposes on energy provision options. Section 5 highlights some 25 issues in the interaction between energy and the environment, notes the current policies, and outlines some policy alternatives. Section 6 presents some of the philosophical choices which underlie policy stances. Section 7 highlights the policy gaps and opportunities, as well as the key research needs.

TAIT H E and LEKALAKALA J S

Optimization of a coal-based low-cost, low-smoke reconstituted solid fuel. Jul-1994. 25p.
Report No. EO9203

Presents the results of the optimisation study on low-cost, low-smoke reconstituted solid fuels used in some developing areas of South Africa, conducted during June 1993 and the related statistical results. The aim of the study was two-fold: (1) to optimise the fuel briquettes in terms of minimising their pollution and smoke propensity, and to optimise their affordability in terms of the components; (2) to ensure that unsold duff coal could be utilised effectively in this fuel and to evaluate the cost implications of using this duff coal to manufacture the reconstituted fuel. The fuel was tested in a brazier and in a SABS 1111-approved smokeless coal stove. Combustion emissions of SO_2, CO, CO_2, total suspended particulates and VOCs were measured. The study provided valuable insights into the impact that each of five design variables tested has on the emission performance of a reconstituted fuel, and into the interactions between these variables.

TOMECKI A B and TAYLOR M L

Economic evaluation of diesel-driven vehicles versus petrol-driven vehicles. Mar-1994. 55p.

The following specific objectives were set for the project: to identify comparable diesel- and petrol-driven vehicles; to analyse vehicle operating costs of the selected sample of diesel- and petrol-driven vehicles; to analyses and compare the economic efficiency of diesel- versus petrol-driven vehicles; to quantify the benefits of diesel-driven vehicles. The analysis was conducted on two comparable samples of light delivery vehicles. The economic considerations included fuel consumption, vehicle purchase price, cost of insurance and other vehicle operating costs. It was established that diesel-fuelled vehicles are more fuel efficient; and the purchase price of diesel vehicles is higher. It was recommended that the government should review the current petrol/diesel price differentiation and should consider lowering the diesel price to match the situation in overseas countries.

TOMECKI A B and TAYLOR M L

Integrated evaluation of diesel-driven midibuses. Phase I: Development of methodology. Mar-1994. 52p.

The project was undertaken to gain an insight into the current operations and effectiveness of midibuses in South Africa and to assess their potential. The main objective of the project was to develop an integrated evaluation methodology. The work on Phase I is reported here, the objective of which was to develop the evaluation methodology, identify the data requirements and determine which data are available and can be retrieved, and which still have to be surveyed. The methodology developed is based on three aspects: operating efficiency, energy (fuel) efficiency and travel comfort. Important performance indicators for both operators and passengers were identified.

All these reports are Final Reports and are the result of research funded by the Chief Directorate: Energy, Department of Mineral and Energy Affairs.

The publications can be ordered from: The Librarian, Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria 0001, South Africa, unless otherwise indicated. Prices are available on request from the Department of Mineral and Energy Affairs.

Reports marked * are also available from the Information Officer, Energy Research Institute, P O Box 207, Plumstead 7800, South Africa, at the prices indicated.

JOURNAL OF ENERGY IN SOUTHERN AFRICA

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Contributions to the *Journal of Energy in Southern Africa* from those with specialist knowledge in the energy research field are welcomed.

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2. Only original work will be accepted an copy-right in published papers will be vested in the publisher.
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