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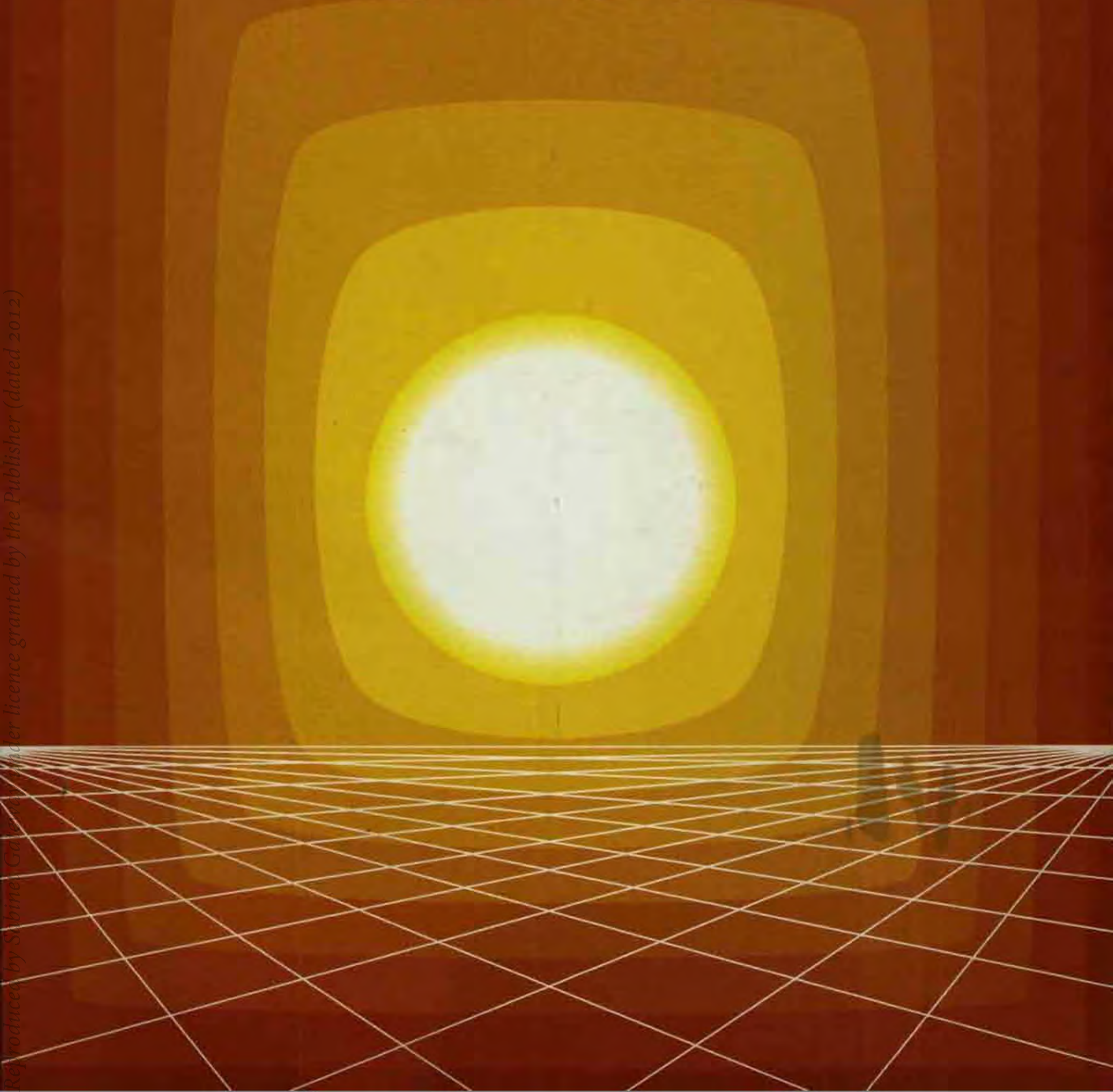


LEADERSHIP IS ACTION
NOT POSITION
"Traditionally business has measured market leadership in volume
and sales and the bottom line. No longer good enough. Righ
now in South Africa the success of a business will als
be gauged by how it values people. Creating
opportunities for those they employ
Empowering the lives of those they don't
It makes good sense. Morally
Economically
Business must lead by
example. Create an
environment in which
all people can reach for
better things. And grasp
them. This is the lead
Caltex has taken. For withou
action, position means nothing.
Mike Rademeyer
Chairman and Managing Director
Caltex Oil South Africa
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Contents

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 Only previously unpublished work will be accepted.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

Those wishing to submit contributions for publication should refer to the guidelines set out in *Information for Authors* on the inside back cover of the Journal. All papers are refereed before publication.

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Profile:

Allen Morgan
SANEA Chairman; Chief Executive, Eskom

Allen John Morgan was born in Cape Town in 1947. He obtained a B.Sc., B.Eng.(Elec.) degree at the University of Stellenbosch, and in 1972 started his career in Eskom as an engineering assistant. His work with Eskom has given him a great deal of operational and strategic experience in utility management. He has worked as Construction Superintendent, Senior Engineer in Operations, Distribution Area Manager, and Hex River Power Station Manager. His corporate career started when he was appointed Management Services Manager of the Eastern Transvaal region. During the next eight years, he steadily climbed the ranks from Orange Free State Regional Manager (1986), Distribution Divisional Manager (1988) and Deputy General Manager (Distribution and Marketing) in the same year. In January 1992, he was appointed Executive Director (Marketing and Electrification) and later that year, Executive Director of Sales and Customer Services. After the retirement of Ian McRae in 1994, Allen Morgan was appointed Chief Executive of Eskom and Chairman of the Management Board, positions which he holds today.

He is also a director of the Atomic Energy Corporation and a board member of the Ort-Step Institute. He has been associated with the World Energy Council (WEC) for some years and in January 1996 became Chairman of the South African National Energy Association (SANEA), the WEC's South African member committee.

Allen Morgan's chairmanship of SANEA brought about a major review of the organisation. He recognised that SANEA had to support the needs of the entire energy industry in South Africa and took steps to ensure that this would be undertaken effectively. One of these steps was to relocate and establish an independent SANEA Secretariat which had, since its inception, been housed on Eskom property and thus, seen to be mainly part of only one segment of the energy industry.

Allen is married and has three children.

Profile:

Bruce Crookes
SANEA Secretary; Executive Director (Generation), Eskom

Bruce T Crookes was born in 1949 and raised in Natal. In 1969 he joined Eskom's Congella Power Station as an apprentice fitter and turner. His early career at the Congella and Umgeni Power Stations included their maintenance, operation and performance. In 1973 he obtained a National Diploma for Technicians (Mechanical) and in 1977, a Certificate in Nuclear Power Training (NUS Corporation). He obtained a B.Comm. from UNISA in 1979 and B.Comm. (Hons.) in 1982. He has been a member of the South African Institution of Mechanical Engineers since 1977 and became its Treasurer in 1990. He is also a registered Professional Engineer.

His varied career in Eskom includes important roles in the Koeberg Nuclear Power Station project, and in the Education and Operations departments.

He has been Power Station Manager (Orange Free State), Generation Technical Services Manager, Deputy General Manager (Human Resources), General Manager (Transmission) and Executive Director (Transmission). His current position is Executive Director (Generation), and he is thus a member of the Eskom Management Board.

Other positions which he holds include Eskom's representative at the General Assembly of the World Association of Nuclear Operators (WANO), Chairman of the Natal Navigational Colliery, and Director of Rotek Industries.

Bruce Crookes has actively supported World Energy Council (WEC) activities in South Africa and internationally since he became SANEA Secretary in 1993. In 1994, the WEC held its Executive Assembly in Cape Town. Bruce Crookes and Ian McRae (past-chairman of what was then known as SANCWEC) were responsible for the resounding success of this event. The same team ensured that the Regional Energy Forum for Southern and East African Countries, held immediately after the Executive Assembly, was as successful.

Bruce is married and has three children.

Profile:

Michael Corrigall
SANEA Director

Michael R V Corrigall was born in 1946. He was appointed full-time Director of the South African National Energy Association (SANEA) in January 1997. The appointment came about as a result of his active participation and involvement in the World Energy Council (WEC) for many years. His contribution during this period was particularly focused on the performance of thermal generating plant, in conjunction with several international utilities and organisations.

He holds an M.Sc. (Elect. Eng.) degree from the University of Cape Town and is registered as a Professional Engineer. He has also completed the Advanced Executive Programme through UNISA's School of Business Leadership. He also holds an Electrical Engineer's Certificate of Competency (Factories) and is a Senior Member of the South African Institute of Electrical Engineers. He has been active in South Africa's energy industry for the past 30 years, having had extensive experience in Eskom's electricity distribution and generation activities.

He started his career in Eskom's Western Cape Region, working in Substation Construction and subsequently the Test Department. In the early days of the Koeberg Nuclear Power Station project, he provided liaison between Eskom Corporate, Region and Site. He subsequently developed the Regional Nuclear Services department, set up and supervised contracts with external organisations that provided off-site support services to Koeberg on, for example, meteorological and marine ecological matters. In the mid-'80s, he also managed Regional Nuclear Emergency Planning and Regional Health Physics related to Koeberg.

From late 1986 until November 1989, as Deputy Power Station Manager, he managed the operation, maintenance and project management functions at Duvha Power Station in the Eastern Transvaal (now Mpumalanga).

As Eskom's Generation Performance Manager and Generation Systems Enhancement Manager (from late 1989 to mid-1992) he established a data management function and developed a strategy for Information Resource Management to assist in achieving Generation's goals.

Michael Corrigall became the Generation Plant Performance Consultant in August 1992 and held that position until his appointment to SANEA. In this position, he was involved in establishing an electronic Executive Information System (EIS) for plant performance, and the development of reporting systems and UNIPEDE indicators in line with international practice. An important element of this role was to support the formulation of strategies for improving plant performance.

Several papers authored by Michael Corrigall appear in WEC publications relating to the performance of thermal generating plant, and he participates actively in international Working Groups relating to this topic.

Michael is married and has three sons.

Solar lanterns: Results of marketing tests in the rural areas of Kenya and Niger[1]

* R J VAN DER PLAS[2]

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Solar companies often regard solar lanterns as too small and unprofitable for large-scale sales. Thus they are usually only found in very limited quantites in a few stores in African capital cities – if at all. In addition, they are generally designed for the weekend market in industrialised countries rather than for everyday use in developing countries. Nevertheless, current solar lantern models provide a substantial increase in living standards in developing countries, and have a relatively short payback period. The solar equipment market is by far the largest of its type in Africa. These observations are the result of a test marketing operation in which hundreds of solar lanterns (several different models) were placed on sale in rural stores in Kenya and Niger. This paper describes the results of this operation and recommends intervention at several levels.

Keywords: solar lanterns; lighting; domestic energy; Kenya; Niger

Introduction

At present most solar lanterns are manufactured for short-term lighting needs in Western countries, such as for camping or other weekend activities. Solar-charging during the week would enable the lantern to provide sufficient lighting during a weekend. However, they fail to provide four hours or more of continuous operation for seven days a week, the typical requirement in Africa. In addition, most solar lanterns are still fairly expensive, varying in price from $80 to well over $350 for a complete kit. This is the retail price range (inclusive of VAT and import duties) in Africa for a kit consisting of a module, battery, controller, switch, lamp and housing.[3]

Rural households generally use kerosene lamps (often made from tomato paste cans with an inserted cotton wick), hurricane lanterns, or candles to satisfy their lighting needs. Such lights have the power to emit no more than 10-15 lumen for the locally made wick lanterns or 40-50 lumen for the imported hurricane lanterns. In fact, most households do not use more than one light point in any one room at the same time. Doubling the number of lamps results in double the cost but there are hardly any incremental lighting benefits. Light is used mainly to make out the outlines of objects and to prevent people from bumping into each other or the furniture. The combined costs of candles, kerosene and dry-cell batteries are quite substantial, for example, the monthly mean expenditure for the sample in Kenya was US$5,6 for kerosene and US$5,0 for dry-cell batteries, and in Niger US$7,7 for kerosene and dry-cell batteries combined.

Solar lanterns will providein many instances, 10 times more light than what is presently used . Thus they can be considered as the first step up the modern lighting ladder. In fact, solar lanterns are the lowest cost-alternatives for lighting, but the upfront investment costs are still high when compared with actual lighting costs. With this in mind, the World Bank, through its ESMAP programme[4], organised an open tender with a view to developing a lower-cost, medium light output solar lantern[5].

The project

These lanterns were offered for sale in the rural areas of Kenya and Niger, with a 6-month unconditional money-back guarantee. Fifty kits were purchased from all the manufacturers who offered models for sale that generally complied with the specifications. A total of 320 lanterns (six different models) were placed in five stores in Kenya. About six months later four of the most promising models were also placed in five stores in Niger (200 in total). Local NGOs managed the projects (the EAA in Kenya and the ERE in Niger)[6] by keeping contact with store owners and households. Although the World Bank purchased the lanterns in Belgium, India, Kenya, the U.K. and the U.S.A. for between $40 and $120 each, manufacturers claimed that long-term retail prices would be of the order of $30-$60 each or lower when sold in large quantities[7].

Shop owners were shown the different lanterns and were given the wholesale price of each lantern[8]. In Kenya they were provided with the long-term price as set by the manufacturers. In Niger they were told that all lanterns would cost the same (i.e. $50 retail). They then took a few lanterns of their choice and placed them on display in their shops at no risk to themselves, as the money was only collected

1 The article will also be published in a French Journal: "Liaison Energie-Francophonie", Institut de l'énergie des pays ayant en commun l'usage du franHais.

* Industry and Energy Department, World Bank, 1818 H St. NW, Washington, DC 20433, USA.

2 This paper reflects the views and opinions of the author and does not, in any way, reflect the views of the World Bank

3 Comparative test of solar lanterns, Technology Demonstration Center (Synopsis), Plataforma Solar de Almeria; August 1995.

4 The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance programme run by the World Bank's Industry and Energy Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and 15 bilateral official donors in 1983, it focuses on policy and institutional reforms designed to promote increased private investment in energy and supply and end-use energy efficiency, natural gas development, and renewable, rural and household energy.

5 The specifications stated: 150-200 lumen light output, 2-year service life, 3 hours of light every day of the week (normal conditions), and $50 retail when sold in large quantities.

6 Many thanks go to Mark Hankins and Daniel Kithokoi of Energy Alternatives for Africa, and Kiri Tounao and Saley Yahaya of Energies Renouvellables et Environement.

7 Private communication with manufacturers.

8 They were free to set the actual selling price, as long as the mark-up did not exceed 20%. The project in a way subsidised the lanterns because it paid the shipping costs (which were unreasonably high because of air freight). Import duties and VAT were omitted due to thenature of the pilot project. The wholesale price communicated to the shop owners was in fact the long-range wholesale price.

after the sale had been made. "Potential" clients were informed of the benefits and inconveniences of the lanterns, and were told that the full purchase price would be reimbursed if the lantern was returned - for whatever reason - within six months of purchase. Every purchaser was asked about expectations and current energy use and expenditure at the time of purchase, and the project teams attempted to visit all households that purchased a lantern to ascertain actual performance details and the user's perceptions. Users of returned lanterns were also asked to fill out a questionnaire. In both Kenya and Niger project personnel were able to interview about 66% of households that had purchased a lantern.

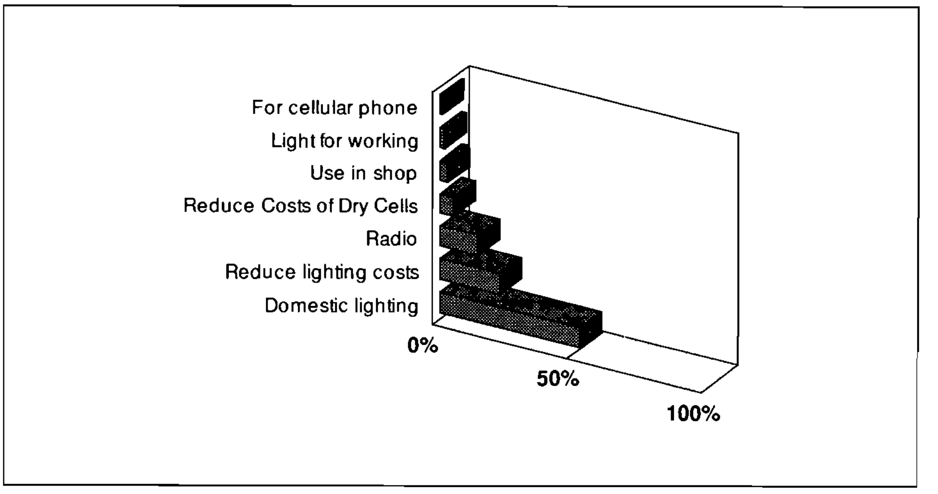

Figure 1: Expectations from solar lanterns

The equipment

Various components were used to make up the lantern kits. However, there is no clearly described method on how to construct the ideal lantern. Most kits contain a PV module that is connected by means of a wire to the lantern. The lantern itself contains the lamp, a battery, and possibly some electronics, as a ballast/inverter for a fluorescent lamp, and a low and/or high-voltage disconnect to prevent battery damage occurring. Light bulbs included are 4 and 6 Watt TLs (fluorescent tubular light), 5 Watt PL (compact fluorescent light), a 3 Watt incandescent krypton bulb, a 1,4 Watt amber LED (Light Emitting Diode) cluster light and a 1,4 Watt "rainbow" LED cluster light. Three of the models had dual lights which could be switched on simultaneously (low- or high output), and one twin-light model allowed the operation of only one light at a time. In general, the more light emitted, the better the user's appreciation. All models except one had separated the module from the lamp and housing. The integrated kit was among those not sold. Modules ranged from 1,75 Watt to 6 Watt (6 volt), and from amorphous (single and triple junction), polycrystalline to monocrystalline. There were no clearly expressed preferences for a particular type of module. Most batteries were sealed lead-acid gel cells of 6 volt, 4 Ah. However, one system used 4 C-cell Ni-Cads. Only one battery was a 12 volt model, 4 Ah gel-cell. It was found that the 12 V battery and the Ni-Cad batteries were used for other purposes. One of the kits was assembled from scrap material (wood and tins) by the informal sector in Kenya, with a view to finding out if people were willing to accept low-cost locally made lanterns (The answer was "No").

On a fully charged battery, lamps were able to operate from 2,5 to 40 hours continuously (mean: 12,1 hours). In practice, users responded that they used the lamps about 3,6 hours per day in Kenya[9] and 3,8 hours per day in Niger (range: 2,5 - 4,3 hours/day for the different lantern models in Kenya) under normal summer weather conditions.[10] This indicates that the systems are well-designed overall[11], and that if a second module is added, greater benefits would be enjoyed without risk of technical problems. This marketing strategy was not pursued by the equipment suppliers.[12]

User expectations

Most of the people who purchased a lantern wanted access to a more modern form of lighting, or wanted to improve the lighting in their homes (more than 70% of responses, as shown in Figure 1). In Niger, about 30% indicated that they would use the lantern in a shop or workshop, for commercial or production purposes. Some 15% in Kenya wanted to use it as a radio connection. However, this was unsuccessful because the design of the lanterns in most cases (except one model) did not allow for this type of usage.

Technical performance

Most lanterns were unacceptable from a strictly technical point of view. They lacked low-voltage disconnects and had poor quality light bulbs or electronic ballasts. Even if low-voltage disconnects were present, they were set to disconnect at below 50% state of charge (SOC). Thus they effectively did not protect the battery. Many of the TL lights were of inferior quality or the electronic ballasts/inverters were of poor quality. As a result, many lamps showed blackening at an early stage. One manufacturer replaced the TLs with others of a higher quality, which gave more satisfactory results. Another manufacturer improved the electronic design of the lantern after having heard the initial results in Kenya. Thus the lanterns sent to Niger were of a much higher standard. (This also explains the late arrival of the lanterns in Niger).

A total of 49% of all the lanterns placed in stores were sold[13] (see Figure 2), and 9% were returned (or 18% of the lanterns sold). Of the preferred model (98% of the lanterns placed in stores in Kenya and Niger combined were sold) only one lantern was returned (1% of the total sold) because of battery failure. Of the second model (93% sold) 28% of the total number of lanterns sold in Kenya were returned, and 9% in Niger, mainly because

9 In Kenya (Meru area): 5 kWh/m^2,day; in Niger on average during the test period 6,4 kWh/m^2,day.

10 Power consumption associated with this usage is likely to exceed the charge built up during the day. This means that over time the batteries are drawn down, and fluctuate on a daily basis to just above a very high state of discharge. This, in turn, results in a short battery life.

11 A full day's charge would allow the usage of 3-4 hours of light (this varies for each lantern, and depends on the actual isolation).

12 See: 'Solar Electricity in Africa: A reality', Mark Hankins and Robert van der Plas. To be published in a forthcoming issue of *Energy Policy*.

13 The remainder was refused by retailers who were unwilling to stock and carry these in their stores.

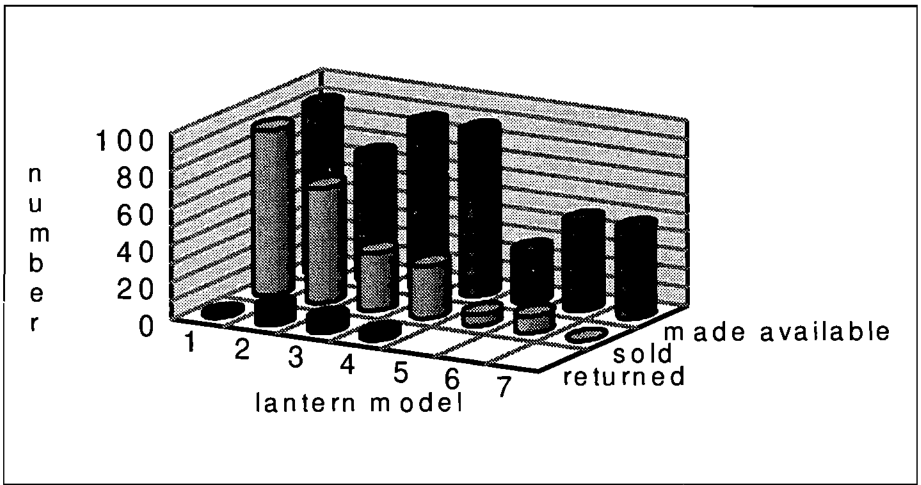

Figure 2: Results of the test marketing of the solar lanterns

of battery problems. Of the third model (35% sold), 8% were returned in Kenya and 32% returned in Niger because of battery problems or failure of the controller card. None of the few lanterns sold of models 4-8 were returned.

The main reason given by people returning lanterns was technical failure, which resulted in unsatisfactory performance. Failures included dead batteries, blackened or failing bulbs, and failing controllers/ballasts. It is difficult to conclude that the batteries themselves are the weakest component, as both controller/low voltage disconnect failure and over-use also result in reduced battery life. Thus it can be claimed that, in general, people were satisfied with the increased services rendered by the lanterns, as dissatisfaction was not given as a reason for returning a lantern.

The results

The first step up the energy ladder is a crucial one as it provides the largest incremental benefits. Stepping up from candles or a small kerosene wick lamp to a 6 Watt TL-type fluorescent lamp represents, literally, the difference between day and night. Although people sought increased lighting levels, once they actually enjoyed these, they quickly adopted them as their new standard and desired still greater illuminance.

The people were offered a choice, as a variety of models were available at a time, and no pressure was exerted on anyone to buy a particular model of lantern. The people seemed able to cope with this new technology that had now been made available to them. They showed a clear preference for one or two models, quickly purchasing their choice in cash. The more popular models of lanterns were sold out in less than three weeks in both countries. It is remarkable that there were so few differences in the responses from Niger and Kenya, suggesting that the results might also be valid for other parts of Africa. Three models were rejected outright (e.g. not a single lantern was sold in Kenya, and therefore these models were not included in the tests in Niger), and the verdict also went against three other models (only a few were sold). Interestingly enough, after the preferred lanterns had sold out, additional lanterns were requested from people who had seen the lanterns in operation and wanted to buy one for themselves. In Niger, one model of the lanterns was delivered several weeks late, at a time when all the preferred lanterns had already been sold out. Project personnel decided to raise the price of this latecomer to actual costs (US$89, excluding duty, VAT, transport costs) in order to see what impact this would have on sales. In fact, this model - which was the second most popular choice in Kenya - was sold out in three days. This certainly shows clear and consistent market preferences.

The lanterns were used in several locations within and around the house and were also carried to the place where they were most needed. Not a single household reported that they used the lantern only in one room. Some 52% could not indicate in which room the lantern was used most, while 23% specified the living room and 17% specified the bedroom. Beneficiaries included (1) children (17% of responses) who used the lanterns to provide light for studying, (2) women (39%) claimed that the lanterns enabled them to extend their working hours, and (3) men (39%) claimed that the lanterns allowed better socialising. Five percent specified that the lanterns were used for other purposes e.g. while travelling, to give away as a present, as "snob" value, etc. Solar lanterns thus provided a direct link to increased living standards, and indirectly, to rural development.

Financial savings

Expenditure on kerosene and dry-cell batteries was significantly lower after people purchased their lanterns. Kerosene expenditure in Kenya showed a reduction of more than 60% (59% of interviewed households responded), and dry-cell battery expenditure dropped by as much as 90% (however, only 11% of interviewed households responded - those who had purchased a model with a 12 V battery or a model with Ni-Cad batteries). Mean monetary savings on a yearly basis amount to $41 for kerosene and $46 for dry-cell batteries, and $46 in Niger for both combined. This suggests a minimum payback time of about 1-1,5 years, indicating that solar lanterns may also generate direct economic benefits.

Consumer preferences

The choice of users was influenced by a high light output of good quality, spare light bulbs that are readily available, and the design and overall look of the lantern. Six Watt fluorescent TL lights are readily available, but four Watt lights are not. These, together with the light output differences (4 vs. 6 Watt) between two lanterns that look remarkably similar, are the main reasons for rejecting one and accepting the other. Other reasons for rejection included locally made, poor-quality light, non-availability of spare light bulbs, overall design and look. The retail price of more than $50 was regarded as acceptable by all users. None of the retailers in Kenya provided informal credit to buyers, although retailers in Niger allowed people to pay in 2-5 payments, which about two-thirds of buyers preferred, while one-third paid in cash.

Discussion

The fact that the lanterns were available in their own villages was greatly appreciated by the people. Although solar modules are readily available in all cities and most large to medium-size towns in Kenya (but available only in the capital of Niger), solar lanterns are not available outside of Nairobi. Solar equipment suppliers, hopeful of increasing their business, clearly need to build the infrastructure for this in the rural areas and should not limit themselves only to large towns or the countries' capital cities.

The assumption that people are willing to accept a low-cost, low-light output lantern is clearly wrong. The light output desired is high: 5 Watt PL and 6 Watt TL bulbs are acceptable, whereas a 4 Watt TL is not. That light output is a greater determinant of acceptability than appearance was demonstrated by the reaction to the model that uses twin 6 Watt TLs (although it can only operate on one at a time). The electronic ballast is designed in such a way that the lamp only consumes 3 Watts, thereby compromising the light quality, and this was not acceptable.

Even though the designs are not sufficiently technically reliable, it appears that the equipment will be fully paid back from the saving of energy and that, in fact, with the purchase of a few spare parts, the physical life of the equipment can be extended to last 3-4 years. Thus it makes sense to promote solar lanterns, albeit with technical modifications, as they provide rural households with access to modern lighting at a low cost – if not the lowest cost.

Counter-productive policies

There are certain additional costs which could be regarded as counter-productive to making solar lanterns economically viable. For example, transport costs will result in solar lanterns costing the end-user an additional 10%, import duties and VAT will add another 20%-30%, and profit margins another 30%-40%. This will put ownership of a solar lantern beyond the reach of many potential customers. The reduction or elimination of duties and taxes will assist in generating higher sales, thus further reducing the need for high profit margins. The rationale for removing duties and taxes is: (i) total tax revenues are likely to be small (assuming a market of 50 000 kits per year at $65 CIF per lantern, and a 30% combined tax and VAT regime, the Treasury will not even gain US$1 million); (ii) subsidies flowing to rural electrification programmes are likely to be higher than the potential tax revenue from solar lanterns; (iii) solar lanterns are likely to benefit more rural people than rural electrification programmes; (iv) it is unlikely that modern lighting could be brought to rural households for less than the cost of a solar lantern; and (v) many countries have abolished duties and taxes on conventional electricity generating equipment but charge levies on solar equipment because they are regarded as "luxury items". There should be a "levelling of the playing fields" with regard to the costs of the different energy alternatives, such as solar energy.

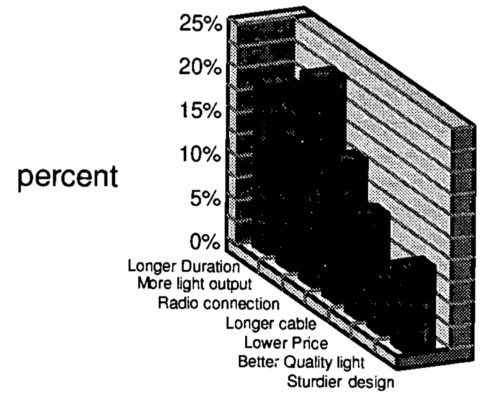

Figure 3: Suggested improvements

Suggested modifications

Data from the surveys suggest the following: (1) about 23% of the total responses (multiple responses were allowed, as can be seen in Figure 3) indicate that people also want to power their radios from their solar kit, and (2) 40% want more hours of light, higher light flux (lumens[14]), or better quality light. This could be accommodated by adding a second panel to the solar kit and by modifying the housing to include a socket for a radio connection. Such a second panel could be purchased some time after the initial purchase of the lantern is made (e.g. after the second harvest), or a larger module than normal could be made optional at the initial purchase of the lantern. Some 16% want a longer cable between the lantern and the module – a simple matter to resolve. A sturdier design (9%), better insect resistance, and lower cost (11%) are all aspects that can and should be considered by manufacturers.

14 Lumen is not a SI unit, but it is a derived unit. The author states that a suitable SI unit had not, up to the time this paper was written, yet been found.

Future directions

Three sets of recommendations are made, one to rural households or to prospective solar equipment users, one to manufacturers of solar lanterns, and one to governments.

To *prospective solar equipment users,* carefully weigh your needs against your costs: a good, small battery (about 20 Ah) plus a small solar module (about 12 Watt) and a few appliances (e.g. lights, radios) give more flexibility and benefits, but also costs more than a solar lantern. A solar lantern can be a good starting point for immediately increasing lighting services in rural areas, and benefits can be built up over a few years if the lantern kit is expandable. However, the time will come when the demand for more benefits will outgrow the lantern kit's capacity to deliver. Nevertheless, the lantern will still pay for itself over time, making the investment worth considering.

The better the user understands the functioning of the lantern, the longer will be its expected life. For example, if the user understands that the storage capacity of electricity is limited, that only a limited amount is stored during the day (less on cloudy days, more on sunny days), and that energy consumption, ideally, should not exceed the energy stored during that day, he/she can expect the equipment to last for a long time. At present, people have no way of knowing how much energy has been stored in the lantern, nor how much they have used.

Manufacturers should listen to the suggestions made by the people in the rural areas and attempt to improve the solar lantern models accordingly. Two examples which demonstrate why this important are described. (i) A manufacturer who saw high returns in Kenya made modifications to his model and included these improvements in the models he sold in Niger. Although he still had a high return rate, the people liked his lantern so much that they bought up the whole stock in just a few days. (ii) ESMAP has taken the concept one step further in another demonstration project in Cameroon. A local investor was merely shown the lanterns and a partial guarantee was given that he would sell 100 solar lanterns within six months. ESMAP gave the investor six lanterns, two each of the number one model described earlier in the paper which was sold in Kenya and Niger, and two of a model that had not been included in the earlier field tests but which is a redesigned model of a lantern that has sold tens of thousands in Africa. The older version of this model was not very good, but field tests of the redesigned model (along the lines described above) are promising. The investor preferred the later model and purchased 100 of them to be sold in Cameroon on a test basis.

In order to obtain better service from their lanterns, users need feedback on the battery's level of (dis)charge in some way or other. An indicator light showing normal battery operation would be useful, alerting the user, for example, when the battery's charge is running low, that consumption for that day has been greater than the amount of energy stored for that day, or that the set number of consumption hours has been exceeded (such as 3 or 4 hours per day). A well-performing, low-voltage disconnect should be included in every lantern which is set at an appropriate level to guarantee a minimum 3-year life of the battery. An audible alarm or a flashing light which operates for a short time would be useful to warn users that the power has almost all been used up.

The demand for solar lanterns will come largely from the rural areas. Thus a suitable infrastructure needs to be set up in these areas, not only for sales of equipment but also for repairs and the sale of spare parts. Rural people would be more likely to purchase a product quickly if it is made available locally, e.g. "in their own neighbourhood". A more modular approach to the availability of equipment (options such as larger modules, modules in parallel, lanterns with one or two lamps, or a detachable lamp, a radio socket, a plug to allow charging from the mains, etc.) will also make solar equipment more accessible to rural households. Low-cost designs are likely to be sold more quickly, and it is up to manufacturers to make sure that this is addressed in the redesigning of their models. The lighting market in developing countries is a new market and is distinctly different from the weekend or the luxury market found in Western countries.

Finally, *enabling policy considerations* that should be systematically addressed include the removal of high import tariffs and excise taxes to ensure that solar lanterns and other solar equipment are not unnecessarily penalised. Solar energy may be the only modern electricity option available to many rural people for several decades to come. In fact, the use of solar equipment should be nurtured, and its efficient and rapid commercial distribution should be facilitated and promoted. This would be a start in bringing the benefits of the 20th century into the homes of many rural people.

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Natural gas from biogas

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Many authors have addressed the usage of biogas from sewage and landfill biomass as a renewable energy source. The extraction and utilisation of crude biogas have been widely discussed. The basic problem in utilising biogas is that it only contains 50%-65% combustible methane. In many instances, the remaining incombustible carbon dioxide increases the storage and transportation costs to an unviable level. This paper gives an overview of a solution to this problem, i.e. by upgrading the methane content of biogas to a natural gas equivalent. All the application equipment pertaining to natural gas can then be used. Natural gas applications have been extensively developed globally and include town gas, electricity generation by gas turbine or gas engine, and vehicle fuel. Natural gas is a more environmentally friendly fuel than liquid fuel and extends engine life. Locally developed and manufactured membrane systems are able to remove the carbon dioxide from biogas thereby enriching the product gas to a natural gas methane equivalent.

Keywords: biogas; digester gas; renewable energy; membrane separation; methane; natural gas; gaseous fuels; South Africa; AEC; natural gas vehicles

Introduction

Biogas is generated from the decomposition of biomass and consists primarily of methane and carbon dioxide in approximately the same proportions. Carbon dioxide is a combustion product of methane that is naturally converted to oxygen and carbon by photosynthesis. Carbon is a building block of all plant material but the oxygen is released into the atmosphere. Biogas is consequently a renewable form of energy[1].

Biogas is a natural product of the anaerobic digestion of sewage and landfill biomass. Sewage digester gas contains approximately 65% methane by volume, while landfill gas contains 50%. After closure, a typical landfill site could produce 1 500 m^3 per hour of biogas. Some 60% of this is extractable. The thermal energy value of the extracted gas (900 m^3 per hour) amounts to 4 MW. If 80% of this energy is recoverable, 3,2 MW of thermal energy are available, which could supply 4 600 households with energy (500 kWh per household per month), fuel for 1 000 light vehicles (3 million litres of petrol per annum), or generate 1 MW of electricity. Landfill gas production, however, diminishes[2] by approximately 50% after ten years or more, and this effect has to be taken into account during capacity planning.

Many authors have addressed the subject of using the energy potential of biogas. Most of these efforts only progressed to the point of extracting, flaring or utilising the gas in its crude form. The basic problem of utilising biogas is that it only contains 50%-65% of combustible methane. The carbon dioxide remainder is incombustible and, in many instances, increases storage and transportation costs to an unviable level.

Natural gas

Piped natural gas contains 85%-95% methane by volume and is found in abundance in many parts of the world, such as the United Kingdom, Europe, the United States, Canada, South America and Russia. A global shift away from liquid fuels is expected in those countries with natural gas resources[3], reducing fuel dependence on the OPEC countries. In Venezuela a government drive is currently shifting the country's vehicle fuel away from liquid to gaseous fuel[4]. Venezuela has crude oil as well as natural gas resources and would benefit from exporting the crude while utilising the natural gas.

Natural gas applications have been extensively developed globally. These include town gas, electricity generation by gas turbine or gas engine, and vehicle fuel. Natural gas is a more environmentally friendly fuel than liquid fuel and extends engine life[5]. More than 300 000 gas-powered vehicles are used in Italy alone. Around 37 000 vehicles run on natural gas in Canada. In Toronto alone, twenty gas refuelling stations are in operation. In Ontario, forty conversion shops carry out vehicle fuel to gas conversions. Small slowfill refuelling systems are available to refuel private vehicles overnight from a domestic gas pipeline. If biogas could be purified to a natural gas equivalent, all the application equipment pertaining to natural gas could be used.

The United Kingdom experience

The United Kingdom is a leader in the development of gas extraction from landfills. Currently more than one hundred and fifty sites are generating electricity from gas and many more have been supplied with pipes and are being monitored for environmental control purposes[6]. Because of this experience, the U.K. has become a world leader in developing cost-effective systems and equipment for the extraction and utilisation of landfill and digester gas. Stringent legislation forces degassing and the installation of flares to minimise harmful greenhouse emissions being transported and polluting residential and commercial areas. The greenhouse effect of methane is around sixty times[7] that of carbon dioxide, its combustion product. Flaring of extracted biogas is therefore the only, albeit unpopular, option. The migration of landfill gas to these inhabited areas can cause explosions, several of which have been reported[8].

Included in government legislation is the Non-Fossil Fuel Obligation (NOFFO). This procedure forces electricity companies to purchase electricity from producers of non-fossil fuels. In the first rounding of the NOFFO, the price paid was around five times that of the current rounding level. However, the next rounding level is expected to narrow the price gap, thus bringing it more in line with standard costs.

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Most of the electricity generation facilities use crude gas with some prefiltration as feedstock for the gas engine generator system. However, engines are subject to high maintenance costs because of various hazardous components in the biogas, particularly hydrogen sulphide. Gas turbines require good quality gas, typically at a gauge feed pressure of 800 kPa. Wet scrubber systems are used to remove the carbon dioxide and hazardous compounds. The equipment is, however, very expensive. In addition, the scrubber water causes effluent problems and the product gas is saturated with water.

The challenge

The challenge in utilising biogas is to find an economically viable way to produce a natural gas equivalent from biogas. An analogous concept is used by Sasol in the production of liquid and gaseous fuels from coal. Sasol is also pursuing the production of a liquid fuel from natural gas[9] in countries which have natural gas resources but lack crude oil.

Gas membrane separation technology can be used to produce a natural gas equivalent from biogas. Membrane-based projects have been reported in California[10] and Germany[11]. This technology has now been proven viable, using locally developed and manufactured membrane modules.

Membrane technology

A microscopically thin polymer layer is manufactured as an integral part of a supporting substrate made of the same material. Various gases display different characteristic rates of permeation through the membrane layer. The greater the difference in the permeation rates of gases, the more rapid the separation process. The separation process is pressure driven and the feed gas mixture is divided into gas passing through the membrane layer and gas retained. The former is called the *permeate* and the latter the *retentate*. Hollow fibres are commonly used to support the membrane layer. These hair-thin fibres are manufactured from polymers but are hollow, like a reed. The feed gas is introduced at pressure into the hollow fibres, the retentate leaves the fibre at the other end, while the permeate is collected on the outside of the fibres and separated from the feed and retentate.

Carbon dioxide permeates the membrane more rapidly than methane. By introducing biogas as the feed gas, a methane-rich retentate and a carbon dioxide-rich permeate are produced. Nitrogen unfortunately permeates at the same rate as methane and is therefore retained with methane. Nitrogen in biogas consequently limits the achievable level of methane enrichment with biogas. Nitrogen levels of 1% by volume have been used to achieve a biogas purification level of 95% methane content. At a methane content of 90%, the purified gas is equivalent to natural gas.

Through the Membrasep Division, the Atomic Energy Corporation of South Africa (AEC) has locally developed and industrialised a membrane technology specifically suitable for biogas purification. These membranes require low pressure (800 kPa gauge) feed and deliver the product gas at the same pressure, containing 90% - 95% methane by volume. Methane recoveries of 80% have been achieved at a 90% content of methane. Prefiltration removes hazardous compounds, resulting in a product gas equivalent in heat value, density and Wobbe Index to natural gas. Product gas can be fed directly into a gas turbine, gas engine, reticulation system, or can be pressurised to 20 MPa for vehicle fuel usage.

The local experience

During 1993 and 1994 the AEC concluded biogas purification trials at the Pretoria Eersterust[12] landfill site. The recovery of methane from landfill gas was demonstrated, using AEC-developed and manufactured membranes[13]. A petrol-driven vehicle was converted to a bi-fuel system, running on petrol or gas. Switching between fuel sources can be done while driving. The gas storage capacity of this vehicle is equivalent to 15 litres of petrol, with a range of up to 200 kilometres.

In collaboration with the Krugersdorp City Council, the trials at Eersterust were extended during 1996 to the Flip Human sewage works[14]. A more mobile demonstration plant was built, two petrol-driven vehicles were converted to run on purified digester gas and the bottling option was demonstrated. Krugersdorp is also investigating the use of the gas for greenhouse heating, brick manufacturing and town gas reticulation. The taxi market in the Johannesburg metropolitan area seems to be attractive, since several landfills are found in the area and taxi services usually operate with short runs.

The demonstration plant is able to produce 15 m^3 per hour of purified digester or landfill gas containing 90%-95% methane by volume in high pressure storage cylinders. This is equivalent to approximately 15 litres of petrol or diesel fuel per hour. During eight hours of operation of the plant enough gas can be produced to power 10 light vehicles, each able to cover 150 kilometres. The two vehicles were converted to bi-fuel systems, enabling gas or petrol selection while driving. Each vehicle was also equipped with onboard lightweight storage cylinders used as standard equipment worldwide on vehicles running on natural gas. The vehicles have a range of 200 kilometres. A diesel-powered vehicle will soon be converted to a dual-fuel system. In this case, diesel is supplemented by gas.

Economics

Electricity generation from natural or purified biogas is marginally economical in South Africa, as electricity costs are low. Niche markets do, however, exist in areas with high electricity costs. Vehicle fuel is a viable option and could be produced at a discount of up to 25% on current fuel prices, inclusive of vehicle conversion and refuelling equipment costs. By removing the carbon dioxide, compression, storage cylinder and transportation costs are reduced. The town gas option is also viable, as it can be produced below the minimum local gas prices. A longer-term view of five to ten years must, however, be taken regarding the financing of these schemes to ensure economic viability because of the capital-intensive nature of such projects.

Biogas and South African energy requirements

According to a local study[15] published in 1993, a total of 24 416 m^3 of biogas per hour were available from the 42 landfill sites investigated. This represented a population of 7,6 million people. Extrapolated to the current 40 million population of South Africa, the total volume of biogas available is in the order of 130 000 m^3 per hour. Of the 42 sites, the five producing more than 1 000 m^3 per hour were estimated to produce 11 111 m^3 per hour. From this information it can be calculated that 12% of the surveyed sites produced 46% of the gas. A few large sites produce most of the landfill gas and are situated in metropolitan areas.

The recoverable thermal heat value of 11 000 m^3 per hour is 40 MW, equivalent to 35 million litres of diesel fuel or 40 million litres of petrol per annum.

Although this constitutes only a small fraction of the total energy requirement of South Africa, the amount of biogas available is substantial and will contribute towards energy cost savings for municipalities as well as towards a better environment. In future, the world will, however, experience a shortage of energy sources and all available sources of energy will have to be used [16].

Membrane technology has the advantage of modular design, enabling the utilisation of biogas sources from 50 m^3 per hour to 5 000 m^3 per hour.

Conclusion

Purified biogas serves as a natural gas equivalent. All applications and equipment relating to natural gas can be used. Membrane technology has been proven to be a viable purification process, and locally developed and produced technology is available. However, biogas is a limited energy source and will never be able to compete with natural gas or crude oil resources. A valuable resource otherwise wasted can be recovered and economically utilised while saving the environment.

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Development of a public energy savings awareness campaign in South Africa

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South African households contribute 15% to South Africa's total electricity consumption and 30% to peak demand. These figures are expected to rise because of the electrification drive. To address this problem, the Department of Minerals and Energy (DME) launched an awareness campaign in 1996, the aim of which was to promote the effective use of domestic energy.

Local and international campaign material concerning domestic electricity was extensively reviewed. However, none proved to be satisfactory to South Africa's situation. The DME campaign was therefore undertaken using a unique holistic approach. Novel art concepts were combined with energy saving suggestions and a new readability index developed.

However, it is suggested that people are unlikely to implement any saving action unless they benefit directly from the saving. Information regarding the potential monetary saving for each action is thus essential. As this could not be obtained from the literature, technical calculations were conducted. The results showed which saving suggestions are economically most important for South Africa.

Such information would be invaluable to role-players such as the DME, Eskom, large municipalities, manufacturers, etc. The success of any future awareness campaigns would be greatly enhanced by only focusing on certain key issues. This article is concluded with some recommendations for future awareness actions.

Keywords: energy conservation; South Africa; public awareness; domestic energy

Introduction

The effective use of energy is a serious issue in the Western world. This is partly caused by environmental concerns over phenomena such as global warming and urban smog. South Africa is no exception.

Studies indicate that South Africa's contribution to the additional radiation load on the global atmosphere through emissions (such as greenhouse gases) is roughly 1,2%[1]. This is high, if one considers what fraction of the world's economy and population is made up by South Africa. Electricity generation accounts for a large portion of unwanted greenhouse gases[1].

The household sector is an important energy consumer. It is one of the largest contributors to peak demand and consumes about 15% of total electricity demand[2]. Energy savings in this sector are thus important. Thus, the DME started its awareness campaign among domestic energy users.

The campaign was expected to produce additional benefits because it was suggested that people who save energy at home will also implement savings at work. Children who are introduced to energy-savings techniques are likely to become energy-conscious leaders of the future. The campaign will thus have an ongoing effect on all energy-consuming sectors.

Ample opportunity exists for energy conservation in the domestic sector[3]. Unfortunately, South Africans are unaware of the potential benefits of energy efficiency. According to Doppegieter et al.[4] energy conservation is not regarded by the South African consumer as a priority because of a lack of available information on the subject.

Doppegieter et al.[4] further stated that many people regard electricity as relatively inexpensive. They also have the perception that South Africa has abundant energy reserves. Thus to many, energy conservation seems unnecessary. An Eskom survey confirmed this lack of concern for energy conservation[5]. Building contractors and home builders indicated that the public was not interested in energy-efficient houses.

It is thus necessary to try and change people's perceptions and behaviour towards the more effective use of energy. Doppegieter et al.[4] suggests targeted information programmes as part of the solution. Unfortunately, the mere supplying of information would be unlikely to permanently alter people's behaviour and perceptions. This can only be achieved through a national awareness campaign which educates and motivates people[6]. It is suggested that the DME campaign is therefore an appropriate beginning.

Several innovative aspects were included in the campaign to ensure its success. Firstly, a number of local and international campaigns were studied. It became clear that a holistic approach must be used that combines artwork with other aspects such as ease of implementation, text writing, readability tests and technical calculations.

Studying other pamphlets helped to set up requirements for the artwork. This included the designing of a logo and slogan, as well as the appearance of the pamphlets, brochures and posters. A cross-section of people were consulted with regard to the art concepts for the campaign - professional artists, architects, engineers, students and housewives. The best concepts were chosen by means of small public surveys.

The success of the DME campaign depended on public participation. As already mentioned, the most effective motivation was considered to be the monetary savings if the energy savings are undertaken. The energy savings should therefore be expressed in financial terms. No calculated monetary values for specific energy saving actions could be found for South African conditions. Specific calculations were therefore conducted for the DME campaign[3].

To ensure that the savings are independent of inflation, it was decided that they should be expressed in a unit which was easily identifiable to the consumer, such as a hamburger. The savings were then

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rated according to the monetary savings potential and ease of implementation. Only the most attractive suggestions were used in the DME campaign.

The analysis of the international pamphlets showed the importance of a good readability level. To test the DME's pamphlets, a new readability formula had to be developed[0]. This was necessary because of the limitations of existing formulas.

The effectiveness of the campaign also had be determined as this would indicate whether people's attitudes towards energy use had changed. Calculated values also had to be compared with actual measurements in a number of the case studies.

It was apparent that this campaign was necessary although its effect may only be fully realised in the future. Follow-up campaigns should therefore be initiated. These must extend to the low-income sector of the population as well as to the commercial and industrial sectors. Only through a continuous effort will people's attitudes and habits be changed permanently.

Collecting information for the campaign

Preamble

The first stage in the campaign was used to determine *what* information was needed and *how* it should be presented. A list of five requirements for the campaign literature was therefore compiled. This list is shown in Table 1.

Appearance, writing style and motivation

Seventy international pamphlets[7-76] were evaluated for their appearance, writing style and motivation[77], with each aspect awarded a score out of ten. The results were then combined into one score for each pamphlet. This score was called the "attraction" of the pamphlet and varied from a low of 2,75 to a high of 8,75. Most of the pamphlets which achieved low scores were those which provided too much information and too few illustrations.

The twenty pamphlets with the highest scores were then evaluated by various people. They were asked to indicate which pamphlets they would prefer to pick up and read. References (8), (9) and (10) were chosen as the best pamphlets.

This exercise showed that bright colours, attractive illustrations and a minimum amount of written information are important requirements for successful pamphlets. Too much information demotivated the reader, despite the attractiveness of the pamphlet. The writing style of the three pamphlets chosen was relaxed and friendly.

From the evaluation of existing literature, it was apparent that the DME's pamphlets and brochures had to conform to the following requirements:

(a) The appearance and layout must be attractive.
(b) Only the most important and interesting information must be presented.
(c) The writing style must be relaxed and friendly.

Readability

The study of the international pamphlets confirmed the importance of a good readability level. Three popular test procedures are usually used to measure readability. They are the *"Gunning Fog Index"*[78], the *"Flesch Reading Ease"*[79] and the *"Flesh-Kincaid Grade Level"*[79]. These indices were set up in a computer program[80] to facilitate speed and ease of use.

The pamphlets were then analysed using this new program. Only the first 200-250 words were considered, as the first part of a pamphlet was regarded as the most important. If the writing style of the pamphlet is deemed from the outset by the reader as difficult to understand, the person will most likely discontinue reading the pamphlet to its end.

The analysis highlighted some limitations of the existing readability indices[80]. The results of the *"Gunning Fog Index"* and the *"Flesch-Kincaid Grade Level"* were therefore combined into a new readability score[81]. The *"Flesch Reading Ease"* was omitted as it uses nearly the same algorithm as the *"Flesch-Kincaid Grade Level"*. The new index was called the *RSA Readability* and this was what was used to rate the international pamphlets. The best as well as the worst cases rated on this index are indicated in Table 2.

The study showed a correlation between readability and other aspects. For example, those pamphlets with poor readability often also seemed unattractive. The DME's pamphlets therefore had to have the lowest possible readability without being childish. As newspapers are often written for a Grade 7 (i.e. Standard 5) level, this seemed to be the level to aim for.

Energy and monetary savings

The success of an energy-savings campaign depends largely on effectively motivating the public. Money is probably the most effective motivator. Suggestions on energy savings should therefore be expressed in monetary terms. No calculated values for specific savings could be found for South African conditions.

A list of energy saving suggestions was compiled from the existing literature. The energy and monetary savings were then calculated for these suggestions. To ensure that the savings remain valid in the future, they must be independent of inflation. One solution was to use a unit which is easily understood by people of all ages and cultures, such as a hamburger.

The list of energy saving suggestions was then rated according to ease of implementation and the potential monetary

1	The **appearance** of the pamphlets and brochures to attract the most attention must be determined.
2	The **writing style** used in the pamphlets and brochures must appeal to the reader.
3	People must be **motivated** efficiently to achieve permanent energy conserving actions.
4	The written information must be uncomplicated and easy to read. It must therefore be pitched at a low **readability** level.
5	The **information** must describe energy and monetary savings. These monetary savings must be researched or calculated.

Table 1: Requirements for the campaign literature

Position		Title and country of pamphlet or brochure	RSA Readability*
Best:	1	(15) Make the most of your heating	4,60
	2	(16) Handy hints to save you energy	4,92
	3	(17) Electricity - how to use it is up to you but don't waste it. (U.K.)	5,22
	4	(18) Energy tips: Save money on hot water (U.S.A.)	5,87
Worst:	1	(19) "Making a corporate commitment"	14,74
	2	(20) "Appliances"	14,65
	3	(21) Energy savings in worship centres (U.S.A.)	14,05
	4	(22) Evaporative coolers (U.S.A.)	14,03

* The readability value corresponds to the years of schooling required to fully understand the text of the pamphlet with ease and understanding.

Table 2: Best and worst readability results

savings. A suggestion could, for example, result in large monetary savings but may be difficult to implement. The time, money and effort needed to implement a suggestion, together with the possible monetary savings must be taken into account. This will determine which suggestions are likely to be accepted by households.

Table 3 shows those actions included in the campaign material. These suggestions are grouped according to the titles of the different campaign pamphlets. One column of the table gives the potential yearly savings. The last column indicates how many hamburgers can be bought with the money saved.

Development of text and artwork

Writing text for the campaign material

As previously stated, the writing style of the pamphlets and brochures must be appealing to the reader. Therefore different writing styles were investigated. These ranged from serious and formal to humorous and childlike. A survey showed that a friendly and informal style (but not childish) appealed to most readers.

Creating a campaign identity

A campaign identity is often established by means of a logo and slogan. Where a more informal approach is needed, the logo can be substituted with a cartoon character. A cartoon character has the advantage that it appeals to people of all ages. Children especially will relate more easily to such a character than a corporate logo. Marketing a campaign with a cartoon character is also much easier. For example, puppets can be used at schools and on television shows.

An added advantage is that people will generally remember a cartoon character rather than an abstract logo. Furthermore, the character can be used in campaigns for other sectors as well. For example, the figure can wear a hard hat for the industrial sector and a suit for the commercial sector.

These advantages make the cartoon character an ideal medium for conveying the message of using energy wisely. However, a formal logo may still be needed for the campaign. Such a logo must show energy conservation with internationally recognisable symbols. Bright colours and natural shapes rather than rigid geometric lines were therefore used. The use of natural shapes would make the character more attractive to the prospective audience as well as show ***environmental*** friendliness.

The logo and cartoon character were used during the whole energy conservation drive in all the main energy sectors in South Africa. It was also important that the logo be understandable to those at all education levels, as well as various age groups and cultures.

Another requirement for both the cartoon character and the corporate logo was that they had to fit in with the campaign's slogan. There were two possibilities. The first option was to use a modern phrase such as "Zap it in the Zibi". It was claimed that people would relate easily to this type of saying. Another option was the use of a more conservative expression such as "Use energy wisely", which could possibly be used with a logo of a wise old owl.

The slogan *"Enerwise, moneywise"* was finally selected. This was seen as containing the main themes to be conveyed, namely effective use of energy and the resulting monetary savings.

Final art concepts

The final concepts for the logo, slogan, cartoon character, pamphlets, brochure and posters are described in a report to the DME[77]. They were developed by a team consisting of professional artists, a housewife, an architect and two engineers. Surveys showed a positive response towards these concepts.

The logo and cartoon character are shown in Figure 1. For the logo, the globe represents the earth while the flash indicates energy. Conservation is shown by the box which contains the earth and the energy flash. The irregular shape of the box is indicative of nature. It is also more "friendly" than a rigid shape.

The cartoon character in Figure 1 was developed from a light bulb as it was seen to personify energy for most people. Also, the cartoon character's head resembles the earth in the logo. Similar to the logo, the bright flash around the cartoon character's head indicates energy.

The globe, flash and light bulb have the advantage that they are internationally recognised symbols. These designs also indicate environmental friendliness. Because of their simplicity, the logo and cartoon character are suitable for use in all the energy sectors.

Creation of children's material

Children were one of the key targets of the campaign. It was reasoned that energy-conscious children will grow up to become responsible energy users for life. They will also use energy efficiently in other sectors. Therefore the DME decided to produce special children's material to convey the message of "Enerwise Moneywise".

Bookmarks were printed with three saving actions most relevant to children. In addition, an educational energy game was also developed, based on the well-known game "Snakes and Ladders". In this energy game, children are repeatedly exposed to various energy-saving

Group[1]	Saving suggestions	Potential savings per year [kWh] units[2]	Hamburgers per year[3]
A	Showering instead of bathing	1 000	35
	Setting the geyser thermostat to 60°C	700	25
	Fixing leaking taps	500	16
	Using the cold water tap	500	16
	Insulating the geyser and pipes	300	10
B	Insulating the ceiling	1 350	46
	Closing doors and windows	550	19
	Using warm or electric blankets	500	16
	Using curtains and pelmets	350	12
	Switching off heaters	250	8
C	Using small appliances	1 300	44
	Using full loads in equipment	900	31
	Sun-drying washing	800	27
	Using economy cycles	650	19
	Checking door seals	400	14
D	Installing movement sensors	2 500	86
	Servicing pool pumps and cleaning filters	1 300	44
	Reducing cycle time of pool pumps	700	25
	Switching off lights and appliances other than heaters	400	15
	Using fluorescent lighting	350	12
E	Insulating the roof	1 350	46
	Insulating geyser pipes, installing short pipes and setting the thermostat at 55°C	1 150	40
	Fitting single bulbs and fluorescents	700	24
	Draught-proofing the house	600	21
	House facing north	350	12

1 Key to groups of saving suggestions

Group A:	Savings with hot water
Group B:	Savings with space heating
Group C:	Savings with kitchen and laundry appliances
Group D:	Savings with household appliances and lighting
Group E:	Savings when designing a new house

2 Approximate savings if these actions were not implemented in the past.

3 Number of hamburgers that can be bought with the money saved on energy in one year. The cost of a hamburger is assumed to be R5 in 1994 terms.

Table 3: The most important saving suggestions used in the campaign

actions. Long ladders are used for suggestions with high energy saving potential while the biggest snakes indicate which actions are most wasteful.

Final stages

Launching the campaign

During the winter months people are more aware of their energy use, mainly because their municipal electricity accounts are higher as a result of more energy being used for space heating. It was therefore decided to launch the campaign just before the winter of 1996. By the time the media covered the event, people would be more inclined to pay attention to the "Enerwise, Moneywise" message.

Testing people's reaction to the material

Thirty people in Pretoria were asked to compare the DME pamphlets with three of the best international pamphlets. The result of this survey are summarised in Table 4. It seems that the DME pamphlets were regarded as more attractive and interesting than the international ones.

The readability of the campaign material was also tested with the new *RSA Readability* index. The results are given in Table 5. The average readability of all the campaign material is at a Grade 7 (i.e. Standard 5) level. This was regarded as acceptable for the campaign.

These surveys were limited as the focus was only on the appearance and readability of the material. In future, people's actual understanding of the message should also be tested. Furthermore, surveys are also needed to ascertain whether household energy consumption decreases because of energy savings awareness actions.

As part of the campaign launch, the DME started a competition to find a name for the energy cartoon character. More than 6 000 of the 90 000 forms distributed forms were received. The name selected for the energy-saving cartoon character was "Enerwizz".

Suggestions for follow-up action

- Promoting the effective use of energy is an ongoing process. Therefore follow-up actions are necessary to main-

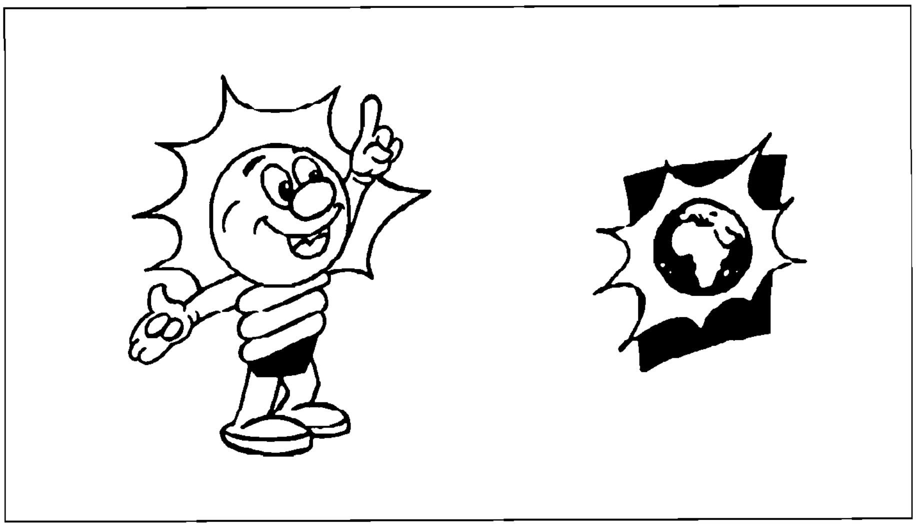

Figure 1: The logo and mascot for the new campaign

Question[1]	DME Pamphlet	Pamphlet 1	Pamphlet 2	Pamphlet 3
1	17	5	6	3
2	20	4	6	1
3	19	3	8	1
4	16	3	9	3
5	17	5	5	4
TOTAL	**89 (52%)**	**20 (13%)**	**34 (22%)**	**12 (8%)**

Key to the five questions:

1: Which pamphlet motivates you the most?
2: Which pamphlet is the most interesting?
3: Which pamphlet is the most attractive?
4: Which pamphlet makes you want more information?
5: Which pamphlet do you think will achieve the most success?

Table 4: Results of the survey to compare DME pamphlets to the three best international pamphlets

Material	*RSA Readability* Index
Brochure	6
Municipal pamphlet	4
Pamphlet 1	4
Pamphlet 2	4
Pamphlet 3	4
Pamphlet 4	6
Pamphlet 5	4
Average	**5**

Table 5: RSA Readability results for the campaign material

tain public awareness of the need to save energy. The campaign discussed in this paper was aimed at middle- to high-income households. It is, however, important that the low-income section of the domestic sector is also included. (More than 300 000 households in this latter sector were electrified in 1995[84]).

- To address low-income households, new campaign material must be created.
- Marketing of the energy-saving concept should also receive more attention. An effective option is to produce and broadcast a television series or adverts on energy savings. The energy savings cartoon character, "Enerwizz , would then teach people about energy savings in a "fun way, reaching millions of people at once.
- Case studies are an important part of these marketing actions. It is hoped that people will be spurred into action after hearing about the large energy-saving achievements of others. The case studies are also important to verify the calculated savings used in the campaign material. These values should be compared with actual measurements in statistically representative samples in different parts of the country.
- These proposed actions cannot be implemented by the DME alone, because of the Department's limited budget. It is therefore recommended that their future campaigns dovetail with campaigns of other role-players, such as Eskom, ceiling insulation manufacturers, equipment distributors, etc.

Conclusion

South Africa needs a national awareness campaign on energy conservation. The DME therefore initiated such a campaign aimed at the domestic sector. A successful campaign would have widespread impact on annual electricity consumption and energy peaks.

A holistic approach that combined artistic, domestic and technical viewpoints was used. By analysing several international campaigns, problem areas and useful ideas could be identified. For example, more emphasis was put on a suitable readability level for the pamphlets which led to the development of a new readability index. Potential energy and monetary savings were also calculated for South African conditions.

All the abovementioned ideas were combined to develop high-quality concepts for the slogan, logo, brochures, pamphlets and posters. By means of this approach, the results of the DME campaign could equal or even surpass international campaigns with access to bigger budgets.

It is true that energy-wasteful habits are hard to break. However, the DME campaign has laid the groundwork for follow-up projects to permanently change people's views on energy conservation.

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Development of power pooling in Southern Africa

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This paper presents the strides that have been made in Southern Africa to promote regional cooperation amongst the electricity utilities. With the permission of their respective governments, the utilities have been instrumental in developing cross-border interconnections to trade in electricity to boost the region's economy, as well as enhancing the social well-being of its peoples. The imbalance of both developed and undeveloped energy resources needs to be addressed by way of pooling of efforts.

Keywords: power pooling; Southern African Power Pool; interconnections; regional cooperation

Glossary

BPC = Botswana Power Corporation
ZESA = Zimbabwe Electricity Supply Authority
ZESCO = Zambian Electricity Supply Corporation

Background

Since the formation of the Southern African Development Community (SADC) in the early 'eighties, Sub-Saharan African countries have had aspirations of economically uniting the communities of this region so that there is equitable sharing of resources available for the benefit of all. To facilitate the realisation of this bold endeavour, various key economic sectoral structures have been identified over the years at national level and turned into regional initiatives geared towards enhancing the economic well-being of the resident communities, irrespective of national boundaries.

One such initiative has been the need to mobilise neighbouring utilities to pool their energy resources and embark on cross-border energy trading. This has led in recent years to the birth and establishment of the Southern Africa Power Pool.

For many years in Scandinavia, Europe and the U.S.A., utilities have made use of interconnected power systems (or power pools) for the more efficient use of their power generation and transmission network resources. In North America, it is estimated that savings of $20 billion a year are made by the utilisation of power pools. In Europe, there are several power pools operating and today it is rare for any country in these developed regions not to exchange energy and power with neighbouring countries. Surely Africa, with its various sub-regional fragments, should follow suit if it is to competitively position itself in the energy business, which is fundamental to economic development.

Southern Africa

The countries in Southern Africa which constitute the body of SADC are: Angola, Botswana, Malawi, Mauritius, Mozambique, Namibia, Lesotho, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. Although the Democratic Republic of the Congo is part of the Southern Africa Power Pool (SAPP), it is not a member of SADC. These countries are each endowed with various kinds of raw materials which may be harnessed for their socio-economic development.

With regard to capacity, there is at present a surplus of generation capacity of approximately 12 000 MW in the region, including the developed generation capacity in the Democratic Republic of the Congo and Mozambique. Unfortunately the existing transmission networks are not adequate to transfer this spare capacity to where it is required. Individually many of the countries in the region are short of capacity, despite the existence this spare capacity. In the longer-term, the Democratic Republic of the Congo, with its huge hydro resources, (which is reported to be of the order of 45 000 MW), could provide power for growth in Sub-Saharan Africa for another 50 years, if these resources can be developed. Other regional resources that could be developed for regional use include the Batoka Gorge and Cahorra Bassa North hydroelectric projects on the Zambezi River. A thermal power station at Sengwa in Zimbabwe and a power station in Botswana could also be developed for export purposes, as there is an abundance of coal in the region. Table 1 below shows the energy and demand requirements in SADC countries, together with projected expectations for the year 2010. These latter schemes, which have already been identified, would add another 6 000 MW-7 000 MW to the region, without including the huge energy potential of Inga in the Democratic Republic of the Congo.

In recognition of these requirements and taking cognisance of the vast and untapped energy potential in the region, utilities are now busy constructing cross-border transmission networks. At present there are 220 kV, 275 kV, 330 kV and 400 kV transmission links between South Africa and Namibia, South Africa and Mozambique, South Africa and Swaziland, South Africa and Zimbabwe, Zambia and the Democratic Republic of the Congo, to name a few of the main cross-border connections operating within the SADC region. The dc transmission line between South Africa and Mozambique is being refurbished at ±500 kV. With the full intent and purpose to aggressively pursue cross-border electricity trading, dc circuits are likely to take the forefront over ac transmission lines because of the long distances involved. But this will depend on the agreed transmission links. Major load centres are far from the favourable generation locations.

Table 1 suggests that, by the year 2010, more grid transmission lines will need to be in place. This may require a change in

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		1995			2010
	Demand (MW)	Energy (GWh)	Inst. Net Capacity (MW)	Demand (MW)	Energy (GWh)
Angola	326	1 042	326	935	5 752
Botswana	204	1 017	172	415	626
Democratic Rep. of Congo		4 106	2 480		6 210
Lesotho	80	-	5	125	430
Malawi	149	731	189	520	2 853
Mozambique	104	978	589	446	2 362
Namibia	277	1 795	387	n/a	n/a
Swaziland	118	603	50	207	1 062
Tanzania	276**	1 672**	514	925	5 400
Zambia	1 108	6 171	1 774	1 396	8 519
Zimbabwe	1 617	9 036	1 957	2 902	18 417
South Africa	25 133	53 547	35 952	38 015	232 253
Totals	29 392	80 698	44 395	45 886	283 884

(Source: World Bank 1993[3] and Eskom Statistical Yearbook -1995[2])

** figures for 1995 not available.

Table 1: Power and energy peak loads of SADC countries

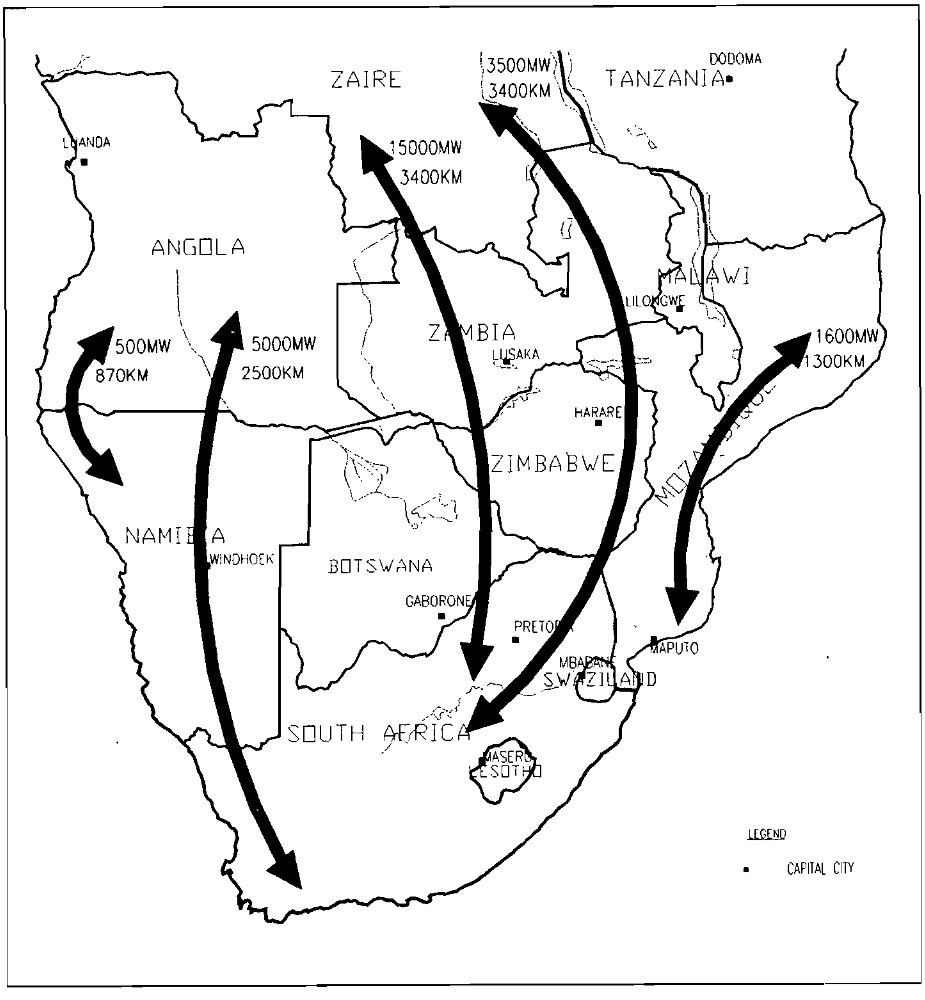

Figure 1: Routes of power pool grid networks

their design and construction, dictated by the distance and the load-carrying capacity requirements for the load centres. Figure 1 shows the main routes that may be taken by the regional grid. Tap–off points will be provided en route should the intervening countries' demand warrant it.

Origins of the Southern African Power Pool (SAPP)

The power interconnection that triggered the establishment of the SAPP was probably the Canadian-sponsored 220 kV interconnection between Botswana and Zimbabwe which was originally intended to transfer surplus energy from the hydropower plants in Zambia into Botswana in the days before South Africa was a member of SADC. In 1989 a standing committee, namely, the Interconnection Operating and Planning Committee, (IOPC) which was comprised of the BPC, ZESA and ZESCO, was formed in order to be responsible for the transmission interconnection between these countries. In 1993 the IOPC invited Eskom, which was already trading electricity with Botswana, to join them to investigate how best their power systems could be operated once the 220 kV links' automatic generation control system was commissioned.

At about the same time, Zimbabwe, which was critically short of electricity due to a severe drought prevalent in the region, sought assistance from Eskom, which was only too willing to make available some of their surplus generation capacity. Initially it was considered that 50 MW-100 MW could be sent to Zimbabwe through the Botswana grid, but this quickly developed into a project with a much higher capacity. In fact, it led to the birth of the Matimba/Bulawayo 400 kV project. Also at this time, Zimbabwe was negotiating to take over some of South Africa's allocated power share of Cahorra Bassa. Eskom was unable to make use of this source because the dc transmission line was out of commission due to the civil war in Mozambique. Eskom, with a longer-term vision in mind, namely, to import cheap hydropower from the Democratic Republic of the Congo, was also very keen to establish transmission lines northwards towards the Democratic Republic of the Congo. When all these factors were added together, the concept of an interconnected power grid system in Southern African was very viable and attractive. As a result these utilities were only too happy to embark on the opportunity to establish a regional power pool and have definitely never looked back !!

Grid interconnections for power pooling

Interconnections with the large resources of South Africa and the Democratic Republic of the Congo will enhance electricity trade in the region and also increase the benefits of improved efficiency for all involved. The bulk of the available thermal and potential hydro generation lies with these two countries. South Africa has well-developed thermal generation facilities, with a total capacity of about 35 000 MW and a peak demand in 1996 of 27 000 MW, while the Democratic Republic of the Congo, on the other hand, is said to have a hydro potential from its Inga region of about 45 000 MW, which could be developed to supply most of the African continent's electricity needs and perhaps, one day, even to supply part of Europe's Mediterranean coast. If these plans are realised, this will indeed be the greatest engineering feat of the next century on the African continent.

Power pooling in Southern Africa, like elsewhere, will have immediate rewards, ranging from economies of scale to fuel economy enhancements through the equal-incremental-cost principle, whereby careful dispatch of high-cost sources will be kept strictly for peaking or as reserves. There will also be sharing of Spinning and Operating Reserve requirements for individual countries. The variance in daily and seasonal (winter, summer) demand with non-coincidence of peaking loads, although not as significant as in the U.S.A. or Europe, will be used to the benefit of the region. The interconnected system will further encourage dissemination of information. which will lead to concurrent technological growth for all member countries. Additions to generating capacity will be staggered on a regional basis, which will also be advantageous to the environment.

With these concepts in mind, the SADC countries' main regional thrusts in terms of the power pool are:

- The formulation of a strategy for fostering regional cooperation through power interconnections in the region as a means of providing opportunities for enhanced electricity trade.
- The analysis of institutional, contractual and organisational aspects for the establishment of a regional power pool in order to determine the most appropriate organisational structure for the implementation of a coordinated planning and integrated operations methodology for the region's interconnected system.
- The determination of the most appropriate pricing policies in power pool operations for the mutual benefit of all participants.

These are critical to the efficient operation of the power pool and members of the power pool are giving careful thought as to how these issues should be addressed.

The following more immediate projects make up the wider integrated development plans that will open opportunities for the fair sharing of benefits between pool members:

- The upgrading of the existing Zambia/ Democratic Republic of the Congo 220 kV link for increased generation capacity.
- Completing the 400 kV line from Songo (Mozambique) to Bindura (Zimbabwe) by mid-1997.
- Building a 400 kV line from Kolwezi (Democratic Republic of the Congo) to Luano (Zambia) by 2002.
- Building a 220 kV line from Pensulo to Liiongwe by 2003.
- Building Batoka (Zimbabwe) - Stage I (400 MW) by 2004 and Stage II (400 MW) by 2007.

In addition to the above, a 420 km, 400 kV line between the Matimba Power Station (South Africa) to Bulawayo (Zimbabwe) was completed at the end of 1995 and is now in operation. The line can transmit up to 500 MW. The construction of this line was initiated and accelerated by the drought that had curtailed hydropower generation from the Kariba (North and South) and Kafue Gorge power stations. This line will be used for power transmission, both northwards and southwards, once the Batoka Gorge hydroelectric project comes on stream. The Songo-Bindura 400 kV line becomes operational in mid-1997, and until 2003, Zimbabwe will be able to import some of Eskom's allocation from this source or, alternatively, to import electricity via the 400 kV line to Matimba. The present excess capacity in South Africa could run out by about the year 2005 and imports from the north would then be cost-effective, if not a necessity by that time.

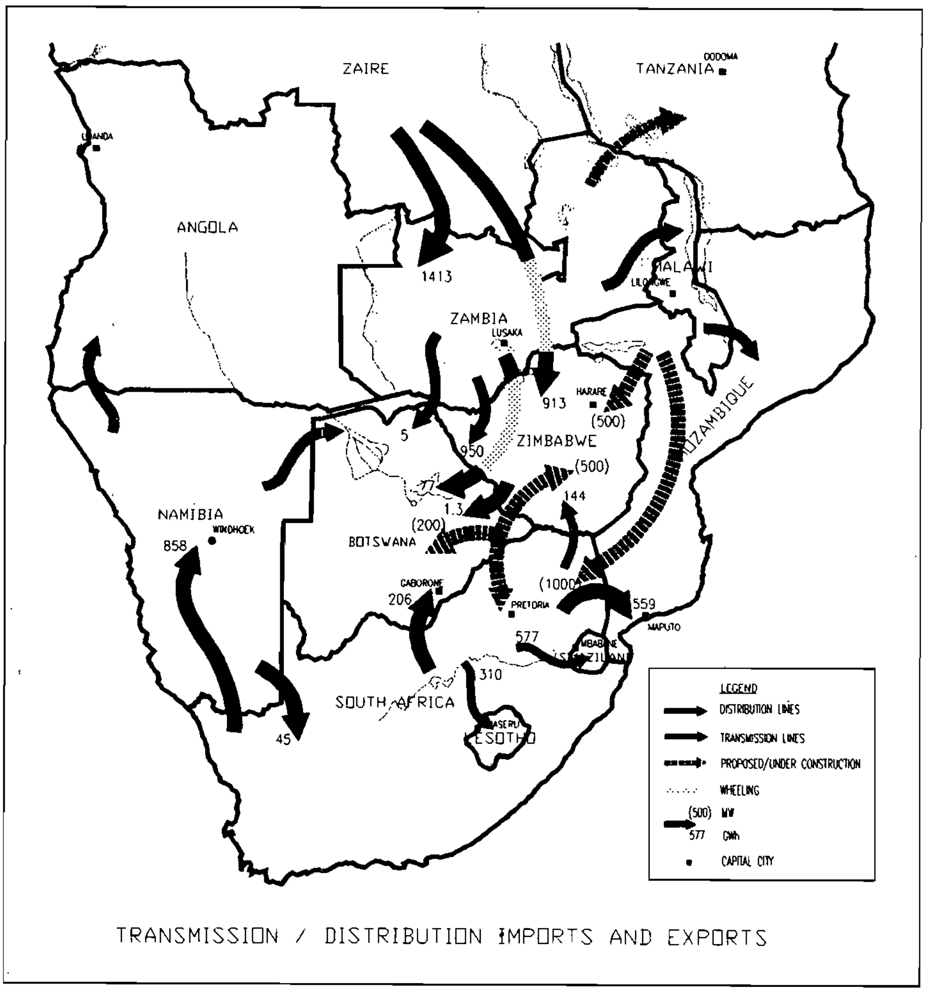

Figure 2: Southern African energy trading 1993-1994

Figure 2 shows present interconnections at voltages ranging from 132 kV to

400 kV ac and ±500 dc. Botswana's grid link to the 400 kV system at the Phokoje sub-station will be commissioned during the first quarter of 1998.

The Southern African Power Pool (SAPP)

There are a number of power pool arrangements, ranging from a "tight", regulated pool structure, such as in the United Kingdom, to a "loose" pool arrangement, where utilities still retain their individual trading autonomy within the framework of the pool. A "tight" pool arrangement for Southern Africa, at this stage, was not considered for various reasons. The ownership of the transmission facilities and a unified generation operation under a central authority would pose crucial and serious problems for utilities which are essentially public enterprises run and operated on behalf of governments, and which are very conscious of their sovereign rights.

However, there are distinct advantages to a properly constituted "loose" pool arrangement. SADC utilities have opted for this pooling arrangement because of its flexibility. Since various networks are combined in such a pool, savings are possible in a number of areas, for example, investments in future generating facilities (economies of scale, more economic use of fuels etc), better hydro-thermal coordination, lower operating reserves, peak load diversity, lower unit start-up costs and more flexible scheduling. The reliability of supply in such a combined system is enhanced with a more stable frequency, save for occasional excursions which arise when a major plant fails. The degree of integration in the planning and operation of such a system could exhibit high levels of savings for all concerned. However, as utilities optimise their imports they reduce their costs, but at the same time they reduce their self-sufficiency. The need to determine a compromise becomes a very important issue. If rigid policies on self-sufficiency are not relaxed by all the pool members, this could have a serious negative effect on optimising the advantages of a power pool.

Implementation of the power pool

At the SADC Electricity Sub-Committee meeting in Arusha, Tanzania in July 1993, all SADC utilities agreed to participate in a Southern African Power Pool. This decision was supported and approved by the SADC Energy Ministers at their August 1994 meeting, which led to the drawing up of an Intergovernmental Memorandum of Understanding between the various governments and agreements between the utilities for the implementation of a SAPP in the SADC region.

As a result, the following power pool enabling documents are now in place:

(1) Intergovernmental Memorandum of Understanding
(2) Inter-Utility Power Pool Agreement
(3) Agreement between Operating Members

Most SADC utilities signed these agreements by the end of 1995, but it was no easy task to get some of the governments to endorse these vital documents.

The major preoccupation today is to equip the various participating Control Centres with the required additional communications equipment and proper computer facilities which are essential for power pool operations. All utilities involved with the operation of the power pool are required to have telecommunication networks of an acceptable standard.

Studies are underway for a coordinated AGC and tie line control system that will monitor the dynamics of the interconnected systems of Botswana, South Africa and Zimbabwe. This facility will enable a much wider and integrated power system to be run as a single entity, with respective area control error zones.

The existing bilateral and in one case, trilateral, inter-utility agreements continue to operate where they do not conflict with power pool operational requirements. The tariffs contained in existing agreements will not change, but any future inter-utility tariffs will now be subject to a top price "capping" restriction as contained in the SAPP Operating Agreement under various schedules. Utilities are free to negotiate their individual tariff rates in line with the overall SAPP Operating Agreement, which sets the limits not only on the charges but also on the conditions of supply. Wheeling charges have been a particularly delicate and difficult problem to resolve, as some

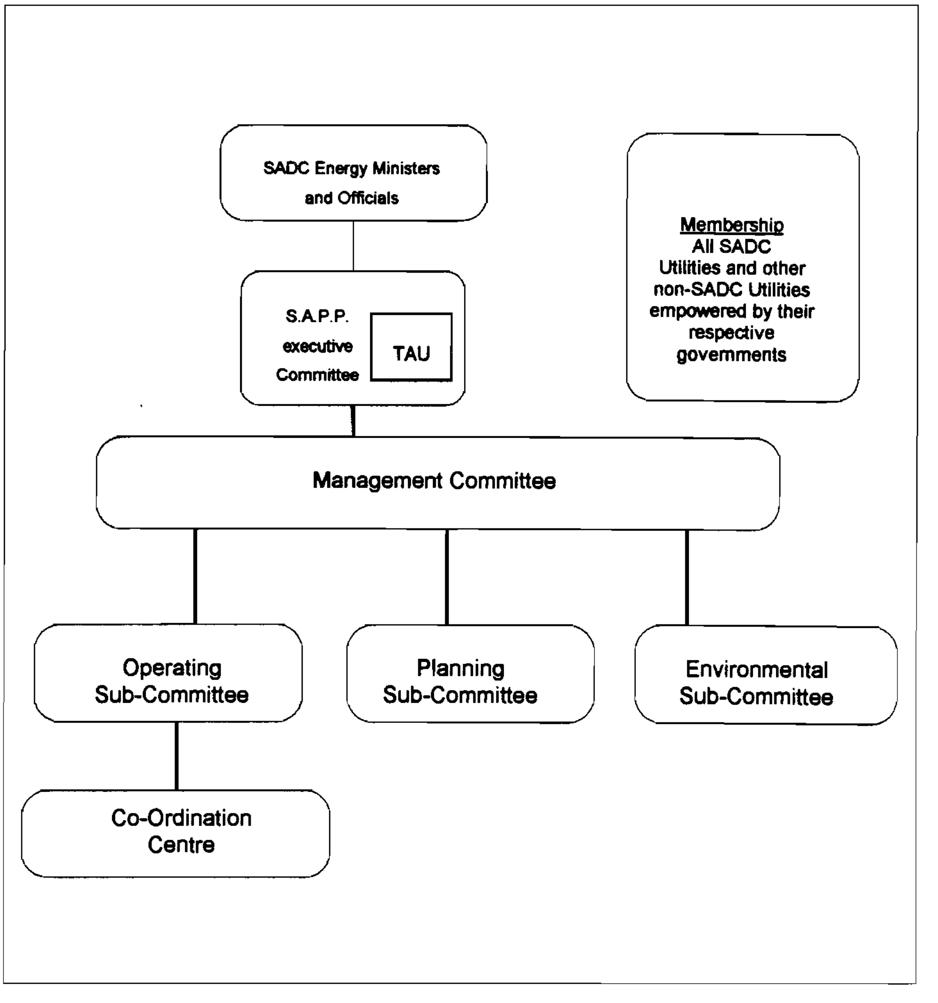

Figure 3: Management structure of the Southern African Power Pool

power pool members tend to take an unfair advantage of their geographical position to the detriment of the power pool as a whole.

The structure of the power pool

In order to implement the planning and operation of the power pool, a structure had to be determined. This was done in the following way:

The overall power pool policy is the responsibility of the Executive Committee, which is comprised of the Chief Executive Officers of the member utilities. A Management Committee, made up of senior engineers from the Operating, Planning, and Environmental Committees, is directly responsible to the Executive Committee for the management of the power pool itself.

The Operating Committee's responsibilities are to investigate the most suitable operation procedures to be adopted, (for example, the precise settings of the AGC's to obtain maximum reliability and stability, whilst taking into account the generating and transmission constraints) and, in general, to optimise system operations through a Regional Coordinating Centre. This Centre will be located in Zimbabwe, a country centrally located and with the greatest number of interconnections with other regional utilities.

The Planning Committee determines and specifies the common criteria for the security and economic optimisation of the supply. This Committee also has the responsibility of indicating the most attractive projects for new generation and interconnections within the power pool. Another function of the Planning Committee is to design and recommend tariff structures and guidelines which take into account the common interests of the members. Not least among these are the guidelines and tariffs for the wheeling of energy. A complete set of schedules for the despatch and pricing of energy exists for use by all operating members.

The Environmental Committee ensures that the planning and operation of the power pool is environmentally sound. The importance of environmental impact awareness has dramatically increased in recent years as it is almost impossible nowadays to obtain international funding without attention being given to these issues.

Conclusion

This is a very critical time for all utilities in the region as they attempt to fine-tune and apply new ways of inter-utility energy trading on a win-win basis. Much will be gained if the spirit of mutual cooperation that was evident during the IOPC-SAPP negotiations, which took more than 36 months, can be maintained. Southern African has much to gain by making optimum use of the power resources in the region at the lowest possible cost for the development and benefit of all people in the region.

Utilities are fully aware of the absolute need to make this bulk electricity transfer available to their consumers. Rural electrification funds have been established in a number of utilities to facilitate the extension of the distribution networks to some remote areas. Beyond that, utilities in Southern Africa continue to review other technical areas and to exchange information on the possibility of diversifying into renewable sources of energy for the more remote regions. Cross-border distribution connections have been possible in some cases, with the cooperation of neighbouring utilities

It is very comforting to know that nine of the eleven utilities that comprise the SAPP are also members of the World Energy Council (WEC), and have embarked on what could be viewed as attesting to the aspirations of the WEC (the WEC's main objective is to "promote the economic development and the peaceful use of energy resources for the greatest benefit of all"). The whole of Africa needs to mobilise its resources. This can only be done through sharing and exchanging information on ways of tackling energy issues for the purpose of attaining the much sought after socio-economic development of the region's communities.

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Hydroelectric power potential in South Africa

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The proportion of hydroelectric power generation in South Africa is small relative to many other developed and developing countries. This may be because South Africa has an abundance of fossil fuels, especially coal, supplied at a relatively low cost.

On the other hand, river flows in South Africa are highly variable and therefore difficult to control for the use of reliable power generation. Pumped storage, however, has proved viable in mountainous areas. The hydroelectric developments in South Africa have been associated with multipurpose developments generally, in order to offset the high cost of storage.

A possible future development in the field of hydropower is small stand-alone hydropower plants for supplying isolated communities. Although the cost of generation is relatively high for small plants, it is offset against the reduced transmission costs from large power stations. However, the Eskom policy to extend the grid throughout the country makes competition difficult, as rural costs are to some extent subsidised from the Eskom grid. Nevertheless, there have been interesting developments in micro hydroelectric power generation equipment in particular, and a number of investigations into possible rural schemes have indicated that a potential exists.

Keywords: hydroelectric power; South Africa; small hydro; micro hydro; costs

Introduction

Generally, the cost of electricity generation decreases the larger the scale of the power station. This is particularly so for thermal power stations, where boilers, cooling towers and steam turbines become prohibitive for very small plants. In addition, the fuel, namely coal, is much cheaper for large-scale mining.

There are many situations, however, where it is uneconomic to transmit electricity over long distances to small consumers. Unless there is a policy of subsidisation in order to extend the grid, it is sometimes more economic to install stand-alone plants. In the past in South Africa, such plants have typically been diesel-powered but a number of investigations are now in hand for small hydroelectric plants.

It is conventional to refer to a hydroelectric power plant as small if it is less than 10 MW in capacity, and it is called a mini hydroelectric plant if it is less than 2 MW capacity. A micro hydroelectric plant has less than 100 kW generating capacity. The philosophy for the planning and design of micro hydroelectric plants, in particular, differs considerably from that for the larger plants. This may be because of the method of funding, reliability and efficiency, and the method of distributing the electricity.

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Hydroelectric power developments in South Africa

Existing hydroelectric power projects in South Africa

Owing to the high variability in flow and the lack of suitable sites, hydroelectricity does not feature significantly in South Africa's power generation. Also, the overall load factor in South Africa is relatively high (60%) because of large mining and industrial loads. South Africa generates less than 5% of its some 30 000 MW power requirements from hydroelectricity. This excludes the Cahorra Bassa project in Mozambique which is being revitalised and could result in an additional 2 000 MW being exported to South Africa, largely on base load. The Drakensberg and Palmiet schemes are also not utilised for normal generation. They are used primarily for meeting peak power demands. The Drakensberg scheme is associated with a water transfer scheme to Gauteng, while the Palmiet scheme is in the Western Cape.

The existing viable projects in South Africa are mainly pumped storage, i.e. they are designed to meet peaks in electricity demand during the day[9]. During the night, thermal power is used to feed energy into the pumped storage stations by pumping water up a mountain to a reservoir. During the peak demand in the day, the water flows down again to generate electricity. There is, therefore, a net loss of energy, but owing to the fact that a hydroelectric plant is considerably cheaper per megawatt installed than a thermal plant, this saves a considerable amount of money. However, large dams are not required for this type of power generation as only overnight storage is required. Therefore the large capital cost associated with the convential hydroelectric power stations is avoided. Table 1 lists the major hydroelectric stations in Africa.

There has been a preliminary investigation into a large hydroelectric power station on the Umzimvubu River, with a capacity up to 2 000 MW. This power station could be used to supply regular energy into the Eskom grid, although the grid would have to be strengthened in the Eastern Cape to receive this amount of power. The proposed dam and power station should also preferably be used on peak power, i.e. with a low load factor, in order to maximise the benefit. A load factor of something like 10% has been suggested.

There are a number of other proposed power stations in the Eastern Cape, including the Tsitsa Falls scheme, which could generate up to 50 MW of peak load and which has a head of about 300 metres[6].

The Eastern Cape and Natal Midlands appear to hold the highest potential for hydroelectric power. The Drakensberg

Name	River	Capacity MW	MAR m^3/s	HEAD m	Notes
Drakensburg	Tugela	1 000	11	450	Pumped storage
Gariep	Orange	180	200	70	
Van der Kloof	Orange	220	200	100	
Palmiet		400		300	Pumped storage
Steenbras		180		200	Pumped storage
Collywobbles	Mbashe	52	10	130	
Umtata	Mtata	17	10	60	
Ncora	Tsomo	2	2	50	
Lydenburg		1	1	40	
Various gold mines				-3 000	
SURROUNDING Kariba	**COUNTRIES** Zimbabwe	1 600	1 400	100	
Cahorra Bassa	Mozambique	2 200	2 800	150	
Kunene	Angola	320	190	100	
Kafue	Zambia	600	12 000	52	
Shire	Malawi	250	1 000	100	
Inga I & II	Democratic Republic of the Congo	1 500	40 000	70	
Muela	Lesotho	80	50	200	

Table 1: Some hydroelectric power plants in Africa

provides the head, and the high rainfall ensures large and fairly regular river flows. The problem is largely that the steep mountains are at the headwaters and the higher flows are nearer the coast. A number of hydroelectric power schemes have been proposed on the Tugela River and its tributaries[7]. The escarpment also provides potential hydroelectric power sites right down to the Western Cape where the Steenbras and Palmiet pumped storage schemes exist.

In the interior of South Africa, the large dams on the Orange River, namely the Gariep (formerly Hendrik Verwoerd) and Van der Kloof, are used to generate power, but these are viable largely due to the regulated flow rate rather than the head. Figure 1 shows the relative river flows and topography in South Africa, both of which are needed for hydroelectric power.

There exists a number of large hydroelectric power stations in surrounding countries, in particular on the Zambezi River, i.e. the Kariba and Cahorra Bassa projects. There has also been talk of further schemes on the Zambezi, i.e. Batoka Gorge or Mpanda Uncua and at Inga in the Democratic Republic of the Congo. The expansion of the Southern African Power Pool has been mooted. At present the only power received from South Africa's northern neighbours is from Cahorra

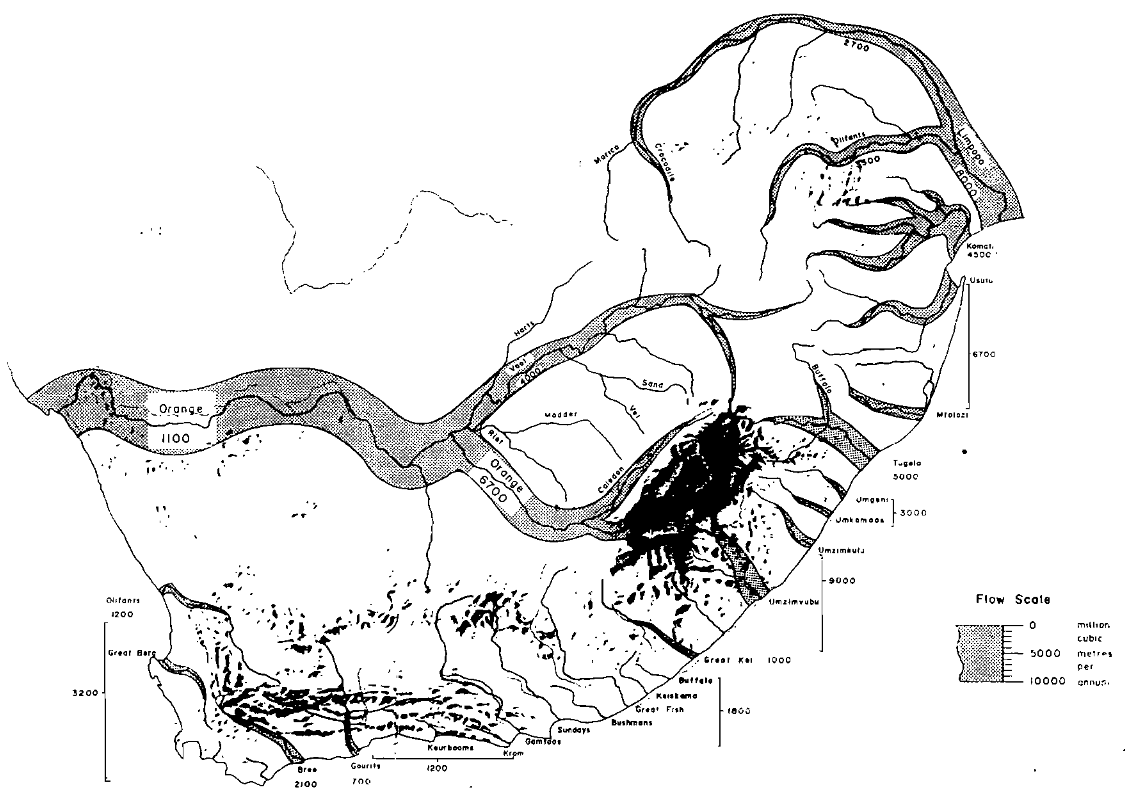

Figure 1: Map of South Africa with river flows and topography

Project	River	Capacity MW	Head m	Cost c/kWh
Tsitsa Falls	Tsitsa	20	300	25
Mt Fletcher	Tina	1	50	60
Lubisi dam	Indwe	1	30	30
Indwe poort	Indwe	0,5	30	50

Table 2: Examples of costs of small hydro schemes in the former Transkei (now part of the Eastern Cape)[4,11]

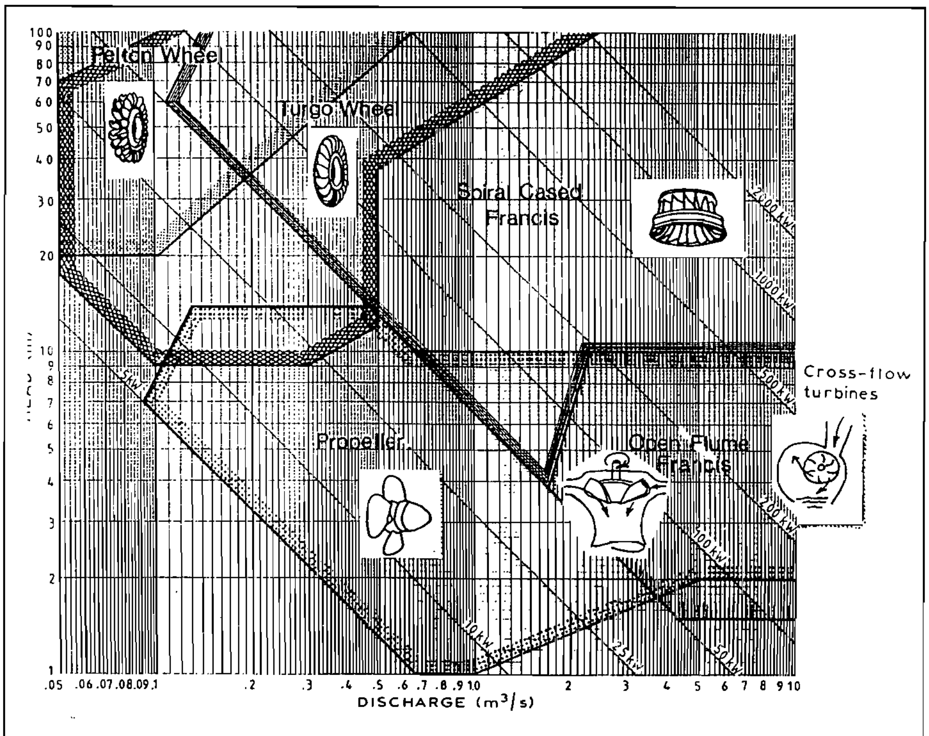

Figure 2: Range of application of various turbines types[13]

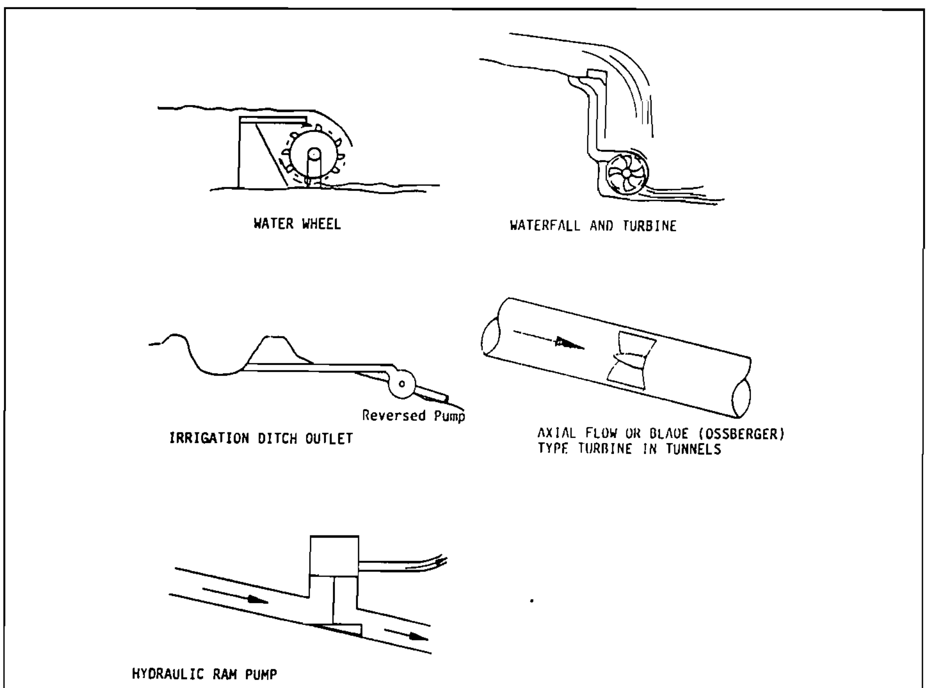

Figure 3: Micro hydro options[12]

Bassa and that has been a financial disaster to the sponsors because of the war in Mozambique. Power is presently, however, exported from South Africa to Namibia, Zimbabwe, Lesotho, Mozambique and Swaziland.

Small hydro

The concept of small hydro or independent hydroelectric power schemes has not been developed in South Africa, possibly due to the policy of Eskom to expand its network wherever possible, even if at the expense of existing consumers. However, smaller rural consumers cannot afford the high cost of transmission lines.

The situation in South Africa may be compared with some Asian countries where small-, and even micro-, hydro plants abound due to the inaccessibility of rural centres. In China, for example, there are of the order of over 10 000 such small stations, generating some 10 000 MW[10]. The heads vary from 1 m to 600 m, so there is a wide variety of such plants. Some of these installations have existed for over 100 years, long before hydropower was considered seriously for the West. The ingenuity of hydraulic engineers in China is perhaps unrecognised in other countries because of the language barrier. The installation of small hydroelectric power stations in South-East Asia is now also proceeding with the assistance of British and other consulting engineers. Most of these small power stations operate independently.

The liberalisation of electricity authorities with monopolistic control of power generation is evidenced in Europe and North America. This may require privatisation or competitors. There are many private organisations generating electricity on whatever scale suits them and selling it to the European or North American grid, whichever is nearest, and operating at whatever scale is most profitable to the developer. One wishes that such private enterprise was encouraged in South Africa as many smaller communities would be prepared to initiate the installation of small power stations, particularly if there was the chance of selling power at a reasonable rate to Eskom. However, with Eskom's present surplus in power station capacity, they are reluctant to pay for kilowatt capacity, paying only for the energy. Even this is not at a highly profitable rate.

The technical potential for micro- and mini hydroelectric power plants in South Africa is large. An estimated 1 000 MW could be installed if generation was liberated and research was undertaken on a scale comparable with that for rural water supply. This figure may be reduced quite substantially once economic feasibility studies are completed. Thus, out of the more than 10 million rural people without electricity (requiring 1 000 MW), 25% are probably within 5 km of a stream which has a flow or head sufficient to generate their electrical requirements on an economic basis. Much of the balance may be from larger plants feeding into the grid. It would also require the cooperation of the Department of Water Affairs and Forestry which owns many dams capable of generating electricity for a small charge. The cost would vary widely depending on the site (e.g. Table 2) but the savings in transmission cost alone could justify many micro hydro schemes.

Types of power plant

There are three generally recognised types of turbine used in hydroelectric power generation. For low heads and large flow rates, the Kaplan-type turbine, which is almost a propeller in the direct flow path, is used. However, this type of plant will rarely be of interest in South Africa. The Francis-type turbine, where the water enters radially and exits axially from the eye of the impeller, is the more common type of turbine in South Africa, and there are many developments to improve its efficiency. For example, variable angled guide vanes can be used to permit different flow rates to achieve the maximum efficiency of generation. For much higher heads, the Pelton Wheel type of turbine is more viable, which has one or more jets impinging on buckets attached around the circumference of a wheel. Figure 2 shows the possible range of heads and flows for the various types of turbines. ABB[1] and Harvey[5] describe the various types of turbines.

There is such a wide range of heads and flows to cater for that there are no standard turbines available off the shelf as there are for many pumps. This is one of the factors which makes hydroelectric power machines financially out of the reach of many communities. The possibility of using pumps in reverse has been considered[8]. Even if the efficiency is not very high, the fact that the unit is very small means that there is probably a surplus of water available, and costs and ease of maintenance are probably more critical than hydraulic efficiency. Figure 3 shows some options on the micro scale.

Eskom supported the development of a local micro turbine[3]. This unit has been installed in KwaZulu-Natal and has

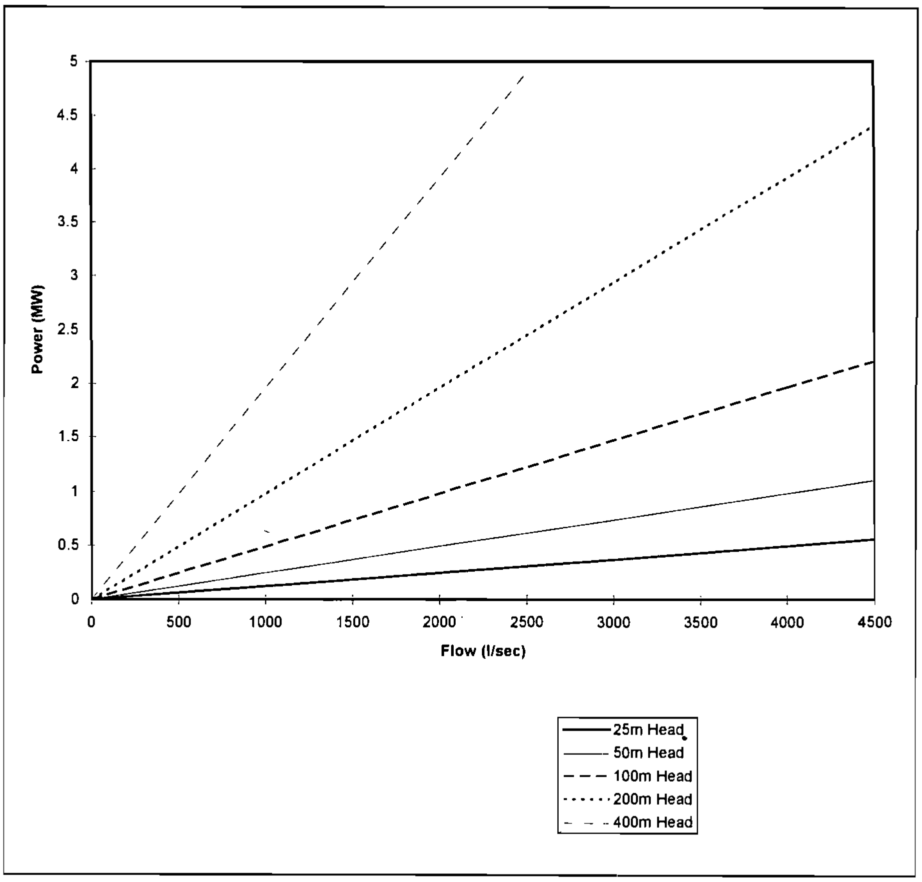

Figure 4: Power output of a hydroelectric plant

achieved an efficiency of around 60%, which is remarkable for this scale.

The biggest cost in hydroelectric power generation, however, is generally the civil engineering works. That is, the dam and the conduit to convey the flow to the turbines. Dams are by far the most expensive item if water is to be stored from the wet season to the dry season. South Africa's power demand, unfortunately, is greatest in winter when the majority of the country is suffering drought, so that large storage dams are required. Owing to the high flood peaks which can occur when it does rain, the dams have to be designed with a concrete flood spillway, which adds to the cost. Clark[2] discusses some cost implications of small hydro.

The use of inflatable rubber dams has been developed in many countries, particularly in Japan, but there is still some reservation about their use in South Africa. They also allow for the discharge of sediment which can be a severe problem, particularly for small reservoirs relative to the size of the river.

The dam can also be used to provide sufficient head or elevation to improve the power available. Power output is given by the equation

$$kW = WHQn$$

where the power generation rate in kilowatts is a function of W the unit weight of water, 9,8 kilo Newtons per cubic metre, H the head in metres, Q the flow rate in cubic metres per second, and n the efficiency of the system as a fraction, which can be as high as 90% for larger plants.

Figure 4 shows the power available as a function of flow rate and head. Bearing in mind that it is a fairly sophisticated household which would use 1 kW, with rural households generally only requiring a fraction of a kilowatt, it is obvious that a small community of about a hundred houses, plus shops and schools, would probably not even require a megawatt. Thus the scale is very small in such cases.

In some cases there are existing dams which have head and flow available. Water is not consumed by the hydropower plant but just passed to a downstream user, if there is one. So it is often easy to add a turbine onto the outlet pipework from a dam without any resulting disadvantages. Such projects have been investigated, such as at the Lubisi Dam in the former Transkei and Jozini Dam in KwaZulu-Natal.

Another high cost can be the transmission lines from the power station to the consumers. It is generally necessary to transmit at a high voltage to minimise losses. It is therefore necessary to transform down from at least 6 kV to 220 V for safety reasons.

With the inauguration of the new Water Act, the question of the cost of water looms. Whereas water was previously often regarded as free, particularly if there are other users of the water downstream, it is likely that the government will charge for water usage. Owing to the large volumes of water required, this may be a deterrent for power generation, particularly from government-owned dams. The question of whether the community should pay for water if the power generator is on a stream and the entire installation is undertaken by the community, is a debatable topic.

Some typical costs of hydroelectric schemes and the cost of the power were prepared during a study of a few possible projects in the former Transkei. As already mentioned, Table 2 indicates that the costs are often comparable with Eskom tariffs, even though the scale is very small. However, Ekom does not appear to accept the advantages of such projects.

The other great advantage of smaller hydropower schemes is that it would be a community project**, and the capacity-building, enthusiasm and learning curve would be of great advantage in the newly developing South Africa.

** *Editor's note:* A paper was published in the May 1997 issue of the Journal on such a project. The reference is: DOOGE, G.R. Implementation of a micro hydropower supply scheme in the KwaZulu-Natal Drakensberg. *Journal of Energy in Southern Africa*, May 1997, 8(2), pp. 54-59.

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Energy news in Africa

Electricity

Gabon

A diesel-powered 4x20 MW power station is to be established at Owendo near Libreville. It will be financed under a BOT formula and the first section is expected to go into service in 2000.

The initial study of the project has been handed to Electricité de France and is underway.

The electrification rate in the domestic sector is to be raised to 55% (from 40%).

(Source: Africa Energy & Mining, 2 July 1997)

Kenya

The Kenyan government has had to concede quite a lot in order to obtain the go-ahead for its energy programme, one of the reasons being the country's elections expected to be held at the end of 1997. Both the World Bank and the IDA have approved funds for energy projects in Kenya. The government will have to honour the World Bank's criteria linked to the loan, as it will need the Bank's permission for any public electricity project worth over US$10 million, beyond scheduled schemes such as, Kipevu I (diesel-powered), Olkaria II (geothermic), Gitaru/Section 3 and Sondu Miriu (hydro). Since the end of last year, rates have been close to 75% of the marginal kWh cost, a previously-accepted criterion.

The country's five-year rolling investment plan will continue to be reviewed each year, but with experts from the Bank. The same applies to the accounts of Kenya Power and Lighting and the Kenya Power Co. An agreement had already been reached to transfer the public power generating sector to the Kenya Power Co., with Kenya Power and Lighting (51,5% owned by the government) becoming a distribution company.

The other key condition is legislation presently being tabled in parliament to restructure the electricity industry. An amendment to the Power Act will set up an independent regulatory agency.

(Source: Africa Energy & Mining, 16 July 1997)

Tanzania/Zambia

Tanzania and Zambia recently signed a MOU on the planned 600 km interconnection between Mbeya and Pensulo, the cost oif which would be about US$130 million.

In Tanzania, the renovation of the Kidatu hydropower station, which is linked to a new power station at Lower Kihnasi, has been awarded a loan from Norway's NORAD.

In Zambia, Finland's Finida is to finance the extension of ZESCO's dispatching system in Lusaka to the copperbelt. The scheme is to cost about US$2 million.

(Source: Africa Energy & Mining, 18 June 1997)

Oil and gas

A third round of bidding for offshore licences is to open early in October 1998 and close in March 1999. Seismic surveys will be carried out in the deep offshore, in addition to those already handed to Genco in the south and to Western in the Namibia basin. New studies are also planned of the basins of Ovambo and Nama, as well as on the onshore Karoo basin.

Shell recently took steps to declare the Kudu gas field "commercial". This will be a reduced version of its "minimum" development for a 700 MW power station in Namibia. It will draw its gas from part of the field housing reserves estimated at 51 billion m^3, using about 1 billion m^3 per year over a 20-year period. The initial project, including the power station, is expected to cost about US$300 million.

(Source: Africa Mining & Energy, 2 July 1997)

General

The Council for Geoscience, Geological Survey of South Africa, recently produced a large colour map (Scale 1: 10 000 000) of the energy resources of Africa, together with an explanatory booklet.

The map was initiated by the Council as early as 1994 with the objective to collate, quantitatively and qualitatively, basic information on the energy resources of Africa and to present them in a format which includes the map itself, supported by written explanations and tables, based on 1993 information. It maps oil, gas, uranium and coal resources on an aggregate country-by-country basis. Symbols represent the sizes of the various commodities. Oil and gas fields, coal deposits, electrical generation points and shipping terminals have also been added. Forestation and peat deposits have not been included.

Basic infrastructural information, such as refinery capacity, ports, the location of hydroelectric schemes, is included. Per capita CO_2 production is also given on a country-by-country basis.

The explanatory booklet includes brief country profiles (as well as energy statistics) on each of the countries.

(Source: Martin ML. Energy resources of Africa: Explanation of Energy Map of Africa. 1996 ed. Pretoria: Geological Survey, 1997)

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Ketane Sithole joined the Botswana Power Corporation in 1978 as a graduate engineer. He was later seconded to British Electricity International between 1980 and 1981, and was attached to the North Eastern Electricity Board at Newcastle -Upon-Tyne.

In 1981, Mr Sithole returned to the Botswana Power Corporation where he gained wide experience in many of the departments. In December 1990 he was appointed Deputy Chief Executive of the Corporation. In May 1992, he was appointed Chief Executive Officer.

Mr Sithole has been very active in the formation of the Southern African Power Pool and continues to participate in its development as a member of its Executive Committee.

Ketane Sithole is vice-chairman of the World Energy Council's Executive Assembly for the African continent, and is also a board member of Barclays Bank of Botswana and the Rural Industries Promotion Company (Botswana).

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David Stephenson commenced his engineering career with the Rand Water Board, and then joined consulting engineers Stewart Sviridov and Oliver in what was then Rhodesia, and later in Johannesburg. He took up his present position in 1977.

He is the author of seven books and many papers on water engineering, several of which have been presented at international conferences. His research interests range from hydraulics of pipelines to water resources. His research group has a number of local and overseas contracts in these fields.

Professor Stephenson is also the chairman of the African division of the International Association for Hydraulic Research.

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Robert van der Plas joined the Industry and Energy Department of the World Bank in 1985. He has mainly been involved in renewable, traditional and rural energy projects for the World Bank.

Forthcoming energy and energy-related conferences: 1997/1998

1997

NOVEMBER 1997

16-22

SECOND REGIONAL CONFERENCE OF AFRICAN MINISTERS RESPONSIBLE FOR THE DEVELOPMENT OF MINERAL AND ENERGY RESOURCES Durban, South Africa

Theme: Strengthening cooperation among development actors in the sustainable development and utilisation of mineral and energy resources in Africa

Enquiries: Dr C Frick, Director for the Council of Geoscience, Private Bag X112, Pretoria 0001, South Africa

Tel.: +27 (12) 841 1230
Fax.: +27 (12) 841 1203/1221

18-19

3RD INDABA '97 ON COAL SCIENCE AND TECHNOLOGY Randburg, South Africa

Theme: From ore to ash

Enquiries: Conference Secretariat, 3rd Indaba '97, Mintek, Private Bag X3015, Randburg 2125, South Africa

Tel.: +27 (11) 709 4321
Fax.: +27 (11) 709 4326
Email: yma@info.mintek.ac.za

24-25

POWER EFFICIENCY Fourways, South Africa

Enquiries: Institute for International Research, Attention: Conference Administrator, P O Box 91052, Auckland Park 2006, South Africa

Tel.: +27 (21) 726 6003/6046
Fax.: +27 (21) 726 1304

1998

APRIL 1998

6-8

5TH DOMESTIC USE OF ELECTRICAL ENERGY CONFERENCE Cape Town, South Africa

Enquiries: Heidi Neves, Domestic Use of Electrical Energy Secretariat, Cape Technikon, P O Box 652, Cape Town 8000, South Africa

Tel.: +27 (21) 460 3657
Fax.:+27 (21) 45 4940
Email: nbeute@norton.ctech.ac.za

MAY 1998

24-26

EFFICIENT ENERGY UTILISATION AND MANAGEMENT: A SEMINAR Johannesburg, South Africa

Enquiries: Rhona Campbell/ Pam Rooney, J H Isaacs Group, P O Box 5575, Johannesburg 2000, South Africa

Tel.: +27 (11) 28 1066

SEPTEMBER 1998

13-18

11TH WORLD CLEAN AIR CONGRESS AND ENVIRONMENTAL EXPOSITION Durban, South Africa

Theme: Interface between developing and developed countries

Enquiries: Congress Secretariat, Mrs Ammie Wissing, P O Box 36782, Menlo Park, Pretoria 0102, South Africa

Tel./Fax.: +27 (12) 46 0170

21-25

CODATU VIII Cape Town, South Africa

Theme: Urban transportation policy: A sustainable development tool

Enquiries: CODATU VIII - Scientific Committee, Christian Jamet, President, 9/11 Av. de Villars 75007, Paris, France

Fax.: +33 (1) 44 18 78 04

Recent energy publications

BURGER W P and BURGER M M

Solar energy for activating rural agri- and home-based industries (Phase I). Dec-1996. 64p. + Appendices.
Report No. EO9607

The following hypothesis was tested: renewable energy resources can serve as a catalyst for economic development in underdeveloped rural communities if used in a cost-effective manner, and in combining human and natural resources in agricultural and home-based industries. Four different rural communities in South Africa's developing regions were identified to test the hypothesis. Included looking at the economic feasibility and social acceptability of using renewable energy resources.

COWAN W D, GEERDTS P C and BANKS D I

Solar home systems: Techno-economic study. Nov-1996. 1V.(various pagings).
Report No. EO9505

The study was conducted between 1995 and 1996. The main aims were: (1) to assist with preparations for solar home system (SHS) pilot projects, designed to test suitable organisational, finance and delivery methods for South African conditions; (2) to monitor and evaluate pilot project experience; (3) based on this, and on broader analysis, to prepare policy recommendations and a plan for large-scale implementation of solar home systems in South Africa. The results of the study address the identification of potential pilot project communities and their concerns, the interplay between solar electrification and expectations of subsidised grid supply, the need for revised rural electrification planning; technology options and costs for solar household electrification; the preparation of quality standards and specifications; training requirements; examination of solar home system finance options and organisations; and proposals for four models of solar home system delivery, to be tested in the future piloting phase of the programme.

MATHEWS E H

Energy consumption standards and national energy audit scheme for specified classes of South African buildings: Phase 1. Sep-1996. 92p. + Appendices.
Report No. ED9501

The first section of the report contains a national and international literature survey with regard to non-domestic buildings (buildings in the commercial, public or service sectors) to investigate the appropriateness of the survey material for adoption and implementation in South Africa. Includes a brief overview of current standards being employed internationally; energy audit schemes; energy auditor and manager training schemes; strategies for the adoption of these schemes. The second section consists of a further literature study and final recommendations to develop standards for South Africa, including a preliminary project proposal.

MATHEWS E H

Computer program for energy policy support and energy savings in buildings. Sep-1996. 53p. + Appendices
Report No. ED9302

The primary objective of this project was to develop a prediction support tool for: developing national energy consumption norms and budgets for different types of buildings and climates; energy efficient building design, including energy consuming systems in buildings and the retrofitting of existing buildings.

MEYER J P, TSHIMANKINDA M and VISAGIE J

Potential for hot-water heating with heat pump reticulation in the domestic sector: Techno-economic study. Jan-1997. 70p. + Appendices.
Report No. EO9517

This project was undertaken to determine the potential for domestic hot water heating with heat pump reticulation in South Africa by means of a system that can also be called "heat pump district heating". The system consists of heating the water with heat pumps, and the subsequent distribution of the hot water through a reticulation pipe system to the domestic user. The project was conducted in three phases. Phase One covered the drawing up of a detailed report on hot water consumption and heating requirements for the different types of dwellings. Phase Two considers the various heat pump district heating systems, viability and selection of the best system for the specific requirements of each case. Phase Three looks at the possible impact, on a national scale, if heat pump district heating systems were introduced.

SZEWCZUK S

Wind turbine techno economical feasibility study. Dec-1996. 38p. + Appendices.
Report No.EO9506

Covers work that was carried out on a techno-economic feasibility study for wind turbine generators in the Cape Town area. It also incorporates an exercise to gather information relating to large wind turbines. A methodology for the selection and evaluation of wind turbine generators and sites is discussed. Wind data for the Cape Town area was assessed. The results of a preliminary environmental impact assessment are discussed. The study recommended a proposal to establish a community-based wind turbine demonstration project emphasising the engineering aspects.

***WONG C T**

National Energy Data Profile: South Africa. Jul-1997. 45p.
ERI Report No. GEN 181
R34,20

Gives a brief outline of South Africa's energy economy. Contains energy balances from 1970 to forecasts up to 2010. Includes figures for emissions from energy combustion by source and sector, and diagrams of energy flow up to 1994.

All these reports are Final Project Reports (unless indicated) and are the result of research funded by the Chief Directorate: Energy, Department of Minerals and Energy.

The publications can be ordered from:

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

Reports marked * are available from the Information Officer, Energy Research Institute, P O Box 207, Plumstead 7801, South Africa, at the prices indicated.

JOURNAL OF ENERGY IN SOUTHERN AFRICA
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XyWrite

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