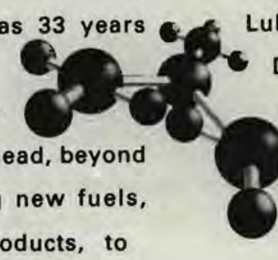
JOURNAL OF ENERGY IN SOUTHERN AFRICA

Vol.6 No.2 May 1995

$e = mc^2$

If you start with the right formula, anything is possible

In 1905 Albert Einstein showed the direct relationship between energy and matter. Energy equals mass times a constant, the speed of light squared. It revised the concept of infinity. It was 33 years before scientists could split the atom and use the knowledge. Engen is also looking ahead, beyond the next century. Developing new fuels, lubricants and chemical products, to make the future work. Every specialised lubricant application we serve benefits from the world's finest technology. Adapted to South African conditions and the ideal specifications of our customers. Only the finest mineral base oil is blended at our Lube Oil Blend Plant at Island View, Durban, where the most modern technology ensures an extraordinarily high standard of quality management. From manufacture through to delivery. With these specialised products, service and backup, the benefit to our customers is infinite.



ENGEN

With us you are Number One

DMB&B C110

Journal of Energy in Southern Africa

Vol.6 No.2 May 1995

A quarterly publication

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

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 Only previously unpublished work will be accepted.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 discussions, not exceeding 500 words, on articles published in the Journal are also invited. Items of general interest, news, technical notes, reviews and research results 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* in the Journal. All papers are refereed before publication.

The Editorial Committee does not accept responsibility for viewpoints or opinions expressed, nor the correctness of facts or figures.

Contents

Special issue: Low-Smoke Fuels in South Africa

Subscriptions (1995)

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

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

Enquiries may be directed to:
The Production Editor, Journal of Energy in Southern Africa,
Energy Research Institute, University of Cape Town,
P O Box 207, Plumstead 7800, South Africa.

Tel.: (+27) (21) 705 0120
Fax.: (+27) (21) 705 6266

ISSN 1021-447X

JOURNAL OF ENERGY IN SOUTHERN AFRICA
INFORMATION FOR AUTHORS

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

1. All contributions should be submitted in English.
2. Only original work will be accepted and copyright in published papers will be vested in the publisher.
3. The suggested length for articles and research notes is 2 500 to 5 000 words, and for book reviews,approximately 1 000 words.
4. The contribution and references should be typed double-spaced with a wide left-hand margin and single-sided using one of the available word processor packages listed at the end. The name and version of the word processor package used must be indicated on the disk. Illustrations, photographs and diagrams should be submitted on separate sheets.
5. Tables should be numbered consecutively in Arabic numerals and given a suitable caption.
6. All graphs, diagrams and other drawings should be referred to as Figures. These should be numbered consecutively in Arabic numerals and placed on separate sheets at the end of the contribution. Their position should be indicated in the text. All illustrations must have captions, which should be typed on a separate sheet. Graphs, diagrams, etc. should be printed with a laser printer, using the high quality option. If possible, all graphs should be produced with Harvard Graphics, Quattro Pro or Lotus 123.
7. The format for references should follow that as for footnotes where a number, in superscript, indicates the reference, as shown below:

   Louw [(2)] states that ...

   Full references for books and journals must appear at the end of the article in numerical sequence. For references to books, all relevant information should be provided: that is, author(s) surname and initial(s), date of publication, full title (and sub-title, where applicable), place of publication, publisher, and pagination. For conference proceedings, the date, the full title of the conference and the place where the conference was held must also be specified. For journal references, the author(s) surname and initial(s) must be provided, dates, as well as the full title and sub-title (if applicable) of the article, title of the journal, volume number, part, and pagination. Numbers identifying all references at the end of the contribution should be enclosed in brackets.
8. Standard international (SI) units must be used.
9. All mathematical expressions should be typewritten. Greek letters and other symbols not available on the typewriter should be carefully inserted in ink. Numbers identifying mathematical expressions should be enclosed in parentheses. A list of symbols marked for the use of the Production Editor, if not included in the body of the text,should accompany the contribution on a separate page. A nomenclature defining symbols must be included, where applicable. All tables and mathematical expressions should be arranged in such a way that they fit into a single column when set in type. All table columns should have an explanatory heading. Equations that might extend beyond the width of one column should be rephrased to go on two or more lines within column width.
10. Line drawings (not photocopies) and accompanying lettering should be of sufficient size to allow for reduction if necessary. Photographs of equipment must be glossy prints and should be used sparingly.
11. The body of the contribution should be preceded by an Abstract not exceeding 500 words, which should be a resumé of its essential contents, including the conclusions. Below the Abstract, a maximum of six Keywords should be included which reflect the entries the author(s) would like to see in an index. The Keywords may consist of more than one word, but the entire concept should not be more than 30 characters long, including spaces.
12. No contribution or figures will be returned following publication unless requested by the author(s) at the time of its original submission.
13. In a covering letter, the author(s) must state that the contribution has not been published or is being considered for publication elsewhere, and will not be submitted for publication elsewhere unless rejected by the *Journal of Energy in Southern Africa* or withdrawn by the author(s).
14. Authors must supply the following personal information: surname, initials, address, qualifications, occupation and/or employment.
15. Authors whose contributions are accepted for publication will receive a free copy of the issue and 3 copies of their contribution.
16. Neither the Editor nor the Publisher accept responsibility for the opinions or viewpoints expressed, or for the correctness of facts and figures.
17. The Editorial Committee reserves the right to make editorial changes to all contributions.
18. All contributions and enquiries should be addressed to: Production Editor, Journal of Energy in Southern Africa, Energy Research Institute, University of Cape Town, P O Box 207, Plumstead 7800, South Africa.

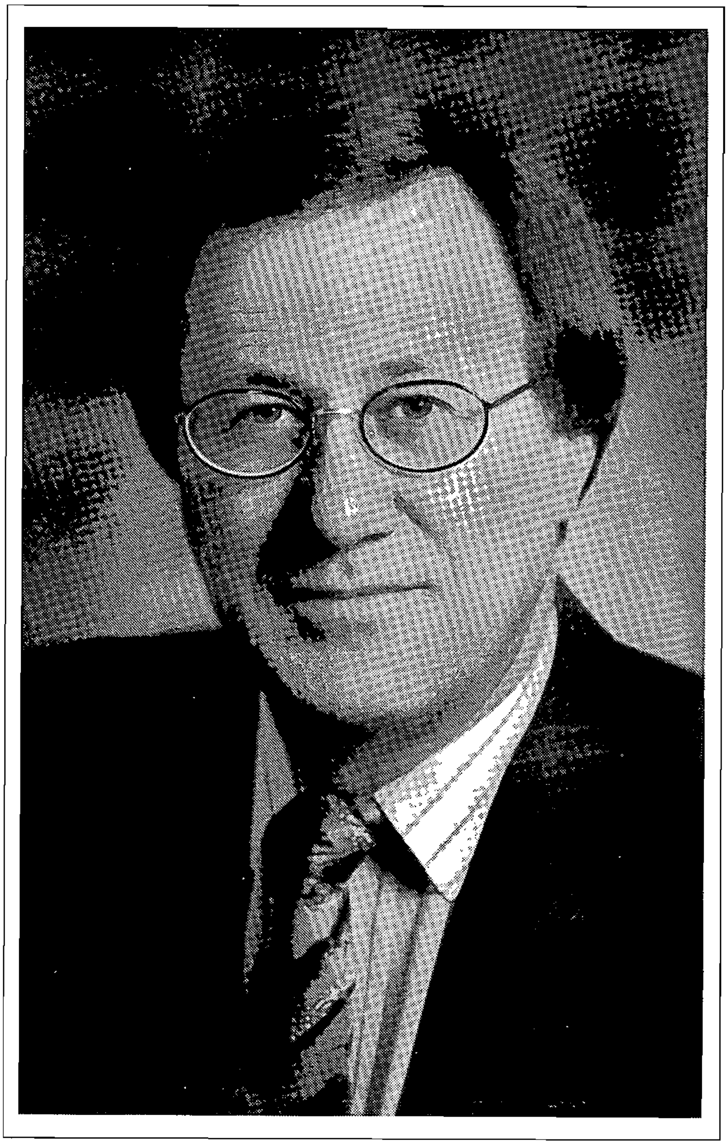
Contributions must be submitted either on a 5¼ inch floppy disk or 3½ inch disk (stiffy), and use must be made of one of the following word processor packages:

Multimate
Microsoft Word (MS Word)
PC-Write
PFS: Professional
PFS: Write
Wordperfect
Wordstar
XyWrite

If the "Windows" version of these programs is used, the file must be saved in ASCII format. If any other word processing packages are used, other than those listed above, the file should be submitted in ASCII format.

The disks must be adequately packed for postage.

Profile: Gert P N Venter



Deputy Director General: Administration and Mineral and Energy Resource Management, Department of Mineral and Energy Affairs

After matriculating from the John Orr Technical High School in 1961 with plans to be an electrician, Gert Venter decided to pursue an academic career. He was awarded a bursary from the CSIR in order to complete his B.Sc. in mathematics and physics at the University of Pretoria. He graduated in 1965. He then completed his M.Sc.(1968) and D.Sc.(1971) in physics through the University of Pretoria, while working part-time at the CSIR.

In 1966 he joined the CSIR's Air Pollution Research Group. In the 1970s he undertook further research overseas in the field of atmospheric physics, air pollution and boundary layer meteorology. This postgraduate research was undertaken at the Institute for Meteorology and Geophysics and the Pilot Station for Air Pollution of the J W Goethe University, Frankfurt, Germany, the Von Karman Institute for Fluid Dynamics in Brussels, and at the Civil Engineering faculty of the Colorado State University in the U.S.A. respectively.

On his return to the CSIR, Dr Venter was appointed head of the Air Pollution Research Group. Between 1980-1987, he became involved in the development, management and co- ordination of the national programmes for energy and micro-electronics research. Dr Venter moved into the area of policy development when in 1987, he was appointed Group Executive to the then newly-established National Energy Council (NEC), with responsibility for electricity, coal, energy efficiency, decision support and strategic planning. When the NEC was absorbed into the Department of Mineral and Energy Affairs, he was appointed Chief Director: Energy in March 1993. In June 1993, he was promoted to his present position of Deputy Director-General: Administration and Mineral and Resource Management in the Department.

Dr Venter currently serves on various local boards and committees related to energy and the environment, such as, Eskom's Electricity Council, the Atomic Energy Corporation and the Central Energy Fund. He is currently Deputy Chairman of the National Air Pollution Advisory Committee of the Minister of Environment Affairs.

In the international context, he is the leader of the South African delegation to the Permanent Joint Committee for the rehabilitation of the Cahora Bassa hydro-electric scheme. He is also currently responsible for managing the energy collaboration between South Africa and the Republic of China (Taiwan). He has also led various energy delegations on formal visits overseas, the most recent one being to Norway in January 1995.

Dr Venter is married to Leonie-Marie (née Leiding), and they have two children - a son and a daughter.

The Low-Smoke Coal Programme of the Department of Mineral and Energy Affairs

* C J GROBBELAAR, * J K ASAMOAH and * A D SURRIDGE

A need has been established for a low-smoke fuel as a transitional energy source to assist in the amelioration of the high levels of air pollution in some residential areas. This paper provides the historical background for the activities of the Department of Mineral and Energy Affairs (DMEA) on the development of low-smoke coal. It further describes the latest activities of the Department in establishing a Low-Smoke Coal Programme and a Low-Smoke Coal Advisory Committee (LSCAC) to advise the DMEA on the further development and implementation of low-smoke coal.

Keywords: coal; low-smoke coal; air pollution; Low-Smoke Coal Programme; Low-Smoke Coal Advisory Committee

Introduction

It is estimated that approximately 3% of national coal consumption is burnt in household units and that this combustion accounts for approximately 20% of national particulate emissions. Although the levels of air pollution in non-electrified residential areas have long been of concern, it is only recently that the effects have been quantified[1].

Coal and wood, used as primary household energy sources, can increase the risk of developing acute and chronic respiratory infections. Results of investigations have indicated that exposures of children to total suspended particulates (TSP) are unacceptably high, with 100% of measurements exceeding recommended exposure limits during winter and a corresponding 96% exceeding the limit during summer. It has been further stated that the use of coal as a household energy source is the single most important risk factor for respiratory illnesses in urban children[2]. Therefore, there is an urgent need for intervention practices to reduce exposures to air pollution resulting from the burning of wood and coal.

During the 1960s a low-smoke fuel was investigated without much success. During the 1970s a low-smoke stove was developed, but despite good sales, this initiative was largely unsuccessful because users modified the combustion chamber (to improve burning) thereby negating the smoke suppression features of this appliance. The 1980s saw the start of an intensive electrification campaign, but this had little effect on residential air pollution.

At first the overall benefits of electrification in the household sector, illustrated by the lower air pollution levels in the developed communities, make the switch from coal/wood to electricity an attractive and logical option. However, the reality of supplying electricity to all people even in the remotest parts of the country is not economically feasible. Moreover, even when electrical energy is accessible, coal is still burnt as the preferred fuel for a variety of reasons. For example, in Soweto, although there is complete electrification of formal housing, coal is still used by approximately two-thirds of the residents for heating and cooking[3]. Reasons for the preference of coal include the following:

(a) Smoke is sometimes not seen as detrimental to health. More importantly, there are other priorities over a pollution-free environment, such as employment, adequate food and housing.

(b) There is a large installed infrastructure to utilise coal and there are insufficient funds or incentives to replace coal stoves with high-cost electrical apparatus.

(c) Electricity supply is unreliable because of breakdowns and vandalism, whilst a well developed and reliable coal-based infrastructure exists.

(d) Coal is a less expensive source of energy than electricity.

(e) During winter the coal stove serves as a multi-purpose device for cooking, space-heating and social gathering point for the family.

As a result of the user preference for coal for cooking and space-heating purposes, especially during winter, electrification has not had any significant effect on decreasing air pollution levels during winter. A recent survey revealed that 83% of households will definitely not get rid of their coal stoves[4]. However, this survey also indicated that 90% of those coal users questioned would very likely/likely switch to a low-smoke fuel if certain specifications were met. These specifications include: the same or better burning characteristics; equivalent or lower prices; the same or better handling characteristics.

Electricity is more expensive than the D-grade coal presently used. For example, it has been stated that the price of useful electrical energy is 24% greater than direct coal energy[5]. Other sources state that the price of electrical energy can be twice that of coal energy - depending on how the statistics are calculated. Price constitutes an important aspect in terms of limited disposable income for household coal users. In the informal settlements, where there is no electricity, coal is a basic and essential energy resource for daily activities. There is therefore a need for the reduction of the use of D-grade coal which causes environmental air pollution and aggressive replacement with low-smoke coal. The philosophy of the low-smoke coal approach is to utilise the existing coal-based infrastructure and to merely replace the fuel feedstock.

Regarding the supply of low-smoke solid fuels, another investigation has confirmed the above as follows:

- Almost two-thirds of electrified households still continue to use coal. The reasons being the higher cost of electricity, often interrupted electricity supply, and the cost- effectiveness of coal as a fuel for space-heating.

- The use of anthracite is also limited by its higher price (almost double that of bituminous coal) and a low awareness level among consumers of its availability and benefits. The health hazard and pollution caused by burning of coal in homes is considered by domestic consumers as a major problem in townships.

* Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria 0001, South Africa

- Different naturally occurring and manufactured low-smoke fuels were analysed and the main finding was that most of the currently known and available low-smoke fuels will need some (financial) assistance to gain entry into the market.
- Anthracite and lean bituminous coal provide the cheapest alternatives, that is, with regard to naturally occurring low-smoke fuels. Results of laboratory tests have shown a significant lowering of air pollution emissions when compared with the usual D-grade coal. However, neither of these sources can satisfy the total current demand for solid fuel in the townships.
- Low-smoke solid fuels can be produced by devolatilising bituminous lump coal or bituminous fines with subsequent briquetting. This devolatilising process involves high capital investment, which makes a low-smoke fuel produced in this manner uncompetitive with normal D-grade coal.

Subsequent to the above-mentioned study, the now disbanded National Energy Council supported some development work on low-smoke coals. The first fuel investigated was the production of a low-smoke coal from devolatilised discards. A second fuel, based on the idea of using ordinary Portland cement as a binder for fine coal, was funded during 1992 to improve the original recipe of this fuel. The Department then funded field trials in terms of the social acceptability evaluation of these fuels. A third fuel developed by private enterprise was also included in the field trials.

Based on the above-mentioned background, this paper describes current activities within the DMEA to promote an integrated and co-ordinated Low-Smoke Coal Programme. Anticipated future steps that will determine the success of low-smoke coals will be addressed.

The establishment of the National Low-Smoke Coal Programme

During 1994 developments in South Africa provided the opportunity to reinvestigate the potential for low-smoke coal as a residential air pollution amelioration tool. Within the DMEA internal co-ordination was effected, which led the way for an integrated low-smoke coal programme to be initiated.

Low-Smoke Coal Workshop

Preliminary work has shown that the technical feasibility of low-smoke coal, together with electrification, will significantly reduce the levels of air pollution in residential areas. Although the currently available low-smoke coals are not 100% pollution free, they represent a significant improvement on the presently available D-grade coal.

In order to address and discuss future developments in the field of low-smoke coal, the DMEA commissioned the National Association for Clean Air (NACA) as a non-governmental organisation (NGO) to solicit the advice of interested and affected parties through a Workshop. The output of the Workshop was to establish the need and strategy for a low-smoke coal programme. The strategy covered a necessary course to evaluate and implement low-smoke coals as an air pollution combatant. The following aspects were considered:

(a) Technical aspects, to ascertain viability and the practicality of low-smoke coals.

(b) Economic aspects and comparisons with other options.

(c) Industrialisation and the production of low-smoke coals.

(d) Social acceptability of low-smoke coals.

(e) Further technological improvements which could be made to low-smoke coals.

The Workshop consisted of two parts. Position papers were presented as background to the discussions. Secondly, discussion groups were formed which formulated the strategy and reported back to the DMEA via the NACA. During the report-back period various aspects of the low-smoke coal option were debated. Key factors identified by the Workshop delegates were to be implemented in three stages, namely short-, medium- and long-term.

Short-term

(a) A comprehensive research and development programme on low-smoke coal should be started immediately covering technical, economic and social aspects.

(b) Energy conservation, including improved insulation of formal and informal dwellings, should be included in an integrated energy policy linked to urban development.

(c) Education and publicity programmes should be implemented in the electronic and other media to show involved parties the optimum way to utilise normal coal, with benefits, both from the economic and health aspects.

(d) A steering or advisory committee should be established to co-ordinate activities and ensure that the programme maintains momentum.

Medium-term

A pilot project should be established in a geographically isolated township in order to test the economic acceptability, health effects and air quality improvement when low-smoke fuels are used.

Long-term

Acceptable standards should be enforced by relevant legislation to improve air quality equal to world standards by the year 2005.

Low-Smoke Coal Advisory Committee (LSCAC)

To facilitate the formation of the LSCAC, a invitation was extended at the Workshop to all interested persons willing to serve on such an advisory committee. The inaugural meeting of the LSCAC was held on 18 August 1994 at the CSIR and attended by 29 delegates.

The terms of reference of the LSCAC were to evaluate the status of the low-smoke coal situation and advise the DMEA of suitable actions regarding the promotion of the Low-Smoke Coal Programme. The primary function of the DMEA was to develop policy and to ensure that the Department does not advance individual companies or industries. The LSCAC should mainly focus on low-smoke coal and that other household energy aspects should be seen to be of general interest only.

The purpose of the inaugural meeting was firstly, to discuss outcomes of the Workshop; secondly, to discuss further developments on low-smoke coals; and thirdly, the formation of the LSCAC and briefing on its terms of reference.

The LSCAC recommended that the goal of the Low-Smoke Coal Programme should be the complete substitution of bituminous coal by low-smoke coal by the year 2000. During the discussions the following areas were identified as critical issues: economics, legislation, user requirements, and technological development. After receiving 16 nominations for the LSCAC, plus the DMEA representatives, it was decided at the meeting that the DMEA should select 10 people from the nominations. However, this proved difficult as it would mean losing valuable expertise in the field of low-smoke coal development. Therefore it was decided to select 10 people to serve on a Working Group (WG) and that all attendees and apologies at the inaugural meeting should form part of the LSCAC. It is envisaged that the WG will formulate detailed recommendations to the DMEA and that these will be circulated to the LSCAC members for comment. From time to time plenary sessions of the LSCAC will be held to discuss the latest developments.

Low-smoke coal synthesis

Following a recommendation by the Workshop, the DMEA commissioned a low-smoke coal synthesis study. The need was for various sources of information on low-smoke coal to be drawn into a single workable document. This study was to concentrate on published and existing data, with particular emphasis on international experience in this field. It was completed during February 1995.

Preparatory investigations on the Low-Smoke Coal Programme

The first meeting of the LSCAC identified the need to establish the viability of low-smoke coal to fulfill its function of ameliorating air pollution. The implications of the implementation of a low-smoke coal also needed to be identified. Subsequently, the DMEA has called for a number of small proposals (commensurate with existing financial resources) in preparation for a more comprehensive Low-Smoke Coal Programme during 1995. The outputs of these projects will influence the future work as well as establish gaps and needs in existing information. These preparatory projects are generally aimed at establishing the overall requirements for attaining the goal of lowering air pollution concentrations in the townships to acceptable levels. A summary of the main outputs of the preparatory projects were as follows:

(1) ***Low-smoke coal synthesis***
- Plant capital requirements for the production of low-smoke coal must be sought from potential manufacturers.
- Field trials need to be undertaken to facilitate market acceptability of low-smoke fuels.

(2) ***Characteristics and requirements for a low-smoke coal***
- The selling price of low-smoke coal must be lower than that of conventional household bituminous coal.
- In closed appliances, the fuel must be able to achieve 50% of appliance-rated output in less than 30 minutes and it should be capable of maintaining 90% of the appliance heating output for a period of two hours.

(3) ***Impacts on the environment of differing energy mixes***

This project proposes a new design parameter, namely, a mass of particles released per effective energy of the source (MPE), which allows easy comparison of the pollution impact of various energy mixes in the townships.

(4) ***Source apportionment of township air pollution***

This project attempts to estimate the contribution of the air pollution burden by coal, industry, road dust and veld fires, using modelling techniques.

(5) ***Impacts of removing the air pollution: Technical aspects***

This study reveals that the main impacts are improved visibility and changed heat balance. The modelling methodology is being applied.

(6) ***Impacts of removing the air pollution: Health aspects***

An examination of issues related to the health impacts of different electrification scenarios in South Africa is made. Policy and socio-economic issues are also examined in this project.

(7) ***Evaluation of the use of coal in Evaton***

This study is aimed at determining the influence of fuel-related and non-fuel-related factors on the respiratory health status of 8-12 year-old children in urban and rural areas.

(8) ***Programme to prove the efficacy of low-smoke coal: Technical aspects***

Air quality data is to be provided for a selected area, covering not only particulate emissions from coal-burning, but also volatile organic emissions with demonstrated health impacts. Analytical emissions data of ordinary coal and of a selected low-smoke coal will be used as a basis for the project design.

(9) ***Programme to prove the efficacy of low-smoke coal: Social aspects***

This project is one of the preparatory studies to the envisaged macro-scale experiment, which is aimed at the social acceptability of low-smoke coal.

(10) ***Market characteristics of a low-smoke coal***

The objective of this project is to determine the potential of the low-smoke coal market with the help of the current "smoky" coal sales.

(11) ***Education programme proposals***

The main aim of this programme is to educate all the stakeholders of the Low-Smoke Coal Initiative. Identifiable groups, particularly in the communities, are the main targets of this campaign.

Low-Smoke Coal Programme schedule

A Low-Smoke Coal Programme was devised during 1994 by the Working Group of the Low-Smoke Coal Advisory Committee. It addressed the Programme as envisaged at that stage, and formed the basis of the 1994/95 work schedule. A plenary session of the Low-Smoke Coal Advisory Committee was held at a Workshop on 2 February 1995 to address progress made up to that stage. Apart from addressing the technical progress, suggestions were also tabled with regard to updating the overall programme.

It is the Department's function to address policy development and this explicitly forms the focal area of the Low-Smoke Coal Programme (Figure 1). (The previous schedule concentrated on technical aspects and only implicitly referred to policy development.)

To date, the Programme has consisted of a number of preliminary studies (mentioned above) which will eventually be synthesised within the Department. However, details will be well publicised through workshops and conferences.

Figure 1 shows that the main thrust of the Programme follows down the centre. The synthesis study will be used to assist in the formulation of a standard for a low-smoke fuel. A standard is required in order to ascertain what quality of coal will be required to ameliorate the air pollution problem. Moreover, it is important to eventually define an official standard (most appropriately through the SABS) to identify product compliance if financial intervention procedures are adopted.

Tests of low-smoke fuels which are presently available will include both laboratory and field trials. The laboratory tests will determine the technical factors of the low-smoke fuel, for example, emissions and ignitability. The field tests will determine the social acceptability of the fuel, i.e. whether the consumer would

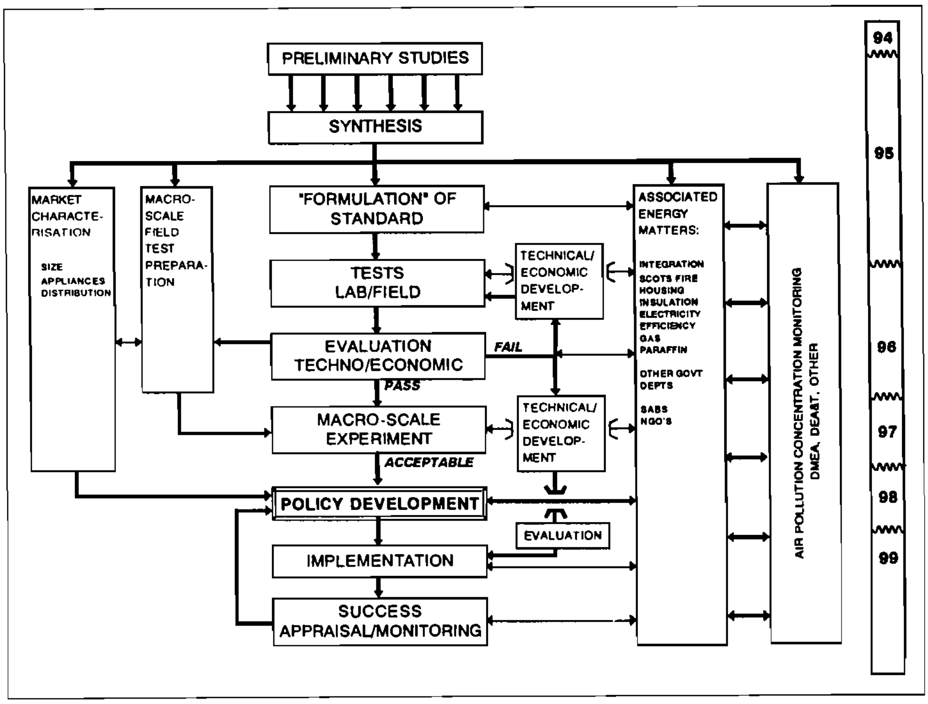


Figure 1: Low-Smoke Coal Programme Schedule: February 1995

be prepared to purchase a low-smoke fuel in preference to the present D-grade coal. At this stage economy is not a factor.

Following the laboratory and field tests, a techno-economic evaluation will be undertaken to determine whether the fuels tested conform to standards and whether they could be economically viable. At this point the prospective low-smoke fuels may take two routes. Potential fuels should not be excluded for future application. Should a fuel not meet the requirements at this stage, it may be possible within certain time constraints to undertake further techno-economic development and then re-test it before the macro-scale experiment. On the other hand, depending again upon the time factor, further techno-economic development and re-testing of a fuel may take place later and then be applied at the implementation of policy.

The macro-scale experiment is designed to ascertain whether the low-smoke fuel will make an appropriate contribution to a decrease in air pollution to an acceptable level. Only fuels that meet specific requirements will be considered for the macro-scale experiment. Once it has been determined that the low-smoke fuel is viable, then the development of policy in terms of its promotion in the townships is scheduled, followed by the implementation phase.

The success of the policy implementation programme should be appraised and monitored. The level of success will determine whether further policy development/amendments are required.

The left-hand side of Figure 1 emphasises the market characterisation aspect (for example, size, appliances, distribution) which is important to consider when developing policy. At the same time the preparatory work for the macro-scale experiment will be undertaken. As it is anticipated that the size of the macro-scale experiment will encompass a small township, appropriate technical and more important sociological factors will be addressed.

The right-hand side of Figure 1, indicates that low-smoke coal is only one component of the household energy sector. It is therefore necessary to integrate the Low-Smoke Coal Programme with associated energy matters, for example, housing, insulation, electricity, efficiencies, etc.

The effectiveness of the Programme and eventual policy in terms of the lowering of air pollution to acceptable levels should be monitored. To this end an air pollution monitoring programme in target areas will be undertaken.

The far right of Figure 1 gives an approximate time schedule which may expand or contract as the Programme progresses and results are made available. Insofar as the timetable is concerned, it is expected that the macro-scale experiment will take place in 1997. This is a complex and expensive experiment and it is important to ensure that enough time is allocated for preparation, in order to ensure success.

Conclusion

The Low-Smoke Coal Programme of the Department of Mineral and Energy Affairs was instigated as part of an integrated effort to provide a relatively clean form of energy in an effort to ameliorate the air pollution problem in the townships - in direct support of the government's Reconstruction and Development Programme (RDP). Although it is expected in the long term that the switch to electricity may alleviate the problem, it is important to address the transitional period, where people still prefer to burn coal even after electrification.

The Low-Smoke Coal Programme is but one component of an integrated household energy programme, and the application of all energy-related factors will be required in order to reduce air pollution to acceptable levels. At the same time the affordability of energy in the poor sectors of the community should be ensured by means of appropriate energy provision.

The goal of the Low-Smoke Coal Programme is to implement low-smoke coal in the townships by the year 2000.

Acknowledgement

The authors gratefully acknowledge the permission of the Department of Mineral and Energy Affairs to publish this paper.

References

(1) NEL R, TERBLANCHE A P S, DANFORD I, OPPERMAN L, BECKER P and POLS A (1993). Domestic fuel exposure as a risk factor for development of upper respiratory illnesses and lower respiratory illnesses in rural and urban communities. Paper presented at the National Association for Clean Air National Conference, held in Dikhololo, South Africa. November.

(2) TERBLANCHE A P S (1992). Health and safety aspects of domestic fuels. Report to the National Energy Council, No. NE14/6/30.

(3) SITHOLE J (1990). Air pollution in Soweto. Paper presented at the 1st IUAPPA Regional Conference on Air Pollution, held in Pretoria, South Africa.

(4) HOETS P A (1994). Low-smoke fuels acceptability study 1992 and 1993. Paper presented at the Workshop organised by the National Association for Clean Air for the Department of Mineral and Energy Affairs, held at Vista University, Soweto. June.

(5) VAN SCHOOR C and HEYL L J (1987). Low-smoke solid fuels: Summary report. LHA Management Consultants report for the FRD,CSIR. November.

The manufacture and combustion of low-smoke coal

* C J GROBBELAAR and * A D SURRIDGE

The Low-Smoke Coal Programme was established by the Department of Mineral and Energy Affairs (DMEA) to contribute to the amelioration of residential air pollution. The manufacture and combustion of the three low-smoke coals tested are addressed in this paper. Results indicate lower smoke emissions from this type of coal than from the ordinary D-grade coal presently used. The establishment of the Programme has also led to the emergence of hitherto unknown low-smoke fuels which will be included in future work.

Keywords: low-smoke coal; air pollution; combustion; emissions, coal discards; coal characteristics

Introduction

It is estimated that approximately 69% of households in the central industrial area burn coal for cooking and heating purposes, especially in winter[1]. A recent survey[1] has revealed that 83% of households would definitely not get rid of their coal stoves, even after electrification. This use of coal has lead to unacceptably high levels of air pollution in these residential areas.

The coal is burnt mainly in inefficient apparatus, such as coal stoves, drums and open fires. The quality of coal supplied to the domestic market has a calorific value of less than 25,5 MJ/kg and an ash content of 22%-24%, a product usually known as D-grade coal. On combustion, this coal, which has a volatile matter content of between 18%-24%, releases the unburnt volatiles as visible smoke. This also represents an energy loss to the domestic coal user.

As an amelioration factor to the air pollution problem, low-smoke fuels have been developed both in South Africa and in other countries. However, local implementation of this type of coal has been inhibited by high cost and a lack of user acceptance of the product. A multi-disciplinary approach, including clean coal technologies, such as low-smoke coals, together with electricity, is regarded as a potential solution to improving urban air quality.

The scope of this paper is to investigate the sources for low-smoke coals and the manufacturing, physical and combustion properties of three low-smoke coals tested.

Availability of sources for low-smoke coal

Natural low-smoke coals like anthracite and lean bituminous coal occur in South Africa. Unfortunately these coals sell for approximately double the price of D-grade coal and it is therefore not surprising that they are beyond the financial resources of the urban and rural poor. Also, anthracite and lean bituminous coal reserves are limited and may not be sufficient to supply the current solid fuel market. These fuels are therefore limited to the more affluent households and merchant markets[2].

Because of the financial constraints in the domestic sector, the price of the final product plays an important role. Table 1 demonstrates the large price gaps between typical smokeless fuels and D-grade coal.

The price of R233 per tonne for D-grade coal is applicable when this coal is beneficiated (washed) at the colliery and then supplied directly to the household market via the coal distributors. Should any supplementary beneficiation or upgrading of this coal be applied between the colliery and the user, the final price to the user would be increased. This is the main reason for the higher costs of low-smoke fuels developed in the past. One way to overcome this problem is to start with a less expensive source coal, e.g. coal discards.

Discards production

The coal resources of South Africa of the Gondwanaland type, where the coal seams are composed of organic and inorganic components, intermixed to varying degrees. The coal can be beneficiated by washing, that is, separating the coal from the mineral impurities using dense medium density variations, which is a wet process.

The relative density of pure anthracite is 1,5 and bituminous coal is 1,25. The relative density of non-pyrite mineral is 2,2-3,9 and pyrite is approximately 5,0. The run-of-mine coal is crushed which induces a certain degree of disassociation, and then by using the density differences, the components of coal and mineral can be separated using the dense medium process. Approximately 23% of the input

		R/t
South African household coal		
D-grade coal		233
Anthracite		418
Charcoal lump		
South African, barbecue	- 5 kg	1 400
South African, barbecue	- 20 kg	1 095
East African, cooking	- 50 kg	282
Charcoal briquette		
South African, barbecue	- 5 kg	2 000
European smokeless fuels		
UK (low temp.cure) briquette		900
Germany (subsidised) briquette		691

Table 1: Retail price data on selected solid fuels: 1994 prices[2]

* Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria, South Africa

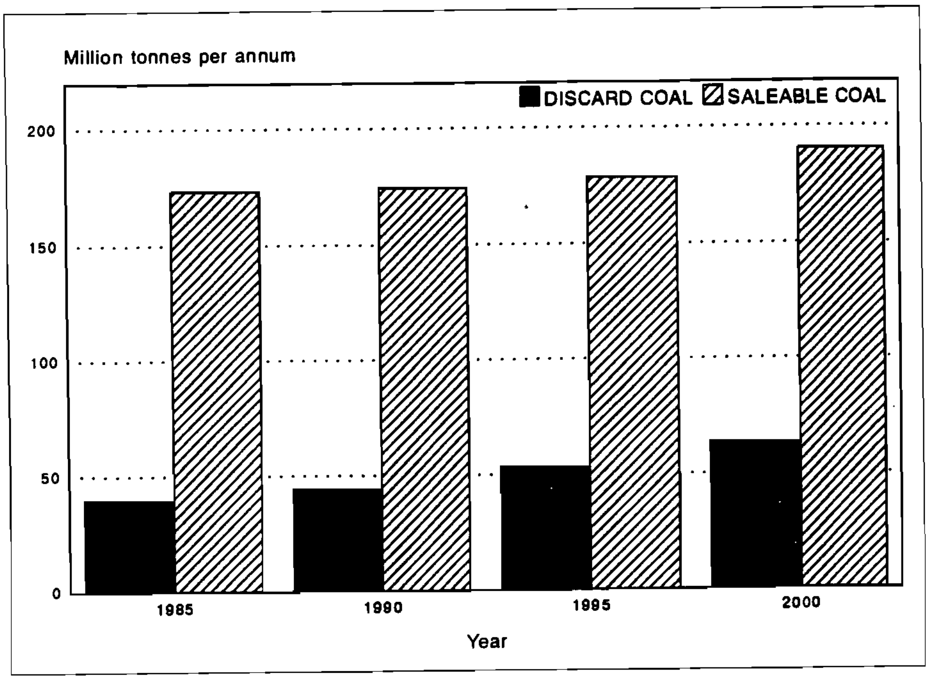


Figure 1: *Discards and saleable production*

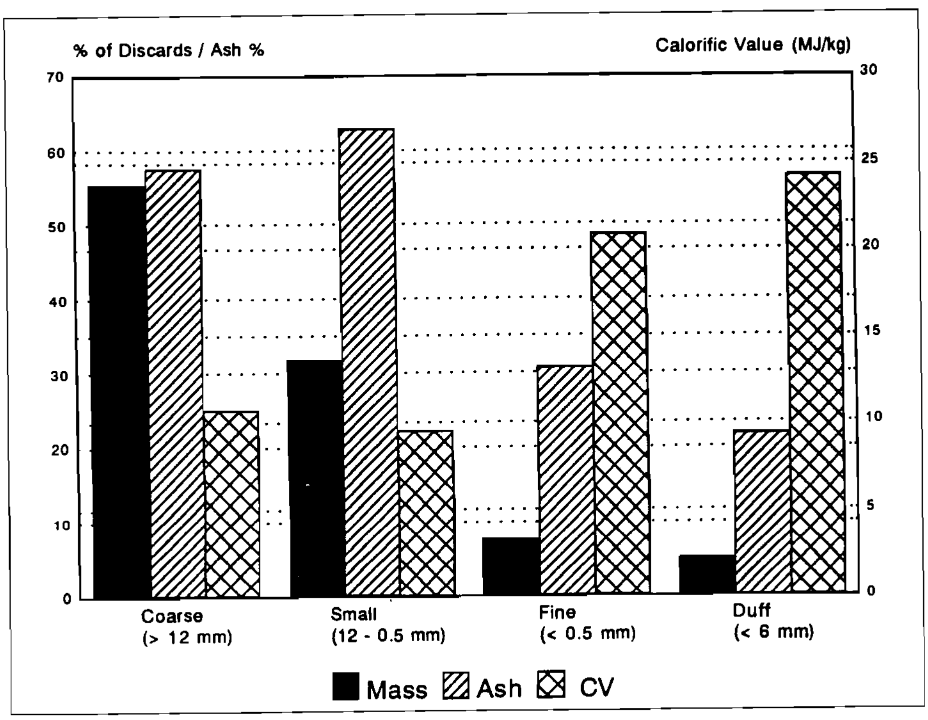


Figure 2: *Quantity and quality of discard coal: 1990*

material is discarded while the remaining 77% is a high-quality coal - depending on customer requirements.

When beneficiating this coal, there needs to be a compromise between maximising the recovery of combustibles and producing a high-grade, commercially acceptable product. The compromise dictates that in the preparation of coals for the export market as well as specific local markets, it is necessary to discard a considerable tonnage of highly combustible material. Such discards must be stored in an environmentally acceptable manner.

In addition to discarding high-ash course material, fines (duff of 6 mm and less) are also discarded. This fine material, which is usually of higher quality than the high-ash coarse material, has no readily available market and it is therefore stockpiled/dumped at or near the production site. From the 224 million tonnes of run-of-mine coal produced in South Africa during 1990, approximately 40 million tonnes discards and approximately 174 million tonnes of saleable coal were generated (Figure 1). By the year 2000 it is expected that more than 60 million tonnes of discards could be produced annually. The current quantities and qualities of the various sizes of discards are depicted in Figure 2 from which it can be noted that the finer the discard material, the higher the quality. Approximately 2 million tonnes of fine discards are produced in South Africa annually.

The fine coal, together with the high volume, high-ash course discards, can form the basis for an expensive feedstock for low-smoke coals.

Manufacture of low-smoke coal

Apart from two naturally occurring low-smoke coals, namely anthracite and lean bituminous coal, three manufactured low-smoke coals were known to the Department at the time of the testing project. Two were developed through the Department's Coal Research Programme, and one was developed by a private concern and evaluated by the Department.

Certain characteristics need to be present if coal is to be used as an energy source. These are ignitability, production of useful heat, physical strength and specific size requirements. Normal D-grade coal, apart from a relatively high ash content, fulfills all of these requirements.

One of coal's constituents is its volatile matter which, on ignition, constitutes the main smoke-forming properties of the coal. On combustion, the volatile matter is partly combusted, which assists in the ignition process of the coal, while the remainder of the volatile matter is released into the atmosphere in the form of visible smoke. This unburnt volatile matter constitutes an energy loss to the household as well as a source of air pollution. The main characteristics of a low-smoke coal are the lower content of volatile matter and that most of the volatiles present are burnt. A compromise is required between high volatile content with easy ignition and low volatile content with low smoke emissions.

Devolatilised sized discards

In most cases, rejected discards contain a significant amount of coal with a calorific value of up to 23 MJ/kg. This energy is reclaimable by rewashing the discard at higher densities of between 1,8 and 2,0, which removes the excess stone as well as the sulphur-rich pyrite. Production of low-smoke coal is based on the recovery of a combustible low-grade coal fraction from currently produced washing plant discards.

The main source of discards is the No.2 coal seam in the Witbank Coalfield. If, however, the No.4 coal seam in the same area is to be beneficiated to an increasing extent, even greater quantities of combustible discards will be produced in future. It is estimated that more beneficiated discards can be produced in the Witbank Coalfield alone (approximately 10 million tonnes per annum) than the current demand for coal in the domestic sector, which represents the potential market for a low-smoke coal.

Apart from being a low-cost feedstock, an interesting and potentially useful attribute of the rewashed discards is their maceral (organic component) composition. The major reactive and smoke-forming component of coal is the maceral, known as vitrinite. In South African coal the vitrinite tends to be concentrated in particles of lower density. The major maceral of the higher density particles is from the inertinite group which has a substantially lower proportion of the tar-forming volatile compounds. Hence, the rewashed discards have the potential for producing less smoke on combustion. It also means that the heat treatment of the rewashed discards to render them a low-smoke coal is faster at lower temperatures than devolatilising a higher quality vitrinite-rich bituminous coal.

The heat treatment

Small-scale tests indicated that heating the rewashed discards for approximately two hours at 600°C would produce a lump coal with approximately 12% volatile matter content, similar to that of anthracite. Smoke measurement tests indicated an 80%-90% reduction, compared to a normal D-grade coal which is usually distributed in the domestic sector. The most promising aspect, however, was that the coal burnt in almost exactly the same way as anthracite.

In order to obtain the required size range for a domestic coal product, only the coarse discards (size 10-150 mm) were considered. Because of optimum handling and combustion characteristics, the ideal size range needed is between 40-90 mm which, allowing for size reduction in the heat treatment process, should give the right size range of the final product. The removal of the volatile content to the required level is done by subjecting the discard to carefully controlled elevated temperatures. Too much removes virtually all volatiles and renders the fuel inactive, difficult to ignite, and gives rise to size degradation. Too little results in a smoky fuel.

Full-scale heat treatment

Waste heat from a commercially operated reductant plant for the production of char[3] was identified as the most cost-effective route for the required heat treatment process. The process usually generates far more heat than is required for char production and the surplus is currently vented to the atmosphere. By modifying the stokers it should be possible to divert the surplus heat to a secondary production unit producing the low-smoke coal. This modification requires investment following satisfactory proof of the viability of the low-smoke coal. Up to now low-smoke coal production at the plant was attempted on unmodified grates in batches of 5-50 tonnes. Although the resultant fuel did not have the properties of the experimental fuel produced under ideal conditions, it performed satisfactorily in closed stoves. The disadvantages were notably with regard to product size and reactivity because of the lack of full control over the heating conditions.

Two factors, namely, using beneficiated discards and the waste heat, form the basis for the production of a low-cost, low-smoke coal provided that the reduction in the volatile matter content can be carefully controlled and the product to be marketed can be screened to deliver the required size range. This will enable a technically feasible low-smoke coal to be produced which is acceptable to the domestic coal consumer. The economic viability of this product is dependent on the infrastructure at collieries to rewash and screen the suitable discard feedstock and at the commercial reductant plant to treat large amounts of beneficiated discards.

Cement reconstituted coal fines

The concept of using cement as a binder for fine coal was already a known technology during the early 1920s. During 1992 this concept was revisited and a novel approach was introduced, the main difference being that the present concept requires no pressure for the binding action[4].

The prototype product was made with unsold duff coal obtained from a local coal depot and bound with normal Portland cement and water. This process closely resembles concrete mixing as done every day in the building construction industry. An advantage is that very little capital or infrastructure is required to produce this low-smoke coal which, because of its labour intensity, also has the potential for job creation.

Production process

Discard fines or duff (size 6 mm and smaller) are mixed in a 100 kg batch concrete mixer with cement, lime and water until a homogenous mixture is obtained. The slurry is then poured into a simple mould consisting of four planks on a sheet of plastic and sun-dried. Tiers are mixed by covering the slab for at least seven days. The slab is then uncovered and allowed to dry. Premature drying should be prevented to enable the cement to develop full strength. Before complete setting takes place, the slab is indented for later fragmentation into the required sized briquettes. Various ratios of fine coal, cement and lime have been studied, including higher pressure briquettes (using a hand-operated brick-making machine), to find the optimum recipe regarding ignitability, combustion, emissions and strength. It was concluded that the amount of lime together with the size distribution of the fine coal particles is critical to prevent friability of the briquette.

As a part of a follow-up phase of the initial development, a study to optimise the various formulation and processing variables was undertaken. Unfortunately, the addition of lime weakened the product mechanically.

Product characteristics

The combustion of this fuel produced less smoke than the normal D-grade coal burnt in a brazier. Further advantages of this process are:

(i) the use of coal fines to reduce the environmental impact caused by such coal waste dumps at collieries,

(ii) creation of job opportunities for unskilled labour, and

(iii) the reduction of air pollution during coal combustion in households.

Considering that approximately 2 million tonnes per annum of coal fines are produced at South African collieries and the potential of using fine coal waste accumulated at coal yards, it is sufficient to provide part of the domestic market for low-smoke coals.

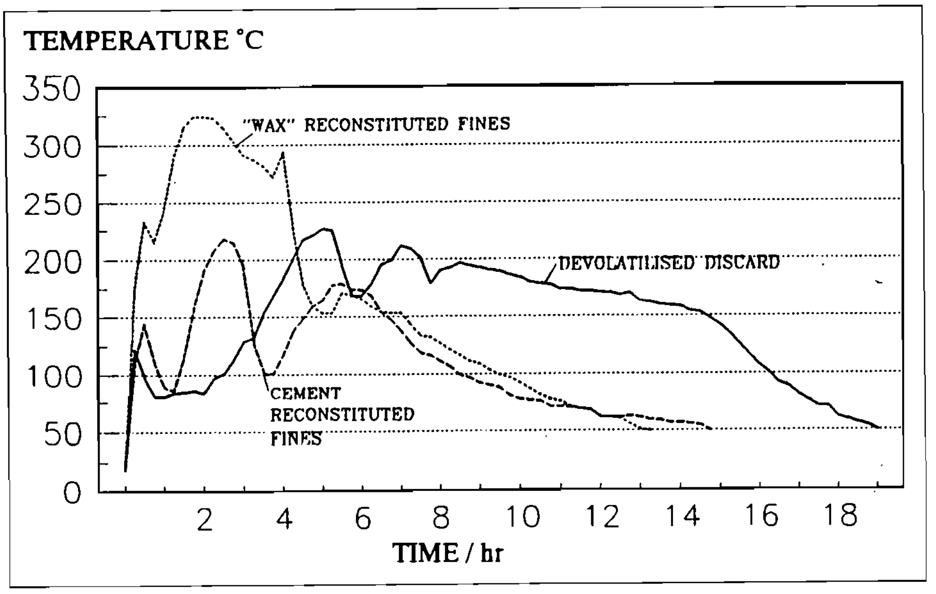


Figure 3: Temperatures of a stove plate heated by three low-smoke coals[6]

Propriety binder reconstituted coal fines

This briquette is manufactured by making use of discard fines (size 3 mm and smaller) bound together with a propriety binder. The physical size of the briquette is a cylinder of average diameter of 45 mm, 35 mm long with a 15 mm hole through the centre. The product which was developed by a private concern is mechanically strong, ignites easily and burns with a hot flame. The coal fines that were used were anthracite and bituminous coal fines while low-grade Botswana coal with poor combustion characteristics was also successfully used. The ease whereby the briquette is ignited makes it suitable to be used not only in stoves or drums, but also on open fires. The manufacturing process was developed to be labour-intensive using specially developed low-cost equipment[5].

Combustion comparison

A combustion test for each of the above low-smoke coals was conducted where 7 kg of each fuel was burnt, under similar conditions, in a typical stove[6]. The surface temperature of one of the stove's cooking plates was measured. The time/temperature relationships for each coal is plotted in Figure 3. The following combustion characteristics were noted:

Devolatilised discard: Slow ignition and combustion rate, reaching a maximum temperature of 225°C and maintaining a plate temperature greater than 100°C for 16 hours.

Cement reconstituted fines: Moderate ignition and combustion rate, reaching a maximum temperature of 222°C and maintaining a plate temperature greater than 100°C for 8,5 hours.

Propriety binder reconstituted fines: Rapid ignition and combustion rate, reaching a maximum temperature of 320°C and maintaining a plate temperature greater 100°C for more than 9 hours.

Conclusion

A successful low-smoke coal must be cost-efficient and should have proper physical and combustion characteristics which will make it acceptable to the domestic coal user. Assuming that the technical requirements can be met, the manufacture of low-smoke coal from "virgin" coal is more expensive than the presently used D-grade coal.

Discard coal has been identified as an inexpensive feedstock for the production of low-smoke coals. Sufficient amounts of this material exist in the coal mining industry to supply the total potential market for low-smoke coals.

Although only three low-smoke coals have been addressed here, other products are being developed. Overall results indicate that low-smoke coals can have a significant part to play in lowering air pollution in residential areas to acceptable levels.

Acknowledgement

The authors gratefully acknowledge the Department of Mineral and Energy Affairs for permission granted to publish this paper. Views expressed herein are those of the authors and do not necessarily reflect the policies of the Department.

References

(1) HOETS P (1994). Low-smoke fuels acceptability study 1992 and 1993. Paper presented at the Low-Smoke Coal Workshop, organised by the National Association for Clean Air for the Department of Mineral and Energy Affairs, held at Vista University, Soweto, 8 June.

(2) OPPERMAN J H (1991). Initial survey of the South African anthracite industry. CSIR Internal Report No. ENER-I92006.

(3) HORSFALL D W (1994). WITS/UCT low-smoke coal and costing. Paper presented at the Low-Smoke Coal Workshop, organised by the National Association for Clean Air for the Department of Mineral and Energy Affairs, held at Vista University, Soweto, 8 June.

(4) TAIT H E (1994). Low-smoke coal alternatives for household energy needs. Paper presented at the WEC's Regional Energy Forum for Southern and East African Countries, held at Cape Town in October.

(5) ROUX F R (1994). Eco low-smoke coal briquettes. Paper presented at the Low-Smoke Coal Workshop, organised by the National Association for Clean Air for the Department of Mineral and Energy Affairs held at Vista University, Soweto, 8 June.

(6) HORSFALL D W (1994). Production of a smokeless fuel. Department of Mineral and Energy Affairs. Final Report No. ES9017, January.

(7) ROGERS D E C and PIETERS C J (1994). Laboratory tests on low-smoke fuels. Paper presented at the Low-Smoke Coal Workshop, organised by the National Association for Clean Air for the Department of Mineral and Energy Affairs held at Vista University, Soweto, 8 June.

(8) ALLISON C B and DUTKIEWICZ R K (1994). The efficiency and cost-effectiveness of space-heating appliances using traditional and transitional fuels in South Africa. Energy Research Institute, University of Cape Town. ERI Report No. GEN 164.

Particulate and gaseous emissions from a low-smoke stove using three low-smoke fuels and one domestic coal

*** D E C ROGERS**

Laboratory tests were carried out on three low-smoke test fuels produced in Southern Africa and one coal sample taken from a coal merchant in Evaton in the Gauteng area of South Africa. These fuels were used in the winter 1993 field trials in Evaton in which the effects of the introduction of low-smoke fuels into the domestic market were surveyed.

Testing was carried out in the laboratories of the CSIR using methodologies published by the Environmental Protection Agency (EPA) in the United States of America. The priority pollutants measured were particulates, SO_2, NO_x, and CO. Total organic gases (TOGs) were also measured and, while not a priority pollutant, the presence of these gases gives an indication of the levels of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Combustion was carried out in a low-smoke stove following the requirements of SABS 1111[4].

It was found that reductions in smoke of between two and six times are achievable by switching from the township coal to a low-smoke fuel. Reductions in SO_2, CO and TOGs are achievable with specific fuels. NO_x is a product of the temperature of combustion and is not fuel specific. Reduced emissions of NO_x will therefore only occur in cooler flames. CO and TOGs are the result of incomplete combustion.

Keywords: smoke; emissions; low-smoke fuels; coal; stoves

Nomenclature

T_a	Ambient temperature in °C or °K
T_c	Chimney flue gas temperature at approximately 1 m from the output of the stove
T_T	Dilution tunnel air temperature at the flow measurement point
NTP	Normal temperature and pressure (0° C and 101,3 kPa)
ATP	Actual temperature and pressure at the measurement point
ppm.vol	Parts per million volume concentration
TOGs	Total organic gases
SVOCs	Semi-volatile organic compounds
VOCs	Volatile organic compounds
NO_x	Sum of nitrogen dioxide and nitrogen monoxide (nitrous oxide)
SO_2	Sulphur dioxide
CO	Carbon monoxide
CO_2	Carbon dioxide
CV	Calorific value MJ/kg

Introduction

Laboratory tests on the three low-smoke fuels were undertaken to support field trials carried out during the winter of 1993 in the Gauteng area of the Transvaal. The field trials were conducted by the Transitional Fuels Working Group in conjunction with the Department of Mineral and Energy Affairs. The purpose of the test was to establish the potential for the reduction of emissions of smoke and gases associated with high urban pollution levels experienced during the winter months as a result of burning coal for domestic purposes.

The ideal combustion products of a carbon-based fuel would be carbon dioxide (CO_2) and water (H_2O). In practice, nitrogen oxides (NO and NO_2) and sulphur dioxide (SO_2) are formed. In the high temperatures during combustion nitrogen from the air burns to form NO and NO_2. Sulphur from the coal burns to form SO_2.

Under the conditions of incomplete combustion in natural draught appliances, such as the domestic stove, additional pollutants are produced. These are particulates, organic mixtures, such as tars and gaseous organic compounds, and carbon monoxide (CO). The quantities of these pollutants are highly variable, depending upon factors such as the rate of combustion and the composition of the fuel. The worst emissions occur prior to full ignition of the fuel, when the combustible gases are drawn out of the combustion zone by the draught of the chimney and are emitted into the atmosphere.

Coal smoke is a dispersal of fine particles and is largely made up of tars which are volatilised as gases in the high temperatures of combustion. These condense as gas-borne droplets (0,01 to 5 m) as the flue gases move out of the combustion zone. The organic gases which do not condense are referred to as total organic gases (TOGs)[1]. Although many innocuous gases, such as methane (CH_4), may be components of the TOGs, it is considered that gases harmful to health are also present[2]. In environmental measurement parlance these are commonly referred to as semi-volatile organic compounds (SVOCs) and volatile organic compounds (VOCs) respectively[3].

Coal being burnt in South African townships can be expected to contain approximately 25 wt.% of volatiles. The volatiles contribute to the ease of ignition. However, in the 10-30 minutes prior to the establishment of full combustion, they cause the bulk of the pollution seen at early morning and early evening. Examples of typical emissions profiles for smoke and CO, and TOGs and NO_x are shown in Figures 1 and 2 respectively.

The main purpose of this study was to establish the potential for the reduction of this visible pollution. Tests were carried out under controlled laboratory conditions following South African and internationally recognised test procedures. SABS 1111[4] is the South African specification covering combustion tests

* Division of Material Science and Technology, CSIR, P O Box 395, Pretoria 0001, South Africa

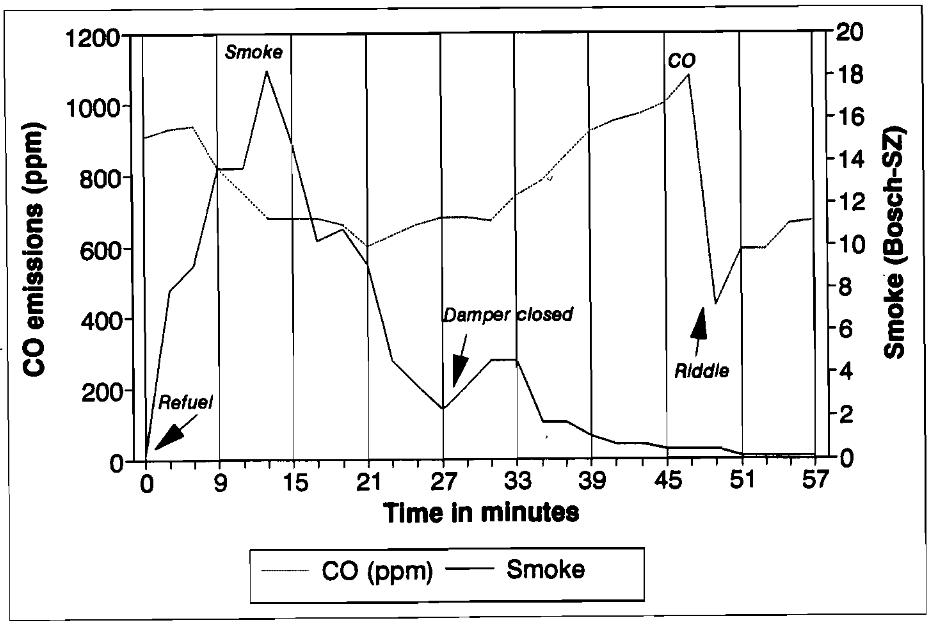


Figure 1: *Plot of smoke and CO emissions with time after a refuel of coal*

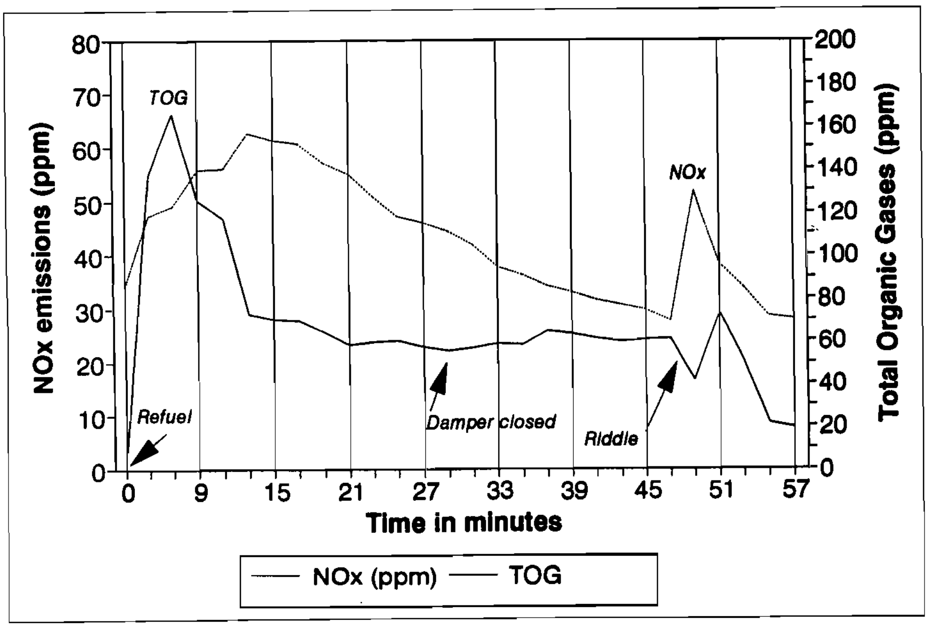


Figure 2: *Plot of NO_x and TOGs emissions with time after a refuel of coal*

for coal in reduced smoke emission stoves. Particulate and gaseous emission measurement procedures are not covered by SABS 1111[4]. The U.S.A.'s Environmental Protection Agency (EPA)[1] has used a comprehensive approach to the testing of emissions from stoves. Methodologies used in these tests have been based on the guidelines contained in these documents.

Main findings

The three low-smoke fuels show significant reductions in emissions of particulates. Measurements (on the standard refuelling cycle) show a reduction in particulate emissions (g/kg fuel burnt) from 8,1 g/kg for coal to between 1,4 – 3,3 g/kg for the low-smoke fuels. Where a light-up cycle was practical, a magnitude of reduction from 13,0 g/kg to 3,2 g/kg is shown.

Of the four gaseous emissions (SO_2, CO, TOGs and NO_x) only SO_2 and TOGs can be reduced by modifying the fuel. Practical reductions in SO_2 are achievable by briquetting with a S binding agent. TOGs can be reduced by either the use of additives to speed up ignition (Ecofuel), or the devolatilisation of the fuel (UCP/Wits smokeless fuel).

When these factors are taken into account it is clear that these stove tests are relevant to an evaluation of the potential impact of introducing these fuels in the South African situation. A forecast of the social impact of the introduction of a particular fuel must be based, however, on the types of domestic appliances and the associated lighting practices.

Methodology

Sampling for test fuels

Samples of the Wits/UCP fuel, CSIR fuel, township coal and Ecofuel were taken from the same batches used in the winter 1993 field trials. The sampling procedure followed SABS 0135/ISO 1988[5]. A composite sample of approximately 60-100 kg was collected for each fuel. The UCP/Wits fuel and Ecofuel were taken from the stockpiles at the Vaal Power Station.

The township coal was sampled in the township prior to distribution to the test locations. CSIR fuel briquettes were sampled at the CSIR. Batches for the combustion tests were graded according to the SABS 1111[4] requirements and weighed prior to loading into the stove.

Combustion test methods

The combustion test methods are based on SABS 1111[4]. This standard covers the construction and performance requirements for free-standing natural draught appliances that operate with a minimum of smoke emission.

Issues associated with combustion of test samples

Description of test fuels

The test procedure is designed for combustion of bituminous coal having a calorific value of at least 24 MJ/kg. The test sample was screened into two sizes, e.g. 40-25 mm and 25-20 mm in a fixed mass ratio of 7:3.

Table 1 summarises the available technical information on the test fuels and the requirements of the low-smoke stove test procedure.

Characteristics of the test fuels and combustion in the low-smoke stove

The effect of the test fuel characteristics on the combustibility in the low-smoke test stove are summarised in Table 2.

Chimney height

The height of the chimney was limited by the space available in the combustion test facility and the requirements for an extraction vent to be mounted inside the laboratory.

The chimney height of 2 m was less than the 2,5 m of the test specification. An early South African study on the effect of the length of the chimney on coal-burning stoves has shown that chimney lengths of 2,7 m and longer are required for good combustion[9]. The rate of increase in oven temperature was, however, within specification for the township coal, and it is considered that the loss of approximately 0,5 m of chimney length is not a serious deviation from the SABS 1111[4] methodology.

Grating dimensions

The grate spacings were adequate for supporting the typical combustion bed from the township coal and the UCP/Wits test fuel. In the cases of the Ecofuel and the CSIR test fuel, the briquettes broke easily during normal stoking and riddling of the grate. Large portions of the fuel could be lost to the ash pan by a vigorous de-ash to an established fire-bed, and for this reason a diamond mesh with 10 mm sides was placed on top of the grate.

Ash content of the CSIR fuel

The high ash content of the CSIR test fuel became a problem as the standard de-ashing procedures resulted in disintegration of the briquettes. This caused difficulties with the testing of the fuel as no satisfactory method for de-ashing was available (see discussion on stoking above).

Low calorific values of test fuels

The calorific value of the CSIR and UCP/Wits fuels are at or below the calorific value for which the SABS 1111[4] stove has been specified i.e. 24 MJ/kg. This limitation was overcome to some extent by building a deep bed of coals and maintaining a good draught up the chimney. The key to this is the judicious use of the damper control. It is considered that the consequence of a lower calorific value is a slower rate of heating of the oven. If too much flue gas is directed around the oven, it is difficult to maintain a strongly glowing bed of coals.

Low volatile content of the fuels

The low-smoke feature of the test stove is the second combustion chamber for volatiles. This region is between the bridge to the fire-box and the damper. When test fuels with low volatile content are burnt in the stove, all things being equal, the result is a lower draught and a slower ignition of the test fuel.

For this reason ignition of a test fuel can be difficult. In the work on the CSIR and the UCP/Wits test fuels it was concluded that the established lighting methodology was not suitable for the low-smoke stove and that the difficulties associated with developing a lighting procedure were beyond the scope of the investigation. In the case of the UCP/Wits fuel, combustion tests were made with a bed of coals ignited by other means, e.g. a gas torch, or by addition onto the bed of another fuel, i.e. Ecofuel.

In the latter case the low emissions observed from an established bed were considerably less than those of a fresh addition of unignited UCP/Wits fuel. Compressed air was used on occasion but was found to contribute to particulate emissions. In conclusion therefore, it is considered that the only meaningful test of fuels with low volatiles content is revival by refuelling.

Test fuel	Product size Min.	Ranges (mm) Max.	CV MJ/kg	Ash (%)	Moisture (%)	Volatile content (%)	Sulphur (%)
Typical bitum. coal as required for SABS 1111[4]	30 20 6	70 40 25	≥24	10-30	1-5	17-30	0,6-2,7[6]
UCP/Wits smokeless fuel [7]	20	90	21,4-24	<30	not specified	12%	not specified
CSIR 1993[+] low-smoke fuel	20	70	16,3[6]	30-40[8]	7,1[6]	15[8]	0,76[6]
Ecofuel[x]	40	45	24,5	24,2	8,3	24,3	0,84

Notes:

[+] CSIR fuel was broken down to size by hand.

[x] Ecofuel is a briquette approximating an annulus 40 mm long with an outer diameter of 45 mm and an inner diameter of 13 mm

[+] Ash content estimated from the sum of coal ash and additives

Table 1: SABS 1111[4] requirements for test fuels and characteristics of the low-smoke fuels

Test characteristic	Dependent combustion characteristic for SABS 1111[4] test
range of product size	combustion bed and heat density
volatile content	ignitability, rate of heating stove from cold
calorific value	rate of heating of stove and oven, generation of draught up chimney, ultimate temperature from stove

Table 2: Characteristics of the test fuels affecting the combustion procedure

Suitability of using SABS 1111[4] for testing low-smoke fuels

As has been discussed above, the SABS 1111-approved low-smoke stove has been designed for reduction of smoke emissions by increasing the efficiency of the combustion of volatiles. The most marked improvement in this efficiency is observed during the light-up period when combustion efficiency is lowest.

Furthermore, the design of the air- and flue gas-flows and the draught is such that fuels with a high inherent volatile content will ignite and burn most easily. Fuels with low volatiles content will ignite and burn less easily.

Fuels with a calorific value higher than 24 MJ/kg will burn well, while fuels with a lower calorific value will burn poorly. Table 3 summarises the factors affecting the suitability of SABS 1111[4] for performing these tests.

Bias of SABS methodology	Consequence
Most efficient combustion with high volatile content	Combustion test results biased in favour of standard bituminous coal and Ecofuel
Most efficient light-up with high volatile content fuels	Ignition tests biased in favour of standard bituminous coal and Ecofuel
Grating designed for coal not for briquettes	Stoking and riddling of grating to maintain combustion of coal bed is not an option with briquettes

Table 3: Bias of SABS 1111[4] methodology to volatiles and briquettes

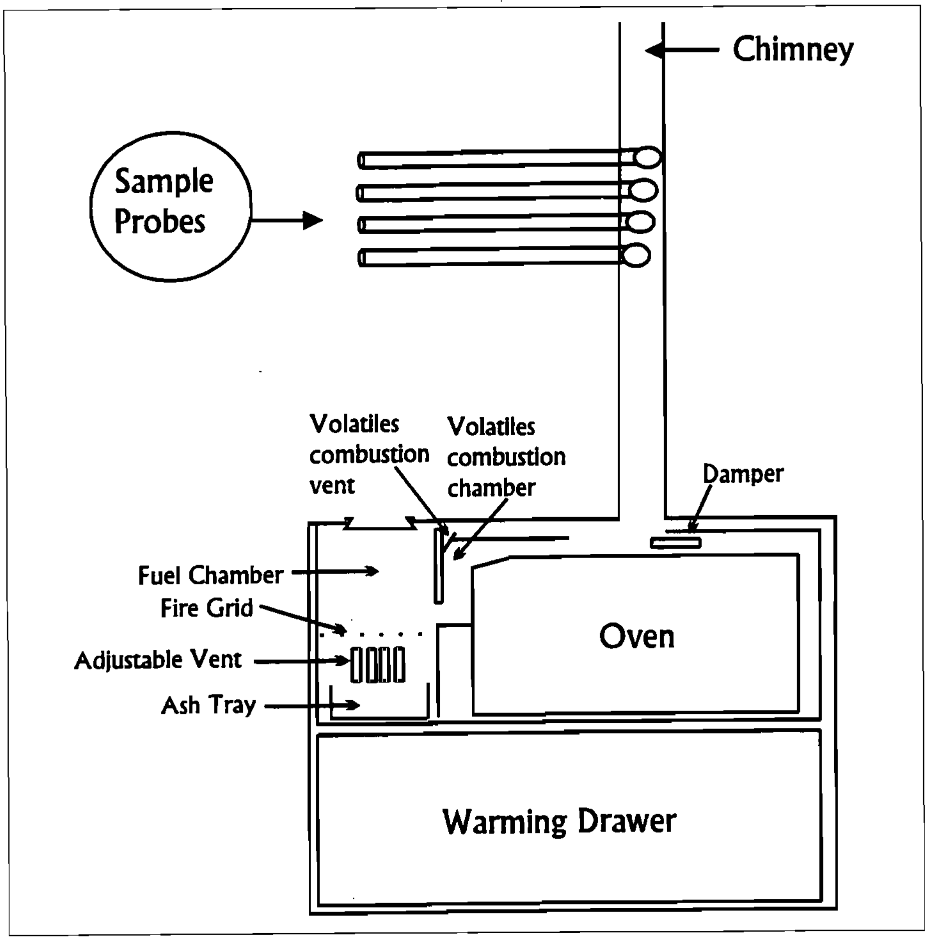


Figure 3: Schematic of the low-smoke stove and gas sampling locations

Emission gas	Measurement equipment	Bias Test procedure	Estimate of bias
CO	Signal* Analyzer Series 2000-IRGA	EPA 3	within 12%
CO_2	Signal* Analyzer Series 2000-IRGA	EPA 3	within 10%
$NO + NO_2$	Signal* Analyzer Series 4000	EPA 7	within 7%
Total gaseous organics	Signal model 3000 Hydrocarbon Analyzer	Not tested	–
Smoke	AVL+- 409/02	Not available	–

* Signal Instruments Company Ltd UK

\+ AVL Ges.m.b.h. Graz, Austria

Table 4: Interference and bias test procedures for on-line analyses

In conclusion, it can be said that the test fuel characteristics are typically not compatible with the SABS 1111[4] test requirements. For each fuel it could be expected that an alternative design of stove or selection of test fuel shapes would give combustion that was better than that observed on the low-smoke stove.

The question to be asked, therefore, is the relevancy of tests of low-smoke fuels using an SABS 1111[4] stove. The following factors can be considered:

* The SABS low-smoke stove is a commercial product.
* There are so many types of stoves used in the townships that a survey would have to be carried out to establish what is a representative stove.
* The scope of this study has been limited to combustion on a nationally recognised standard appliance.

It is clear, however, that these stove tests are relevant to an evaluation of the potential impact of introducing these fuels in the South African situation. A forecast of the social impact of the introduction of a particular fuel must be based, however, on the types of domestic appliances and the associated lighting practices.

Analytical procedures

Particulate sampling

Particulates were sampled isokinetically from the five gases mixed with air in a constant velocity dilution tunnel. The methodology follows that given in EPA-5G[11].

Gas analytical procedures

Gas analyses were carried out using the CSIR combustion test facility at the Pretoria campus. Flue gas samples were taken from the chimney via a set of probes inserted 1-1,5 m downstream from the stove. On-line gas analyses were carried out for NO_x, CO, CO_2, TOGs and smoke. Off-line gas analyses were carried out for SO_2 and particulate concentrations. The procedures used for NO_x, CO, CO_2, TOGs, SO_2 and particulate emissions meet the basic requirements of the EPA's emission measurement standards for sampling and for stove set-up[1,10,11,12,14,15]. EPA methodology requires that on-line instrumentation is to be checked for interferences and bias by means of the EPA test procedures for which the effects of interference and bias have been well characterised[10,12,13]. A schematic of the stove and gas sampling arrangement is given in Figure 3.

The measurement equipment, the test methods by which the equipment is validated, and the estimate of bias are given in Table 4.

Results

Particulate measurements

The summary of all light-up and refuelling revival data which associated both with the various ignition procedures is given in the Table 5.

Test fuel	Light-up	Refuel	Average refuel
Township fuel	13,0	8,03; 7,44; 8,86	8,11
Ecofuel	3,19	1,01; 1,6; (2,64(+))	1,34
CSIR	(4,15; 19,27)(x)	2,29; 1,52; 2,62	2,16
UCP/Wits	(27,1(o))	2,30; 3,62; 3,52	3,31

Notes:

(+) approximately half of the contents of the fire-box fell into the ash box and was partially smothered when the fire was riddled. For this reason this measurement is excluded from the average.

(x) 4,15 g/kg was obtained during an easy light-up when compressed air was used. 19,27 g/kg was obtained during a difficult light-up when a lot of wood and paper was used. No recommended light-up emission value can be taken.

(o) 27,1 g/kg was obtained during a difficult light-up when a lot of wood and paper were used.

Table 5: *Particulate emissions observed for light-up and refuelling revivals for the four test fuels (units of g(particulates)/kg (fuel burnt excluding wood and paper))*

Gas emissions

Problems associated with obtaining representative measurements of gas occurred to a lesser extent than for the particulates. Township coal and Ecofuel gaseous emissions from light-up were sampled and the average of the refuelling revival runs for each test is summarised in Table 6.

Unlike the method for measuring the particulate emissions, the gaseous emissions cannot be related back to the mass of coal burnt. The data is not then directly comparable from one fuel to another. The dilution factor related to chimney draught and air flow through the stove and the rate of combustion of each fuel differs from fuel to fuel.

A good indicator of the relative draught and combustion rate is the CO_2 concentration. For example, if the CSIR fuel emissions were generated at a CO_2 level comparable to the Ecofuel and UCP/Wits fuel, the NO_x and smoke meter readings would be comparable.

Due to the difficulties associated with burning the test fuels in the low-smoke stove, fire lighting practices were not always optimum and not all the data are considered representative of combustion that could be achieved with a burning practice specific to the fuel.

In the case of the CSIR fuel, addition of fresh fuel or riddling resulted in the briquettes collapsing and smothering the flame. This combined with the difficulty of achieving ignition from start-up, either by lighting with paper and wood, or on an existing fire bed, resulted in a set of three values that can be taken as typically representative of a successful refuelling revival.

Test fuel	Test Period	SO_2 ppm Vol.	CO ppm Vol.	CO_2 % Vol.	NO_x ppm Vol.	Smoke S-Z Bosch	TOG ppm
Township	light-up	80	1 490	2,7	64	1,4	406
	refuel	101	724	2,5	58	0,6	71
Ecofuel	light-up	12	945	3,2	68	0,11	128
	refuel	16	922	2,1	30	0,05	21
CSIR	refuel	9	935	1,05	13,4	0,02	56
UCP/Wits	refuel	60	825	2,3	35,2	0,06	32

Table 6: *Gaseous emissions for each test fuel*

The UCP/Wits fuel could not be ignited with wood and paper and it was found that two sets of refuelling revival are unaffected by the method of establishment of combustion.

SO_2 emissions are less dependent upon combustion conditions, e.g. collapsing briquettes. All four sets of SO_2 measurements, with the exception of the UCP/Wits fuel are not considered to contain outliers in the data set. For those fuels only the average values are taken.

For the UCP/Wits fuel a high concentration (426 ppm) of SO_2 has been identified as a significant outlier and has been excluded from the average calculation in the Table 6. On the basis of the variability of the SO_2 results it is considered that the variability of the S content is such that the 1 kg refuelling mass is too small to ensure homogeneity. The finding is consistent with the information given in SABS 0135[5] for sample mass and lump size.

Potential for the impact of low-smoke fuels on the reduction of emissions

These testing procedures are not ideal for low-smoke fuels due to the difficulties associated with burning them in the SABS-approved low-smoke stove. However, the following statements can be made on the results of this work:

(1) Ecofuel in the low-smoke stove:
   - low particulate and smoke emissions because of good ignition and combustion;
   - reduction in TOGs through better combustion;
   - reduced CO emissions due to rapid combustion;
   - low SO_2, possibly due to cleaner coal. It is not known if additional steps were taken to suppress SO_2.

(2) CSIR fuel in the low-smoke stove:
   - reduction in particulate emissions;

- reduction in SO_2 emissions due to the presence of additives;
- mechanical strength problems need to be rectified so as to ensure more efficient combustion of CO and the volatiles.

(3) UCP/Wits fuel in the low-smoke stove:
- reduction in particulate and smoke emissions;
- reduction in TOGs;
- SO_2 emissions dependent upon the origin of the waste coal;
- the fuel could be used in conjunction with coal once an established fire bed is in place.

Utilisation of laboratory tests to establish expected emission levels from low-smoke fuels when they are used in the domestic situation

Several clear trends emerge from the data:

(1) Combustion of fuel
Lower calorific fuels are more difficult to burn in a low-smoke stove. These fuels will have given similar problems to the participants in the survey. In practice they may have been combined with other fuels to get an easier ignition, or may have been burnt in cooking appliances less sophisticated than the low-smoke stove which were able to supply a stronger draught through the fire bed, e.g. a brazier.

(2) Emissions of NO and NO_2
The highest emissions of pollutants are associated with higher combustion efficiency as indicated by the highest CO_2 concentrations in the flue gases. The CSIR fuel shows the lowest NO_x value for refuelling. Lower NO_x indicates a cooler fire and weaker combustion in the fire bed. While lower NO_x may also be related to the passage of air through the bed or other conditions occurring during the runs, the only clear conclusion is that NO_x is combustion-specific and not related to the low-smoke fuels.

(3) Emissions of CO and TOGs
These two gases are associated with incomplete combustion. In the excess air conditions obtained (average CO_2 in flue gases 1,0-3,2%) during these tests the township fuel and CSIR fuel had the highest TOGs. It can be expected that this trend would have occurred in the field trials.

CO levels were similar for all fuels, indicating a poor combustion efficiency. Relative to the rate of combustion (taken from the CO_2 concentration) the CSIR fuel shows high CO emissions.

(4) SO_2
Unless an additive is included in a fuel to bind the SO_2, e.g. lime, then SO_2 values should reflect the amount of reduced S present in the unburnt fuel.

(5) Particulate emissions
All three test fuels should have a clear and significant reduction in particulates emitted into the atmosphere. These trends should be translated directly in reduced smoke emissions when used in the domestic situation.

Acknowledgements

Funding for the emission measurements was provided by the Department of Mineral and Energy Affair's Energy Branch as part of the Transitional Fuels Initiative. Support for the preparation of this paper was provided by the Division of Materials Science and Technology, CSIR.

The work associated with the methodologies described in the paper, which was undertaken by numerous individuals, is gratefully acknowledged.

References

(1) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Title 40: Protection of the environment. Part 60, Appendix A. U.S. Government Printing Office, Washington D.C., U.S.A.

(2) MARBURY M C (1991). Wood smoke. *In:* Indoor air pollution: A health perspective. Ed. by J M Sanet and J D Spengler. Johns Hopkins University Press, Baltimore, pp.209-221.

(3) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1986). Test methods for evaluating solid waste (SW 846). 3rd Ed. Environmental Protection Agency, U.S. Government Printing Office, Washington D.C., U.S.A.

(4) SOUTH AFRICAN BUREAU OF STANDARDS (1976). SABS 1111: Standard specification for coal-burning domestic cooking appliances (reduced emission type). SABS, Pretoria.

(5) SOUTH AFRICAN BUREAU OF STANDARDS (1977). The sampling of coal and preparation of a sample for analysis. SABS Code of Practice 0135, based on ISO 1988. SABS, Pretoria.

(6) TAIT H E (1994). Personal communication. October.

(7) SOUTH AFRICA (DEPARTMENT OF MINERAL AND ENERGY AFFAIRS (1994). Proceedings of the Low-Smoke Coal Workshop, held at Vista University, Soweto, 8 June 1994, and commissioned by the Dept. of Mineral and Energy Affairs, Pretoria, South Africa.

(8) TAIT H E and LEKALALA J S (1993). Optimization of a coal-based, low-cost, low-smoke reconstituted solid fuel (ENER-C930409). November. CSIR, Pretoria.

(9) SCOTT T W (1966). Chimney design for township housing (R/Bou 150). CSIR Pretoria.

(10) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Gas analysis for the determination of dry molecular weight. Method 3. *In:* Title 40: Protection of the Environment, Part 60, Appendix A, pp. 717-721.

(11) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Determination of particulate emissions from wood heaters from a dilution tunnel sampling location. Method 5G1. *In:* Title 40: Protection of the Environment, Part 60, Appendix A, pp. 773-783.

(12) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Determination of sulphur dioxide emissions from stationary sources. Method 6. *In:* Title 40: Protection of the Environment, Part 60, Appendix A, pp. 796-808.

(13) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Determination of nitrogen oxide emissions from stationary sources: Ion chromatography method. Method 7A. *In:* Title 40: Protection of the Environment, Part 60, Appendix A, pp. 820-828.

(14) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Determination of nitrogen oxide emissions from stationary sources (Instrumental analyzer procedure). Method 7E. *In:* Title 40 Protection of the Environment, Part 60, Appendix A, pp. 840-841.

(15) PIETERS C J, GRIES G and ROGERS D E C (1994). Unpublished work. MATTEK, CSIR, Pretoria. June.

(16) UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (1992). Determination of total gaseous organic concentration using a flame ionization analyzer. Method 25A. *In:* Title 40: Protection of the Environment, Part 60, Appendix A, pp. 1063-1065.

(17) INTERNATIONAL STANDARDS ORGANISATION (1992). ISO 9096: 1992(E). Stationary source emissions determination of concentration and mass flow of particulate material in gas-carrying ducts. Manual gravimetric method.

*Respiratory health impacts of three electrification scenarios in South Africa

** A P S TERBLANCHE, *** C M E NEL AND **** G R TOSEN

The health status of a community and the energy sources available to that community are closely related. The study reported here compared the exposures to total suspended particles (TSPs) and the prevalences of respiratory tract illnesses in children living in Evaton and Sebokeng in the Vaal Triangle in unelectrified (no electricity available), partially electrified (electricity used for lighting but coal for cooking and/or space-heating) and completely electrified homes. These homes represent three electrification scenarios for urban areas in South Africa. The key findings indicated that the difference in total human exposure to TSPs between children living in unelectrified and those living in partially electrified areas is not significant. This illustrates that partial electrification, which is often associated with a clean atmospheric environment, will not necessarily result in an improved quality of life. For children in the 8-12 years age group there is no significant difference in the risk of developing respiratory tract illnesses, whether they are living in unelectrified or partially electrified areas. However, the risk of developing respiratory illnesses is 130% higher for children living in partially electrified areas compared with completely electrified areas. The results of this cross-sectional evaluation of the prevalences of respiratory tract illnesses in children indicate that the availability and full utilisation of electricity (for lighting, cooking and space-heating) would benefit the health of the community significantly.

Keywords: electrification; health; air pollution; urban areas

Introduction

The World Health Organization (WHO) concluded its 1991 report on Urban Air Pollution[1] with the following statement:

> By the year 2005, every second person on earth will be an urban resident, and by 2025, the total urban population in developing countries will have more than doubled to 4 050 million. Against a prevailing background of rapid urbanisation and variable treatment of pollution problems, the future health of the majority of the world's urban residents is in jeopardy.

An important and challenging problem in urban health protection is directly related to energy utilisation and distribution. In developing countries, an estimated 200 million people are potentially exposed to hazardous levels of air pollution related to "dirty" energy sources, such as wood and coal[1]. Whereas the energy consumption of developed countries, such as the U.S.A., has stabilised over the last 10-20 years, that of developing countries is increasing at a steady rate[1]. An energy policy to prevent the impacts and increase the efficiency of energy sources is therefore a major priority for countries such as South Africa, which is very much an energy-from-coal dependent country.

> "... what is of key importance for South Africa and the electrification drive is the fact that partial electrification does not offer the complete health benefits anticipated. The continued use of coal for space-heating and cooking in an area significantly reduces the health benefits of electrification. The message is clear: supplying electricity will not solve this country's air pollution and related problems."

The objective of this paper is to examine the health impacts of different electrification scenarios (no electrification, partial electrification and complete electrification) for urban areas of South Africa as determined by cross-sectional surveys performed in Evaton and Sebokeng in the Vaal Triangle during 1990-1992.

Methods

The methods used to collect exposure information and prevalences of respiratory tract illnesses are discussed separately. The detailed methodologies have been published elsewhere[2-4].

Exposure monitoring

Exposure monitoring was done using personal TSP monitors. Children from the Evaton and Sebokeng areas were solicited through the regional health clinics to participate in the personal monitoring study. They were selected from unelectrified (homes using coal as the primary household energy source), partially electrified (using electricity for lighting but coal for cooking and/or space-heating), and completely electrified homes. Informed consent was obtained from the parents of each participant. The children were informed of the requirements for carrying the monitors and trained in their use, and were encouraged to follow their usual daily activities while carrying the monitors. Light-weight monitors (Gill Air Model 224 X-R) with glass fibre filters were used to sample TSP over a period of 12 hours (starting at 08h30), recording the exact monitoring time. Gravimetric analyses were done according to standard procedures of the South African Chamber of Mines adapted from NIOSH[5].

Statistical analyses using Wilcoxon matched pairs tests were done to compare exposures in the different categories.

* All correspondence regarding this paper to be addressed to: Dr A P S Terblanche

** Environmental, Health and Safety Management Services, CSIR, P O Box 395, Pretoria 0001, South Africa.

*** Medical Research Council, Private Bag X385, Pretoria 0001, South Africa

**** Environmental Services, Technology Group, Eskom, Private Bag 40175, Cleveland 2022, South Africa

Disease prevalence survey

A questionnaire formed the basis for assessing the health effects. It was in standardised form, comprising elements similar to those adopted by the American Thoracic Society, the Harvard Six Cities Air Pollution Health Study and the Canadian Health and Welfare questionnaires[6]. This questionnaire collected data on home characteristics, sources of indoor air pollution, socio-economic status, respiratory tract symptoms, general health status of the child, parental smoking and perceptions on air pollution. The questionnaire was tested and evaluated by several national and international experts before pilot testing. Following the pilot testing, questionnaires in English were used as the interviewers were all able to speak English as well as the local black languages (South Sotho, Tswana, etc.).

Selection of study populations

The target population consisted of children aged 8-12-years old living in Sebokeng in Zones 10 and 13 (completely electrified and partially electrified (mixed) respectively) and Evaton (unelectrified, predominantly coal-burning). Children were primarily selected for the study because they are often more susceptible to the effects of air pollution, because of their higher intake relative to their body surface area, their enhanced absorption of pollutants, their underdeveloped immune systems and their characteristic behaviour, all of which may result in increased exposure to certain pollutants. The fact that children do not smoke enhances their suitability for a study on the health effects of air pollution from domestic coal-burning. The first home visit survey was performed during January 1992 and the follow-up survey was conducted during August 1992.

Questionnaire distribution, coding, validation and reproducibility testing

Questionnaires were administered through person-to-person interviews. The interviewers were all trained nurses and health advisors who assisted with the project's design and pilot testing. In most cases the mother was interviewed. The questionnaires were in English but the interviewers (who were completely bilingual) explained questions in the most common local language, namely, South Sotho.

Following completion of questionnaires the data were coded by temporary workers. Accuracy tests of the coding procedures were done by drawing 20% of the coded questionnaires and evaluating them for accuracy. If a 5% or bigger error rate was found, the whole batch (100 at a time) was recoded and rechecked.

Reliable data are essential in any data collection programme and the reproducibility of answers documented in the questionnaires therefore had to be tested. Reliability refers to the degree of similarity in answers when the same questions were repeated, after a reasonable elapse in time, to the same person. The interviewers were therefore requested to repeat questions on the health questionnaire to 10% of the participants (randomly selected) after a period of 2 months. This

Respiratory symptoms	Unelectrified area	Partially electrified area	Electrified area	P-value
Chest illness that kept person at home for > 3 days	49,1%(n=165)	38,5%(n=130)	33,6%(n=130)	0,03
Usually phlegm	29,6%(n=169)	19,5%(n=133)	15,9%(n=113)	0,02
Wheezing	20,1%(n=164)	11,7%(n=128)	10,9%(n=110)	0,05
Shortness of breath	15,5%(n=97)	8,6%(n=58)	15,2%(n=46)	0,44
Past 2 months:				
Bronchitis	17,3%(n=173)	14,5%(n=131)	7,0%(n=115)	0,04
Pneumonia	3,5%(n=173)	3,8%(n=131)	0,0%(n=115)	0,12
Runny nose	62,4%(n=173)	71,0%(n=131)	62,6%(n=115)	0,24
Earache	15,6%(n=173)	22,9%(n=131)	5,2%(n=115)	0,00
Hay fever	16,3%(n=172)	21,4%(n=131)	21,1%(n=114)	0,45
Sinusitis	27,2%(n=173)	19,8%(n=131)	20,0%(n=115)	0,22
Asthma	1,7%(n=172)	0,8%(n=130)	3,5%(n=115)	0.,29
Continuous coughing	38,8%(n=147)	31,1%(n=122)	26,5%(n=102)	0,11
Sore lungs	27,9%(n=147)	28,7%(n=122)	16,7%(n=102)	0,07
Sneezing	40,8%(n=147)	43,4%(n=122)	41,2%(n=102)	0,90
Sore nose	3,4%(n=147)	4,1%(n=122)	4,9%(n=102)	0,84
Sore throat	32,7%(n=147)	24,6%(n=122)	26,5%(n=102)	0,31
Phlegm	22,4%(n=147)	20,5%(n=122)	11,8%(n=102)	0,09
Blocked nose	33,3%(n=147)	36,1%(n=122)	30,4%(n=102)	0,67

Table 1: Respiratory symptoms and illnesses of urban residents living in three different fuel usage areas in the winter-time

exercise was performed after the summer data collection period. The excellent reproducibility obtained was an added quality assurance exercise[3].

Statistical analysis

Descriptive statistics were performed using Fischer's exact test (non-parametric statistical methods) and Chi-square test. These tests were used to draw correlations between different variables in the total population. The Statistical Analysis System (SAS) was used to run the different tests. Odds ratios (OR) and confidence intervals (95% level) were performed to determine the comparative risk between the development of respiratory illnesses and various potentially causative agents.

Category	Prevalence of LRI		OR	95 % *	
				Lower	Upper
Unelectrified versus completely electrified area	21,9%	8,7%	2,9	1,4	6,2
Unelectrified versus partially electrified area	21,9%	17,7%	1,3	0,7	2,3
Partially electrified area versus completely electrified area	17,7%	8,7%	2,3	1,0	4,9

* If 1 is included, the OR is not significant

Table 2: Odds ratios for lower respiratory tract illnesses (LRI) for children living in different urban fuel use areas in the winter-time

Results

Exposure study

A total of 45 children, aged between 8 and 12, participated in the TSP monitoring programme which consisted of 72 individual 12-hour monitoring sessions during the summer of 1991 and winter of 1992. The results[9] indicated extremely high levels of exposure to TSP. These exposures, taken over a 12-hour period, were in 99% of the cases higher than the U.S.A. 24-hour health standard of 260 g/m^3, and in 100% of the cases above the lowest-observed-effect level of 180 g/m^3 documented by the World Health Organization. (Although the U.S.A. 24-hour health standard is based on a different monitoring technique and one cannot strictly use direct comparisons of the exposure data collected here over time, the exposures are regarded as high by any standard). These measurements are well within the range of measurements taken from fixed indoor monitors in Kenya (300-1 500 g/m^3 overnight), China (2 600 g/m^3 all-day in kitchen) and Gambia (1 000-2 500 g/m^3, 24 hours)[8].

Significant seasonal differences in personal exposures to TSPs were found, with significantly higher exposures during winter periods compared to exposure during summer [9]. The variations found in exposures from different monitoring days, weekend *vs.* school day or school day *vs.* school holiday day, are probably not very important in the light of the overall extremely high exposures measured. No statistical differences nor slight differences were found between electrified, partially electrified and completely electrified households. This is important and could be attributed to the close proximity of these areas and the nature of low-level coal-burning, which is classified as an area source and spreads for kilometres without proper dilution or dispersion. It is particularly evident during winter. Further research on specific factors which influence exposures is under way.

"... it was found in this study of the personal monitoring of TSP in 45 children living in completely electrified, partially electrified, or unelectrified areas of South Africa, that exposures are unacceptably high, with 100% of measurements exceeding recommended exposure limits during winter and 96% of measurements during summer. The highest risk for exposures identified in this study was during winter periods in the partially electrified or unelectrified areas."

In conclusion, it was found in this study of the personal monitoring of TSP in 45 children living in completely electrified, partially electrified, or unelectrified areas of South Africa, that exposures are unacceptably high, with 100% of measurements exceeding recommended exposure limits during winter and 96% of measurements during summer. The highest risk for exposures identified in this study was during winter periods in the partially electrified or unelectrified areas.

Respiratory illness survey

A total of 543 children participated in the survey in the summer of 1991 and 430 of the 543 participated in the winter of 1992. As already mentioned, these children were selected from unelectrified, partially electrified and completely electrified areas. The prevalences of respiratory tract illnesses in the three groups are summarised in Table 1.

From this table it is evident that there is a tendency for lower prevalences of potentially air pollution-related respiratory tract symptoms and illnesses, e.g. phlegm, bronchitis, etc. in the children living in the electrified areas. This, however, was on a univariate level. Multivariate analyses were conducted to determine the relative risk (expressed as an OR in Table 2) for children in the different categories to develop upper and lower respiratory tract illnesses. These analyses were performed controlling for parental smoking, socio-economic status, age and gender. The results are given in Table 2 for lower respiratory tract illnesses (LRI). LRI was defined as the presence of either bronchitis, continuous coughing, chest illness, asthma and pneumonia during the past two months (survey conducted in August).

From this table it is evident that the risk for LRI in an unelectrified area is almost 3 times higher than that in an electrified area. The striking lack of a significant decrease in risks in partially electrified areas compared with unelectrified areas stresses the importance of complete electrification as the ultimate risk minimisation strategy. The personal exposure monitoring programme results support these data. For upper respiratory tract illnesses (defined as sinusitis, runny nose, earache and hay fever) during the past two months, no specific pattern could be identified.

In a multivariate regression model of 11 different potential risk factors, coal usage was found to be the single most important risk factor for respiratory illnesses in these children[9]. This was found in the winter as well as summer disease prevalence data.

Discussion

The adverse health impacts of coal used as a household energy source are directly related to the air pollution caused by the coal. The research project clearly illustrates that the extent to which coal is used (as a primary and sole energy source) in a given area is the most important determinant of respiratory tract illnesses in children aged between 8 and 12 years, and is likely to be the same for the total population. The reduced risk for the development of LRI in children living in completely electrified areas (no coal used) compared with the unelectrified (no electricity available) and the partially electrified (electricity available but used only for lighting and recreation) is important but not surprising. However, what is of key importance for South Africa and the electrification drive is the fact that partial electrification does not offer the complete health benefits anticipated. The continued use of coal for space-heating and cooking in an area significantly reduces the health benefits of electrification. The message is clear: supplying electricity will not solve this country's air pollution and related problems. The people must be empowered and assisted to utilise electricity fully or, alternatively, it should be supplemented with a low-smoke coal or other cleaner but efficient space-heating source. That is the real challenge.

Acknowledgements

The Department of Mineral and Energy Affairs, Department of National Health and Population Development, EMSA, the Medical Research Council and the Primary Health Clinic in Sebokeng are acknowledged for their participation and funding of the Sebokeng project reported in this paper.

The Steering Committee and funding bodies of the Vaal Triangle Air Pollution Health Study is acknowledged for its support.

References

(1) WORLD HEALTH ORGANIZATION (1991). Urban air pollution. UNEP/GEMS Environment Library, No.4.

(2) TERBLANCHE A P S, NEL C M E, OPPERMAN L and NYIKOS H (1993). Exposure to air pollution from transitional household fuels in a South African population. *Journal of Exposure Analysis and Environmental Epidemiology*, Vol.3 (Suppl.1), pp.15-22

(3) TERBLANCHE A P S, NEL C M E and DANFORD I R (1993). Health and safety aspects of household energy sources: Phase II. Report to the Department of Mineral and Energy Affairs. Report No. EO 2120.

(4) TERBLANCHE A P S, NEL C M E and OPPERMAN L (1992). Health and safety aspects of domestic fuels. Report to the National Energy Council. Report No. NE 14/6/30.

(5) CHAMBER OF MINES OF SOUTH AFRICA (1988). Measurements in mine environmental control. 2nd ed. CTP Book Printers, pp.14-21

(6) TERBLANCHE A P S, OPPERMAN L, NEL C M E, REINACH S G, TOSEN G and CADMAN A (1992). Preliminary results of exposure measurements and health effects in the Vaal Triangle Air Pollution Health Study. *South African Medical Journal*, Vol.81 No.6, pp.550-556.

(7) SMITH K R (1992). Household fuels in developing countries: Global warming, health and energy implications. Proceedings of the 1992 Greenhouse Gas Emissions and Mitigation Research Symposium. United States Environmental Protection Agency.

(8) SMITH K R (1988). Total exposure assessment: Implications for developing countries. *Environ*, Vol.30 No.10, pp.16-20, 28-35.

(9) TERBLANCHE A P S, NEL C M E and DANFORD I R (1993). Health and safety aspects of household fuels: Phase II. Report No.EMP-C 93017 to the Department of Mineral and Energy Affairs, July.

The acceptability of three coal-based, low-smoke fuels in Evaton

* P A HOETS

In 1992 and 1993, what was then known as the Energy Branch of the Department of Mineral and Energy Affairs, as part of its Energy for Development programme, sponsored a two-phase project to determine the acceptability of low-smoke fuels based on discard coal.

These fuels were developed in response to the high levels of coal smoke-based pollution in areas where coal is cheap and readily available. This pollution is particularly marked on the Transvaal Highveld and the Gauteng area where dispersal of these pollutants is hampered by the nocturnal surface radiation inversion, which is in turn facilitated by the high pressure system. In winter, when usage of coal rises significantly, the temperature inversion creates a stable atmospheric layer at a low level which traps polluted air within it[1].

The belief has been that the electrification of townships would play a major role in the elimination of township pollution caused by the burning of coal in coal stoves and braziers. However, this ignores the "social" role played by coal stoves in township homes. Coal-burning stoves, in addition to cooking and heating water, provide their users with the most economical means of warming their homes in winter. Currently, people with coal stoves attach greater value to a warm, friendly home in winter than they do to clean, smoke-free air[2,3].

Given the cost and high incidence of ownership of coal stoves in black townships, it seems likely that usage of coal stoves will remain at high levels and that the high levels of coal smoke will persist in the townships during winter.

However, almost all respondents said that they would be prepared to change to a coal which gave as much heat as normal coal, but with much less smoke - provided that it cost the same as their usual coal and was distributed in the same way.

The coal-based, low-smoke fuels tested on a total of 135 households in Evaton in 1992 and 1993, during Phases 1 and 2 of this project, all performed excellently in terms of reducing the levels of visible smoke and with varying degrees of acceptability in terms of other criteria. Provided that they were competitively priced or offered attractive alternative benefits (for example, job creation opportunities in the case of the Enertek fuel, or ease of lighting and speed of heat generation in the case of Ecofuel), the results from these two studies indicate that there would be a market for them.

Provided that emissions of gases and suspended particulates prove acceptable, it is recommended that these fuels receive strong official support and funding in order to replace coal as the standard solid fuel on the Highveld and hence significantly reduce coal smoke-based pollution. The solution to township smoke is therefore not electricity alone but electricity in conjunction with low-smoke coals.

Caveat: A change in the formulation of the Enertek fuel in 1993 resulted in the rejection of this fuel which had been enthusiastically accepted in 1992. The extreme difference in Enertek's results for the two phases has made it necessary to include 1992 (Phase 1) results, where appropriate, in this paper in order to provide a true reflection of the potential of the Enertek product.

Keywords: coal; low-smoke fuels; air pollution

Introduction

In 1992 and 1993, what was then known as the Energy Branch of the Department of Mineral and Energy Affairs, as part of its Energy for Development programme, sponsored a two-phase project to determine the acceptability of low-smoke fuels based on discard coal.

The programme was initiated in response to growing concern about coal smoke-based pollution in areas where coal is cheap and readily available. This pollution is particularly marked on the Transvaal Highveld and the Gauteng area where dispersal of pollutants is hampered by the nocturnal surface radiation inversion, which is in turn facilitated by the high pressure system. In winter, when usage of coal rises significantly, the temperature inversion creates a stable atmospheric layer at a low level which traps polluted air within it[1].

It has always been believed that the electrification of the townships would play a major role in the elimination of township pollution caused by the burning of coal in coal stoves and braziers. However, reluctance on the part of householders to get rid of their coal stoves has led to an appreciation that coal smoke-based pollution was not going to be eliminated by electricity alone and that a low-smoke, solid fuel alternative to coal must be sought[2,3].

A major objective of the programme was to produce a low-cost, low-smoke fuel for township use which would be acceptable to township residents and which would reduce unacceptably high township air pollution levels. If successful, this would not only contribute towards decreasing the accumulation of discard coal, but it would also assist in reducing air pollution resulting from the combustion of high-volatile coal in domestic appliances[4].

The low-smoke fuels

The fuels that were tested during this project were:

(1) UCP/Wits Low-Smoke Fuel: developed by Professor D W Horsfall, Shell Professor of Coal Studies, University of the Witwatersrand, Department of Metallurgy & Materials Engineering and produced by United Carbon Producers (UCP). The process united two waste products, waste coal and waste heat, in order to produce a low-cost, low-smoke fuel. This fuel was tested in 1992 and 1993 during Phases 1 and 2 respectively of this project[2,3].

(2) Enertek Coal Cement Low-Smoke Fuel: developed by the Energy Technology Division (Enertek) of the CSIR. Cement was identified by engineers as a low-cost option for an agglomerating material in the manufacture of a non-briquetted

* P O Box 509, Halfway House 1685, South Africa

coal-based fuel based on coal dust and cement. The addition of lime to the 1993 mixture resulted in a pronounced weakening of the product, which led to the rejection of Enertek's test fuel by its users. Since the product was so strongly supported by its users in the first phase of this project, findings from the 1992 study are included where appropriate. This fuel was tested in 1992 and 1993 during Phases 1 and 2 of this project[2,3].

(3) Ecofuel's Low-Smoke Fuel: (brand name Wundafuel), a briquetted low-smoke fuel made from waste products (anthracite or coal dust) manufactured by Ecofuel (Pty) Ltd. This fuel was tested in 1993 during Phase 2 of this project[3].

These fuels were tested to determine:

- their "market" acceptability amongst current users of coal
- their "environmental" acceptability in terms of their emissions of toxic gases and levels of total suspended particulates (TSP).

This paper deals only with the market acceptability of the three fuels.

Objectives

The primary objectives of the Low-Smoke Fuels Acceptability Study were:

- to determine the extent to which smoke is a problem to township residents
- to determine the acceptability of the three fuels described above

Secondary objectives were to determine attitudes:

- to coal and coal stoves
- to electricity

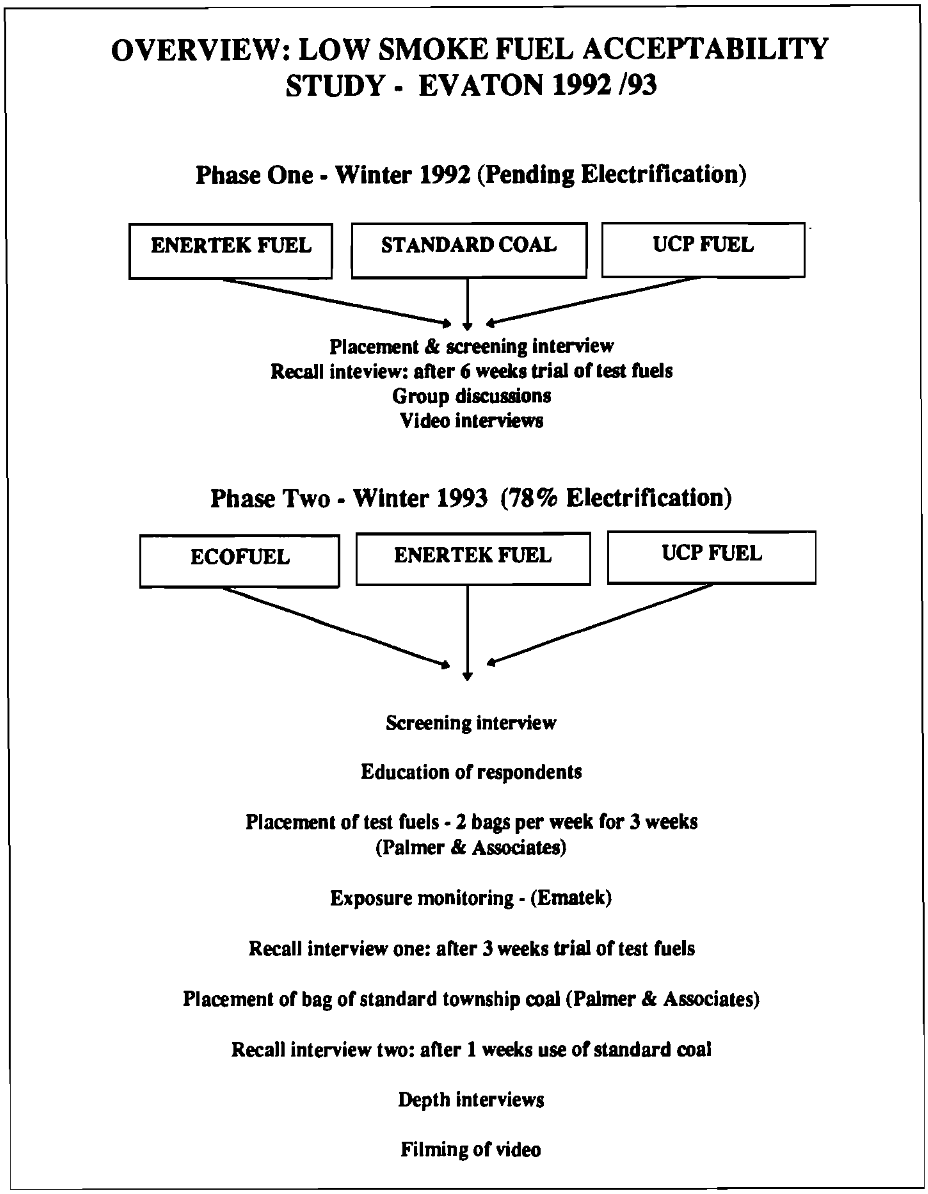


Figure 1: Overview of the Low-Smoke Fuels Acceptability Study: Evaton 1992/93

Methodology: Project overview

Evaton is an older township which is situated in the Gauteng area, in the so-called Vaal Triangle. It is located to the north of Sebokeng, and the enormous growth of settlements in the area has resulted in Evaton merging into the informal settlement area of Orange Farm to form what appears to be one massive, sprawling informal shack settlement. Evaton is a mixture of older formal houses with large yards where large numbers of shacks (up to 12 per yard) have been constructed together with newer informal settlements, and is considered to be fairly typical of townships in the Gauteng area.

Evaton was selected for the testing of low-smoke fuels as a result of work conducted in the Vaal Triangle by Dr Petro Terblanche[5] of the CSIR, in collaboration with the Medical Research Council during the winter of 1991, in which she investigated the health and safety aspects of domestic fuels and monitored personal exposure to total suspended particulates (TSPs) which are primarily emitted by the burning of domestic coal. Effectively this provided a benchmark study of the effect of air pollution caused by domestic fuels in the Sebokeng/Evaton area and provided a starting point for the study of low-smoke fuels.

The interviewing process

In both 1992 and 1993 multi-staged personal interviews were conducted with the person responsible for energy decisions in each household. Unless otherwise stated all field-work was undertaken by Social Surveys.

Screening interview

This was undertaken

(a) to determine whether the household fulfilled the criteria for selection;

(b) to ascertain attitudes to and usage of various fuels (in 1993 particular emphasis was placed on attitudes to coal and coal smoke and to electricity);

(c) to determine details of the dwelling as well as socio-demographic information.

Education of respondents (1993 only)

In 1993, respondents were invited to attend a training session on the use of "their" fuel - this was in response to difficulties experienced by respondents in 1992. This was an important component of the 1993 study and interested readers are referred to the description of the process in the original report[3].

Placement of test fuels

1992 (Phase 1): The placement of test fuels had to be scheduled around the week of mass action following the Boipatong Massacre on 17 June 1992. Sufficient test fuel was delivered to each household for two weeks of use - four bags. After that, two bags of test fuel were delivered to each participating household for the next four weeks. The six-week trial period was longer than required for people to test the products but was considered necessary to allow for the completion of the exposure monitoring, given the volatility of the area.

1993 (Phase 2): Once respondents had been educated, the test fuel was delivered to their households. Each household received two bags of test coal initially and thereafter two bags a week for the next two weeks. The test coal was bagged in hessian bags, each containing 70 kg of the fuel. The original intention was to allow each household a four-week trial period with their fuel but problems experienced with the fuels led to a decision to reduce the trial period for all three fuels - experience in the 1992 study proved that this period was quite sufficient for trial and exposure monitoring.

In both 1992 and 1993, the co-ordination of coal deliveries was organised by the Palmer Development Group. In order to prevent any confusion different coal merchants handled each fuel. This meant that each coal merchant was only dealing with one type of fuel and only delivering it to the specified houses. Coal merchants in the area undertook all deliveries of the test fuels for the project as it was considered essential to obtain their involvement and co-operation.

Recall interviews

1992 (Phase 1): One recall interview was conducted after the household had been using the test coal for six weeks.

1993 (Phase 2): The first recall interview took place after a three-week trial period. On completion of the first recall interview the respondent was supplied with a bag of standard township coal. The second recall interview was conducted approximately one week after completion of the first recall interview. During this week respondents reverted to using standard township coal.

In the second recall interview, respondents were asked to comment on the differences between standard township coal and the test fuels, and to give an overall evaluation of the test fuel in relation to standard township coal.

Qualitative research

1992 (Phase 1): This took the form of group discussions held with users of each test fuel.

1993 (Phase 2): Loosely structured depth interviews were conducted with a selection of participants.

The group discussions and depth interviews were intended to assist in the interpretation of the results by giving participants an opportunity to discuss their reactions to and experiences with "their" test fuel.

Video

In both 1992 and 1993 a video covering the area and households sampled was prepared by Social Surveys.

Methodological differences

A significant difference in the methodology was that in 1992 there were only two test fuels (Enertek and UCP's fuels) and there was a control group of households using standard township coal. In 1993, there were three test fuels (Enertek, UCP and Ecofuel) but no control group. Instead, all households participating in the 1993 study were given a bag of standard township coal after the first recall interview, and a second recall interview was conducted a week later to obtain comparative ratings. This was felt to be a better method because:

- direct comparisons could be drawn between standard coal and the test fuel;
- given the budget limitations, a larger sample of households could be assigned to each test fuel.

Timing

1992 (Phase 1): The fieldwork was undertaken between the 22 July and 14 September 1992.

1993 (Phase 2): The fieldwork was undertaken from 1 July and 16 August 1993.

The 1992 study commenced too late in the season and literally "ran out of winter" as maximum daytime temperatures ranged between 25 and 30 degrees C during the first two weeks of September when recall interviews were being conducted. The 1993 survey was carefully planned to commence at the beginning of July and had the advantage of a shorter trial period.

Sample

1992 (Phase 1): 45 households participated in the study - 15 households per fuel.

1993 (Phase 2): A total of 90 households were selected - 30 households per test fuel.

In both phases a number of participants did not complete the study and the drop-out rates are shown in Table 1.

	1992	1993
	No. of Repondents	
ECOFUEL		
Placement	n/a	30
Recall 1	n/a	34
Recall 2	n/a	23
ENERTEK FUEL		
Placement	15	30
Recall 1	13	25
Recall 2	n/a	25
UCP FUEL		
Placement	18	30
Recall 1	13	25
Recall 2	n/a	24

Table 1: Sample "drop-out" rates 1992 and 1993

Both phases of the study were undertaken in Evaton - a relatively small, long-established township in the Vaal Triangle between Orange Farm and Sebokeng, and consists of a mixture of formal houses with backyard shacks and informal settlements.

In order to qualify for inclusion in the study, all households had to be: coal users; using a coal-burning stove for cooking (1993 only - in 1992 part of the sample was made up of brazier users) and consist of at least two members. Household income was established and used in the selection of households in order to obtain a representative "socio-economic" profile of the area.

It is estimated that as much as 75% of Evaton had been electrified since the completion of Phase 1 of this project in September 1992. In the 1993 study 78% of households sampled had electricity installed. When areas were selected for sampling the level of electrification was taken into account but was not a variable in the final selection of households. However, awareness of the benefits of reviewing the effects of electrification on fuel usage and attitudes led to the incorporation of an extensive section on electricity in the 1993 study.

Caveat: A sample of 90 households with final results based on approximately 30 households per fuel is not adequate for quantification of the results and does not have any statistical reliability. However, from a qualitative basis, the doubling of the sample from 1992 to 1993 did permit a more in-depth analysis of the results.

Note on circumstances affecting the study

1992 (Phase 1): The so-called Boipatong Massacre, which took place on 17 June 1992, seriously de-stabilised the already volative Vaal Triangle region. Fieldwork had to accommodate a week of "rolling mass action", but with the involvement and co-operation of the Evaton Civic Assocation, the study was able to go ahead.

1993 (Phase 2): A week before the commencement of field-work, ten people in Evaton were killed in "random shooting" incidents. This increased the difficulty of recruiting and educating respondents for the acceptability study. It also resulted in increased militancy amongst the township youth which led to delays in deliveries when coal merchants' trucks were not permitted to leave Evaton to collect test fuels.

"The "bottom line" is that these people are not prepared to trade-off their coal stoves for clean air. However, 90% of respondents said that they would be prepared to use a coal which gave off as much heat as their usual coal but which had much less smoke."

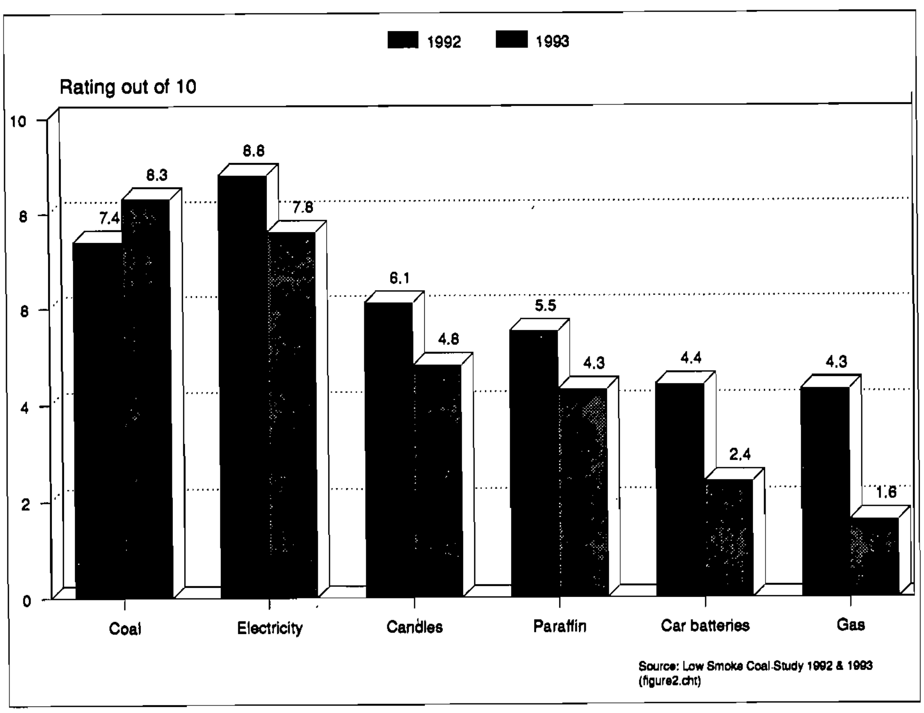


Figure 2: Rating of major fuels (1992 and 1993)

The main findings

Fuel types normally used

All households sampled used coal and 98% used wood. The advent of electricity resulted in significant decreases in the use of transitional fuels such as, paraffin (92% to 61%) and candles (100% to 52%) between 1992 and 1993. Since television was such a priority amongst electrified households it is not surprising that usage of car batteries declined from 49% to 2%.

Rating of major fuels

Asked to rate major fuels out of ten, those sampled in Evaton responded as follows in 1992 and 1993:

Bearing in mind that the 1992 results were obtained before electrification and the 1993 results when 78% of households sampled had electricity, it is significant that coal received a higher overall rating than electricity in 1993 (this was also true of users of electricity).

Even though these ratings are based on small samples (particularly in 1992), they appear to indicate that the "halo" effect surrounding electricity may start to dissipate once people become users and is certainly worth exploring in related research.

Electricity

1992 (Phase 1): Evaton was not electrified at this stage but respondents had very positive attitudes to electricity and were looking forward to the imminent "switch-on". Dwellings whose occupants had opted for electricity were being wired for electricity and fitted with prepayment meters by Eskom at a very low cost of R30 per house.

1993 (Phase 2): Seventy-eight percent of households claimed that they normally used electricity. All electrified houses had Eskom's prepayment meters installed. Eighty-eight percent of respondents bought an electricity card once a month. The last time a card was purchased, the average price paid was R13.

Households are mainly using electricity for lighting and entertainment (television, radio and hi-fi). Since these activities draw low amounts of power, it would account for the very low current expenditure on electricity. People also commented that they were spending less on lighting and powering their TVs than in the past when they were buying candles and re-charging car batteries. Respondents in houses where electricity was used solely for lighting mentioned that where they had previously spent R20 per week on candles, they were now spending R10 per month on electricity. Because the prepayment meters are in their kitchens, users are very aware of what each appliance is costing them to run, hence their reluctance to use electricity for cooking. This begs the question as to how Eskom will recoup its capital expenditure when households are using so little electricity.

Fifty-five percent of respondents said that they had not bought any electrical appliances since having their houses electrified. The first priority of householders who had bought electrical appliances was a television set followed by a kettle and a hi-fi set. Once they had purchased a TV, householders tended to buy smaller convenience appliances, such as kettles, irons and toasters. A fridge is the only major appliance that respondents are currently considering buying.

Electricity: *Likes*

Electricity was liked by its users for: providing a bright light; its speed; making life easier, more convenient; ideal for TV.

"Before we had electricity, we felt we were not able to live the good life like other families who did have it. Now we have it we feel great, especially when it comes to lighting as it makes everything very bright". (Depth interview)

In a clear endorsement of electricity, three-quarters of the respondents who already have electricity claimed that they would recommend it to people who do not presently have it.

Electricity: *Dislikes*

Although 39% of users of electricity had no dislikes, others found that it was: too expensive; dangerous; switches off without warning.

Coal

Coal purchasing and usage habits

Most households buy their coal off a coal truck, with the remainder buying buy directly from coal yards. The average price paid for a 70 kg bag of coal in 1993 was R14. On average, households sampled used 1,4 bags of coal per week.

Coal: *Likes*

When asked what they liked about coal, respondents spontaneously mentioned: it heats the house; they like it for cooking; it does many things; they like it for baking; it heats water; they like it for ironing; its economical.

Coal: *Dislikes*

When asked what they disliked about coal, users focused mainly on smoke, smog, and that it makes things dirty. A quarter of users had no dislikes.

Rating of coal

Respondents were shown a list of attributes and asked the extent to which they agreed or disagreed with them as descriptors of the fuel they had tested. From these ratings it is apparent that respondents sampled in Evaton are generally favourably disposed towards coal. They like it for cooking, believe that it is safe, easy to use, the best way of warming their homes, the cheapest way of heating water, easy to light, retains its heat for a long time, and that it is the cheapest fuel to use. (See Table 2).

However, amongst these high scoring attributes there were also high negative ratings which indicate that coal users have problems with the amount of ash left by coal and with coal smoke. Coal smoke causes problems for respondents in that it: is a problem outside and causes pollution; dirties their washing; dirties their walls and makes things dirty inside; is a problem inside their homes; is unhealthy (makes us sick); dirties pots.

It is evident that coal smoke is perceived as being a problem by its users but the finding that they tend only to agree rather than agree strongly with coal smoke-

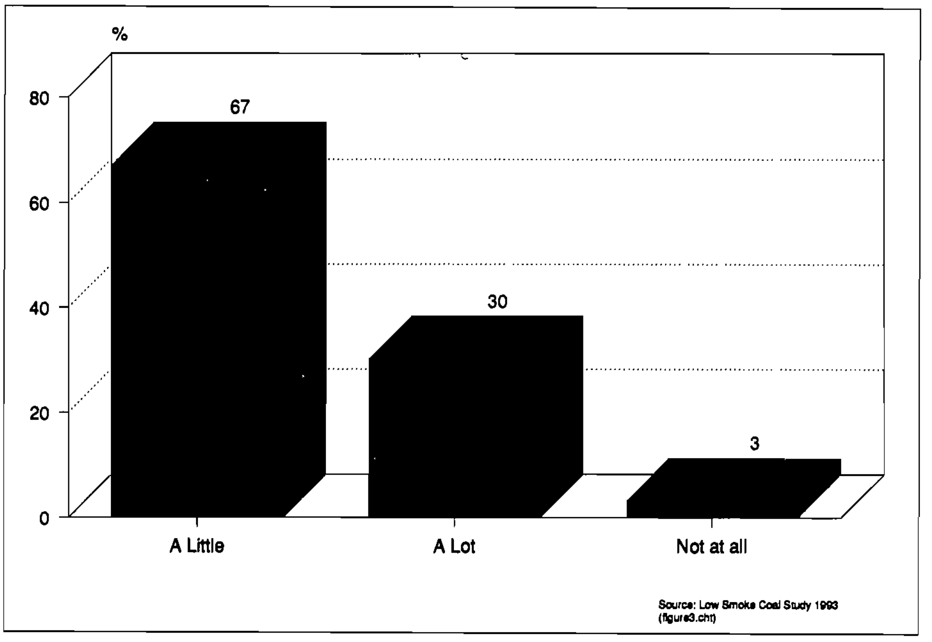


Figure 3: *Extent to which respondents are worried about coal smoke*

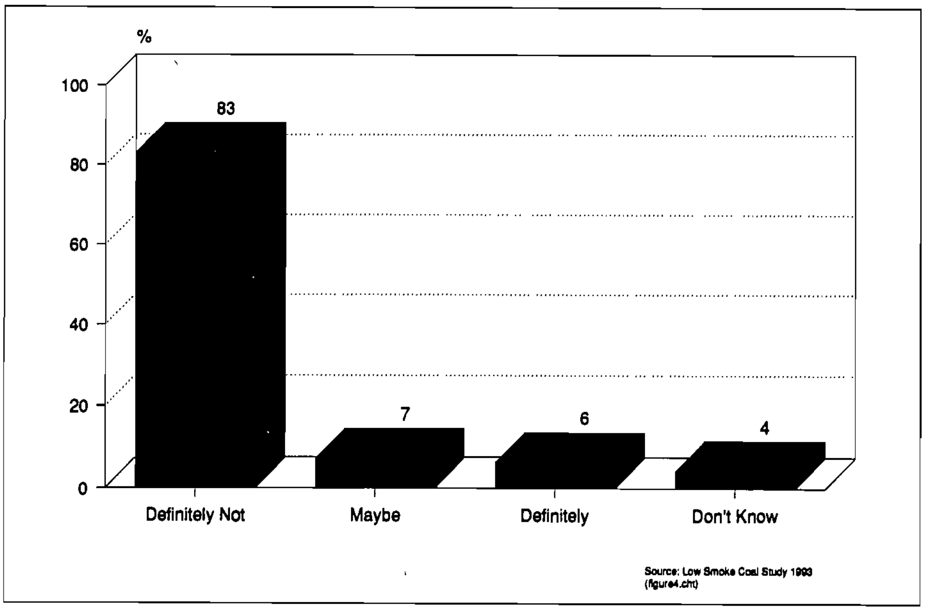


Figure 4: *Preparedness to stop using coal stove to eliminate coal smoke*

related attributes gives further insight into their actual level of concern. It appears to indicate that even though coal smoke is a problem to coal users, it is not of overwhelming concern!

Attitudes to coal smoke (1993)

It is significant that the highest level of strong agreement reflects their concern about smoke outside their homes causing pollution. It must be emphasised that all households sampled had coal stoves with chimneys to the outside and that the inside of their homes would be less smoky than the outside.

"Inside my house it is not a problem. It is a problem outside. Here in Evaton in the evening or early morning one cannot see a person who is at a distance of one metre." (Depth interview)

Two thirds of respondents said that coal smoke worries them "a little".

In view of this somewhat equivocal attitude towards coal smoke, it is hardly surprising that 83% said that they would definitely not be prepared to stop using their coal stoves in order to eliminate coal smoke from the area.

Significantly, 81% of people living in electrified households also said that they were definitely not prepared to give up their coal stoves in the interest of clean air.

Even though township dwellers are aware of the negative aspects of using coal, the social role of coal stoves and people's emotional attachment to their coal stoves (and hence to coal) must not be underestimated when formulating energy policy, as depicted by these quotes obtained during the 1993 depth interviews:

"I love my coal stove. Especially in winter it provides heat for our home. With the new service of Eskom we can't use stoves and heaters because it will cost us a lot of money. With a coal stove we really save."

"The high levels of smoke have not dropped in any way because people use coal stoves even though they have electricity."

"I can't get rid of my coal stove even though I can afford an electric one."

"My coal stove is my life, without it my life will be meaningless because I won't be able make a warm house, cook, heat water for my children or iron for them."

People who already own coal stoves show no inclination to give them up even when their homes are electrified. There are many reasons for this:

- the high cost of purchasing electrical appliances;
- the multiple functions fulfilled by a coal stove (heating the house, cooking, baking, heating water, heating irons);
- the belief that a coal stove is the best and most economical way of heating a house (particularly a shack) in very cold Highveld winters;
- the unreliability of the electricity supply in townships;
- two-thirds of coal stoves in households sampled in Evaton had six plates. Thirty-eight percent of households owned a Jewel coal stove.

Given that the average household income amongst this Evaton sample was R830 per month and that the retail price (Ellerines, November 1993) of a six-plate Jewel coal stove is R3 698, their coal stove is likely to be the household's biggest single investment, a factor which would certainly contribute to their reluctance to get rid of it.

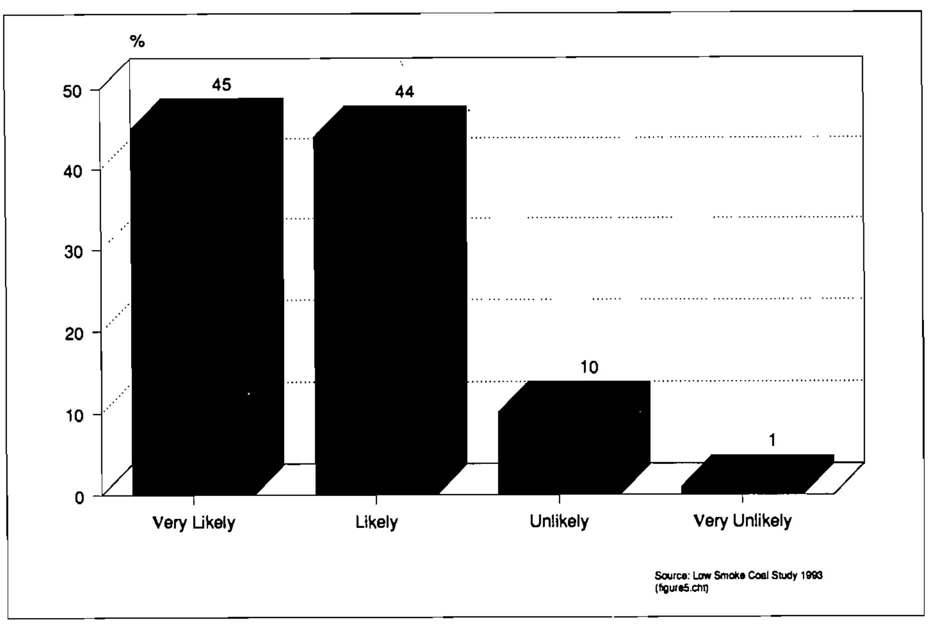


Figure 5: *Likelihood of changing to a low-smoke coal*

Preparedness to switch to a low-smoke coal (1993)

Significantly, even before they were aware that they were to be asked to test a low-smoke coal, 90% of respondents said that they would be likely to change to a coal which gave as much heat as normal coal, but with much less smoke.

Bearing in mind that residents of Evaton are generally poor, the results indicate that a low-smoke fuel which is competitively priced against standard township coal would be highly acceptable to coal users.

Acceptability of the test fuels

Spontaneous likes and dislikes of the three test fuels

The aspects of each fuel that users particularly liked and disliked are highlighted below. Users of all three fuels spontaneously mentioned liking the lower levels of smoke. Ecofuel users see the speed with which their fuel burns as both an advantage and a disadvantage but enjoyed the ease of lighting this fuel. The UCP fuel is seen as burning for longer and lasting well, but users were unhappy with the amount of formulation problems. Enertek users complained about their fuel breaking up and turning into dust.

(a) *Likes*

Ecofuel

It burns very fast	73%
Doesn't produce so much smoke	23%
Produces more heat	19%
Easy to light	19%
Burns very well	12%
Doesn't need wood	19%
No smog	8%
Lasts longer	8%
Use it without getting dirty	4%

Enertek Fuel

Nothing	36%
Doesn't produce so much smoke	40%
Lasts longer	8%

UCP Fuel

Doesn't produce so much smoke	36%
Coal lasts longer	24%
Heat lasts longer	24%
Burns very well	20%
Produces more heat	12%
Heats the whole house	12%
Smells less of chemicals	8%

(b) *Dislikes*

Ecofuel

Doesn't last	23%
Burns too fast	23%
Breaks up easily	12%
Heat doesn't last long	12%

Enertek Fuel

Coal breaks up easily	40%
Size is too big	16%
Warms rather than heats	12%
Does not burn well	12%
Goes out when you add more coal	12%
Lots of dust, I only used half a bag	8%
Does not keep a fire for long	8%

UCP Fuel

I had to use too much wood to start it	28%
It warms rather than heats	12%
Makes smoke with a chemical smell	12%
Makes too much ash	8%

Differences between the test fuels and usual coal

Users were asked to describe how the test fuels differed from their normal coal.

Enertek Fuel: Users were more aware of the appearance and extrinsic characteristics of the product. Over half of the users of the Enertek fuel mentioned the size of the blocks. They that the fuel did not look like coal, commented on the fuel breaking easily and making lots of dust, and spoke of how it did not make them dirty when they used it.

UCP Fuel:
Users felt that the UCP fuel looked like normal coal and most of their comments referred to product intrinsics, e.g. takes longer to catch fire, less smoke, heat is good, needed more wood to start fire.

Ecofuel:
A quarter of users commented that Ecofuel burned very quickly with a very high flame and they felt that the manufacturers had added oil or paraffin to it. They found that they could light it without using any wood. They commented that it smelled different, with some users not liking the smell. They noticed differences in the appearance of the ash, commenting on its fineness and saying that it "looked brown like soil".

Rating of coal and test fuels (1992 and 1993)

Respondents were shown a list of attributes and asked the extent to which they agreed or disagreed with them. Means were calculated based on the following values: strong agreement (5), agreement (4), disagreement (2) strong disagreement (1). To facilitate comparison, all ratings are shown Table 2:

	STD COAL	ECOFUEL USERS		ENERTEK FUEL USERS			UCP FUEL USERS		
	Placement 1993	Recall 1 Ecofuel 1993	Recall 2 Std Coal 1993	1992	Recall 1 Enertek 1993	Recall 2 Std Coal 1993	1992	Recall 1 UCP 1993	Recall 2 Std Coal 1993
Number of Respondents	**90**	**24**	**23**	**13**	**25**	**25**	**13**	**25**	**24**
Like this coal for cooking	4,7	5,0	4,0	4,2	2,7	4,0	3,2	4,1	4,2
This coal is best for keeping house warm	4,6	4,9	4,0	4,1	2,3	3,9	3,0	4,0	4,0
This coal is difficult to light	2,1	1,3	2,5	n/a	3,8	2,3	n/a	3,2	1,7
This coal is cheapest way to heat water	4,2	4,4	4,2	3,8	2,1	3,8	3,2	3,4	4,0
This coal is too expensive	2,7	3,0	4,2	1,7	1,0	3,8	1,6	1,7	4,5
This coal is safe to use	4,4	4,7	4,8	3,4	3,4	4,0	4,1	4,2	4,6
Like the smell of its smoke in my home	2,4	2,7	4,7	n/a	2,0	2,4	n/a	2,0	4,6
This coal's smoke is a problem in my home	3,8	1,2	3,9	1,1	1,3	3,7	1,7	1,8	3,6
This coal's smoke is a problem outside	4,2	1,3	3,8	1,0	1,3	3,9	2,5	2,1	4,4
This coal smoke is unhealthy	3,7	1,1	3,6	1,0	1,2	3,7	2,7	1,7	3,5
This coal dirties things inside	3,9	1,2	3,8	1,0	1,3	4,2	2,1	1,6	3,5
This coal smoke dirties my washing	4,0	1,1	3,7	1,0	1,3	3,5	2,2	1,4	3,5
Pots get dirty when cooking with this coal	3,5	1,2	4,1	1,0	1,3	3,7	2,2	1,5	3,8
This coal smoke can kill you in your sleep	3,3	1,0	4,6	3,9	1,3	4,4	2,8	1,4	4,9
This coal burns well	3,8	4,9	4,1	3,5	2,4	3,7	2,9	3,8	3,9
This coal lights easily	4,2	5,0	3,8	3,6	2,1	3,8	2,9	2,4	4,3
This coal keeps its heat for a long time	4,3	2,5	4,2	n/a	1,9	3,1	n/a	3,1	4,0
This coal is the cheapest fuel to use	4,0	4,0	4,0	n/a	1,0	2,8	n/a	3,2	3,8
This coal is easily available	3,6	3,2	2,8	2,8	3,9	2,1	2,5	3,3	3,1
Can't use this coal in hot weather	2,0	1,7	2,1	2,1	1,4	1,5	3,2	1,3	1,5
This coal smells bad	2,7	2,4	1,3	1,2	1,2	2,0	1,9	2,5	1,3
This coal is easy to use	4,4	4,8	4,3	4,1	1,9	4,3	2,8	3,4	4,8
This coal lasts a long time	3,4	2,6	4,1	3,4	1,9	2,8	2,8	3,5	3,9
This coal makes too much ash	4,4	2,8	4,0	2,2	4,6	3,9	3,1	3,7	4,0
The coal we get is of poor quality	3,3	1,8	3,2	2,1	4,1	3,9	3,2	2,9	4,3
I use this coal as there is no alternative	2,1	1,5	2,3	2,2	1,8	2,2	1,7	1,4	2,3
This coal burns too fast	n/a	4,6	2,7	n/a	1,8	2,3	n/a	2,2	1,3

Table 2: Mean rating of attributes: 1992 and 1993

Standard coal was rated at the placement interview. In 1993 it was rated during the second recall interview when respondents had reverted to using it for one week. Ratings of standard coal at the second recall interview are shown for users of each test fuel separately as experience of a specific fuel has been shown to affect their final rating of standard coal. In 1992, the test fuels were rated by their users during the recall interview when they had been using the fuel for six weeks. In 1993, the test fuels were rated by their own users during the first recall interview, at which stage they had been using the test fuel for a minimum of three weeks.

Rating of Ecofuel (1993 only)

Respondents really liked Ecofuel for cooking. They felt that it burned well, was good for heating their house, lights easily, is easy and safe to use. Ecofuel performed excellently on all smoke-related aspects (Table 2).

"I would prefer to use the test coal in summer and use normal coal in winter". (Depth Interview)

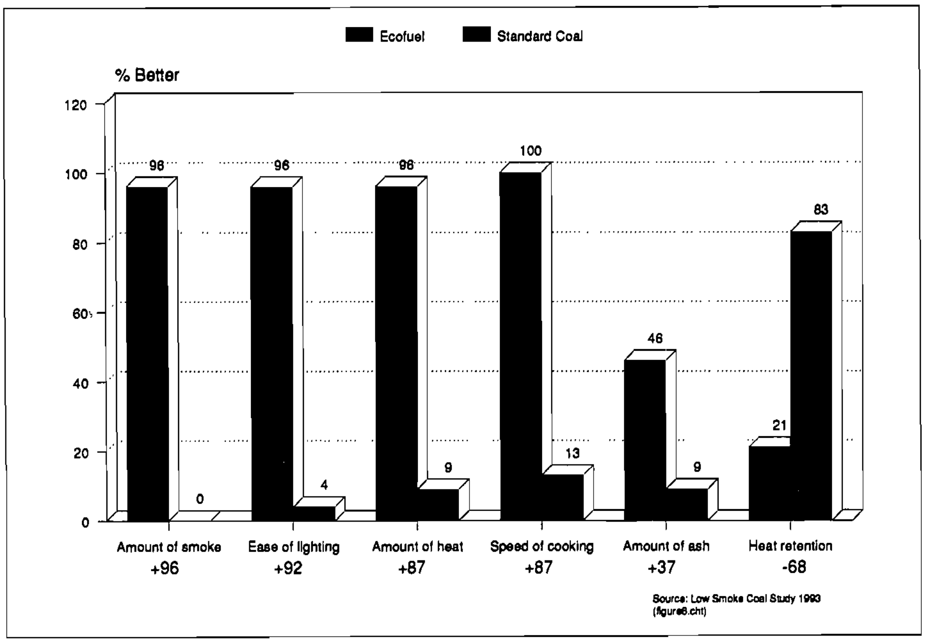


Figure 6: Ecofuel versus standard coal

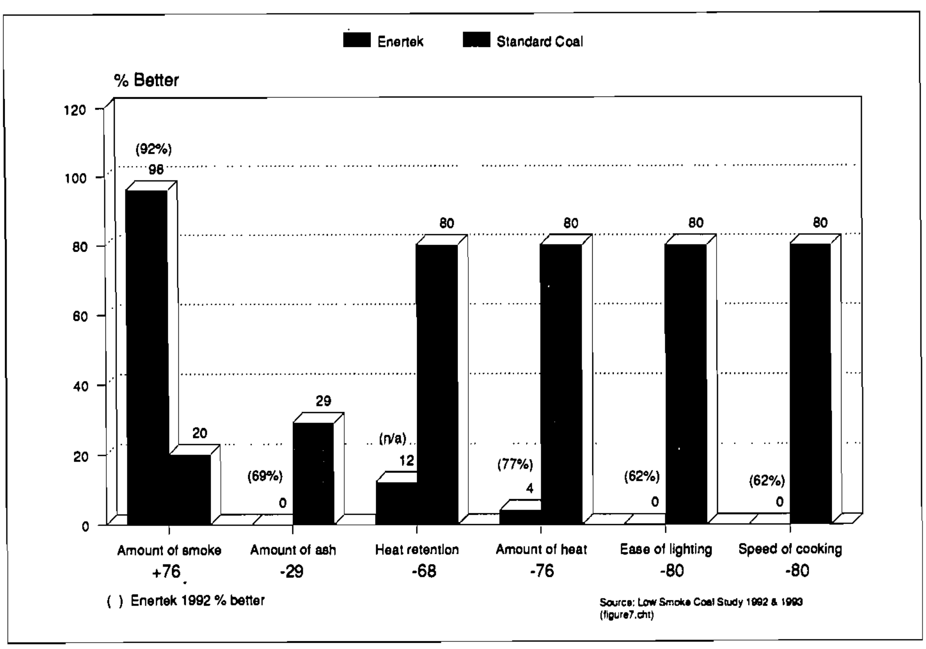


Figure 7: Enertek versus standard coal

Rating of the Enertek Fuel (1992 and 1993)

Reference to Table 2 indicates that Enertek fuel was rated much more positively by its users in 1992 than in 1993 - the exception being smoke-related attributes where the fuel was rated well in both years.

<u>1992 (Phase 1)</u>: Respondents rated the Enertek fuel very favourably with regard to cooking, keeping the house warm, heating water, ease of use, and favourably when it came to, lasting a long time, burning well and lighting easily.

<u>1993 (Phase 2)</u>: Respondents were not enthusiastic about the Enertek fuel. It was seen as having too much ash, as being difficult to light, associated with poor quality, and was really only used because it was available.

Rating of UCP fuel (1992 and 1993)

The UCP fuel generally received somewhat higher ratings in 1993 than in 1992. Compared with 1992, there was a marked improvement in ratings of key product characteristics, such as, it was liked for cooking, keeping the house warm, and burning well. In both 1992 and 1993 it was well rated by users for its lack of smoke and its safety. On the negative side, users in both phases felt it had too much ash and that it was difficult to light (Table 2).

Effect of trial of test fuels on rating of standard township coal (1993 only)

A comparison of pre- and post-trial ratings of standard township coal suggests that use of the test coal has resulted in respondents generally being less positive about standard coal. They are not as enthusiastic about it for cooking or heating their homes, they feel it is expensive, and are less satisfied with the quality of the coal available to them.

Having used low-smoke coals, they are now much more concerned about the safety of using standard coal and fear that they are more likely to be killed while they sleep from the fumes from standard coal.

Interestingly, users are much more positive about the smell of standard coal, with ratings on "like the smell of coal smoke in my home" having increased from 2,4 in the pre-trial interview to 4,0 in the post-trial interview.

This reinforces findings from Phase 1 of this study which concluded that coal smoke is positively perceived by its users, and even coal smoke which is identified as a major problem evokes nostalgic feelings of welcome and warmth. It seems that respondents may have missed the familiar smell of standard coal smoke and only really became aware of this when they started using standard coal again!

Test fuels versus standard township coal

Comparative ratings: Test fuel and usual coal

The following charts indicate the extent to which each test fuel was rated better in the first recall interview and the standard township coal as better in the final interview - the difference between the two percentages is indicated at the base of each chart and provides an effective means of comparing the performance of each test fuel against standard township coal on the 6 key product attributes.

Ecofuel: Normal coal was only rated as being better than Ecofuel on heat retention.

Enertek fuel: With the exception of the amount of smoke emitted, the Enertek fuel was consistently rated well below standard township coal. However, reference to the 1992 results indicates that in terms of the 5 key product attributes monitored (heat retention was not asked), over 60% of users rated Enertek's fuel as being better than their usual coal.

UCP fuel: The UCP fuel was judged to be better than standard township coal in terms of smoke emissions, the amount of heat produced and the retention of heat, but continues to experience problems in terms of ease of lighting and speed of cooking - both exceptionally important product characteristics. Compared to 1992, the UCP fuel has shown a marked improvement in the percentage of users rating it better than their usual coal in terms of heat produced and quantity of ash produced.

For example: on ease of lighting, Ecofuel was rated better than normal coal by 96% of users, whereas normal coal was rated better by 4% of Ecofuel users - a difference of +92%; UCP fuel was rated better than normal coal by 16% of users but normal coal was rated better by 100% of UCP users - a difference of -84%.

From Table 3 it can be seen that the Enertek and UCP fuels, in the eyes of their users, are outperformed by normal coal in terms of ease of lighting and speed of cooking. In addition, the Enertek fuel is rated worse than normal coal in terms of

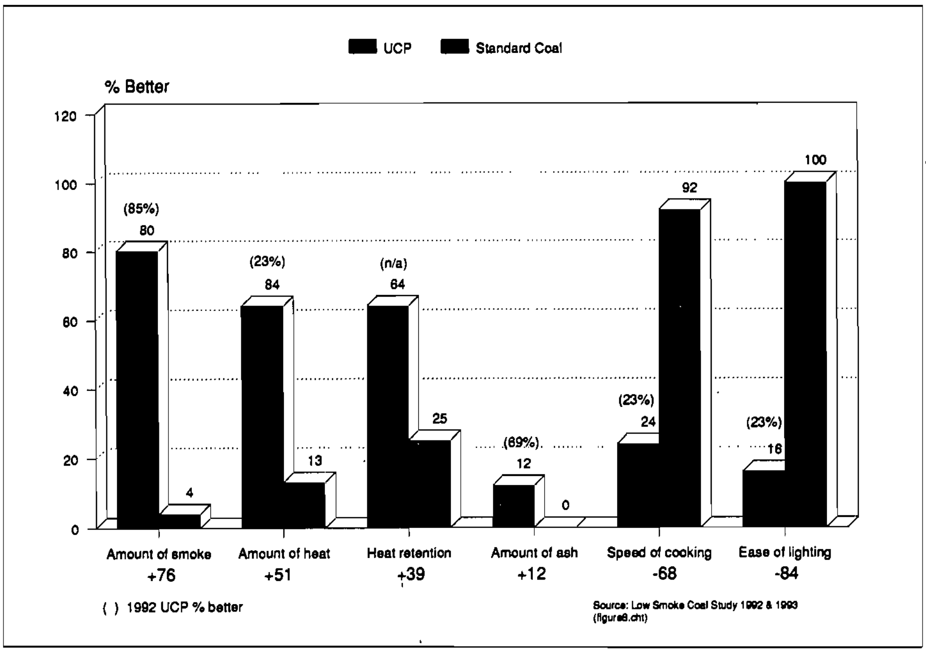


Figure 8: *UCP versus standard coal*

	ECOFUEL	ENERTEK	UCP
	% Diff.	% Diff.	% Diff.
Amount of smoke	+ 96	+ 76	+ 76
Ease of lighting	+ 92	- 80	- 84
Amount of heat	+ 87	- 76	+ 51
Speed of cooking	+ 87	- 80	- 68
Amount of ash	+ 37	- 29	+ 12
Heat retention	- 83	- 68	+ 39

Table 3: *Extent to which test fuels were rated better or worse than standard township coal (summary)*

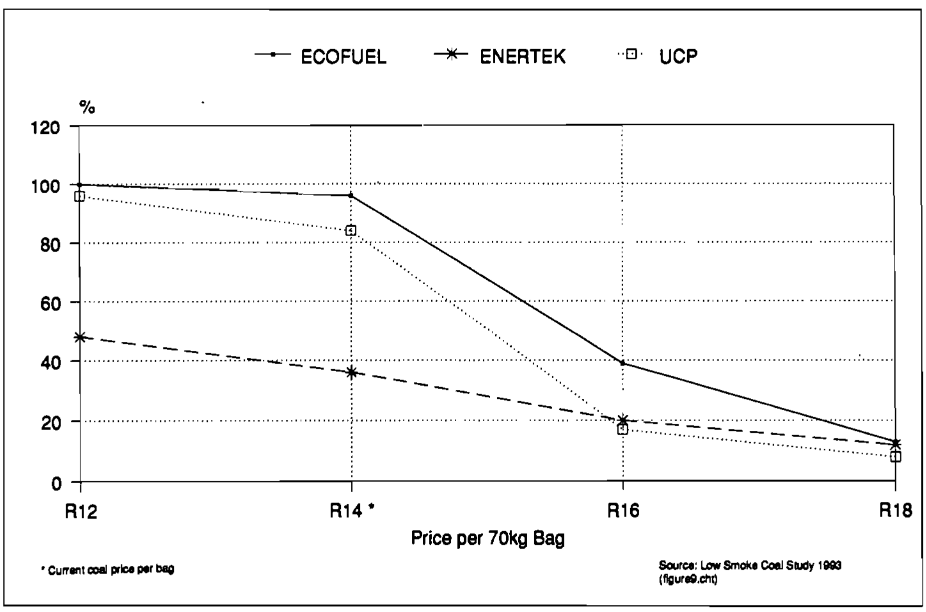


Figure 9: *Price elasticity 1993*

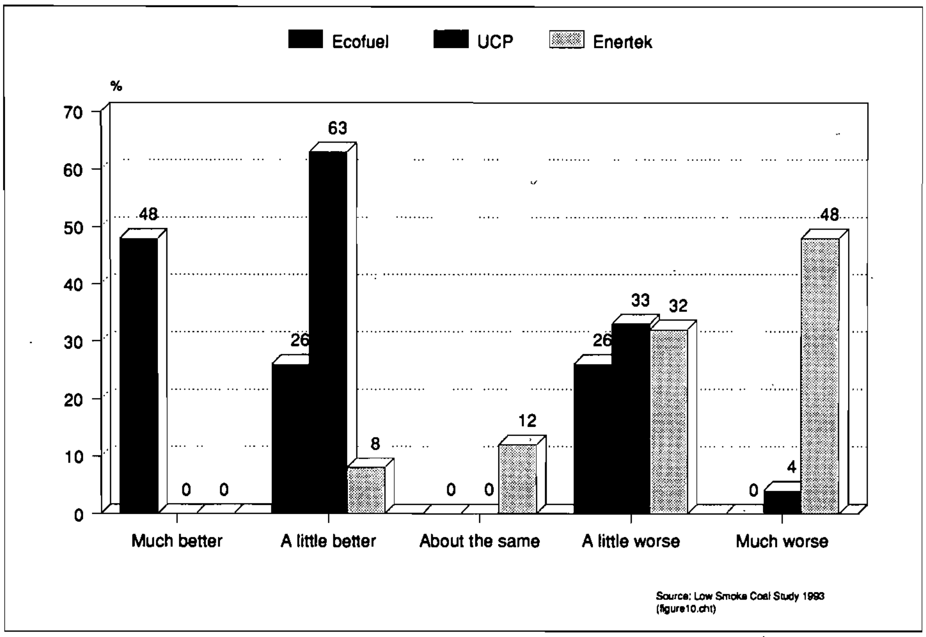


Figure 10: Final rating against standard coal 1993

the amount of residual ash. Normal coal is seen as retaining its heat longer than either the Enertek or Ecofuel fuels.

Pricing of the test coals

Ecofuel: A market would exist for Ecofuel at the same price as standard township coal, but the likelihood of purchasing it decreases rapidly when premium prices are proposed. Compared with the other two test fuels, more than twice as many users would be very likely or fairly likely to purchase it at R16 per bag, which is indicative of its greater level of acceptability amongst this market (see Figure 9).

Enertek fuel: Enertek's 1993 fuel would not find a viable market even if it was priced below the current price of a bag of coal (see Figure 9).

However, results from the 1992 study indicate that, when correctly manufactured, users would even be prepared to pay a premium price for it (31% would be very likely and 46% fairly likely to buy it if it was priced at R16 per bag - 20% above the retail price of standard township coal in 1992).

UCP fuel: As was the case in 1992, users would only be very willing to buy the UCP fuel if it was priced at R2 below the current market price of standard township coal. UCP's fuel would encounter resistance if priced at the same price as standard township coal and there would be no demand for it if it was priced above the current market price (see Figure 9).

Overall rating of the test fuels

The following chart provides a comparison between the three test fuels in terms of the final overall rating against standard coal.

Ecofuel: The chart indicates that 48% of users rated Ecofuel as much better than their usual coal, with 26% feeling it was only a little better. In total, 74% of users felt it was better than their usual coal.

UCP fuel: Sixty-three percent of UCP fuel users rated it as being a little better than their usual coal. No one rated it as much better. In 1992, only 40% of UCP fuel users rated it as being a little better.

Enertek fuel: Eighty percent of users found this fuel to be worse than their usual coal - 48% felt it was much worse and 32% a little worse. In 1992, the opposite applied: 77% of users felt it was much better than their usual coal and 8% felt it was a little better - an overall positive rating of 85%. The change in formulation has really had disasterous consequences for the acceptability of Enertek's fuel in 1993.

Conclusions and recommendations

Results from this project indicate that although the people living in Evaton are concerned about coal smoke causing pollution and sickness, their concern is tempered by the reality of their economic circumstances and hence, may not be as strong as that of policy-makers, white residents of adjacent electrified townships, environmentalists or the media!

The "bottom line" is that these people are not prepared to trade-off their coal stoves for clean air.

However, 90% of respondents said that they would be prepared to use a coal which gave off as much heat as their usual coal but which had much less smoke.

Users of all three test fuels rated them as much better than standard township coal in terms of the amount of smoke emitted.

Ecofuel

Ecofuel outperformed standard township coal in terms of amount of smoke, ease of lighting, amount of heat, speed of cooking and amount of ash. Standard township coal was judged much better in terms of heat retention.

Since the manufacturing and briquetting process means that this fuel will be significantly more expensive than standard township coal, it is not recommended that it be marketed as a substitute for standard township coal to low-income families.

If it is to be sold to users of coal stoves it will be necessary to market it quite differently in order to command a premium price. It is recommended that a marketing campaign be developed targeting black coal stove owners, which stresses Ecofuel's unique product strengths (e.g. speed of lighting, speed of cooking). By recommending it as a substitute for coal in coal stoves in summer, this makes a strength out of its low heat retention. The multiple uses of the product should be clearly demonstrated on the packet and the fuel should be distributed through spazas, supermarkets and petrol stations rather than through coal merchants.

Enertek fuel

The Enertek product tested in 1993 is unmarketable. However, Enertek has identified the cause of the problem and is confident that it will be able to adapt its final product accordingly. When Enertek's fuel was tested in 1992, there was no problem with the strength of the product and 77% of respondents rated it as much better than their usual coal. In 1992, it was rated well ahead of standard coal on amount of smoke, ease of lighting, amount of heat produced, speed of cooking and amount of ash.

It would appear that Enertek's concept of promoting this fuel as a product which could be manufactured informally by members of the community and hence, assist in the creation of employment opportunities in communities where unemployment levels are generally very high, is the most appropriate marketing strategy for this product - provided, of course, that the product formulation has been corrected and properly tested before the product is launched.

Results from the 1992 study indicated that this product could command a premium price and this would certainly be achievable if it was sold informally.

UCP fuel

UCP's fuel was judged as being better than standard township coal based on the amount of smoke produced, amount of heat produced as well as heat retention. As in 1992, UCP's fuel is outperformed by standard coal in terms of ease of lighting and speed of cooking - both important factors for township residents.

UCP's fuel will have to enter the market as a direct competitor to standard township coal. Its USP (Unique Selling Proposition), low-smoke, has been shown to be an insufficiently compelling reason on its own to make people switch fuels. However, findings that in addition to offering the benefit of low-smoke, it also keeps its heat for longer and, once established, produces more heat, all of which combine to make it a more attractive proposition. These three benefits will need to be promoted strongly.

The UCP fuel's major drawback is that, despite being trained in its use, respondents found it difficult to light and complained of the amount of wood they had to use in order to light it. Respondents were also dissatisfied with the length of time it took to get ready to cook - they could not light it up and start cooking as soon as they would have been able to with normal coal. Unless these problems can be resolved, the UCP fuel is only likely to be bought if it is priced below the current market price of coal.

This is unfortunate because the UCP fuel is the only fuel of the three low-smoke coals tested that provides a viable alternative to standard coal in terms of price, distribution and the quantities that can be manufactured. Provided its emissions of gases and total suspended particulates (TSPs) prove satisfactory, it is the only fuel of the three tested that could significantly impact on the coal smoke-based pollution levels in Highveld townships, such as Evaton, and it is recommended that funding be allocated for the enhancement of the product.

Caveat: The results from this study relate to one small Transvaal Highveld township, Evaton, and are based on a sample of 90 households.

Conclusion

Even when they have electricity, people living in townships on the Highveld, like Evaton, are not going to give up their coal stoves in the interests of clean air. Policy-makers in the Department of Mineral and Energy Affairs will need to develop a joint strategy with the Department of Environment Affairs to ensure that the elimination (or at least significant reduction) of coal smoke-based pollution receives due priority, and that sufficient funding is allocated for the enhancement and development of low-smoke fuels that would be a substitute for coal in coal stoves and braziers.

However, there is no point in developing low-smoke coals if they provide a cosmetic rather than real solution to the pollution problem. The levels of gases and suspended particulates emitted have to be monitored to ensure that the smog from coal smoke is not just replaced by equally dangerous but less visible pollutants.

References

(1) RAMPHELE M (Ed.) (1991). Restoring the earth. Panos Publications.

(2) HOETS P A (1992). Low Smoke Fuels Acceptability Study: Phase 1. National Energy Council.

(3) HOETS P A (1993). Low Smoke Fuels Acceptability Study: Phase 2. Department of Mineral and Affairs.

(4) NATIONAL ENERGY COUNCIL (1992). Annual Report 1991 - 1992.

(5) TERBLANCHE A P S, NEL C M E and OPPERMAN L (1992). Health and safety aspects of domestic fuels: Phase I. Department of Mineral and Energy Affairs.

Energy news in Africa

Electricity

The Caisse Francaise de Developpement (CFD) and its affiliate for the private sector, Proparco, put up loans worth a total of Ffr991 M ($199 M) in the electricity sector in 1994. This represents a substantial increase in funding to the electricity sector. The electricity sector accounted for 21% of the money put up by the CFD group for projects in 1994, compared with 7% in 1993.

Guinea received the largest amount of funding, Ffr222 M, for its Garafiri hydro project. A smaller amount was made available for a project at Kaleta, which is downstream from Garafiri.

The Ivory Coast, Burkino Faso, Mozambique, Ghana, Tunisia, Congo and Benin also received loans from the CFD for electricity projects.

(Source: African Energy & Mining, 22 March 1995)

Morocco

The U.S. Overseas Private Investment Corporation (OPIC) has offered the CMS Energy Corporation in Morocco a guarantee on a contract that its affiliate CMS Generation has won with ABB to build the third and fourth parts of the coal-fired Jorf Lasfar power station. The deal also covers the private management of the first and second parts of the station, which like the section still to be built, have a combined capacity of 660 MW. The contract marks the first real American breakthrough in the electricity sector in Morocco.

(Source: African Energy & Mining, 22 March 1995)

Swaziland

Swaziland is to invite tenders for the engineering and supervision of work on a dam at Maguga on the Komati River which will provide electricity and be used for irrigation. The estimated cost of the project is R1,3 M and it will be financed mainly by the Development Bank of Southern Africa. The power station, with two 7,5 MW turbines and its 66 kV transmission lines, will cost about R60 M.

A project for a thermal power station fueled by coal from Mkapa near the border with Mozambique, has been revived. The U.S. company, Applied Energy Services (AES), has made an offer to build the 100 MW power station.

(Source: African Energy & Mining, 19 April 1995)

Tunisia

There are no plans to privatise Tunisia's Société Tunisienne de l'Electricité et du Gaz (STEG). However, plans are underway to allow private foreign firms to carry out franchise contracts.

In 1994, STEG's installed capacity amounted to 1 570 MW. Its output was 6 031 GWh and its sales 5 700 GWh. Work has been completed on the 350 MW combined cycle power station built by GEC Alsthom at Sousse. One turbine has been in operation since last year. The station is still undergoing tests and is expected to be inaugurated shortly.

(Source: African Energy & Mining, 19 April 1995)

Zaire

Zaire's Société Nationale d'Electricité (SNEL) is to introduce performance contracts with "basic regional entities". This is an attempt to rectify some of the shortcomings in commercial management and billing, and to rehabilitate equipment and transmission. In particular, it wanted to improve the reliability of the Inga-Shaba line and to build up the Zaire-Zambia interconnection to meet present needs and the future requirements of its foreign partners.

(Source: African Energy & Mining, 22 March 1995)

Hydro-electricity

Electricidade do Mozambique (EDM) is considering undertaking two hydro projects on the Zambezi River, and has requested ADB to finance the feasibility studies. Cahora Bassa II would consist of a new 550 MW power station on the northern bank of the river, at an estimated cost of $450 M. The other project, expected to cost over $1,3 billion, would involve building a second power station of 1 600 MW some 60 km downstream at Mepanda Uncua.

Work on rehabilitating the high voltage line between Cahora Bassa and South Africa is underway. It is expected that the European Development Fund (EDF) will take part in the project.

(Source: African Energy & Mining, 19 April 1995)

The Zimbabwe Electric Supply Authority (ZESA) has issued tenders for a programme to renovate and boost the capacity of the Kariba South power station on the Zambezi River. The project will entail the upgrading of each of the six turbines from 11 MW to 125 MW, and the tenders concern the adaptation of the hydraulic part of the dam to increase its capacity.

(Source: African Energy & Mining, 19 April 1995)

Natural gas

Madagascar's Office des Mines Nationales et des Industries Strategiques (OMNIS) has signed a contract with the British firm, Intera, for a study to be undertaken on the country's gas potential. The study will cover mainly the upstream side. Intera will reprocess all available seismic data and then carry out reservoir studies on small gas discoveries recorded in the past in the west (Mananbolo) and in southern Madagascar.

The study will also review the possibility of developing the use of natural gas and LPG as alternatives to wood and charcoal as sources of domestic heating fuel. Presently, wood and charcoal provide 80% of Madagascar's energy consumption, which amounts to 1,65 million TOE (1993), the remainder coming from hydro power (420 GWh), thermal power stations (180 GWh) and oil products, imports of which swallow up 30% of revenue from Madagascar's overall exports. Household users account for 83% of consumption, transportation 9% and industry 8%.

(Source: Africa Energy & mining, 5 April 1995)

Nuclear Power

Egypt is technically ready to launch construction of its first nuclear power station. Egypt's Nuclear Reactor Agency (NRA) is in the process of obtaining a 22 MW research reactor designed by Argentina. Construction of the reactor is expected to begin this year and be completed by the year 2000.

(Source: African Energy & Mining, 22 March 1995)

Solar Energy

The Global Environment Fund (GEF), a World Bank/UNDP agency, has offered Tunisia a $4 M grant for the solar energy part of its rural electrification programme. The funds will be used for the solar heating aspect of the project.

The project is being carried out by STEG and involves about 100 villages. It consists of extending the electricity grid, providing direct and PV solar energy, and the production of wind energy by means of the construction of a wind-powered power station at El Haouaria at Cap Bon. The French firm, Apex Ingenierie was awarded the $1,03 M contract to supply 1 250 PV systems.

By late 1994, the electrification rate in rural Tunisian areas reached 62%, boosting the overall rate to 86%.

(Source: African Energy & Mining, 19 April 1995)

Wind Energy

Spanish, French and American companies have submitted bids in a tender for the construction of a wind-powered power station at Tetuan, near Morocco's Mediterranean coast. The power station, with a capacity of 50 MW will be linked to the Office National de l'Electricite's grid, and it is hoped to put it into service by January 1997.

Germany is to finance a 3 MW wind unit in the same region, which is expected to cost $4 M.

(Source: African Energy & Mining, 19 April 1995)

Details of Authors

ASAMOAH J K

B.Sc.(UST, Kumasi), M.B.A.(Edinburgh), MSAIChE, MIQ, MSAIM
Chief Energy Specialist: Coal, Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria 0001, South Africa
Tel.: (012) 317 9212
Fax.: (012) 322 5224

Joe Asamoah started his career in 1977 as a Development Engineer with Firestone (Ghana) Ltd. After three years, he joined Tarkwa Goldfields (Ghana). In 1982 he was employed by Cocoa Products Factory (Ghana) as a Senior Chemist. He migrated to the then Transkei in 1986 and after teaching for four years, joined Transkei Mining Corporation as a Project Manager from 1990-1994. In January 1995 he was transferred to the Department of Mineral and Energy Affairs (DMEA) as a Chief Energy Specialist. Joe is the co-ordinator of the DMEA's Low-Smoke Coal Programme.

GROBBELAAR C J

B.Sc.(Pretoria), B.Sc.(Hons.)(RAU), M.Phil.(Energy)(RAU)
Chief Energy Officer: Coal, Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria 0001, South Africa
Tel.: (012) 317 9213
Fax.: (012) 322 5224

Chris Grobbelaar started his career in 1979 as a researcher at the Industrial Hygiene Branch of the Chamber of Mines, during which time he enrolled for further studies in the field of energy at RAU's Institute for Energy Studies.

In 1983 he joined the Energy Planning Division of the Department of Mineral and Energy Affairs (DMEA) where he was responsible for coal and coal-related activities. From 1989 to 1991, he was Programme Co-ordinator for Coal and Energy & the Environment at the former National Energy Council.

In 1992 he was appointed to his present position at the DMEA's Chief Directorate: Energy, where his responsibilities involve activities for the development and formulation of a coal policy with specific emphasis on the efficient and clean beneficiation and use of coal.

HOETS P A

B.A.(Natal)
Marketing Research Consultant, P O Box 509, Halfway House 1685, South Africa
Tel./Fax.: (011) 805 4184

Penny Hoets joined Market Research Africa (MRA) in 1972. She was appointed to the board of MRA in 1984, where she was responsible for the development and management of MRA's Sociomonitor (a study of the changing social values of white and black South Africans) from 1975 to 1988. She represented MRA at five international RISC (Research Institute for Social Change) conferences. In 1987, Penny accepted an invitation from RISC to work as a consultant on their ACE (Anticipating Change in Europe) programme based in Paris and Lausanne.

She resigned from MRA in 1988 to set up her own marketing research consultancy.

She was Vice-Chairman of SAMRA (South African Marketing Research Association) for 1988 and 1989.

Penny is currently involved primarily in social research.

NEL C M E

M.Sc.(Occupational Physiology) (Potchefstroom), B.Sc.(Natural Science)
Scientist, Urbanisation and Health Research Programme, Medical Research Council, Private Bag X385, Pretoria 0001, South Africa
Tel.: (012) 324 1680
Fax.: (012) 324 1695

Riëtte Nel is a scientist at the Urbanisation and Health Research Programme of the Medical Research Council. She is primarily involved in atmospheric pollution an health research projects of which the Vaal Triangle Air pollution Study (VAPS) forms a major part.

ROGERS D E C

B.Sc.(Chem)(LaTrobe), Ph.D.(Physical Chemistry)(LaTrobe), M.B.L.(Unisa)
Project Leader, Environmental and Processing Measurement Laboratory, Division of Materials Science and Technology, CSIR, P O Box 395 Pretoria 0001, South Africa
Tel.: (012) 841 3450
Fax.: (012) 841 4395

Dave Rogers was born and educated in Australia and came to South Africa to work at the National Physical Research Laboratory at the CSIR on completion of his Ph.D. at LaTrobe University, Melbourne. His Ph.D. studies included the fields of instrumental design and construction in mass spectrometry and the development of soft ionisation techniques for the ionisation and volatilisation of labile molecules. Work at the NPRL exposed him to the analytical and materials characterisation activities associated with the technologies of solid state and gas phase materials processing. Specifically, this has lead to studies of gases in states other than those occurring in the ionisation regions of mass spectrometers. Currently he is working at the CSIR's Division of Materials Science and Technology (MATTEK) in the area of analytical measurements. His main focus is on chemical and physical analyses of problems related to processes involving gases and the measurement of emissions of environmental interest.

He was married in South Africa and is presently living in Pretoria. He used to play rugby at club level in Pretoria. However, now he is less energetic and more interested in Southern African fauna. He is a member of the Scientia Toastmasters Club and the CSIR running club.

SURRIDGE A D

B.Sc.(Canterbury), M.Sc.(Canterbury), Ph.D.(Otago), Dip.E.(Christchurch), M Inst.P., C.Phy., Pr.Sci.Nat., FSA Inst. E
Deputy Director: Energy, Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria 0001, South Africa
Tel.: (012) 317 9221
Fax.: (012) 322 5224

Tony Surridge joined the CSIR during 1979, working with the Air Pollution Research Group. Late in 1979 he joined ESD, a company working in radar and avionics. Then in October 1993 he joined the Department of Mineral and Energy Affairs.

Tony is a Past President of the National Association for Clean Air (NACA), and is the current World President of the International Union of Air Pollution and Environmental Protection Associations which is based in the U.K.

TERBLANCHE A P S

D.Sc.(Zool.)(Pretoria), B.Sc.(Hons.) (Zool.)(Pretoria), B.Sc.(Botany, Zool.) (Pretoria)
Manager: Environmental, Health and Safety Management Services, EMATEK, CSIR, P O Box 395, Pretoria 0001, South Africa
Tel.: (012) 841 4410
Fax.: (012) 841 2103

Petro Terblanche was appointed as manager of Environmental Air Quality Management Services of the Earth, Marine and Atmospheric Science and Technology (EMATEK) Division of the CSIR in 1992. She is also a specialist scientist at the Medical Research Council, and is principal investigator and project manager for the Vaal Triangle Air Pollution Health Study. Dr Terblanche started with environmental health research in South Africa following post-doctorate training at Harvard University, Boston, U.S.A. in 1989. She has specialised in air pollution health impact assessment with the focus on community health.

TOSEN G R

B.Sc., Dipl. Meteor., Pr. Sci. Nat.
Manager: Environmental Sciences, Technology Group, Eskom, Private Bag 40175, Cleveland 2022, South Africa
Tel.: (011) 629 7061
Fax.: (011) 629 7291

Greg Tosen joined the South African Weather Bureau (SAWB) in 1970 and started his career as a meteorologist with the 27th South African National Antarctic Expedition. He spent some 14 years with the SAWB before moving to Eskom's Research and Development Division in 1984. He became Head of the Environmental Section in 1989 where he was responsible for all of Eskom's air pollution and related environmental impacts research. In 1987 he was awarded the Best Young Scientist Award for his research on boundary layer studies by the S A Society of Atmospheric Sciences. He is on numerous national and international environment-related committees.

Forthcoming energy and energy-related conferences: 1995/1996

1995

JULY 1995

18-21

HOUSEHOLD ENERGY FOR DEVELOPING COMMUNITIES Midrand, South Africa

Enquiries: The Conference Organiser, P O Box 2862, Randburg 2125, South Africa

Tel.: (011) 886 8313 (Estelle Lotter)
Fax.: (011) 886 9916 (Estelle Lotter)

SEPTEMBER 1995

9-16

ISES 1995 : IN SEARCH OF THE SUN Harare, Zimbabwe

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

Tel.: (263)(4) 730 707

Fax.: (263)(4) 730 700

Email: XCARELSE@ZIMBIX.UZ.ZW

OCTOBER 1995

26-27

TWELFTH ANNUAL CONFERENCE ON ATMOSPHERIC SCIENCES Pretoria, South Africa

Enquiries: Chairman of the Organising Committee, Mr S O'Beirne, S A Society for Atmospheric Sciences, c/o Ematek, CSIR, P O Box 395, Pretoria 0001, South Africa

NOVEMBER 1995

20-23

ENERGY AFRICA '95 Accra, Ghana

Enquiries: Water Africa Limited, 37 Upper Duke Street, Liverpool L1 9DY, United Kingdom

Tel.: +44 (0) 151 709 9192
Fax.: +44 (0) 151 709 7801

1996

APRIL 1996

14-17

ELEVENTH INTERNATIONAL SYMPOSIUM ON ALCOHOL FUELS (ISAF XI) Sun City, South Africa

Enquiries: ISAF XI, P O Box 207, Plumstead, South Africa

Tel.: (021) 705 0120
Fax.: (021) 705 6266

Recent energy publications

CHARLES ANDERSON ASSOCIATES

National electricity policy synthesis study. Mar-1995. 115p.; 69p.

This synthesis study was carried out to serve as input for a national energy policy discussion document being prepared for the DMEA. It provides background information on the policy development of the electricity supply industry (ESI), but also embodies a large number of inputs from various representatives of the ESI and its external environment. There are also inputs from others that will change the way electricity is dealt with in the future, the recent/current policy, policy strengths, weaknesses and gaps, and policy and priority proposals. The study showed, *inter alia*, that the challenge facing a revamped ESI should be met by means of an integrated national electricity policy, of which the most important component should be a revised mode of goverance.

DE KORTE G J

The utilization potential of coal from the Waterberg Coalfield: Aspects of utilization. Feb-1995. 43p.
Report No. ES9011

Reviews some of the main industrial applications of coal and compares the quality parameters required for each application with the quality of coal available from the Waterberg Coalfield. The applications covered are combustion, gasification, carbonisation, liquefaction and chemicals.

DU CANN V M and DE KORTE G J

The utilization potential of coal from the Waterberg Coalfield: Petrography - Benches 6,7 & 8. Feb-1995. 1V.(various pagings)
Report No. ES9011

The objectives of the petrographic investigation were: (1) to determine the rank and changes in the type of coals from the lower successions of the Waterberg Coalfield subjected to washability tests; (2) to correlate the results of the petrographic maceral analyses with those of proximate analyses and calorific value determinations; (3) to monitor the behaviour of pseudovitrinite with changes in relative density.

HOLTZHAUSEN J P

A method for measuring pollution severity and a warning device for excessive pollution. Oct-1994. 35p.
Report No. EL9011

An insulator pollution monitoring apparatus was designed and built to measure the surface conductance of test insulators while producing artificial wetting of the insulators. It can be used to facilitate site severity measurement and can be used as a pollution warning device. The apparatus was evaluated at a site near the Koeberg nuclear power station. Useful results regarding the relationship between surface pollution, leakage currents and weather conditions were obtained.

HOLM D *et al.*

Towards a policy for passive thermal design in low-cost housing. Aug-1994. 133p.
Report No. EO9307/8

The report deals with three categories of improved passive thermal design housing, namely, informal retrofit, formal retrofit and new formal, mainly in the Highveld region of South Africa. The study was to determine possible constraints and suggest solutions, including technical, socio-economic and socio-political, which lead towards the formation of a policy for passive thermal design in low-cost housing. Begins with a description of the general approach and methodology. Each of the three categories are discussed in terms of collected data and relevant conclusions and recommendations. The information presented led to the establishment of the impact of passive thermal design with reference to social, architectural, thermal and financial constraints. The primary objective is to investigate the impact of passive thermal design with reference to social, architectural, thermal and financial constraints. The impact of passive thermal design on low-cost housing is investigated with special energy consumption, and within architectural parameters and social acceptability.

MAAS N J

A synthesis of IES studies on natural gas policy: The interventionist option.
Mar-1995. 93p.
Report No. EL9403

Contains a synthesis of the studies by the Institute for Energy Studies (IES) at RAU on South Africa's natural gas policy, as well as the proposals put forward on specific aspects. Some of the topics covered include gas reserves, use of gas from Sasol and Mossgas, gas for power generation, replacement of coal with gas in certain instances. Also mentions gas pipelines, gas prices, gas costs, and possible pollution.

MORGAN D L

The preparation and techno-economic evaluation of products derived from coal solutions. Apr-1994. 49p.
Report No. ES9014

Discusses the techno-economics of the process aimed at recovering the major part of the organic fraction of suitable coals, and the further development of this process in the light of economics. The evaluation of the conversion of this material into a cost-effective fine silicon carbide and other products is also discussed.

PALMER R

The cost and distribution of transitional fuels in the rural Transvaal. Dec-1994. 75p.
Report No. EO9121

Concentrates on the purchase and retail prices and distribution of three transitional fuels: paraffin, LPG and domestic grade coal - at the wholesale and retail level in four rural areas of the Transvaal. The primary objectives of the study are to detail and describe the changes in price of the three transitional fuels as they are first bought by the wholesalers, handled by the retailers and finally sold to the end-users; and to describe the distribution of retailer and wholesaler outlets at the local regional level.

THORNE S J and QANGULE V

Analysis of new electrification schemes in the Western Cape: Phase III. Aug-1994. 150p.
Report No. EO9108

The project entailed the examination of electricity and other fuels used in newly electrified, poor urban settlements in Cape Town (Khayelitsha, Langa, Guguletu). The project has been monitoring and analysing energy consumption data and relevant socio-economic information for three years. An important aim is to understand factors which affect the movement from multiple fuel use to greater electricity consumption. The project involves a longitudinal study of changing energy use patterns over time. This report covers Phase III, that is, 1993.

WOOLRIDGE J

Evaluation of the effect of oxidised coal-based trace element carriers on deciduous fruit. Feb-1995. 18p.
Report No. ES9301

Using the deciduous fruit-growing areas of the Western and Southern Cape, the project was carried out to establish the efficacy of such coal-derived products (oxyproducts) as trace element carriers for deciduous fruit. The use of oxyproducts was not recommended for deciduous fruit because of concentrated symptoms of phytotoxicity in the fruit.

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

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

"Electrical energy is the common factor that binds us in our quest for a better quality of life for all our peoples. By concentrating on the positives, on common development factors, we are building bridges for tomorrow. I believe that electricity could be a catalyst not only for illustrating the interdependence of all Southern African states, but also for stimulating a new development in our subcontinent."

Dr. John Maree, Chairman,
Eskom Electricity Council.

ESKOM