ENERGY EFFICIENCY IN THE SOUTH AFRICAN CLAY BRICK INDUSTRY

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Submitted in fulfilment of the degree of
Master of Science in Engineering

DECLARATION

I declare that this is my original work and has not been submitted in this or in a similar form for a degree at any University.

Signed by candidate

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SYNOPSIS

This report presents the results of an energy study carried out on the clay brick industry of South Africa.

The clay brick industry consumed approximately 38 PJ of energy in 1995, about 5% of manufacturing energy consumptions and had an energy intensity five times the average for the manufacturing sector. This combined with the uniform nature of the output and the fragmented nature of the industry made the clay brick industry an appropriate choice for the energy study.

The Clay brick industry

Although brickmaking technology has progressed to a high level of sophistication, the basic process remains the same. This is:

- Mining the clay from the ground.
- Crushing and refining the raw clay.
- Forming the clay into the required shape.
- Drying.
- Firing the brick.

The main differences between factories occur in the drying and firing processes. Bricks are either dried in the open air or in drying chambers or tunnels. Firing can also take place either in the open, in clamp kilns, or in more sophisticated kilns such as transverse arch or tunnel kilns. South African brick factories can be divided into two types; clamp kiln factories, mostly using open air drying, and non-clamp kiln factories, often recovering heat from the kiln to use for drying.

The types of energy used in these operations may differ from factory to factory, but is generally a combination of :

- Various types of coal e.g. duff coal, filter cake, coal fly ash, and nut coal.
- Diesel.

- Electricity.
- Heavy Fuel Oil.
- Gas.

The Methodology

Information on energy use in the industry was obtained by means of a postal and telephonic survey, followed by selected factory visits.

Names and contact information for factories were obtained from the Clay Brick Association and a questionnaire was sent out. When additional names were obtained, a questionnaire was filled out telephonically.

From the factories surveyed, it was necessary to select a number of factories for individual visits. The factories needed to represent:

- Different geographical regions
- Different sizes of factory in terms of production output
- Different production technologies.

Based on these criteria thirteen factories were selected, representing the regions of; the Western Cape. Eastern Cape. Kwa Zulu-Natal and Gauteng. The kiln types used by these factories were either clamp kilns, Hoffmann kilns, transverse arch kilns or tunnel kilns. For the purposes of this study, kiln types were divided into either clamp or non-clamp kilns.

In total the survey covered 42% of the factories in South Africa and 60% of total brick production.

The Results of the Surveys

Total brick production. based on the survey, is about 3.7 billion bricks per year. The factories visited indicated that they were operating at 70 to 80% of total capacity which indicates that the total industry capacity is about 4.6 to 5.2 billion bricks per year.

Brick production is equally split between clamp and non-clamp operations. The average specific energy consumption for clamp kilns is 3.97 MJ/kg and for non-clamps is 2.93 MJ/kg. Clamp kiln factories use almost 50% more energy for drying and firing than non-clamps do.

The cost of the energy consumed in the brick making process depends on factors such as the purchase price of a fuel, the mix of fuel types used, and the efficiency of energy use. The average cost of energy for a clamp kiln factory is R79 per thousand bricks and for non-clamp, R128 per thousand bricks.

On the strength of the survey information, therefore, clamp kilns have a higher energy consumption, but their average cost per 1000 bricks is lower than for non-clamp kilns. The reason for this is that clamp kilns use mainly coal, whereas non-clamp kilns also use more expensive higher grades of energy such as HFO and gas.

The Results of the Factory Visits

On the whole, the factory visits reflect the results the survey. The greatest area of inconsistency lies with the energy costs. The following is a comparison of the factory visits and the surveys is :

	SURVEY		VISITED	
	Clamp	Non-clamp	Clamp	Non-clamp
Number of factories	33	22	7	6
Energy consumption (MJ/kg)	3.97	2.93	4.27	2.45
Cost of energy (R/1000)	79	128	76	83

Comparison with other countries

In comparison with other countries, South Africa has the third highest specific energy consumption. It is not possible to make any firm conclusions about this due to the difficulties involved in comparing energy consumption in different countries. Some of these difficulties are due to differences in:

- Clay properties.

- Legislation.
- Climatic conditions.
- Firing temperatures.
- Brick standards.
- The level of mechanization.

It is evident that there is a technology gap between South Africa and the developed countries in brick manufacturing. Most of the production in these countries is from highly automated tunnel kilns whereas 60% of bricks in South Africa are produced in clamp kilns. There is little doubt that a move towards tunnel technology is inevitable for the South African clay brick industry. Such a move is, however, long term and the interim objective of the industry should be to improve energy efficiencies of existing technology.

The options facing the South African brick factory are thus;

- To carry on business as usual in the face of rising energy prices and increasingly stringent legislation,
- To invest capital in tunnel kiln technology, or
- To improve the energy efficiency of existing technology to optimum levels, using the savings to fund more efficient technology.

Energy Savings Potential

It is unrealistic to expect every factory to improve energy efficiency to the lowest specific energy consumption levels in South Africa. In order to estimate the potential for energy saving, and improved average figure has been selected between the current average and the best practise. If factories reduce energy consumption to this level, an overall reduction of energy requirements of 32% will be realised, saving the industry approximately R139 million per year.

If factories change technologies to more efficient methods, such as installing tunnel kilns at existing clamp kiln factories, there is an added potential for energy saving. A total of 43% of energy could be saved, a cost saving of R186 million per year.

Some barriers to these potential savings are:

- High capital costs.
- Lack of incentive to change.
- Demand for low grade bricks.
- Low energy prices.
- Lack of gas infrastructure.

The overwhelming barrier to a large scale change of technology is cost.

Energy Saving Opportunities

Various energy saving opportunities were identified during the course of the study. These savings are in the areas of:

- Electricity usage. For instance; tariff switching, power factor correction, load management, and load shedding.
- Supply, storage and handling of coal.
- Correct operation and maintenance of the compressed air supply.
- Insulation of ducts and pipes.
- Reduction of scrap.
- Production of perforated bricks.
- Additives to the clay.
- Optimising the moisture content of the clay.
- The monitoring and managing of energy use.
- Research into energy efficient kiln design.

Recommendations

Each brick manufacturer must:

- Motivate staff to save energy.
- Record specific energy consumption.

- Experiment with ideas for saving energy.
- Join the Clay Brick Association in order to liaise with other brick makers and solve common problems.

The clay brick industry needs to combine efforts in the area of energy efficiency. The Clay Brick Association can play a role in:

- Broadening its membership base.
- Collecting data on brick manufacturing.
- Supporting and encouraging research.
- Arranging demonstration projects on new technologies and good practise.
- Establishing ties with overseas brick organisations.
- Organising seminars and workshops.

The government can provide assistance by:

- Co-funding of a seminar on energy and brickmaking.
- Co-funding of demonstration schemes which could result in the more effective use of energy in brick-making.
- Joint research on more energy effective technologies.

Opportunities for demonstration projects include:

- A simple energy management program for clamp kiln factories.
- Use of alternative energy types.
- The production of highly perforated bricks.

Opportunities for joint research could include

- Fast firing methods.
- Additives to the body of a brick to reduce firing energy requirements.
- The development of perforated bricks.
- A locally designed energy efficient kiln.

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1. INTRODUCTION

Improved energy efficiency means a reduction in energy consumption without compromising quality or quantity of production. Sometimes energy efficiency results in improved product quality and greater production. The vehicle for achieving this is energy management which is an ongoing task requiring commitment throughout an organisation. The starting point for an energy management program is the energy audit. This is a detailed survey of the present use of energy as well as the identification of opportunities for saving energy.

There are a number of reasons for using energy more efficiently.

(i) The only certainty that exists about the world's reserves of fossil fuels is that they are finite. Reducing energy consumption will buy more time for the search for a sustainable replacement source of energy.

(ii) The production of energy causes pollution which is resulting in increasingly stringent environmental legislation and standards. Less energy used means less pollution.

(iii) The use of energy results in emissions which contribute to global warming. Energy efficiency has been recognised as one of the most important control measures for global warming.

(iv) By reducing energy consumption large energy cost savings can be made.

The manufacturing sector consumes 47% of South Africa's net energy[(1)]. In the manufacturing sector, the clay brick industry can be identified as having one of the highest energy consumptions per Rand of value added, or energy intensity. This, together with the relatively uniform output and fragmented nature of the industry, prompted an investigation into energy use in the industry.

This investigation took the form of a sectoral energy audit, drawing on information from statistics, the industry association, literature and surveys of individual factories.

The study was restricted to the geographical boundaries of South Africa and excluded independent and neighbouring states. Factory visits could only be carried out near the major centres due to constraints in travelling time and costs. Only energy consumed directly in the brick making process was accounted for and externals such as transport of the finished product and sales overheads were excluded.

The objectives of this study are:

- To provide an energy profile of the clay brick industry.
- To estimate the potential that exists for saving energy in the industry.
- To identify energy saving opportunities.
- To make recommendations to the key players in the sector.

The report is divided up into the following sections.

Literature Review

A review of the background reading and theory on which the study is based.

Description of the clay brick industry in South Africa.

Briefly describes the brick industry in South Africa in terms of major players, technology and types of energy used.

The methodology of the study

The details of the postal and telephonic surveys are discussed along with the selection of factories for individual visits. The extent of the coverage of the survey is assessed.

The results of the survey

This chapter presents the results of the postal and telephonic surveys. The results are discussed under the headings of:

- Number and type of factories.
- Production.
- Specific energy consumption.
- Energy costs.

- Regional analysis.
- Percentage of production costs.

The Results of the factory visits

In this section the data obtained from the individual site visits is examined. The types of energy used in the factories, the specific energy consumption of the individual factories, and the cost of energy to the factories is presented. Finally, the site visit data is compared with the survey data to asses the accuracy of the survey data.

Comparison with other countries

The specific energy consumption of the South African brick industry is compared to that of other countries. The technology, energy management practises and research programmes of selected countries is discussed. General trends in brickmaking in overseas countries are also discussed.

Energy savings potential

This chapter assesses the potential for energy saving in the South African brick industry. Savings by using existing technology as well as by updating technology are quantified.

Energy saving opportunities

The opportunities for saving energy as observed during the survey and site visits are presented and discussed. Where possible case studies are cited to illustrate the potential that exists.

Conclusions are then drawn from the study and recommendations are made regarding the more efficient use of energy in the clay brick industry.

2. LITERATURE REVIEW

A literature survey was undertaken to establish the extent of previous research, both locally and internationally, on the subject of energy management in the clay brick industry.

Specific information on the industry in South Africa such as employment figures, overall production, output, energy use etc, published statistics from the Central Statistical Services [2] and the South African Energy Database of the Institute for Energy Studies [1] were consulted. Further information came from articles and reports on previous studies of the industry.

Overseas information was obtained from government departments as well as from the outputs of energy efficiency schemes. The international heavy clay industry journal, Ziegelindustrie International, provided information on trends in international brick making.

2.1 The energy situation in South Africa.

The primary energy types consumed in South Africa are, coal, crude oil, natural gas, hydro, nuclear and renewable energies. Of these, coal has the highest consumption, 72% of the total as indicated in figure 1[3].

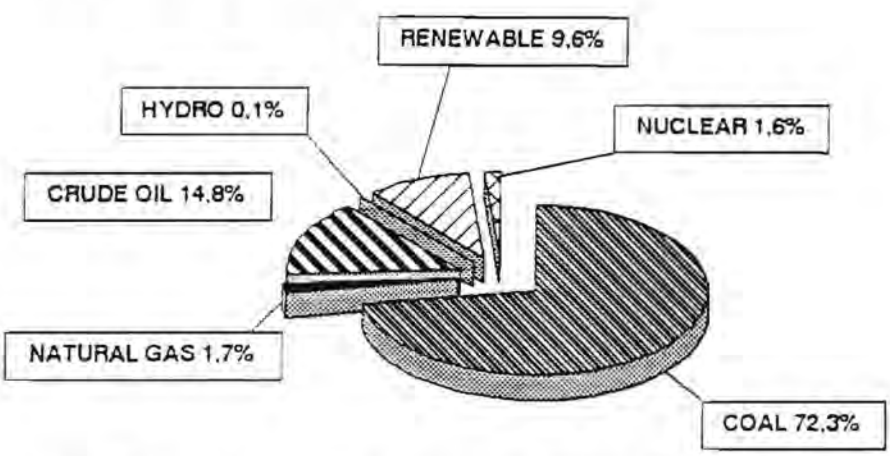

Figure 1. Total primary energy consumption in South Africa - 1993

Coal is either used as a primary energy form or converted to secondary energy types such as electricity, gas and liquid fuels. Ninety percent of electricity is generated from coal with the remainder being produced by nuclear and hydro operations[4]. Coal is also used to produce liquid fuel products and gas. It is therefore instructive to examine the consumption of total net energy, or final energy. This is done in figure 2[1].

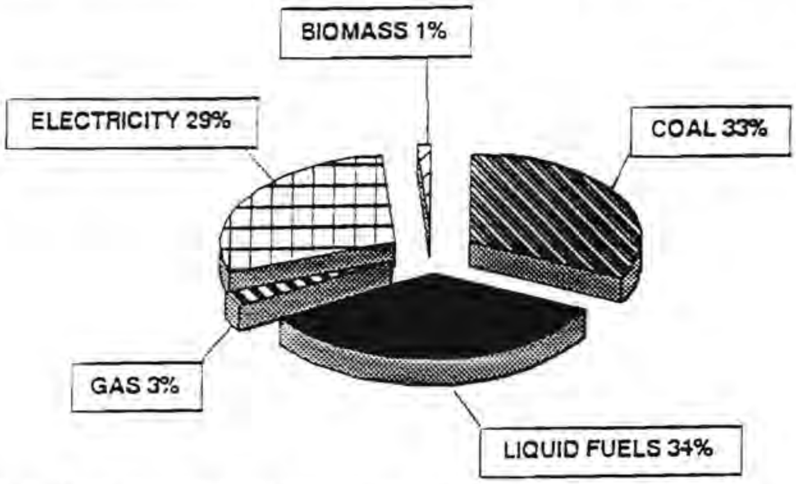

Figure 2. Total final energy consumption in South Africa - 1993

There are six main energy consuming sectors in South Africa. These are: commerce, industry, mining, transport, domestic and agriculture. The industrial sector, which includes the manufacturing sector, is the main energy consumer accounting for 47% of the total energy consumption. The situation is shown graphically in Figure 3[1].

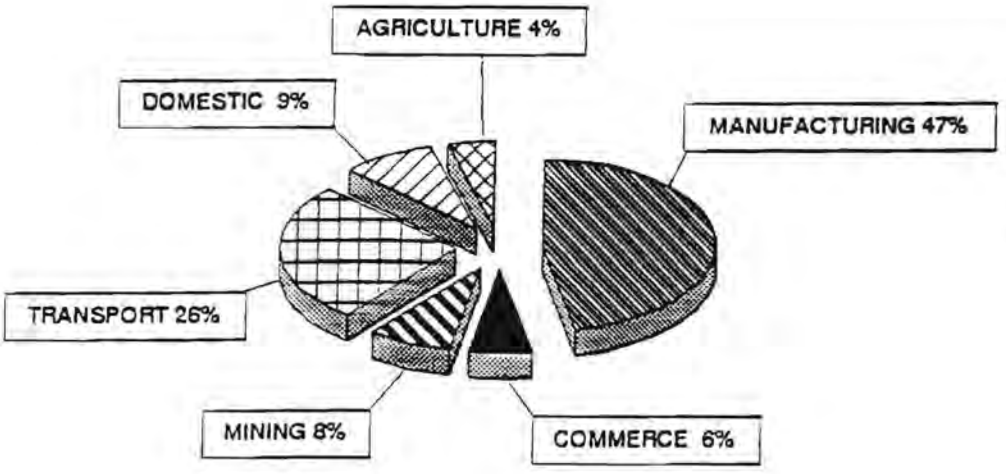

Figure 3. Net energy consumption in South Africa per sector - 1993

Any reduction in the energy consumption of the industrial sector therefore will impact significantly on the overall energy consumption of the country. It makes sense, therefore, to examine the industries with large energy consumptions with a view to optimising the efficient use of this energy. Table 1 shows the consumption of energy per fuel in the different industrial sectors[1].

The seven largest large energy consumers in industry namely; mining, ferrous metals, refineries, food, paper and paper products, basic chemicals, and other non-metallic minerals; together account for 90% of consumption in industry.

2.2 The position and relative importance of the brick industry in S.A.

2.2.1 Industrial classification

All economic activities can be classified in the "Standard Industrial Classification"(SIC) of the Central Statistical Services. In the latest classifications[5], the clay brick industry is classified under the heading "Other structural non-refractory clay products" (SIC 3423) which in turn falls under the group heading of "Other non-metallic mineral products" (SIC 342). The previous classification placed the clay brick industry in the same group as refractories, named simply "Structural clay products". Ngoasheng[6] calculates that the clay brick industry accounts for approximately 80% of the energy consumption of the structural clay group with refractories consuming 20%. Most of the data for this study was obtained under this old classification and so the energy consumption of refractories must be accounted for.

2.2.2 Energy consumption

Figures obtained from the South African Energy Database[1] show that the manufacturing sector consumed 836 PJ of energy. The "other non-metallic minerals" group consumed 67 PJ of this. The cement industry reported an energy consumption of 29 PJ for 1993[7] thus leaving 38 PJ as the energy consumed in the Structural clay subsector. If the clay brick industry accounts for 80% of this, the energy consumption of the clay brick industry is about 30 PJ. Since this figure is not directly measured and based on dated information the accuracy is not known.

Table 1. Energy consumption per industrial sector and fuel - 1993 (PJ)

SIC	MAJOR GROUPS	COAL	LIQUID FUELS	GAS	ELEC	BIO-MASS	TOTAL
21	Coal	0.00	2.71		8.67		11.38
23	Gold and uranium	2.49	1.18	0.42	80.52		84.61
24	Metal ore	6.22	4.15		23.44		33.81
25	Other		0.35	0.05	5.32		5.72
	Total mining	8.71	8.39	0.47	117.95	0	135.52
301-4	Food	35.55	8.47	0.61	17.30	15.83	77.58
305	Beverages	7.51	0.38	0.08	2.62		10.59
306	Tobacco	0.40	0.02		0.45		0.87
311-3	Textiles	6.07	0.68		4.17	1.12	12.04
314-5	Clothing	0.15	0.13		1.27		1.55
316	Leather	0.95			0.31		1.28
317	Footwear		0.01		0.41		0.42
321-2	Wood excl. furniture	2.55	0.56	0.58	3.50	4.57	11.76
323	Paper and products	47.91	0.10	0.31	13.74	1.28	83.34
325	Printing		0.11	0.02	0.27		0.40
332	Refineries	130.39	13.08	0.51	51.53		195.51
334	Basic chemicals	54.72	0.45	1.07	14.79		71.03
335	Other chemicals	2.77	1.11	0.64	10.98		15.50
337	Rubber	2.91	0.51	0.05	2.10		5.57
338	Plastics	0.34	0.04	0.79	2.51		3.68
341	Glass	0.16	1.98	1.56	3.03		6.73
342	Other non-metallic minerals	44.17	7.61	4.58	10.84		67.20
351	Ferrous metals	152.21	2.41	32.68	62.18		249.48
352	Non-ferrous metals	3.76	0.37	0.97	11.98		17.08
353-9	Fabricated metal	0.66	1.49	3.45	6.39		11.99
36	Electrical machinery	0.24	0.11	0.59	3.39		4.33
37	Electronic equipment	0.07	0.08	0.04	0.45		0.64
381	Motor vehicles	0.55	0.47	0.02	4.22		5.26
382-7	Other transport equipment	0.11	1.87	0.31	1.15		3.44
39	Furniture & other	0.05	0.04	0.14	0.61	0.11	0.95
	Total manufacturing	494.20	42.08	49.00	230.19	22.71	836.18
	Total industry	502.91	50.47	49.47	348.14	22.71	973.70

2.2.3 Energy intensity

The energy intensity of an industry is defined as the ratio of its energy consumption to the value added. Figure 4 compares the energy intensities of selected industries for 1993.

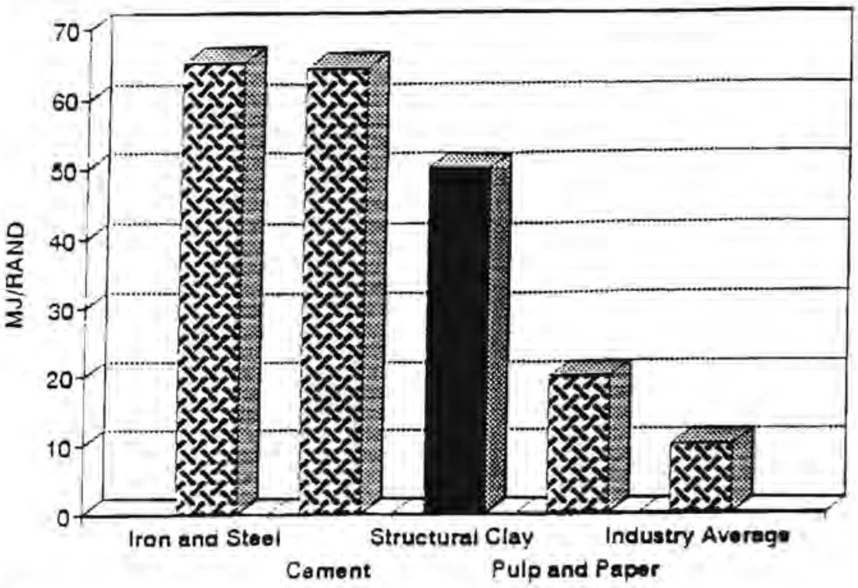

Figure 4. Energy intensities of major Industrial groups for 1993

Comparison of energy intensities highlights the industries for which energy costs form a significant part of production costs and that might have the most scope for improved energy efficiency. The structural clay sector, which has an energy intensity five times that of the industry average, clearly falls into this category.

2.3 Production

Competitiveness makes factories reluctant to divulge their production figures and there is no official figure for total production. A report in the Sunday Times [8] places production capacity at 4.2 billion bricks per anum and current production at 60 to 80 % of capacity, that is between 2.5 and 3.5 billion bricks per year. An article in Engineering News [9] confirms this, giving a figure of 3.2 billion bricks. These articles both quote the Clay Brick Association as a source.

The production trend for the past 15 years is shown in figure 5. The graph is based on indexed data obtained from South African Statistics [10] and the accuracy of the data is uncertain.

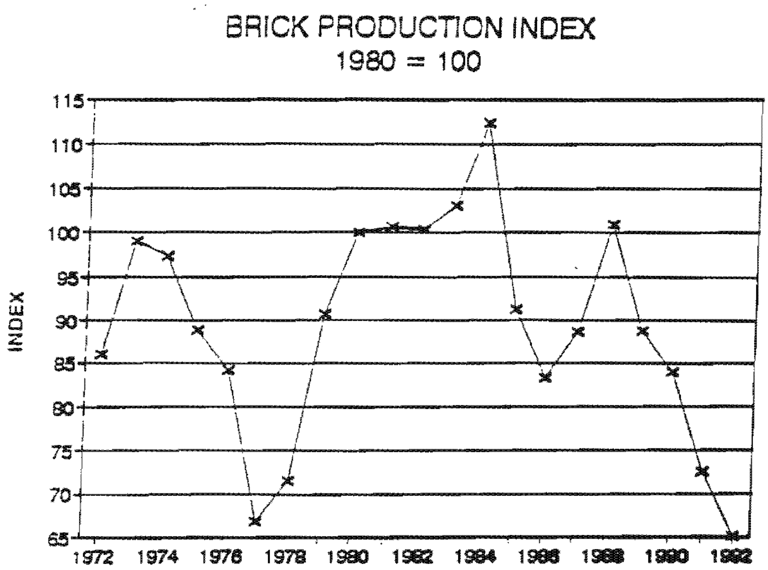

Figure 5 Graph of production trend over 10 years

The brick industry is dependent on the building industry which is in turn dependent on the state of the economy as a whole. The graph in figure 5 shows a boom period in the early 1980's followed by a sharp drop until 1988 where there was a brief resurgence. Since then there has been a gradual tapering off until 1992.

Ngoasheng [(6)] reports a production high of 6000 million bricks in 1983 compared to 1991 figures of 4000 million.

2.4 Number of factories.

The number of brick factories is bound to be determined by the demand for bricks at any given time. Ngoasheng [(6)] reports that in the building boom of 1980, 300 to 450 brick factories were operating and only 105 factories in 1991. The most recently figure quoted by the Clay Brick Association is 131 factories [(8)].

2.5 Clay characteristics

The mineralogical composition of the clays used in brickmaking can vary quite considerably even within one deposit. Varying concentrations of kaolin and quartz are the main constituents with mica, illite and other elements also occurring. The suitability of a clay for brickmaking does not depend on its mineralogical composition alone, however. For example, there are no established limits to the amount of free quartz in clay, although excessive free quartz may produce cracking due to the α to β expansion at about 580°C.

Investigations into the composition and behaviour of brickmaking clays tend to be quite general in nature. The tests done include a mineralogical composition by x-ray diffraction, a chemical analysis, and a particle size analysis. After these tests, sample briquettes were made up and fired to determine thermal expansion and ceramic properties. These tests are performed under ideal laboratory conditions.

2.6 Technology

South African brick factories can be separated into clamp kiln (intermittent) and non clamp kiln (continuous) factories. Clamp kilns are labour intensive operations and generally not as energy efficient as the non clamp kilns. Non clamp kilns require more capital expenditure initially for their construction but are more energy and labour efficient than clamp kilns. The main types of non clamp kilns used in South Africa are tunnel, transverse arch and Hoffmann kilns.

Some 80% of bricks produced are non face and semi face bricks and 80% of these are made in clamp kilns [(11)]. Since clamp kiln factories make only non face and semi face bricks, this means that 60% of all bricks are made in clamp kilns. The reason for this is the favourable climate for open air operations as well as the relatively low capital investment required for clamp kiln operations.

2.7 Labour

The labour intensity of the brick industry varies with the technology used. A non clamp kiln is generally more capital intensive than labour intensive, and a clamp kiln the other way around. Labour costs for clamp operations are approximately 40% of production costs and for non clamps as low as 20%[(6)].

According to the Census of Manufacturing 1988[(2)], 32 836 people were employed in the whole subsector, including refractories and tiles. Ngoasheng[(6)] quotes a figure of

30 000 employed in the brick industry in 1990 and goes on to say that this is twice the amount employed in the U.K brick industry. The reason for this is the level of sophistication of the factories.

A productivity report by the Clay Brick Association[12] shows a slight increase in productivity over a four year period from 1989 to 1993. This increase is attributed to the increasing mechanisation of plants. Ngoasheng[6] reports that one of the reasons for the low productivity is the lack of skills and literacy training offered in the industry.

2.8 Energy Consumption

The question of how much energy is required to manufacture a brick does not have an easy answer. de Villiers and Mearns [13] estimate the energy required for reactions in the brick at 0.2 MJ/kg and the energy required to heat and evaporate the water from the brick 0.54MJ/kg for a total of 0.75MJ/kg. The energy required to heat the brick to the temperature required for the reactions to take place is theoretically recoverable although in practise most of it goes to losses. Heimsoth [14] predicts the losses in a tunnel kiln can be broken down as follows:

- 25% wall losses.
- 30% exhaust losses.
- 30% cooling air (recoverable).
- 10% bricks and kiln cars leaving the kiln.
- 5% Reactions in brick.

Therefore only 5% of energy input actually goes to the reactions in the brick. Based on the estimate of 0.2MJ/kg for reactions, this means that total energy consumption is approximately 4MJ/kg.

The journal Bauverlag Weisbaden[15] provides the following typical energy consumptions:

- 3.5 - 4.2 MJ/kg for clamp kilns
- 1.3 - 2.2 MJ/kg for Hoffmann kilns
- 1.3 - 2.1 MJ/kg for transverse arch kilns

- 1.3 - 2.5 MJ/kg for tunnel kilns

In South Africa, energy consumption is slightly higher overall. Carey[16] gives the following figures:

- Tunnel kilns 3.51 MJ/kg
- Transverse arch kilns 2.94 MJ/kg
- Downdraught kilns 8.49 MJ/kg
- Clamp kilns 3.69 MJ/kg

In non clamp kilns, energy is recovered for drying while clamp kiln factories in South Africa generally dry their bricks in the open air.

2.9 Innovations

Although there is generally little deviation from the brickmaking process , a number of innovations have been tried. Briefly some of these are:

- Perforations.

  Not so much an innovation as standard practise in most tunnel kiln factories nowadays, although there is ongoing experimentation with bricks containing higher percentages of perforations. Perforations reduce direct energy consumption by reducing the effective volume of clay. This allows brick of larger dimensions to be manufactured, the so called "maxi" bricks in South Africa. These larger bricks reduce cement requirements in building as well as reducing building times. The total reduction in energy per m2 of wall is estimated to be 40%[17].
- Sewerage sludge.

  One factory in South Africa produces clay bricks using sewerage sludge as a body fuel, reducing conventional energy input by two thirds[18]. In addition to this the extrudability of the clay is improved and less water is required. An estimated 7 Ml of water is saved[19].
- Extrusion with hot water/steam.

  This has been tried with some success, reducing the water requirement as well as preheating the extruded brick.[20] There are problems, however, of the bricks cooling down before reaching the drier. Also the energy used to raise the steam needs to be taken into consideration.

These are only a few of the innovations the brick making process and need to be taken into consideration when examining energy consumption. Many of them depend on local conditions and are therefore only applicable to a small percentage of the industry.

2.10 The Clay Brick Industry in Other Countries

The energy crisis of the 1970's prompted many countries to take swift action in the conservation of energy, including government sponsored industrial energy efficiency programs. These programs have evolved to meet changing needs since then but are mostly still in place in one form or another.

The clay brick industry of selected countries is examined below.

2.10.1 Australia

Technology:

Most of the kilns in use are intermittent type kilns although the bulk of the total production comes from tunnel kilns. A survey carried out in 1987[21] showed that 72% of kilns were intermittent, 21% tunnel and 9% Hoffmann. Tunnel kilns accounted for 79% of the total production. The same survey attributed 88% of production to kilns which were less than 20 years old, indicating that the technology in use was relatively modern.

The tunnel kiln factories in Australia operate in the same way as in South Africa. Bricks are extruded and then packed onto kiln cars either manually or by automatic loading devices. The bricks then proceed through the dryer which is fed from the cooling zone of the kiln. In some cases auxiliary heat is provided to the dryer although a study into the industry[21] suggested that this was being done unnecessarily. Carbonaceous matter is added to the clay prior to extrusion to assist in the firing.

Most tunnel kilns fire with natural gas although there are kilns using pulverised coal and wood planings. The factories using solid fuels claimed fewer firing problems and a better product since switching fuels, and also had a lower specific energy consumption. The moisture content of the solid fuels is critical and the burner and fuel handling systems are more complex and expensive. The main disadvantage of solid fuels is seen to be the particulate emissions from the combustion process and the report recommends more work is done on improving the efficiencies of natural gas firing.

The average specific energy consumption for tunnel kilns was found to be between 1.5 and 5.5 MJ/kg fired product.

The type of intermittent kiln used in Australia is the downdraught type. The method of operation for these kilns is shown in figure 6 and a typical firing cycle is shown if figure 7.

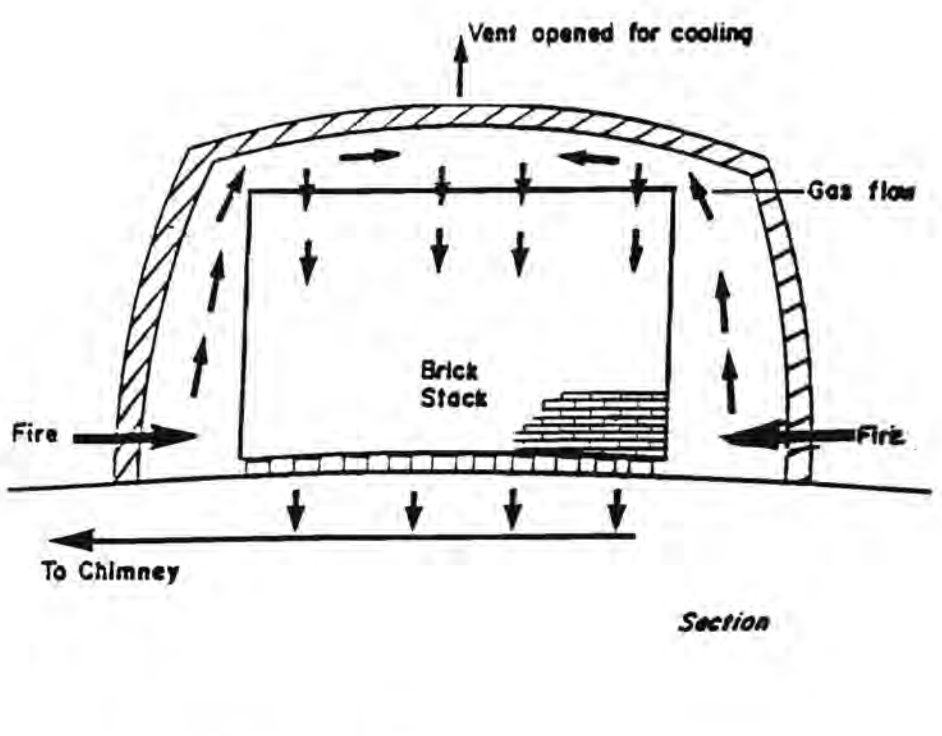

Figure 6. The Downdraught Kiln[21]

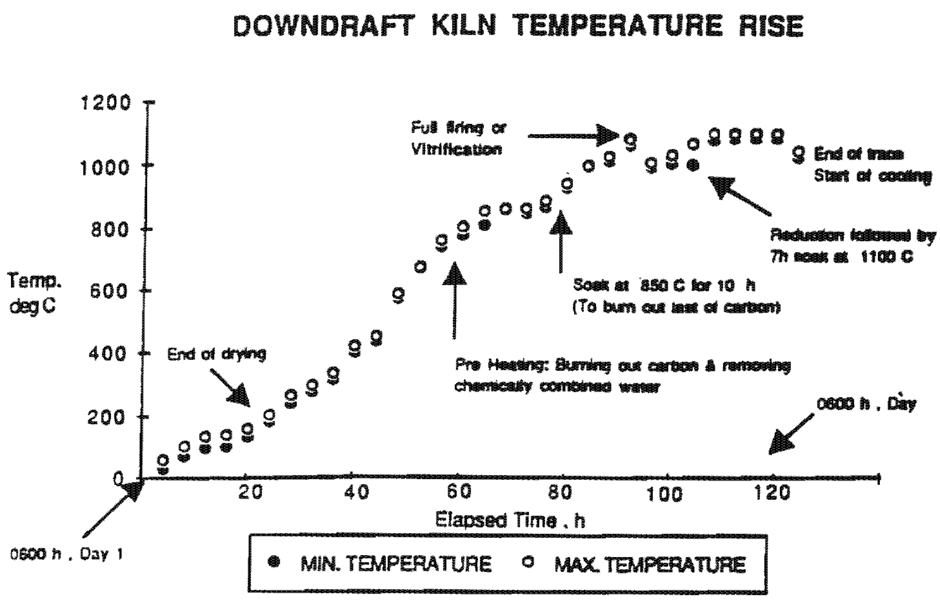

Figure 7. Typical firing cycle for Downdraught Kiln[21]

The firing is more controlled than in clamp kilns and heat is available from the cooling cycle to be used for drying. Downdraught kilns fire with a variety of fuels, from natural gas to coal and the largest energy loss identified by the report was incomplete combustion of solid fuel fired kilns. The use of automatic stokers was recommended[21].

The average specific energy consumption for intermittent kilns in Australia was found to be 21 GJ/thousand bricks, approximately 6 MJ/kg of fired product[21].

Energy Management:

The energy management situation in Australia is similar to South Africa, namely that the average brick factory manager is aware of the potential for saving energy but is not sufficiently motivated to actively pursue it. Often it is the initial capital cost of changes that deters a manager from implementing energy saving opportunities.

The main recommendations of a study into energy use in the Australian brick industry[21], were to increase awareness and provided information to brick factories to start monitoring energy consumption and to tie up energy consumption with production.

Research:

Australia has brick manufacturers associations in each of the states as well as a national body, the Brick Development Research Institute. The main functions of the brick industry associations are:

- To represent members before outside bodies.
- To provide a forum for discussion on the manufacture of bricks.
- To promote the use of bricks.

The Brick Development Research Institute focuses its energy on the following activities:

- Research activities to extend and improve the uses of bricks.
- Providing a testing facility for bricks.
- Promoting the use of bricks through courses at colleges and Universities.

A study into the brick industry was carried out in 1987 by the Energy Authority of New South Wales as part of the National Energy Research Development and Demonstration program run by the Department of Resources and Energy. Part of the output of the project was an information booklet aimed at increasing energy awareness in the brick industry[22].

2.10.2 Canada

Technology:

Canadian factories are described as "highly automated operations with computerized controls" with an average energy consumption of 3.6 MJ/kg fired product[23]. Although this seems high in comparison with South African non-clamp kilns, it must be remembered that Canada's climate is very different from South Africa. Factors such as space heating requirements and higher surface losses must be taken into account.

The Canadian brick industry consumes 3 PJ of energy, only 0.15% of the national total. This energy consumption is broken down into the following fuel types: 86% natural gas, 9% electricity, and 5% light fuel oil. This split in fuel types tends to support the comment on high technology kilns.

Energy Management and Research:

Although no specific information on energy management schemes in the Canadian brick industry could be found, the highly organised nature of the energy industry in Canada suggests that energy awareness would be high. The Canadian Industry Program for Energy Conservation (CIPEC) has a number of task forces in different industrial sectors with the specific goal of monitoring energy consumption within that sector and suggesting ways of reducing that consumption. The brick industry falls under the Industrial minerals industry task force.

2.10.3 India

Technology:

The majority of kilns in operation in India are "Bulls trench kilns", annular kilns mainly using coal as a fuel. Figure 8 shows a typical plan view of a Bulls trench kiln.

It is not clear how the Bull's trench kiln operates but it would seem to follow a similar method to the Hoffmann kiln. Bricks are placed in the kiln around which the fire travels. A "roof" placed over the bricks is covered in sand to act as an insulating layer. A movable stack advances around the trench, thereby advancing the fire. The rate of advancing the fire is critical to the final quality of the bricks and is optimally 5 to 6 m per 24 hours. Once the fired bricks have cooled, they are removed and sorted.

The main disadvantages of the kiln are seen to be:

- Poor air flow resulting in poor combustion of fuel.
- Inadequate insulation.
- Incorrect firing practises resulting in poor quality bricks.

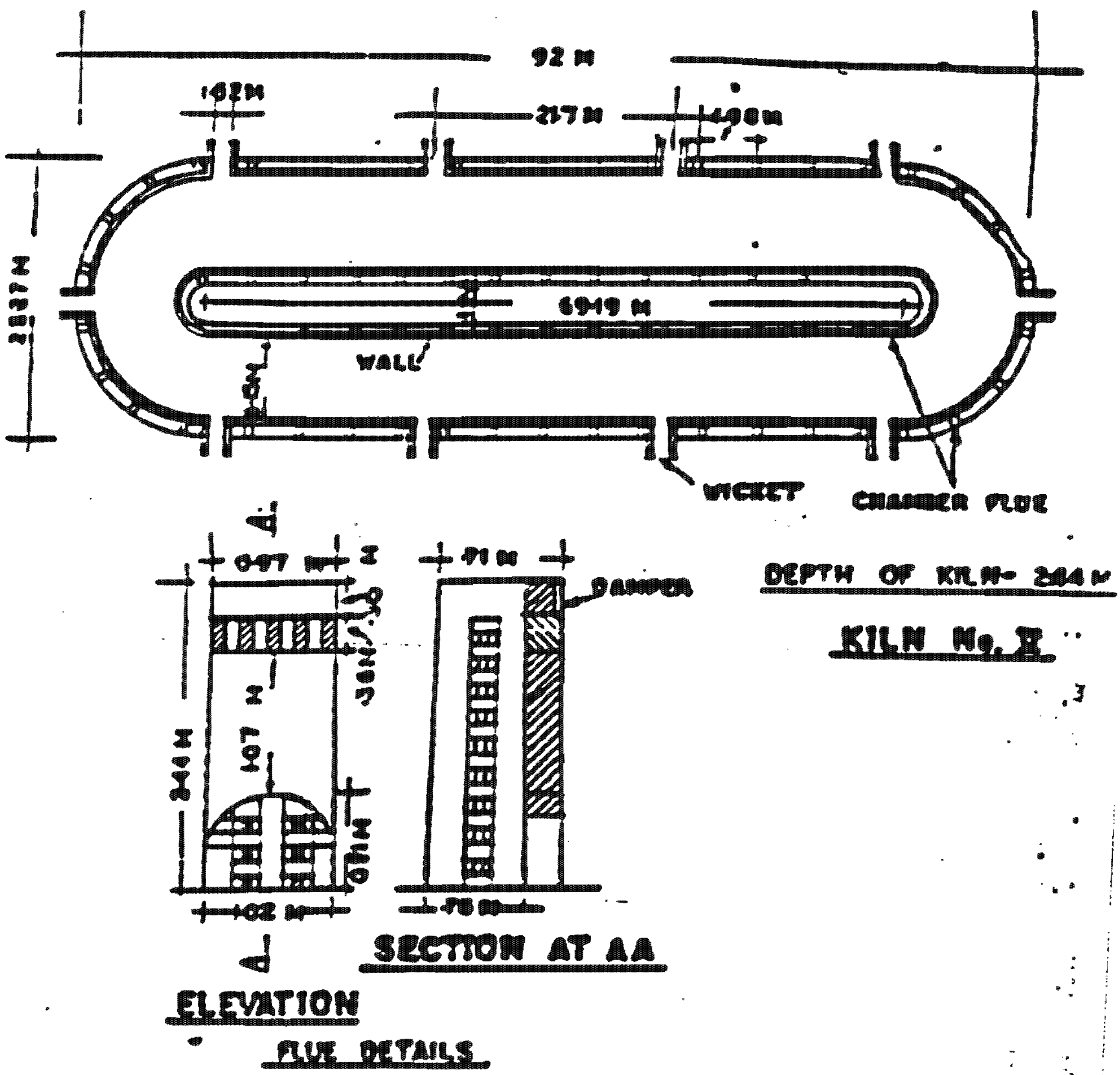

Figure 8. Plan view of a Bull's Trench Kiln

These kilns are labour intensive and are regarded as primitive and wasteful by energy researchers in India. Although their specific energy consumption of 3 MJ/kg of fired product[24] compares favourably to the South African clamp kiln figure, there is some question as to the quality of product produced in the Bull's kilns.

A small percentage of bricks are produced in automated tunnel kilns in India. The actual figure is not known but is thought to form an insignificant part of the industry.

Energy Management and Research:

According to an article[25] there is little awareness of energy efficiency in the Indian brick industry. The reason for this lack of awareness is the large demand for bricks at present due to a housing shortage, and therefore no incentive to reduce energy costs. The report goes on to identify a number of measures to improve efficiency:

- A change of technology.
- Better control of the firing process through monitoring flue gases.
- Repairing leaks and improving the insulation of the kiln.
- Improving quality control.
- Reducing the moisture content of unfired bricks through more effective drying.
- The use of renewable energy sources.

It was also stressed that although updating technology would bring about savings through improved efficiency, there was much that could be done to improve the way in which energy was being used in the existing situation[25].

2.10.4 United Kingdom

Technology:

The clay brick industry in the U.K. is divided into two, Fletton brick production and non-Fletton brick production. Fletton bricks are made from a type of clay high in carbonaceous content and consequently have a lower energy requirement than the non-Fletton bricks.

Fletton bricks account for approximately 25% of total brick production in the U.K. and use mainly coal as firing fuel[26]. Because of the nature of the clay, it is not useful to compare Fletton brick production with the South African industry and so only non-Fletton bricks are dealt with here.

Ninety percent of non-Fletton bricks are produced in continuous kilns (hoffmann, transverse arch, tunnel) with the remainder being produced in intermittent kilns such as clamps, downdraught or shuttle kilns[26]. The continuous kilns have the same method of operation as the South African kilns, although the U.K. has more high-Tech tunnel kilns. The average specific energy consumption for continuous kilns is 2.42 MJ/kg[26].

The intermittent kilns in use in the U.K. are mainly large shuttle type kilns. These operate by moving over a stack of bricks and taking them through the firing process while another stack of unfired bricks is packed next to the kiln. Once the firing cycle is finished, the kiln moves over the unfired bricks, leaving the fired stack to be unpacked and replaced with unfired bricks again. During the cooling cycle, the hot air is drawn from the kiln and ducted into a drying chamber. These kilns are not regarded as being as efficient as tunnel kilns since the whole structure needs to be heated and cooled for each cycle. The shuttle kilns are able to exercise precise control however and are used for producing "specials". The average specific energy consumption for intermittent kilns is 4.40 MJ/kg.[26]

Seventy five percent of the total energy input for the industry is provided by natural gas, with 12% by liquified petroleum gas (LPG) and only 2% each for solid fuel and oil[26].

Energy Management:

The U.K. began with energy efficiency drives in the 1970's to create awareness in opportunities for energy savings. Since then ongoing energy audit schemes have continued with this objective. The Best Practise Programme run by the Energy Technology Support Unit (ETSU) has had a number of applicants from the brick industry, indicating that there is an awareness of the benefits of energy saving opportunities.

Research:

Efforts started in the 1970's with the energy crisis, and the Department of Industry produced a booklet prepared by the British Ceramic Research Association as part of an Industrial Energy Thrift Scheme[27]. This was followed by an energy audit report on "The Building Brick Industry" in the Energy Audit Series prepared by ETSU for the Departments of Industry and of Energy[28].

Since then, ETSU have continued research by operating various schemes, one of which, the Best Practise Scheme produces Consumption guides on a regular basis. The best practise scheme also identifies and publishes information on best practises. In the brick industry, some of these are:

- Reduction in firing energy in brickmaking using a high carbon content shale clay (1983).
- Heat recovery from a Scotch kiln (1981)
- Automatic control in a refractory tunnel kiln (1981)
- Automatic control of firing in a brickmaking kiln. (1983)
- Automatic control of clay preparation at a brick plant (1985)
- Development of a highly perforated building brick. (1986)
- Improved heat distribution in tunnel kiln. (1988)
- T-T-T diagrams for brick and tile clays. (1988)
- Optimisation of firing schedule using T-T-T
- Microwave assisted firing (1994)
- Airless drying of bricks (1994)

This information is made available to all brick factories in order to promote energy efficiency.

2.10.5 Europe

In 1985, a report on the brick industry in member countries of the EC was published[29]. This report was part of a series looking at various industrial sectors in the EC. The report discussed the structure of the industry, market issues, but mainly energy use and improving energy efficiency.

Information was obtained from brick associations and research centres in the countries concerned.

Topics covered were:

- Size and structure of the industry.
- National energy consumptions and costs.
- Market aspects and competition.
- Energy used and relative usage of fuels.
- Ways of improving energy efficiency.
- Energy monitoring.

The conclusions drawn from the report are:

- Production had declined over the period 20 years prior to the report.
- As a result of the decline, small factories were closing or merging to form larger companies. This means that in some cases, a small proportion of companies produce a large proportion of all bricks manufactured.
- The Specific Energy Consumption (SEC) in the brick industry is lower than other industries like steel, cement and plastics.
- Competition to bricks comes from alternative building materials such as precast masonry products and concrete blocks and bricks.
- The Specific Energy Consumption for each country is:

-Belgium :	2.93
-Denmark :	2.60
-Eire :	4.0
-France :	2.62
-Germany :	2.79
-Greece :	2.61
-Italy :	3.84

-Netherlands : 3.22

-U.K : 2.93 (non-fletton)

Some ways of improving energy efficiency were given as:

- Housekeeping measures such as repairing insulation, stopping leaks etc; 5% savings.
- Low cost measures such as additional insulation, improved burners and better instrumentation; 10% savings.
- High expenditure measures such as new plant; 50% savings.

2.11 General Trends in Brickmaking Overseas

The international brick and tile journal Ziegelindustrie International carries articles profiling individual factories in the major industrialised countries. These show a level of technology seen in only two or three South African factories. Energy efficiency is a major consideration in overseas factories and there has been considerable development in that sphere.

Recent international trends in brickmaking that affect energy use include:

- Greater automation therefore reducing scrap requirements.
- The use of lighter and more efficient kiln insulation materials thereby minimising heat loss and allowing a quicker start-up period.
- The use of lighter and more efficient kiln car materials thereby reducing firing requirements and minimising kiln car exit losses.
- Improved air and heat flow in kilns thereby ensuring that each brick receives the same treatment.
- One-high stacking of bricks resulting in firing times of less than 24 hours.
- The use of additives to the clay to improve firing characteristics.
- Production of perforated bricks.

3. DESCRIPTION OF THE CLAY BRICK INDUSTRY

3.1 Key players

We can define the key players of an industry as any person or organisation who has a material interest in that industry. As with any industry, the brick industry supports many "sub industries" by creating a demand for supplies, machinery and services. The industry itself is in turn dependent on customers for turnover.

The key players in the clay brick industry are:

- **The manufacturers**. Made up of the individual factories and the large groups of factories.
- **The Clay Brick Association (CBA)**. The CBA is the industry association for the brick industry. Its chief function is to provide a forum for discussion of mutual problems faced by members. The maintaining of quality standards in brick manufacture is of primary importance.
- **Researchers**. The CSIR, Pretoria Technikon and University of Cape Town amongst others perform analyses on clay to determine mineralogical composition and firing characteristics.
    - Soilcon is a private company that tests the physical properties of the finished product in accordance with SABS standards.
    - Research into the actual brickmaking process does not take place formally in South Africa although a few brick makers experiment on their own. Currently Eskom are involved in examining microwave assisted drying and firing.
- **Energy suppliers**. The major suppliers of coal, electricity, gas and liquid fuels also have a stake in the industry. Most of these suppliers have liaison personnel to advise clients on the use of their energy.
- **Equipment suppliers**. Most of the equipment used is imported. Local companies act as agents and offer technical backup and advice.
- **Customers**. Merchants and large building companies are the main customers of brick factories with private individuals taking small quantities. Since transport adds significantly to the cost of the bricks, a customer will usually buy from a

nearby factory.

3.2 The brickmaking process

Although brickmaking technology has progressed to a high level of sophistication, the basic process remains the same. This is to say; mining the clay from the ground, crushing and refining the raw clay into a usable consistency, forming the clay into the required shape, drying out the bricks, and firing the brick. The energy carriers required for each operation may differ from factory to factory, particularly in the drying and firing operations. Figure 9 outlines the brick making process and the main energy carriers used in each operation.

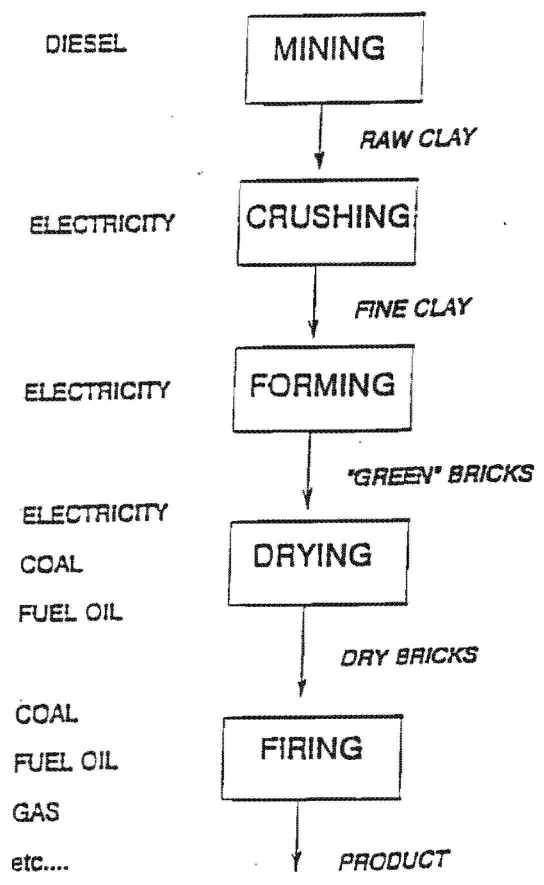

Figure 9. The brickmaking process

Each operation is described in more detail below.

3.2.1 The mining operation

A brick factory is usually situated on or near clay deposits to minimise transportation and the associated costs. The clay is open cast mined by means of bulldozers and front end loaders and typically takes place during the dry months during which time enough clay is stockpiled for the years' production.

Often clays with different characteristics are found in the same area and these are then blended in different proportions to produce bricks with different effects and properties. It is particularly advantageous for clay to have a high carbonaceous content since this acts as and "internal fuel" and reduces the firing energy requirements.

Many factories retain sub contractors to mine the clay for them. This eliminates the capital expense of mining equipment which is typically used for only short periods at a time. The subcontractor will service a number of brick factories in the same area, mining enough clay for a number of months at each factory in turn. In this way the cost of the capital equipment is effectively spread between the factories.

3.2.2 The crushing operation

Before being formed into bricks, the clay needs to be refined to a uniform consistency with a particle size of approximately 2 mm. The process varies from plant to plant and usually involves a combination of the following machinery.

The Lump Breaker or Disintegrator - This is the primary crusher used to break up the large lumps. It consists of two toothed rollers rotating at different speeds. The large lumps are then broken down by a combination of a crushing and grinding action.

The Pan crusher - The pan crusher has two large, heavy wheels which rotate on a perforated pan. The clay is introduced into the pan and the wheels force the clay through the perforations thereby ensuring a certain maximum particle size.

Screens - Vibrating screens are used to grade the particle size during the crushing operation. The clay is fed onto screens of a certain mesh size and that which does not fall through is either returned to the crushers or discarded.

High speed refining rollers - These are usually used as the final crushing operation. Two large, smooth rollers rotate at different speeds and are set approximately two millimetres apart. This ensures a maximum particle size of two millimetres once the clay has passed through.

3.2.3 The forming operation

The clay can be formed into the shape of bricks in a number of ways, namely: hand forming, dry pressing, and extrusion.

Due to the labour intensity and low output of hand forming bricks, this is not practised on a large scale anywhere in the world. Rather, machinery has been developed to give bricks a hand formed finish to supply the demand in mainly the European countries for this type of finish. There are no such operations in South Africa.

Extrusion and dry pressing are the two main methods practised in this country.

Extrusion:

Extrusion is the most popular method of forming bricks due to the high throughput that can be maintained and the flexibility of being able to extrude different shapes by changing the die. It is also possible to extrude bricks with perforations which are particularly desirable from an energy efficiency point of view.

A screw feeder mixes and feeds the clay into the vacuum chamber of the extruder. The vacuum chamber de-aerates the clay and the clay is extruded in a column, called a "slug", which is then wire-cut into bricks. The whole process is continuous and once the extruder is properly set up, the entire days' production can be extruded in a matter of a few hours.

Water content of the clay is critical to extrusion. The more water, the softer the clay and easier to extrude. However, the softer the brick the more likely it is to be damaged during handling. Also to be considered is that the bricks need to be dried to a moisture content of less than 6% before firing. Therefore the higher the moisture content, the more energy is required to dry the brick. Generally then bricks are extruded at as low a moisture content as possible, normally between 15 and 20%.

Dry pressing:

Dry pressing produces bricks of a high quality but is slower than extrusion. The clay is fed into a press and then mechanically forced into a cavity. The brick is then ejected from the cavity and finished off with a final pressing operation. No perforations are possible with dry pressing, but indentations, or "frogs", are pressed into the face of the bricks to reduce clay volume.

The moisture content required by dry pressing is typically 10% and is normally significantly lower than for extrusion. In some cases, the bricks are packed directly into the kiln using the preheating period to achieve the required dryness.

3.2.4 The drying process

Prior to firing, the bricks need to be dried to less than 6% moisture otherwise the pressure of the escaping steam will burst the brick. This drying is performed in one of the following ways:

Open Air - Bricks are packed in the open air, making sure there is a good air flow through the pack, and then left to dry. The drying time depends on the weather conditions and takes from 7 days to a number of weeks. This method is completely at the mercy of the weather conditions, rain in particular has been known to wipe out entire productions, reducing the packs of bricks to mud.

Hot Floor - Bricks are packed in a chamber in which the floor is heated. In some cases the dryer is situated above the kiln so that the floor of the dryer is the roof of the kiln. This is an inefficient drying method and is not often used nowadays.

Chamber Drying - The bricks are packed in a chamber into which hot air is blown and circulated. The hot air can be supplied from a separate furnace but is usually recovered from the cooling section of the kiln, if possible.

Tunnel Drying - Factories operating tunnel kilns often have adjacent tunnel dryers which utilise recovered heat from the kiln. The bricks are packed on kiln cars and travel through the tunnel through which hot air is circulated.

3.2.5 The firing process

The firing process involves raising the temperature of the bricks up to approximately 1000°C in order to vitrify the clay. This involves a large amount of energy, most of which can theoretically be recovered from the bricks by cooling them down. The effectiveness with which this can be done depends on the type of kiln. The various types of kiln are:

The Clamp Kiln:

In simple terms a clamp kiln consists of a stack of bricks, interspersed with coal, and covered with an outer layer of fired bricks for insulation. The clamp is then lit and allowed to burn thereby effecting the firing of the bricks. The size of a clamp kiln varies depending on the factory and can contain up to a million bricks. Clamp kilns take up to four weeks to burn out completely.

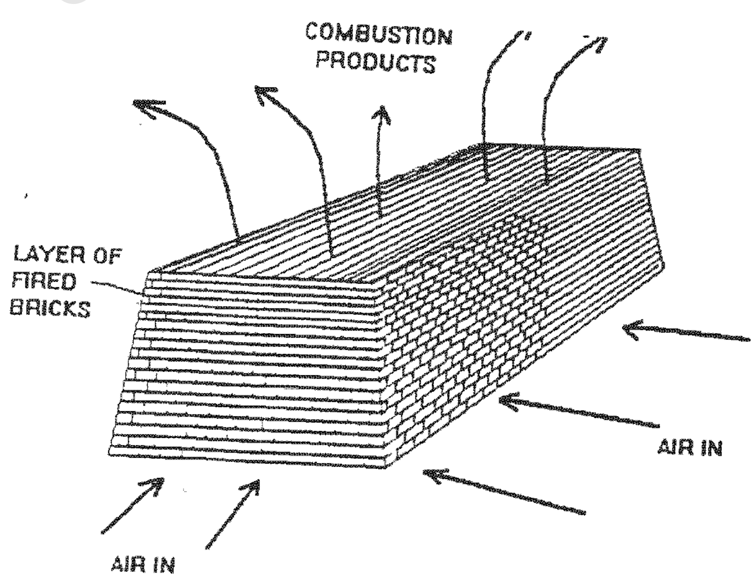

Figure 10. The Clamp Kiln

A clamp kiln is dependent on the elements. wind can cause overfiring problems and rain can cause underfirng. Consequently these kilns have a high scrap and, since the bricks have to be hand sorted, are labour intensive. In spite of this, these kilns are the most common type because of their low capital cost.

The Downdraught Kiln:

This kiln works by drawing air down through the stack of bricks and then out through the flue. The fire is built behind retaining walls around the stack of bricks and is effectively drawn through the bricks. This type of kiln is not used extensively in South Africa.

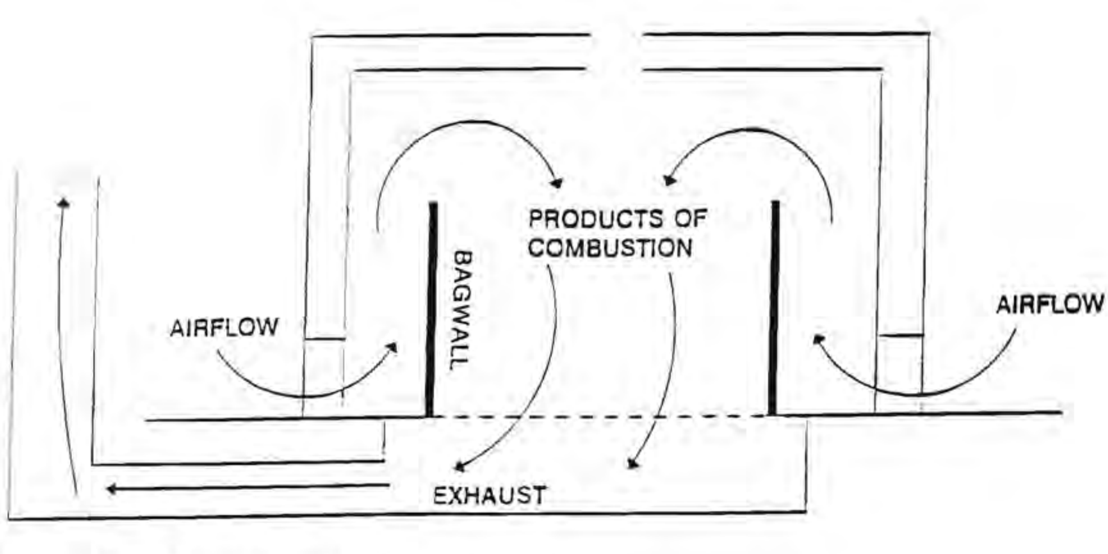

Figure 11. Downdraught Kiln

The Annular Kiln:

Also called "Hoffmann" kilns or longitudinal arch kilns. This is a kiln in which the fire burns continuously and is advanced through the kiln. Unfired bricks are packed in front of the fire and fired bricks are unpacked behind. A plan view of the hoffmann kiln is shown in figure 12.

Air is drawn across the fired bricks to cool the bricks and preheat the air, then into the firing zone. The combustion products are then either exhausted out of the flue immediately, or drawn across the unfired bricks to preheat them before being exhausted.

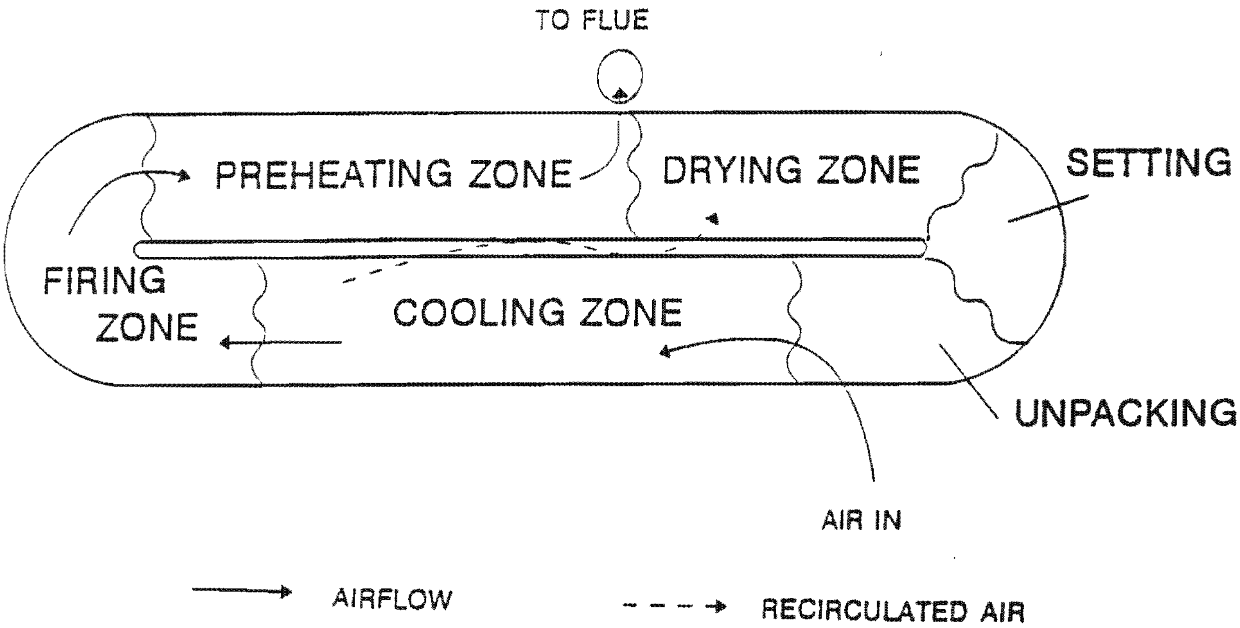

Figure 12. A plan view of a hoffmann kiln showing the method of operation

The Transverse arch kiln:

The transverse arch kiln is similar in operation to the annular kiln with the fire "chasing" the packing. The main difference is that the transverse arch kiln consists of separate "transverse" chambers connected by "fire holes" in the walls. The fire then moves from chamber to chamber with the fired bricks being unpacked behind the fire and the unfired bricks being packed in front of the fire. A sketch of a transverse arch kiln is shown in figure 13.

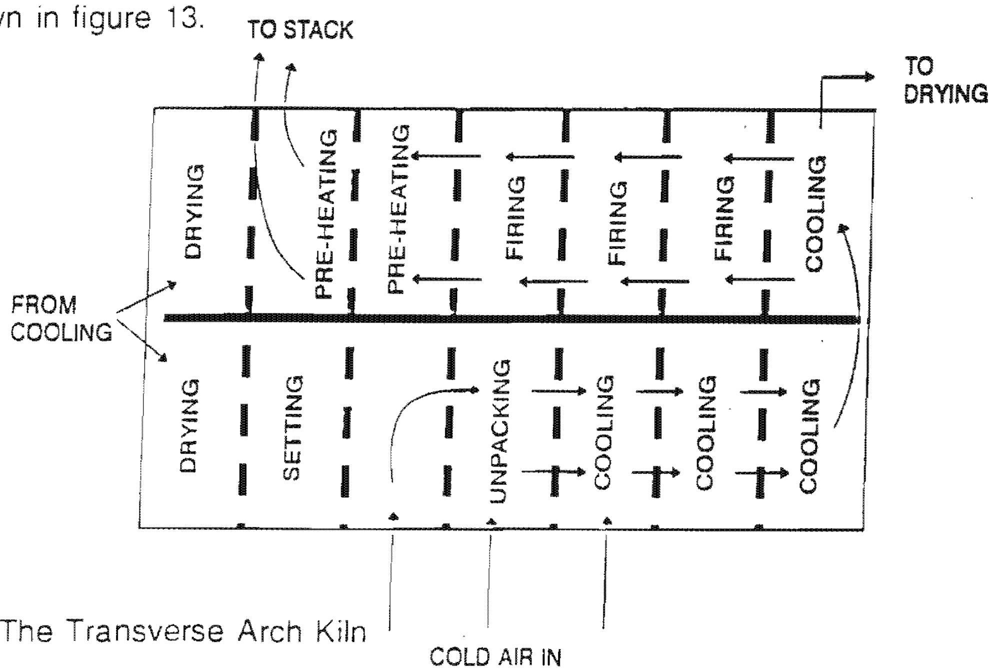

Figure 13. The Transverse Arch Kiln

The Tunnel Kiln:

This is the most sophisticated type of kiln and is used almost exclusively in the major developed countries. It has superior energy efficiency and produces top quality bricks. The kiln operates by creating a stable temperature profile along the length of the kiln by controlling the air flow using circulating fans.. The bricks pass through the kiln on kiln cars and thereby pass through the pre-heat, firing and cooling zones.

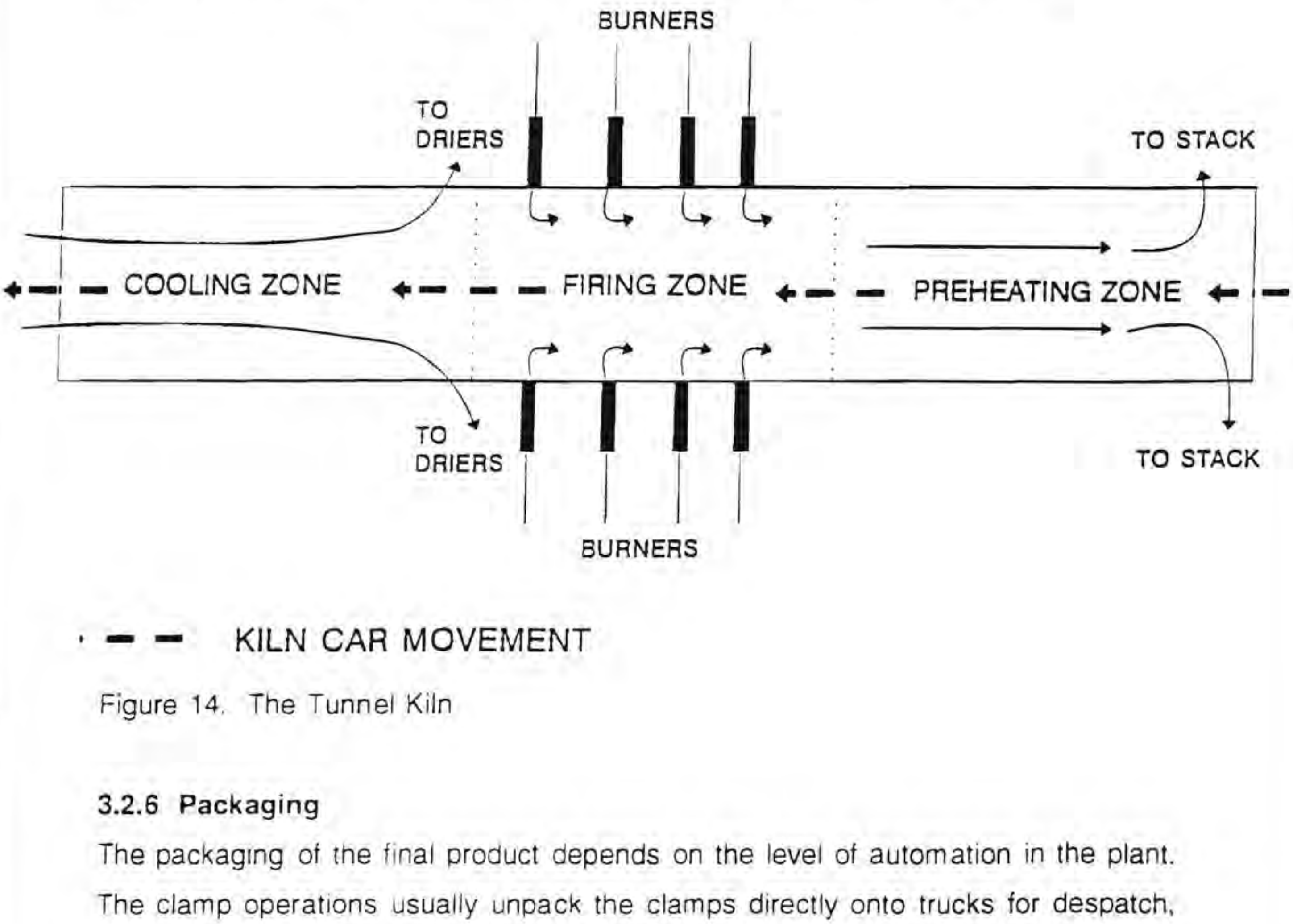

Figure 14. The Tunnel Kiln

3.2.6 Packaging

The packaging of the final product depends on the level of automation in the plant. The clamp operations usually unpack the clamps directly onto trucks for despatch, sorting as they go.

The more sophisticated factories either have automatic strapping machines or shrinkwrapping machines which make up packs of bricks that can be easily transported and used.

3.3 Types of energy used in the brick industry

The following fuels are used in the brick industry:

3.3.1 Coal

Various types of coal are used and these shall be dealt with separately.

Duff coal:

Mining methods result in 'small' coal (less than 6 mm) being produced. It is not economically viable to use coal in this form in combustion devices due to its lower calorific value. For the local market a limited quantity of these 'smalls' can be blended in with the larger grades to produce 'mixed smalls' and the remainder is termed 'Duff' coal.

The brick industry is one of the few users of this coal. The coal is used mainly as an additive to the clay prior to forming, to add to the body and provide 'internal fuel' during the firing process. In some cases Duff coal is also used as the primary firing fuel, mostly for Transverse arch and Hoffmann kilns.

Filter Cake:

For the export market it is economically feasible to wash the smalls and recover the coal larger than 0.5 mm. Below this size the calorific value is too low (15 MJ/kg) and these particles are filtered out as filter cake. This is used in brickmaking, but only as an additive to the clay prior to forming.

Coal Fly Ash:

This can also be used as an additive to the clay. Fly ash is the fine uncombusted coal which is precipitated out of the flue gas of coal fired boilers. A major source of fly ash are the pulverised coal boilers of the power stations. The calorific value of the fly ash varies according to the efficiency of the boiler.

Nut Coal:

Nut coal (large and small) is used in brick factories primarily for firing clamp kilns and fuelling dryers. This tends to be grade A coal with a calorific value of, depending on the mine from which it comes, around 28 MJ/kg.

3.3.2 Diesel

This is mostly used for transport and mining in the factory. Costs prohibit the use of diesel for firing a kiln or dryer.

3.3.3 Electricity

Brick factories either buy power directly from Eskom or from the local municipality. Sometimes various tariff options are offered. Most tariff structures include incentives for using electricity in times of low demand (e.g. night time, weekends, holidays). Thus savings are available to those users with flexible requirements.

Users are generally penalised for low electrical power factor. Power factor correction equipment can be installed to bring the overall cost of the electricity down.

3.3.4 HFO

Heavy Furnace Oil is sometimes used in brickmaking, especially in areas where gas is not available and coal costs are high, e.g. the Cape. It is inexpensive relative to other hydrocarbon fuels but has a high sulphur content and due to its high viscosity, it needs to be heated to approx 45°C to be pumped and heated to 100°C to be atomised.

3.3.5 Gas

Gas is only an option in the Gauteng area, serviced by Sasol's Gaskor. Generally only factories equipped with sophisticated tunnel kilns use gas. Gas burns cleaner than oil, is more convenient to use, and easier to control.

4. THE METHODOLOGY OF THE STUDY

Information on energy use in the industry was obtained by means of a postal and telephonic survey, followed by selected factory visits.

4.1 Sourcing of the factories

Names and contact information for factories was obtained from the following sources:

- The membership list of the Clay Brick Association of South Africa.
- The Central Statistical Services Register of Manufacturers(30).
- Telephone directories.
- Discussions with people in the industry.

4.2 The postal survey

The Clay Brick Association provided a covering letter to each of their members encouraging them to participate in the study. A questionnaire on energy use was then posted together with a letter explaining the project to the 75 member factories. After a number of weeks, a fax follow up was sent to the factories that had not responded. The data obtained from the surveys was entered into a database and spreadsheet program for manipulation.

A total of 23 factories responded providing an overall success rate for the postal survey of 30%. A copy of the questionnaire is included in Appendix A.

4.3 The telephonic survey

The factories that were sourced in the Register of Manufacturers(30) that had not been contacted in the postal survey, were contacted telephonically. It was often not possible to speak to a person of authority and sometimes information was promised and not delivered. Overall the success rate of the telephonic survey was better than for the postal survey with 32 factories providing information telephonically. This information was added to the postal survey database.

A copy of the telephonic questionnaire is included in Appendix B.

4.4 Selection of factories for visits

It was necessary to select a number of factories for individual visits from those surveyed. These factories needed to be a representative sample of the clay brick industry in South Africa and therefore the selection could not be done on a random basis since this may have resulted in the sample being skewed towards one particular type of factory or region.

Specific criteria for selection needed to be considered and it was decided that the sample of factories needed to represent:

- Different geographical regions
- Different sizes of factory in terms of production output
- Different production technologies.

Based on these criteria thirteen factories were selected. The regions represented were the Western Cape, Eastern Cape, Natal and Gauteng regions. The technologies represented were clamp kilns, Hoffmann kilns, transverse arch kilns and tunnel kilns.

The visits to the factories were carried out as short energy audits. The procedure followed for the visits was:

- Make contact with the company's management and make an appointment for the audit.
- On arrival, tour the factory with the factory manager/engineer.
- Obtain copies of the energy accounts and production figures for the past twelve months.
- Walk around the factory, become familiar with the process, make sketches etc.
- After the visit, perform analysis and identify opportunities for the improved management of energy.
- Write a report and hand to management.

4.5 Results and extent of visits

In order to evaluate the effectiveness of the survey, it is necessary to examine the results and extent of the survey. This is done in Table 2.

Table 2. The extent of the survey

TYPE OF FACTORY / LOCATION	NUMBER OF FACTORIES VISITED	NUMBER OF FACTORIES SURVEYED	ESTIMATED TOTAL NUMBER OF FACTORIES IN S.A.
Clamp			
- Inland	4	18	49
- Coast	3	15	41
Non-clamp			
- Inland	3	14	25
- Coast	3	8	15
TOTAL	13	55	130

In total the survey covered 42% of the factories in South Africa, which accounted for approximately 60% of total brick production. The production split for the surveyed factories is roughly fifty percent clamp kiln and fifty percent non-clamp kiln. It has been reported that clamp kilns account for sixty percent of total production[11,31] which indicates that the survey may be slightly skewed towards the non-clamp production.

The Clay Brick Association membership list which was provided for the study contained 75 names of factories. Cross referencing this list with the total number of factories sourced for the study shows that the association represents 57% of the number of factories and about 75% of total production.

5. THE RESULTS OF THE POSTAL AND TELEPHONIC SURVEYS

The information obtained in the surveys is used to form a picture of the industry in terms of energy consumption and cost of energy.

5.1 The number and type of factories

A total of 150 names of factories were obtained for the surveys. Of these factories, approximately twenty had since closed down and could not be contacted, leaving the estimated total number at 130.

There are approximately 90 clamp kiln factories and 40 non-clamp factories, which seems to indicate that seventy percent of factories in the country are clamp kiln factories. Huiras[11] and the Clay Brick Association[31] place the estimate at sixty percent, suggesting that a higher proportion of clamp kiln factories responded to the surveys.

5.2 Production

The total brick production of the South African brick industry, based on average figures obtained in the survey, is about 3.7 billion bricks per year. The visited factories indicated that they were operating at 70 to 80% of total capacity which indicates that the total industry capacity is about 4.6 to 5.2 billion bricks per year.

A recent newspaper report[8] quotes a total production capacity of 4.2 billion bricks and current production at 3.5 billion or 70% of capacity.

5.3 Percentage of production costs

Cost of Energy:

The cost of energy as a component of the total cost of production was discussed with brick makers during the factory visits. The proportional contributions to these running costs varied between factories and regions. The price difference of coal between the coastal areas and Gauteng in particular caused a lot of variation between factories. In some factories energy contributed 50% of running costs, while other factories reported energy accounting for 25% of running costs.

Generally the two major running costs are energy and labour, with labour being the larger of the two. Typical running costs of a brick factory are:

Labour	30	-	50%
Energy	25	-	50%
Materials	5	-	15%
Other	10	-	20%

5.4 Specific Energy Consumption

The data obtained by questionnaire is shown in Table 3 in range and average format. The process relating to each fuel type is included in the table.

Table 3. Specific Energy Consumption in the surveyed brick factories (MJ/kg fired product)

FUEL TYPE (Process)	DIESEL (Mining)	ELECTRICITY (Forming)	COAL, HFO*, GAS (Drying and Firing)	TOTAL
Clamp				
Range	0.03 - 0.26	0.01 - 0.18	1.70 - 5.68	1.80 - 6.18
Average	0.08	0.06	3.83	3.97
Non-Clamp				
Range	0.03 - 0.12	0.10 - 0.27	1.26 - 3.63	1.25 - 4.84
Average	0.06	0.15	2.65	2.93
Average	0.07	0.11	3.21	3.42

* Heavy Fuel Oil

Clamp factories consume slightly more diesel than non-clamps. This is due to a clamp kiln operation requiring more transport within the factory. The bricks need to be moved from the extrusion to the open air drying area, then to the clamp firing area and finally to dispatch. This transport is typically done with a fork lift truck, using diesel. Non-clamps on the other hand tend to have automated transport within the factory, for example a kiln car system running on electricity. This, along with the more extensive use of fans in the kilns, accounts for the higher electricity use in non-clamp factories.

The main difference between clamp and non-clamp kilns is seen in the drying and firing energy. Clamp kilns use on average almost 50% more energy for drying and firing than non-clamps. This is an indicator of the efficiency of the respective practises and is discussed later in the report.

5.5 Total energy consumption

Total energy consumption for the clay brick industry can be calculated by multiplying total brick production (3,7 billion bricks for 1995) and average specific energy consumption (3,42 MJ/kg) and average brick mass (3,0 kg). This gives a total energy consumption of 38 PJ for 1995.

5.6 Energy costs

The cost of the energy consumed in the brick making process depends on a number of factors. The purchase price of a fuel varies from region to region and supplier to supplier. Added to this is the transport cost involved in getting the fuel to the user. Table 4 shows a comparison of energy prices between regions.

Table 4. Comparative energy prices[32]

ENERGY	COST PER UNIT OF ENERGY (C/MJ)	
	INLAND	COAST
Coal		
-Filter Cake	0,25	0,81
-Duff	0,30	0,79
-Nuts	0,30	0,98
HFO	1,93	1,54
Electricity*	6,09	5,56
Diesel	4,33	4,07
Gas	1,72	--

* - Municipal Tariff

In the light of these energy prices, the range and averages of the energy costs for the surveyed factories is presented in Table 5.

Table 5. Energy costs of the surveyed brick factories (Rand/1000 bricks)

FUEL (Process)	DIESEL (Mining)	ELECTRICITY (Forming)*	COAL, HFO, GAS (Drying and Firing)	TOTAL
Clamp				
Range	3 - 31	2 - 30	18 - 181	33 - 211
Average	10	10	59	79
Non-clamp				
Range	3 - 15	16 - 45	11 - 240	31 - 270
Average	7	25	96	128
Average	9	18	78	105

* In non-clamp kilns, electricity is also used for fans and kiln car movement.

On the strength of the survey information, the clamp kilns have a higher energy consumption, but their average energy cost per 1000 bricks is lower than for non-clamp kilns. This is because clamp kilns use mainly coal, whereas non-clamp kilns also use more expensive higher grades of energy such as HFO and gas.

5.7 Regional analysis of survey data

The price of energy in the different regions often determines the choice of fuel in these regions. The types of energy used in each region is shown in table 6.

Clamp operations predominantly use coal with some in the Western and Eastern Cape also using HFO. For non-clamp kilns, the favoured fuel is HFO except for in Gauteng where gas is sometimes used.

In the Western Cape particularly, brick factories have problems drying bricks in the winter due to the high rainfalls. Some factories close down production completely over this period while the larger factories switch to drying bricks in chamber dryers and firing clamp kilns under large roofs.

Table 6. Percentages of energy used in the regions (excl. electricity and diesel)

REGION	COAL	HFO	GAS
Clamp			
Gauteng	100	0	0
Western Cape	98	2	0
Eastern Cape	86	14	0
Natal	-	-	0
Non-clamp			
Gauteng	28	33	39
Western Cape	28	72	0
Eastern Cape	20	80	0
Natal	41	54	0

A clear picture of the different costs of energy between regions is shown in table 7 which shows a comparison of the average energy consumption and the average cost per thousand bricks for each of the regions.

Table 7. Regional comparison

REGION	ENERGY CONSUMPTION (MJ/KG PRODUCT)	COST OF ENERGY (R/1000 BRICKS)
Clamp		
Gauteng	4.39	48
Western Cape	3.20	81
Eastern Cape	4.14	121
Natal	-	-
Non-clamp		
Gauteng	3.52	127
Western Cape	2.43	107
Eastern Cape	1.21	43
Natal	2.44	65

In the Eastern Cape, the results are dominated by a factory that uses sewerage sludge as an additive to the bricks. This significantly reduces the energy requirements as well as the cost of the energy.

There could be a variety of reasons for the differences between regions. Energy prices, clay characteristics, production technology, energy management systems and climatic conditions all play a part in the efficiency of energy consumption and hence the overall cost of energy. For example, the carbon content of the clay in Natal is known to be relatively high, this provides additional firing energy and therefore reduces commercial energy requirements.

6. THE RESULTS OF THE FACTORY VISITS

The factories that were chosen for individual visits could be studied in more detail and with first hand data. This will then serve as a credibility check on the survey data as a whole since it is expected that trends will be similar in similar types of factories.

A sample of an energy audit report for a clamp kiln factory is included in Appendix C and a sample of an energy audit report for a non-clamp kiln factory is included in Appendix D.

6.1 Types of energy used

Table 8 shows the types of energy used by the factories visited. In order to protect confidentiality, the factories are given the codes CL for clamp kilns and NC for non-clamps.

Table 8. Energy used in factories visited

FACTORY	DRYING ENERGY	FIRING ENERGY
Clamp		
CL1	HFO	Coal
CL2	Coal	Coal
CL3	Open Air	Coal
CL4	Open Air	Coal
CL5	Open Air	Coal
CL6	Open Air	Coal
CL7	Open Air	Coal
Non-clamp		
NC1	Recovered	HFO
NC2	Recovered	Coal
NC3	Coal	Coal
NC4	Recovered	Gas
NC5	Recovered	HFO
NC6	Recovered	Coal

Note that few factories have a specific energy input for drying. The clamp operations mostly dry in the open air and the non-clamp factories recover the kiln heat for drying. In most cases therefore, the "drying and firing energy" in fact pertains to firing only.

6.2 Specific Energy Consumption

The specific energy consumption (SEC) is the amount of energy consumed per unit mass of product. In the case of the brick industry, this is expressed in Megajoules per kilogram of fired product.

The energy consumption and production figures obtained from the factory visit information are used to calculate specific energy consumption. The results are shown in tables 9 and 10.

Table 9. Clamp kiln Specific Energy Consumption (MJ/kg fired product)

FACTORY	DIESEL	ELECTR	COAL, HFO, GAS	TOTAL
CL1	0.05	0.04	1.70	1.80
CL2	0.07	0.08	5.68	5.83
CL3	0.06	0.03	5.15	5.24
CL4	0.10	0.03	4.16	4.30
CL5	0.07	0.04	2.61	2.71
CL6	0.08	0.09	4.81	5.30
CL7	0.06	0.08	4.05	4.13
Averages	0.07	0.05	4.13	4.27

Table 10. Non-clamp kiln Specific Energy Consumption (MJ/kg fired product)

FACTORY	DIESEL	ELECTR	COAL, HFO, GAS	TOTAL
NC1	0.05	0.15	1.77	1.96
NC2	0.04	0.14	3.01	3.19
NC3	0.10	0.17	3.63	3.90
NC4	0.05	0.16	1.74	1.95
NC5	0.09	0.12	3.38	3.59
NC6	0.03	0.10	1.26	1.39
Averages	0.05	0.14	2.23	2.45

In the above tables, the diesel consumption can be linked to the mining process and the transport within the factory e.g. forklift trucks. The electricity consumption can be attributed to the crushing machinery, air circulation fans and kiln car movement. The coal, HFO and gas consumption relates to the drying and firing energy which accounts for over 90% of the total.

Comparing the averages for the two types of kiln, one can see the higher energy consumption overall of the clamp operations due to a higher energy consumption in the firing process. The electricity consumption of the non-clamp kilns is more than the clamp kilns due to a higher level of automation and more fans in the kilns.

Tables 9 and 10 highlight the large variations in total SEC even within the respective kiln groups. The reasons for the variations could be regional differences as discussed in section 4.4 but there could also be factors affecting energy consumption within the same region. These are, attitude towards energy efficiency, clay characteristics, fuel supplier and characteristics and quality of product.

6.3 Cost of energy

The energy costs per thousand bricks for the visited factories is shown in table 11 for clamp kilns and table 12 for non-clamp kilns.

Table 11. Energy cost per thousand bricks for clamp kilns

	DIESEL	ELECTRICITY	COAL, HFO, GAS	TOTAL
CL1	5.77	7.46	52.94	66.17
CL2	8.06	14.94	52.03	75.03
CL3	7.23	5.89	74.27	87.39
CL4	12.25	5.84	36.46	54.55
CL5	8.00	7.20	23.59	38.79
CL6	8.76	16.67	148.33	173.76
CL7	7.86	16.51	136.22	160.59
Average	8.52	8.79	58.62	75.93

Table 12. Energy cost per thousand bricks for non-clamp kilns

	DIESEL	ELECTRICITY	COAL, HFO, GAS	TOTAL
NC1	5.84	23.78	90.78	120.40
NC2	4.54	25.94	27.78	58.26
NC3	14.53	31.56	35.56	81.65
NC4	8.00	29.69	89.58	127.27
NC5	7.88	16.36	24.75	49.00
NC6	2.99	16.55	11.22	30.76
Average	6.36	24.15	52.34	82.85

Even with the high energy costs of CL6 and CL7, which are both Western Cape factories with municipal electricity supply, the factory visit data generally confirms the survey data. The low energy cost of NC 6 is due to the fact that the factory uses clay with a high carbonaceous content, and obtains coal at a favourable price.

While statistically, the questionnaire is the more valid method of collecting the data, the factory visits produce more reliable data since the information is audited personally on site. The survey data can therefore be compared to the factory visit data to form a picture which can be considered to be fairly representative of the industry as a whole.

6.4 Comparison with survey

The large range of values makes it difficult to establish or confirm trends although on the whole, the factory visits do reflect the results the survey. The greatest area of inconsistency lies with the energy costs.

Because the factory visits were conducted personally, the information obtained can be used with more confidence than the survey information which may have been provided from memory by the factory manager. It is therefore useful to see how the factory data compares with the survey data.

This comparison is done in Table 13.

Table 13. A comparison of survey and factory visit information

	SURVEY		VISITED	
	Clamp	**Non-clamp**	**Clamp**	**Non-clamp**
Number of factories	33	22	7	6
Energy consumption (MJ/kg)				
Diesel	0.08	0.06	0.07	0.05
Elec	0.06	0.15	0.05	0.14
Coal, HFO, gas	3.83	2.65	4.13	2.23
Total	3.97	2.93	4.27	2.45
Coast of Energy (R/thousand bricks)				
Diesel				
Elec	10	7	9	6
Coal, HFO, gas	10	25	9	24
Total	59	96	59	52
	79	128	76	83

7. COMPARISON WITH OTHER COUNTRIES

7.1 Comparison between countries

A straight comparison of the SEC's of brick making in various countries is shown in table 14. The countries are arranged in order of increasing SEC.

Table 14. Comparison of the brick industry in a number of countries

COUNTRY	FACTORIES (UNITS)	PRODUCTION (MILLIONS OF TONS)	FUEL CONS PJ	SEC (MJ/KG)
Morocco	77	1.50	3	1.78
Germany	185	10.00	19	1.94
Greece	81	2.16	5	1.96
Ireland	7	0.95	2	1.97
Italy	343	17.60	42	2.37
Spain	600	12.60	30	2.40
France	178	5.41	14	2.57
U.K.	220	5.00	13	2.66
Denmark	27	0.86	2	2.69
Netherlands	63	3.10	9	2.76
India	?	55	120	2.80
Portugal	257	4.15	12	2.86
Algeria	40	3.00	9	3.14
South Africa	130	11.1	38	3.42
Canada	?	0.84	3	3.59
Australia	105	5.73	20	3.88

? - Not specified in source material

In terms of the specific energy consumption South Africa has the third highest consumption. There are, however a number of factors that prevent the making of any firm conclusions. Some of these are:

(i) Large differences in clay properties (e.g. Moroccan clays have a high carbonaceous content).

(ii) Differences in legislation (e.g. clamp kilns would not be allowed in most developed countries because of air pollution legislation).

(iii) Climatic conditions (e.g. the need for comfort heating in northern countries)

(iv) Different firing temperatures. For example, in India, most bricks are fired in "Bulls' trench kilns", these are a continuous type of kiln similar in operation to a Hoffmann kiln and fire to a relatively low temperature.

(v) Different standards e.g. the strength of bricks.

(vi) The move towards more mechanization in most developed countries.

Apart from these factors which can be regarded as beyond the control of the manufacturer, there are also factors within the control of the manufacturer which influence energy consumption in different countries. The most significant of these are technology, energy management, and research. These areas were dealt with in detail in chapter 2.

7.6 Conclusions on comparison with other countries

Recent international trends in brickmaking that affect energy use include:

- greater automation therefore reducing scrap requirements
- the use of lighter and more efficient kiln insulation materials thereby minimising heat loss and allowing a quicker start-up period
- the use of lighter and more efficient kiln car materials thereby reducing firing requirements and minimising kiln car exit losses
- improved air and heat flow in kilns thereby ensuring that each brick receives the same treatment
- one-high stacking of bricks resulting in firing times of less than 24 hours
- the use of additives to the clay to improve firing characteristics
- production of perforated bricks,

It is evident that there is a technology gap between South Africa and the developed countries in brick manufacturing. Most of the production in these countries is from highly automated tunnel kilns whereas 60% of bricks in South Africa are produced in clamp kilns. The South African situation shows similarities to India where most of the bricks are also produced using dated technology.

There is little doubt that a move towards tunnel technology is inevitable for the South African clay brick industry. Such a move is, however, long term and the interim objective of the industry should be to improve energy efficiencies of existing technology.

The developed countries use mostly natural gas to fire bricks whereas this option is not available in South Africa. For the majority of the country, coal is in plentiful supply and relatively cheap. It therefore makes sense that this will be the primary fuel used for brick making and a practical way of drying bricks in a country with wide open spaces and a favourable climate, is in the open air. Clamp kilns are therefore suited to South Africa at the present time, just as Bull's trench kilns are suited to India. A change may be forced in the future by either, pollution legislation or rising energy prices.

The options facing the South African brick factory are thus;

- To carry on business as usual in the face of rising energy prices and increasingly stringent legislation,
- To invest capital in tunnel kiln technology, or
- To improve the energy efficiency of existing technology to optimum levels, using the savings to fund newer, more efficient technology.

These options may be over simplified but the data presented in this report shows that there is the potential for the South African brick industry to reduce specific energy consumption to world standards.

8. ENERGY SAVINGS POTENTIAL

8.1 Energy requirements

The energy required to heat bricks is equivalent to the energy available from cooling bricks. Theoretically then the only energy required for drying and firing the bricks is for the removal of moisture and the heat of reaction of the bricks. The energy required to vaporise water from a brick containing 20% moisture on a dry basis is 0.5 MJ/kg. The energy required for reactions in firing a brick is about 0.2 MJ/kg. The remaining energy input constitutes losses, some of which are unavoidable. The following table provides a rough breakdown of energy usage.

Table 15. Specific energy use in brick manufacture (MJ/kg)

	CLAMP[1]	NON-CLAMP
Water Evaporation	0.1	0.5
Heat of Reaction	0.2	0.2
Dryer Exhaust		0.3
Surface Heat Loss		0.4
Firing Air Loss	3.5	0.9
Heat Exiting in Bricks and Kiln Cars		0.2
Miscellaneous Losses		0.2
Diesel and Electricity Requirements	0.2	0.2
Total	4.0	2.9

[1] - Assuming open air drying.

It is clear that the non-clamp factories are more energy efficient due to the lower losses. This is further illustrated in table 16 which compares a clamp kiln factory to a tunnel kiln factory both firing on coal, both in the same region, and both with a fairly typical SEC.

Table 16. Comparison of a Clamp Kiln and a Tunnel Kiln operation

	DIESEL	ELEC	COAL	TOTAL
CLAMP KILN				
SEC (MJ/kg)	0.10	0.03	4.16	4.30
Cost (Rand/1000 bricks)	12.25	5.84	36.46	54.55
TUNNEL KILN				
SEC (MJ/kg)	0.04	0.14	3.01	3.19
Cost (Rand/1000 bricks)	4.00	15.00	13.00	32.00

The tunnel kiln produces bricks at a cost, per thousand, 41% lower than the clamp kiln. In addition to this the tunnel kiln produces a superior quality brick and has a lower scrap rate than the clamp kiln. The non-clamp does however bear a significantly higher investment cost than the clamp kiln. This explains the proliferation of clamp kilns in South Africa at present.

8.2 Existing energy savings potential

It is unrealistic to expect every factory to improve energy efficiency to the lowest specific energy consumption levels in South Africa. Many factors exist beyond the control of the brick-maker which affect energy consumption, such as clay characteristics and climate. In order to estimate the potential for energy saving an improved average SEC, existing somewhere between the current average and the best practise, needs to be established.

Because the data from the factories visited was obtained and audited personally and the SEC of these factories can be expressed with confidence, it follows that this should provide the basis for selecting the improved average SEC. The lowest SEC for each kiln type is not a realistic target - but the second lowest can said to be both achievable and realistic. These values are 2.71 MJ/kg and 1.95 MJ/kg for clamp kilns and non-clamp kilns respectively.

Table 17 examines the savings that would be achieved by factories working at these improved SEC levels.

Table 17. Existing energy cost savings potential

	CLAMP	NON-CLAMP	TOTAL
Present Average SEC (MJ/kg)	3.97	2.93	3.42
Improved Average SEC (MJ/kg)	2.71	1.95	2.33
Saving	32%	33%	32%
Present cost of Energy (R million/anum)			
Cost Saving (R million/anum)	222	198	433
	71	65	139

In practise some factories will be able to achieve even lower SEC's while others will not be able to reach the improved level. Overall though, there is the potential for a cost saving of R139 million by factories improving their energy consumption to an improved SEC level.

8.3 Energy savings potential by changing technology

If factories change technologies to more efficient methods, such as installing tunnel kilns at existing clamp kiln factories, there is an added potential for energy saving. By using the improved SEC for non-clamp kilns for the previous section, table 18 shows the savings potential.

Table 18. Energy savings potential for change in technology

Present Average SEC (MJ/kg)	3.42
Improved Average SEC (MJ/kg) for Non-clamp kilns	1.95
Saving	43%
Present cost of Energy (R million/anum)	433
Cost Saving (R million/anum)	186

Table 18 suggests that almost half of the cost of energy can be saved by changing technology and operating at the improved SEC. There are however some barriers to this making it an unlikely scenario for the near future. These barriers are:

- High capital cost. Non-clamp kilns and especially tunnel kilns are only available on import and cost typically between R10 million and R30 million depending on capacity. Few brick manufacturers are able to afford these costs and interest rates on borrowing are prohibitively high.
- Lack of incentive to change. A brick factory becomes established in terms of client base, demand and price structure. Owners of factories may see no reason to move out of this "comfort zone".
- Demand for low grade bricks. As long as there is a need for low cost housing, there will be a market for low cost bricks. It would not be possible for a factory with a high capital payback component of production costs to compete with, for instance, cement blocks in this market.
- Energy costs. The relatively low cost of coal means that in most cases although a non-clamp factory is more energy efficient than a clamp factory; the energy costs are higher if the non-clamp factory is, say a tunnel kiln firing on HFO.
- Lack of gas infrastructure. At present gas is only available in the Gauteng area. This excludes the option of using this otherwise particularly suitable tunnel kiln fuel in most of the country.

The overwhelming barrier to a large scale change of technology is initial cost. This may change however if tunnel kiln technology could be locally developed.

9. ENERGY SAVING OPPORTUNITIES

During the course of this study, through the factory visits and discussions with people in the brick industry, various energy saving opportunities were identified which would be likely to go some way to realising these savings.

9.1 Electricity

The supply and use of electricity offers a number of saving opportunities. Some of these such as tariff switching may not be possible in some areas but it is more often the case that staff are not aware of the options available to them.

9.1.1 Tariffs

Industries supplied by Eskom have a number of electricity tariff options open to them. The main options are:

- Standardrate. This is fixed rate for large consumers with a constant demand pattern. It consists of a basic charge, a demand charge based on the maximum demand recorded in a month, and an energy charge for the total amount of energy consumed.
- Nightsave. This rate is for large consumers who can move their demand to off peak, night time hours. The tariff consists of a basic charge, a demand charge which is only applicable to the maximum demand registered during peak hours, and an energy charge.
- Maxiflex. This is a time-of-use tariff for consumers who are able to adapt their energy use to Eskoms time schedule. Electricity is charged out according to whether it is used within high or low demand times of the year; as well as peak, standard and off peak times of the day and week.

Changing to a more favourable tariff will not result in any reduction in energy consumption but can yield cost savings of up to 10%.

Case Study: One factory with a monthly electricity bill of approximately R100000 that was visited had recently changed tariffs to make use of off peak electricity and in the first month achieved approximately R8000 saving for no decrease in electricity consumption.

9.1.2 Power factor correction

A simplified explanation of power factor is as follows:
The coils of an electrical motor or a transformer store energy in the form of a magnetic field. This is termed reactive power and forms part of the maximum demand in Volt Amperes. The power factor is the ratio of power consumed in the machines, in Watts, to the power supplied to the factory in Volt Amperes. This power factor can be corrected by installing banks of capacitors thus reducing the reactive power component of the demand charge. By installing power factor correction equipment a factory typically saves between 10 and 25% of their maximum demand charge which makes up in the order of 30% of their total bill.

Generally, the larger factories surveyed have power factor correction equipment installed but very few smaller factories do in spite of the savings possible. Some factories are charged for their power per kilowatt and so there is no penalty for reactive power.

***Case Study*:** One factory installed power factor correction equipment at a cost of R9000. This resulted in savings of R1000 per month in maximum demand charges, making payback on the installation less than one year.

9.1.3 Load management

In a typical industrial factory, electricity use peaks at mid morning with a slight drop at lunch time and then tapers off towards evening. The maximum demand is the highest level (normally averaged over a half an hour) reached in the month which is then charged at the prescribed rate.

Load management means trying to keep the maximum demand as low as possible. This can be done by spreading the load through the day and not using high power equipment all at once. For example building up a stockpile by running the crushing section without the extruder operating and then switching over and extruding from stockpile with the crushing section switched off. Some factories that were visited did this but the majority ran machinery simultaneously and kept stockpiles only for emergencies.

The efficiency with which electrical load is managed can be determined by the load factor. The load factor for electrical supply is defined as the ratio of the actual kilowatt-hour consumption, to the product of maximum demand and number of hours worked in a month.

$$L.F = \frac{kWh}{\max kVA * (\text{number of working hours})}$$

In the factories visited, those with demands that were relatively smooth over the day - e.g. tunnel kiln operations where the kiln and fans ran 24 hours a day - had load factors generally over 0.5. Clamp kiln operations that used electricity for short periods of the day, for crushing and forming only, had load factors of under 0.5 and sometimes as low as 0.2.

It is suggested therefore that a factory tries to get as accurate an estimate of their load curve as possible, either by having it measured directly by a consultant or by estimating it at various times of the day. By observing or estimating the time that maximum demand occurs, a strategy can be developed to shift some load and obtain a better load factor. Figure 15 shows the relationship between load factor and cost for Eskom's standardrate.

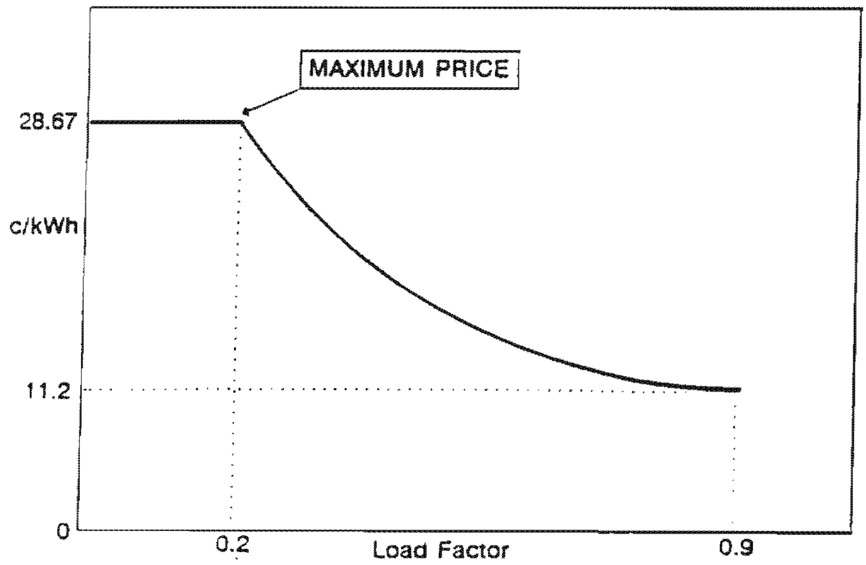

Figure 15. Variation of electricity price with load factor

It can be seen that the price of electricity decreases with an improvement of load factor. Being able to improve a load factor from 0.3 to, say, 0.5 by spreading the maximum demand over more hours would result in cost savings of 30-40 %.

9.1.4 Load shedding

Load shedding is the controlled shutting down of a non essential electrical load, for example the hot water supply to the bathrooms, when the demand reaches a predetermined level. This is normally done automatically although sometimes an alarm is activated and the factory engineer will determine what to shut down. The effect of this is similar to improving load factor.

9.2 Coal
Coal is the most widely used energy type in the South African brick industry. Opportunities for the more efficient use of coal exist in the areas of selection, supply, storage, handling, and end use.

9.2.1 Selection
Coal type is selected for a number of different criteria all of which need to be considered before a final selection is made. For example, at coastal prices, filter cake works out 28% more expensive than grade A peas in cost per unit energy. The peas must be crushed before adding to the clay and this extra cost also needs to be taken into account. Savings are nevertheless available through careful selection of coal type.

9.2.2 Supply
Coal prices vary between suppliers and significant savings are available to those who compare periodically.

9.2.3 Storage
The storage of coal is an area which has a large potential for wastage. Coal stockpiles are often not covered and wind and rain erosion occurs. Coal also wasted when stored on a gravel surface due to the coal on the ground mixing with the gravel and becoming unusable, this is termed "carpet losses".

9.2.4 Handling
Care needs to be taken when handling coal in the factory to minimise spillage. Coal that is transported by front end loader often spills from the scoop in transit.

9.2.5 End use
In coal fired continuous kilns the coal should be fed by automatic stokers to ensure optimum feed rate. A manually fed kiln often has problems with excess ash and unburnt coal being left in the kiln after firing. This ash and coal mixture covers the bricks and forms an insulating layer around them, causing underfiring problems. Installing automatic stokers would provide savings in three areas; scrap, unburnt coal and labour.

9.3 HFO

Opportunities for optimising the use of HFO lie in the maintenance of equipment and the accurate metering of consumption.

The burners should be serviced regularly and should be run in accordance with the manufacturers specifications. Part of this is ensuring the HFO is delivered at the right temperature and that the supply pipes are trace heated. HFO requires a pumping temperature of about 45°C and an atomising temperature of 100°C. Too large a variation on this makes the burner operate inefficiently.

The supply piping from the storage tank to the burner should be inspected regularly for leaks.

9.4 Gas

The same procedures as for HFO apply for gas in the maintenance of burner equipment and piping.

Gas is charged out by determining a combined load factor based on hourly and daily, average and maximum demands. For 1995, the formula was:

$$\text{TARIFF}(R / GJ) = \frac{1560}{\text{LOAD\_FACTOR}^{1.084}}$$

For a load factor of 90% or more, the tariff is R11.87 per GJ. For a load factor of less than 40%, the tariff is R30.76 per GJ. A load factor between 40% and 90% is charged according to the formula above. In graph form, this formula is shown in figure 16.

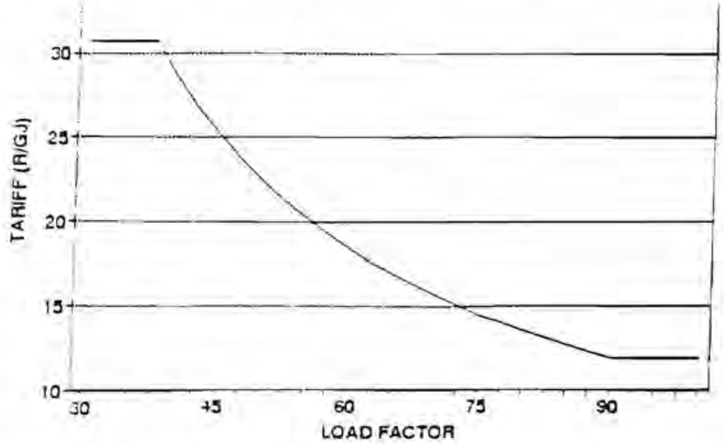

Figure 16. Variation of gas tariff with load factor

As with electricity, an improvement of gas load factor will result in a lower tariff.

9.5 Diesel

Diesel is mainly used for the mining of the clay and the transport of bricks within the factory. Energy saving opportunities lie in the maintenance of vehicles and management.

Regular maintenance work should be performed to keep vehicles running optimally. Drivers should also be given training to drive more fuel-efficiently.

One factory that was visited kept detailed consumption records for all diesel equipment on site. By referring to previous months consumption figures, any increase in fuel consumption of a particular vehicle could be acted on.

9.6 Compressed air

Compressed air is one of the most expensive industrial services to provide. Even so it is often the most neglected and badly maintained service in a factory.

The compressor is the starting point in the compressed air circuit and consequently it must be ensured that it runs efficiently. The inlet air to the compressor should be dust free and as cool as possible, filters should be inspected and cleaned regularly.

Water in the compressed air system corrodes pipes and generally reduces efficiency. Water traps should be installed and maintained. The air should be compressed to as low a pressure as possible. Reducing the delivery pressure by 20% reduces power requirements by up to 10%.

Because compressed air leaks are seen as non threatening compared to a fuel leak, they are often ignored or given a low priority for maintenance. Table 19 shows the cost of compressed air leaks for different size leaks.

Table 19. Cost of compressed air leaks

HOLE DIAMETER (mm)	AIR LEAKAGE AT 700kPa (Nm^3/hr)	POWER REQUIRED (kW)	TOTAL COST OF AIR LEAK* (Rand/yr)
1	4	0.4	484
3	42	3.5	5077
5	110	8.9	13298

* At an estimated cost of electricity of R 0.17 / kWh

9.7 Insulation

The ducts and fans carrying hot air for drying or recirculating should be insulated to minimise heat loss. At many factories the insulation was inadequate, in poor repair or non-existent. Table 20 shows the heat lost and cost per month of an uninsulated surface per square meter of surface area.

Table 20. Heat loss and cost for uninsulated surfaces

SURFACE TEMP ABOVE AMBIENT (C)	HEAT LOSS (W/m^2)	COST PER MONTH* (R/m^2)
50	500	13
100	1250	32
200	4000	101
300	8000	202

* Energy costs are for HFO at R0.56 per litre and for a factory working 500 hours per month.

A rule of thumb to follow is that if a surface is too hot to touch by hand (over 70°C), then it requires insulation.

The selection of insulation is governed by what is termed economic thickness. Since the cost of the insulation increases with an increase in thickness, there is an economic limit to the level of insulation required. This varies depending on the situation but generally for a one year payback, a pipe with a surface temperature 100°C above ambient will require 40mm thick insulation costing approximately R90 per meter.

***Case Study*:** Some factories were observed to have un-insulated surfaces in excess of 150°C. It was calculated that the surface losses from the ducting in one factory was costing R18 500/anum.

9.8 Shape of the brick

Perforations reduce energy requirements both by reducing solid volume and hence mass and by increasing surface area to facilitate drying and firing.

Because perforations reduce the mass of a brick, the bricks can be made larger without becoming unreasonably heavy for the bricklayer. This is being done in a number of factories and termed the maxi, which is a brick of approximately 220 mm x 115 mm x 90 mm in dimension with four perforations running the length of the brick. Because fewer bricks are needed per m^2 of wall, savings in energy of up to 41% per m^2 of wall are estimated[20].

***Case Study*:** A clamp kiln factory which has recently started adding small three hole perforations in their bricks claims that their drying time has been cut in half.

9.9 Additives to the brick

Additives to bricks include those to reduce water content and those to reduce firing temperature. An additive to improve extrudability and thus reduce moisture content is being used at some factories but is expensive. The question of additives for reducing firing temperatures needs to be the subject of further investigation.

9.10 Moisture content

The moisture content of the clay at extrusion must be optimised. A high moisture content reduces extrusion energy but increases the energy required for drying. The factors that must be considered when optimising water content are extrusion energy, drying energy and the potential for cracks to form during the drying and firing processes.

9.11 Scrap

The production of scrap represents one of the biggest areas of wastage in the brick industry. Scrap rates for clamp kilns are approximately 20% which represents a direct waste of energy. In the following case study, a factory saves 15% of energy by managing scrap more effectively.

***Case Study*:** One of the clamp kiln factories visited had a comprehensive scrap management system in place. The factory kept a detailed account of production at each step and incentives were offered to the workers for reducing scrap. The scrap rate was claimed to be less than 5%.

9.12 Research support

There is a need for more research into the brick making process in S.A.

- A co-operative effort to develop a locally designed and manufactured tunnel kiln. This would place the energy saving benefits of tunnel kiln bricks within the reach of more factories.
- A central research organisation funded by the industry. The organisation would collect energy information and trends and disseminated to industry without compromising confidentiality.

The brick industry is fragmented and few companies have the resources to pursue these issues alone. The CBA therefore has an important role to play in the following area.

- Collecting data on brick manufacturing and making this information available to interested parties.

- Research support.
- Demonstration projects on new technologies and good practise.
- Establish ties with overseas brick organisations e.g. British ceramic research institute.
- Organise seminars and workshops, inviting overseas and local speakers.

10. CONCLUSIONS

A postal and telephonic survey of the clay brick industry shows that the South African clay brick industry could reduce energy costs by as much as 40% or R139 million per year through the more efficient use of energy. Even by increasing energy efficiency by half of what is possible, R70 million can be saved.

Although the technology presently in operation in South Africa is largely out of date, a large scale move towards the advanced tunnel kilns seen overseas is a long way off. Energy saving opportunities available using the present equipment thus need to be fully pursued.

These opportunities exist in:

- Supply, storage and handling of coal.
- Correct operation and maintenance of the compressed air supply.
- Insulation of ducts and pipes.
- Reduction of scrap.
- Perforated bricks.
- Additives to the clay.
- Optimising the moisture content of the clay.
- The monitoring and managing of energy use.
- Research into energy efficient kiln design.

11. RECOMMENDATIONS

11.1 Recommendations to the brick manufacturers

The brick manufacturers are the heart of any energy efficiency drive. Without the co-operation and input of the individual brick factory managers, no improvement will be made in energy consumption. Each brick manufacturer must:

- Motivate staff to save energy.
- Record specific energy consumption.
- Experiment with ideas for saving energy.
- Join the Clay Brick Association in order to liaise with other brick makers and solve common problems.

11.2 Recommendations to the Clay Brick Association

The clay brick industry needs to combine efforts in the area of energy efficiency. Competitiveness makes brick factories reluctant to divulge information to competitors and therefore the Clay Brick Association needs to act as a facilitator. Some of the areas in which the CBA can play a role are:

- Broaden membership to encompass more of the industry.
- Collecting data on brick manufacturing and making this information available to members and other interested parties.
- Support and encourage research both financially and technically..
- Arrange demonstration projects on new technologies and good practise.
- Establish ties with overseas brick organisations e.g. British ceramic research institute.
- Organise seminars and workshops, inviting overseas and local speakers.

11.3 Recommendations to the DMEA

DMEA assistance to the clay-brick industry should be directed in collaboration with the Clay Brick Association which represents about 75% of total clay-brick production.

It would be premature to expect the clay-brick industry to commit itself to a targets for specific energy consumption. It is first necessary to set up a mechanism to gather information and a methodology to calculate specific energy consumption on an annual basis. The collected information and calculated data can be fed back to the clay brick industry through a concise report which will provide brick-makers with energy consumption guidelines. The more interpretation that goes into the calculated data the more benefit that can be derived by brick-makers. Such information will also provide the DMEA with energy efficiency indicators enabling them to assess improvement in energy efficiency in the clay-brick industry. If DMEA involvement is strong in industry it will assist them in assessing the effectiveness of their assistance to the clay-brick industry. The DMEA can provide incentive for the Clay Brick Association to produce such a report in two ways:

(i) They can partially contribute to the costs of a consultant to carry out an annual study.

(ii) They can offer the Clay Brick Association other types of assistance under the condition that a report on energy consumption is submitted to the DMEA on an annual basis. This type of arrangement may take place under the umbrella of a formalised assistance scheme for industry.

Other forms of assistance to the clay-brick industry can include:

- Co-funding of a seminar on energy and brickmaking. One or more international experts could be invited.
- Co-funding of demonstration schemes which could result in the more effective use of energy in brick-making.
- Joint research on more energy effective technologies.

Opportunities for demonstration projects include technology that exists currently but is costly to install, for instance:

- A locally designed energy efficient kiln.
- A simple energy management program for clamp kiln factories.
- The use of alternative energy sources.
- The production of highly perforated bricks.

Opportunities for joint research include future developments such as:

- Alterative energy sources.
- Fast firing methods.
- Additives to the body of a brick to reduce firing energy requirements.
- Perforations.

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APPENDIX A

QUESTIONNAIRE FOR THE POSTAL SURVEY

UNIVERSITY OF CAPE TOWN - ENERGY RESEARCH INSTITUTE

BRICK INDUSTRY - QUESTIONNAIRE

Name of Company:

____

Address: ______________________________

____

Tel No: ______________________________

Fax No: ______________________________

Contact Person: ______________________________

1. Please indicate the percentage of production each process accounts for

STAGE	PROCESS	PERCENTAGE OF PRODUCTION
Drying	Open Air	
	Chamber	
	Tunnel	
Firing (kiln)	Clamp	
	Intermittent	
	Annular	
	Transverse Arch	
	Tunnel	

2. **Average Production**

	PER MONTH (SUMMER)	PER MONTH (WINTER)	ANNUAL
Non Face Bricks			
Face Bricks			
Other			

3. **Average Energy Usage**

	PER MONTH (SUMMER)	PER MONTH (WINTER)	ANNUAL
Electricity (kWh)			
Coal (tons)			
Oil (litres)			
Gas (m^3)			
Other (specify)			

4. **Would you be willing to participate in an Energy Audit?** Yes/No

APPENDIX B

QUESTIONNAIRE FOR THE TELEPHONIC SURVEY

PROJECT 0201 - ENERGY MANAGEMENT IN THE CLAY BRICK INDUSTRY

SECTORIAL STUDY - TELEPHONIC SURVEY

All information will remain strictly confidential.

Name of Company:

____

Address: ____________________________

____

Post Code: __________

Tel No: ____________________________

Fax No: ____________________________

Contact Person: ____________________________

1. What products are produced? (e.g. Bricks, Tiles etc.)

____

____

____

2. What is the average fired mass per product?

____

3. Technologies used?

Drying: ______________________ for _____ % of production

______________________ for _____ % of production

Firing: ______________________ for _____ % of production

______________________ for _____ % of production

4 Approximate Annual production? ______________________________

5. Percentage Split between

Summer: __________ %

Winter: __________ %

6. Quantities of Different forms of Energy used?

Coal:

Duff: ______________________ tons per ____________

Filter Cake: __________________ tons per ____________

Peas: ______________________ tons per ____________

Nut: ______________________ tons per ____________

HFO: ______________________ litres per ____________

Diesel: ______________________ litres per ____________

Petrol: ______________________ litres per ____________

Gas: ______________________ [GJ][m^3] per ____________

7. Typical monthly Electricity consumption?

kVA: ___________ @ ________________ R/kVA

kWh: ___________ @ ________________ R/kWh

8. Would you be willing to have an energy audit performed at your factory?

____

APPENDIX C

SAMPLE ENERGY AUDIT REPORT - CLAMP KILN FACTORY

EXECUTIVE SUMMARY

This report sets out the results of a short energy audit carried out at CL3 brick factory.

CL3 fires bricks in a clamp kiln, using nut coal as the base fuel with duff coal being added to the body of the brick. Prior to the firing operation, the clay is extruded and wire cut into bricks which are dried in chamber driers fuelled by furnaces burning coal cobbles.

The average specific energy consumption for CL3 is 5.9 MJ/kg and the average cost of energy is R49.25 per thousand bricks. This SEC is higher than the industry average of 4.01 MJ/kg although the cost of energy is below the industry average. The reason for the low cost of energy is the extensive use of coal, and the fact that the factory is located in the Gauteng area with a relatively low coal price.

The dryer at CL3 is the main source of energy loss. Most clamp kiln operations dry bricks in the open air and so the use of the chamber dryer at CL3 represent an extra energy input. In addition to this, the ducting of hot air from the furnace to the dryer is inadequately insulated, resulting in losses estimated to be equivalent to 30 kg of coal per hour.

CL3 also appears to have a high duff coal consumption, with roughly 10% duff coal per volume being added to the clay during the forming operation. This is well above the industry average and the effects of reducing this should be examined.

In conclusion, energy efficiency relies on management practises. CL3 already have a sound management system in place and it would not require any major changes to include energy in this system.

1. INTRODUCTION

This is a report on the results of a short energy survey carried out at CL3 on 3 May 1995. This forms part of a Sectoral study of the clay brick industry funded by the Department of Mineral and Energy Affairs.

The Clay brick industry is one of most energy intensive industries in terms of energy consumed per value added in South Africa. Also, in comparison with developed countries, the South African brick industry lags in technology and energy efficiency.

This report shows a brief overview of energy use at CL3 and then a comparison with industry averages in South Africa. Possible areas of energy saving are then suggested.

This report is not a comprehensive energy study and should be seen as a starting point towards energy awareness.

2. TYPES OF ENERGY USED IN THE PROCESS

PROCESS	ENERGY TYPE
Mining of the clay	Diesel
Crushing	Electricity
Extrusion	Electricity
Setting	Manual Labour
Transport to drying	Diesel
Drying	Coal cobbles
Transport to kilns	Diesel
Setting in clamp kiln	Manual Labour
Firing	Nut coal in the kiln and Duff coal in the body of the brick.
Sorting / unpacking	Manual Labour

3. SUMMARY OF MAIN RESULTS

Based on the accounts for twelve months the energy consumption for CL3 can be presented as follows. Information on individual energy types is presented in the Appendix C1.

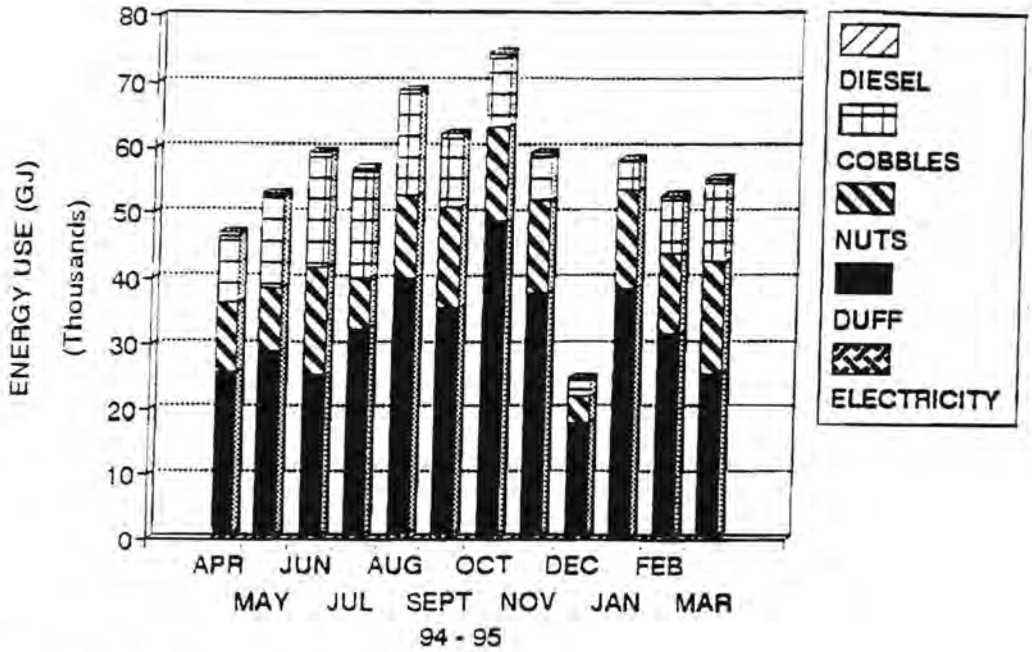

Figure 1. Total Energy used per month

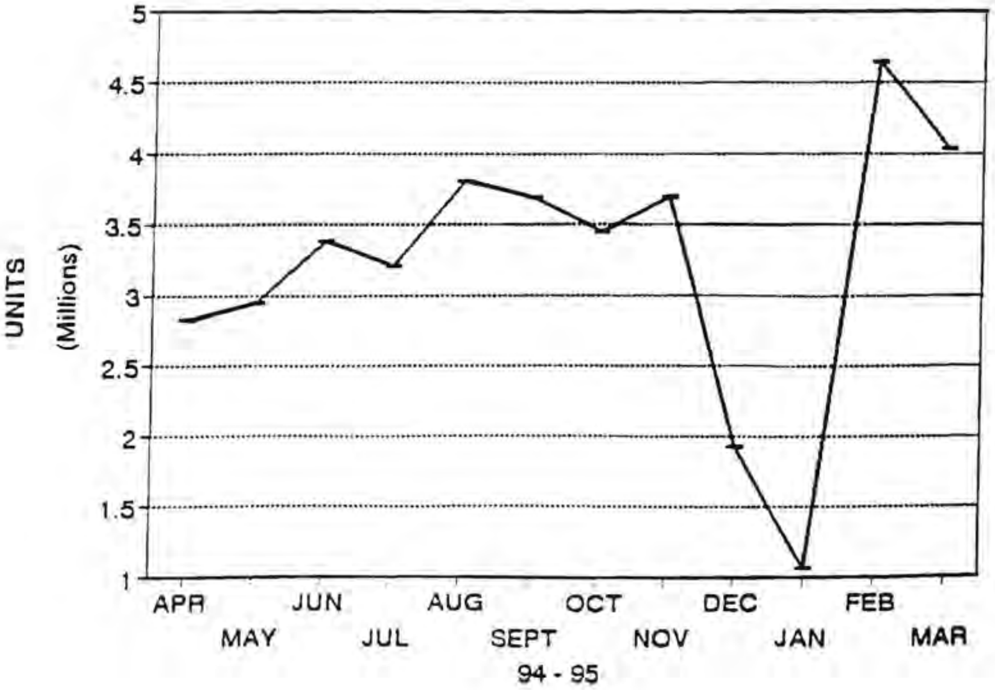

Figure 2. Total production per month

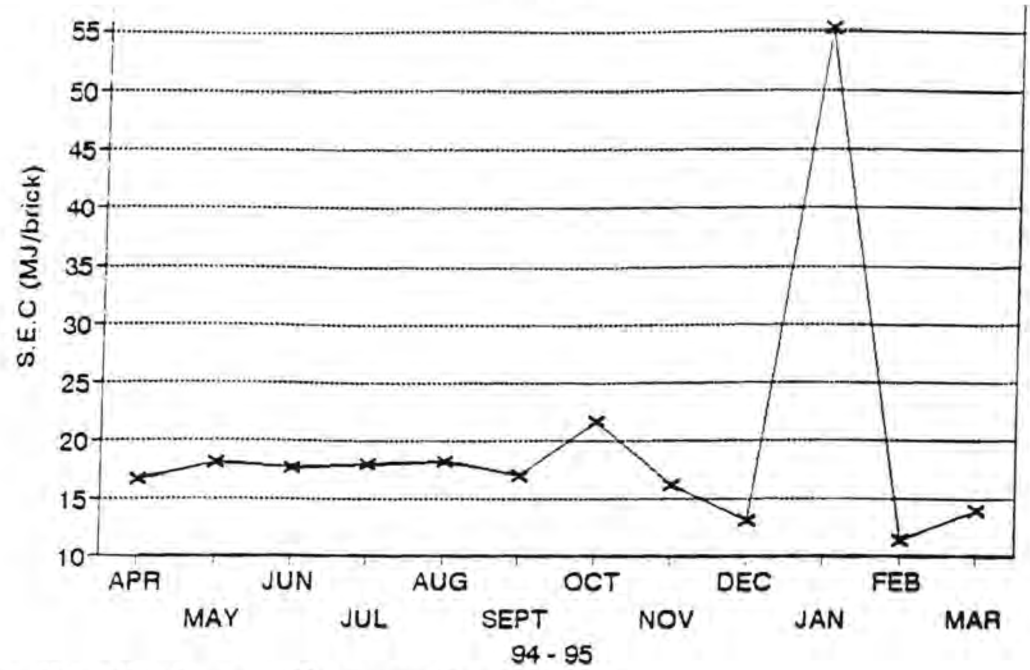

Figure 3. Specific Energy Consumption

Comments:

Specific energy consumption is obtained by dividing total energy by production. It is more commonly expressed in the form of MJ/kg thereby enabling different factories producing different size bricks to be compared.

For CL3, the average SEC is 17.84 MJ/brick or, at 3 kg per brick, 5.9 MJ/kg. This energy is split up as follows:

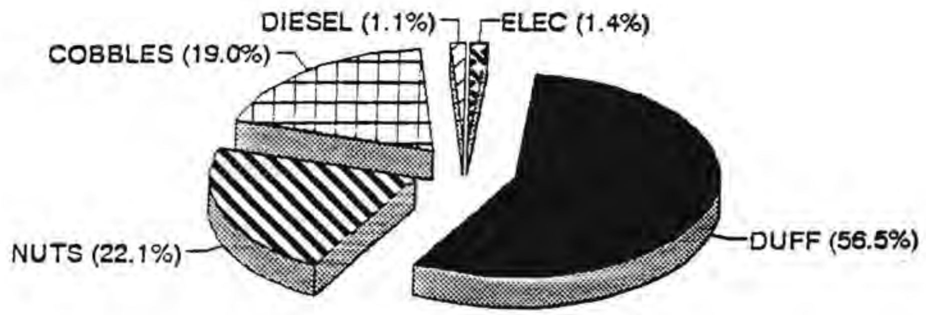

Figure 4. Energy use per brick (Total energy = 17.48 MJ/brick)

Taking the cost of each energy type into account, the split changes quite significantly.

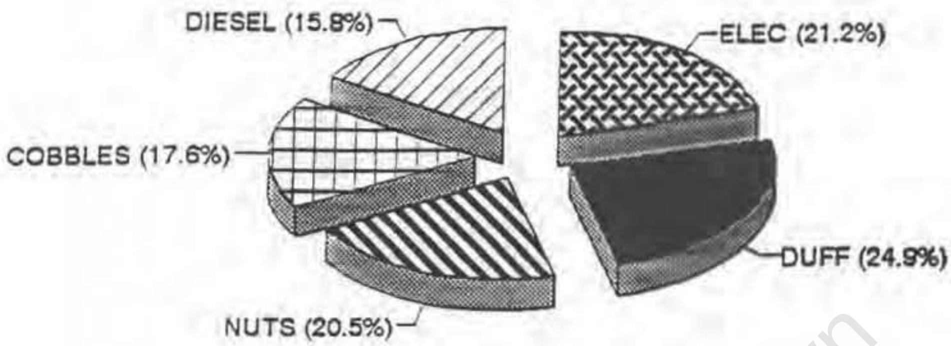

Figure 5. Cost of energy per brick (Total cost = R49.25/1000 bricks)

The energy used can be divided up into processes as follows:

Mining and transportation (Diesel);

Crushing and Forming (Electricity);

Drying (Coal cobbles);

Firing, Body (Duff);
Base (Coal nuts);

4. COMPARISON OF SEC WITH INDUSTRY AVERAGES

Figure 6 shows the distribution of SEC for the clamp kiln brickyards surveyed in South Africa.

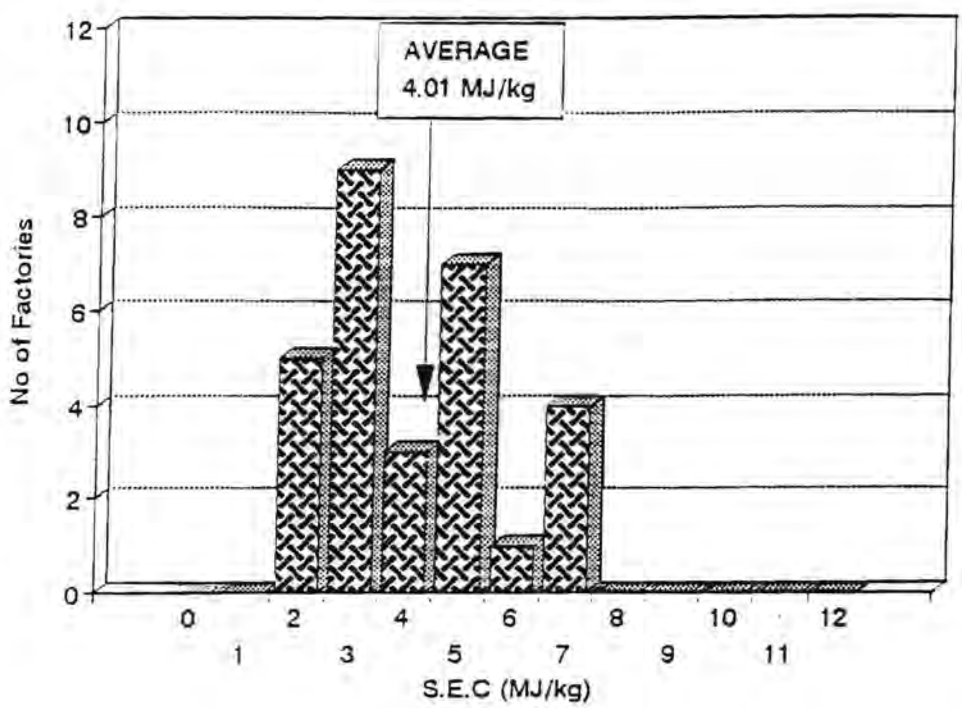

Figure 6. Distribution of SEC for clamp operations

Table 1. A comparison of energy per process with the industry averages for all types of kiln

PROCESS	CL3 (MJ/KG)	INDUSTRY AVERAGE (MJ/KG)
Mining	0.07	0.06
Forming	0.08	0.10
Drying	1.11	0.37
Firing, body	3.29	1.49
base	1.29	1.22

The majority of Clamp kiln factories dry bricks in hack lines in the open air and hence have no energy input for drying. This brings the industry average down.

5. GENERAL COMMENTS

5.1 Drying

The largest potential for energy saving is in the drying process. Much of the ducting is not insulated leading to heat loss to the surroundings. Roughly 130 m^2 of ducting at 150°C above ambient temperature is uninsulated. This equates to a heat loss of 859 MJ or 30 kg of coal per hour .

In addition, some of the dryer doors do not close properly causing more heat loss to the surroundings.

The scrap rate of clamp kiln factories is another large source of energy wastage. In some cases up to 20% of production is lost in this way.

5.2 Energy management

Often, substantial benefit is derived from merely keeping track of energy use. Increases in energy consumption or prices are picked up immediately and can be acted upon timeously.

CL3 have the basis of such a system in place, it would be a simple task to extend it to focus on energy as well.

6. CONCLUSIONS AND RECOMMENDATIONS

Due to the nature of the clamp kiln operation and the shortness of the factory visit, limited opportunities for energy saving are identified in this report.

The SEC for CL3 remains steady throughout the year, the high peak in January caused by a breakdown. The average SEC of 5.9 MJ/kg is above the industry clamp kiln average of 3.6 MJ/kg. From table C1, the reasons for this appear to be the drying operation and the high body firing (Duff coal) consumption.

Opportunities for saving energy exist in following areas:

- The drying operation - by insulating ducting and ensuring a better seal on the dryer doors.
- Reducing the scrap rate.
- Instituting an energy management scheme.
- Examining Duff coal consumption.

Clamp kiln operations are difficult to analyse from an energy point of view because they are so susceptible to outside influences. In short, what works in one operation may not work in another. Therefore true energy savings will only come from a concerted energy management effort from within the company.

APPENDIX C1

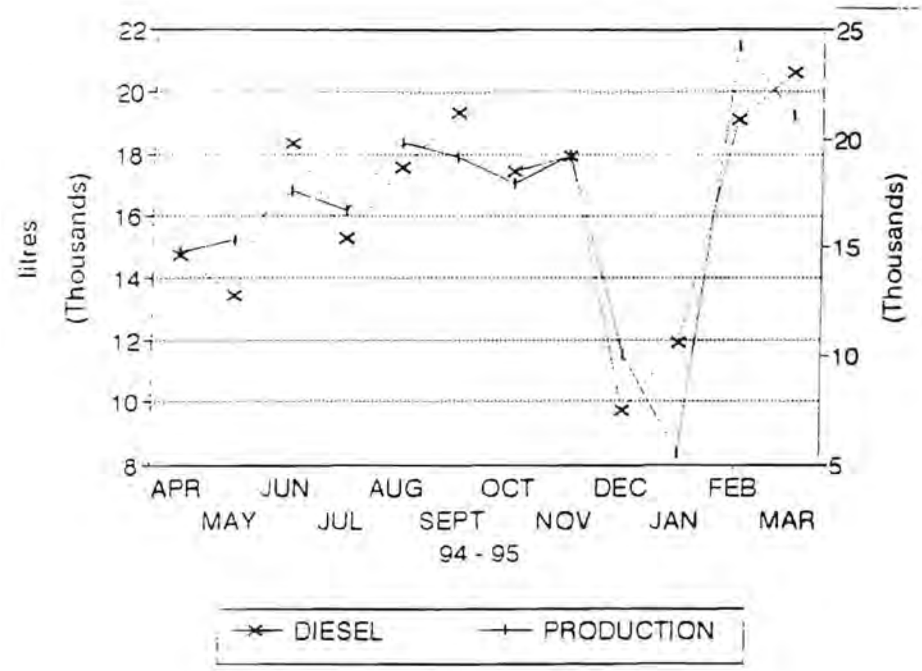

Figure 1. Diesel Consumption

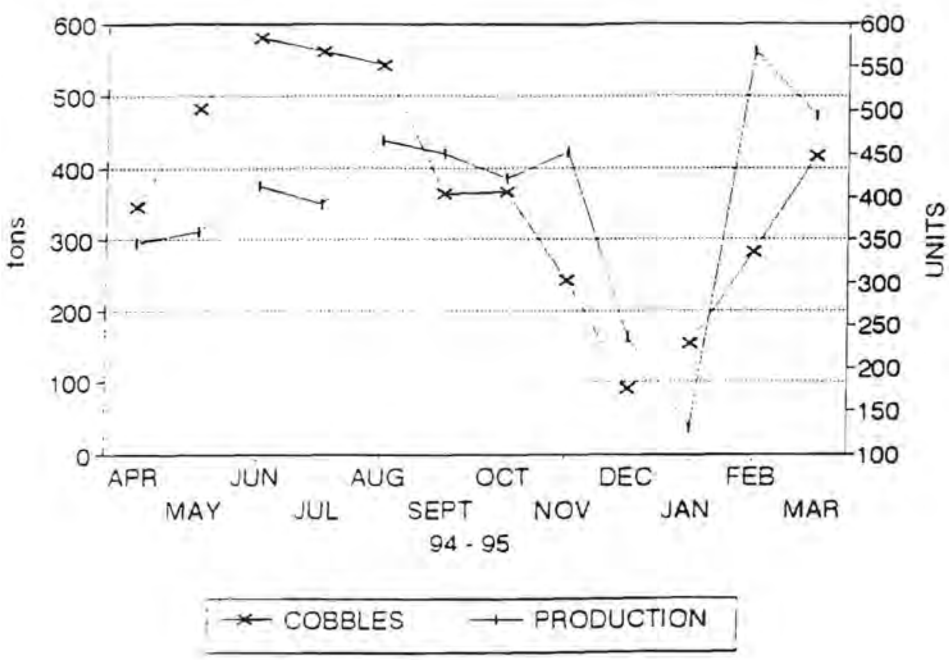

Figure 2. Coal cobbles conumption

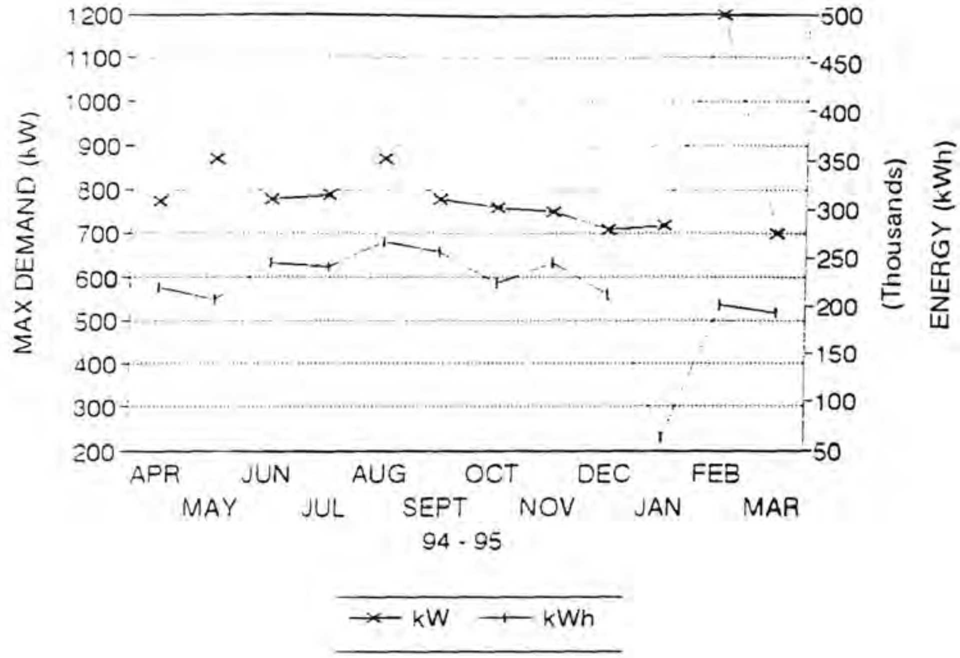

Figure 3. Electricity consumption

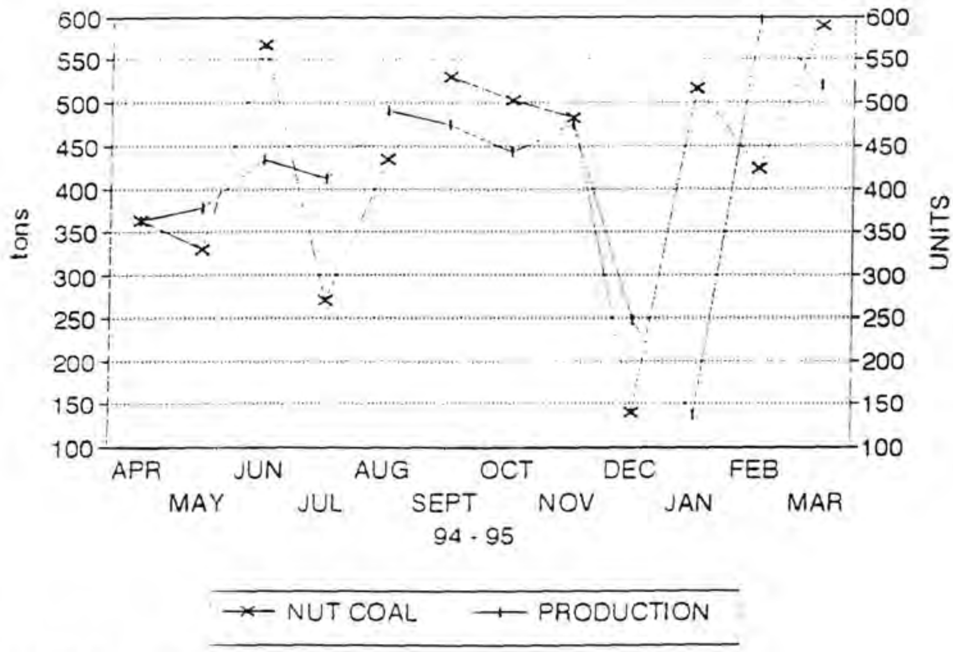

Figure 4. Nut coal consumption

APPENDIX D

SAMPLE ENERGY AUDIT REPORT - NON CLAMP KILN FACTORY

EXECUTIVE SUMMARY

This report sets out the findings of an energy audit performed at NC3 Brickworks. The audit forms part of a project commissioned by The Department of Mineral and Energy Affairs to investigate the establishment of a national industrial energy audit scheme.

The audit proceeded as follows. Energy accounts and production figures for a twelve month period were examined after which a walk through survey of the factory was conducted. The accounts provided a figure for specific energy consumption (SEC) to be compared with industry standards. The walk through survey was to identify inefficient use of energy, and note areas requiring further investigation.

The overall specific energy consumption was calculated to be 3.9 MJ/kg which is similar to the national average of 4 MJ/kg. Overseas, the newer factories operate at between 1.5 and 2 MJ/kg.

Suggestions for improving energy efficiency and estimated cost savings are as follows:

- Reducing the electrical maximum demand could result in significant savings.
- Improving the methods of handling coal will also result in savings.
- The possibility exists to replace coal with either Coal Tar Fuel or Gaskor Gas as the primary fuel. The options need to be thoroughly investigated and money may be better spent upgrading the coal handling system.
- An uninsulated duct four meters long and a half a meter wide with a surface temperature of 200°C above ambient wastes two tons of coal per month. Insulating all exposed surfaces at NC3 will save such wastage.
- A monthly energy consumption summary should be produced to enable changes in use and costs to be investigated immediately.

This report is not meant to be a detailed energy analysis. The feasibility of implementing some of the changes suggested in it need to be the subject of further study. The measures relating to housekeeping and management, however, should be carried out without delay as a first step to energy efficiency.

1. INTRODUCTION

This report describes the findings of an energy audit conducted at NC3.

There is often a lack of awareness in industry of the benefits of using energy more efficiently and many companies are not willing to invest in examining energy use. In some countries the government facilitates the examination of energy efficiency by means of a national industrial energy audit scheme. Although details and methodologies of these schemes differ from country to country, all have met with success and are being continued or being expanded.

In the light of this and due to the fact that the manufacturing sector accounts for approximately 46% of the total energy requirements of South Africa[1], the Department of Mineral and Energy affairs has commissioned a project to investigate establishing a national industrial energy audit scheme in South Africa. Part of the project involves performing energy audits on sample factories from a particular industrial sector. The industrial sector chosen is the structural clay industry which accounts for approximately 6% of total industrial energy consumption.

The objectives of this report are to examine energy usage in the production of bricks at NC3 and identify possible energy saving opportunities. This was done by analysing the energy accounts and production figures for a twelve month period, and conducting a "walk through" factory visit.

This report is not a detailed energy analysis, rather a brief overview of energy use and identification of some energy saving opportunities. An in depth analysis would take more time and resources, yielding more detailed and precise results. This report should be viewed as the first step to energy efficiency, highlighting areas for further investigation.

2. GENERAL DESCRIPTION

The clay is mined on the property and formed into bricks which are then dried in a chamber drier and fired in a tunnel kiln.

2.1 Description of the process

Figure 1 shows a schematic diagram of the process.

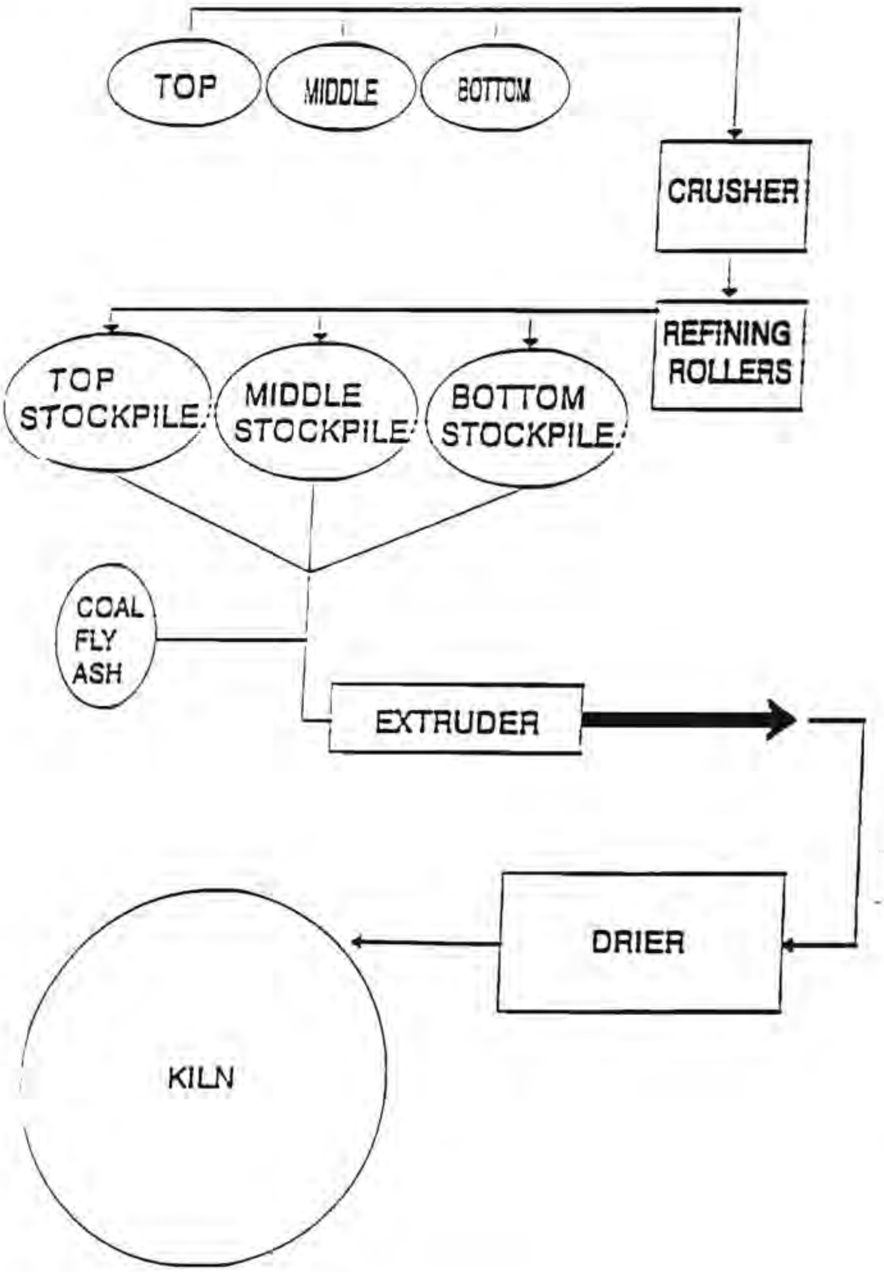

Figure 1. Schematic diagram of the process

Mining and Preparation:

The mining is performed by bulldozers and front end loaders. The mined clay is loaded into separate piles for top, middle and bottom layers (the properties of the clay vary between layers and are discussed in section 2.2). The clays are then mixed in proportions dependant on the brick type and effect desired. This mixture is passed through a primary crusher and a set of refining rollers and then stockpiled for weathering.

Forming and Setting:

The weathered mix is fed, along with coal fly ash, through another mixer and into the extruder. Water is added just prior to the extruder and the clay column is extruded at approximately 19% moisture. The column is cut into bricks and packed by hand onto pallets for dispatch to the dryer.

Drying and Firing:

Drying takes place in two stages. The bricks are first stacked in a drying shed for approximately 5 days. After this, they are placed in drying chambers through which hot air is circulated. There are two drying chambers, one is supplied with hot air from the cooling section of the kiln and the other by two coal fired furnaces.

Once dried to about 2% moisture, the bricks are taken to the circular tunnel kiln to be fired. The bricks are stacked on a moving floor and pushed through the kiln. One push sees one stack of bricks going into the kiln and one stack coming out. There are approximately 30 pushes per day and total time spent in the kiln is about 40 hours. The kiln is fired by duff coal which is fed into the firing zone by chain stokers from the roof of the kiln. The maximum temperature reached in the kiln is 1060°C.

Sorting and Dispatch:

The bricks are hand sorted and packed onto pallets, ready for dispatch or collection.

2.2 Clay and brick characteristics

Types of Brick Produced:

Face brick, non face brick and paver bricks are produced.

Dimensions and fired weights are as follows.

110 mm x 73 mm .... 3.4 kg

102 mm x 73 mm .... 2.8 kg

110 mm x 55 mm .... 2.5 kg

Characteristics of the Clay:

An investigation was undertaken to determine the mineralogical compositions and the ceramic properties of clay samples taken from a proposed new mining area close to the existing one.

The details of the investigation are outside the scope of this report but the findings are, briefly:

- There are three clay layers, top, middle and bottom layers.
- The top layer is mainly topsoil and not suitable for brickmaking except for small quantities in the mix for colour.
- The clay from the other layers shows sensitivity to rapid drying and bricks should by dried under cover.
- The clay has a favourable firing range of approximately 60°C.
- The bottom layer of clay is of a carbonaceous nature but may be too deep to mine economically.

These properties were found to compare closely to the clay from the present mine.

2.3 Production quantities

Average production is between 1.5 million and 2 million units per month. Figure 2 shows actual monthly production figures.

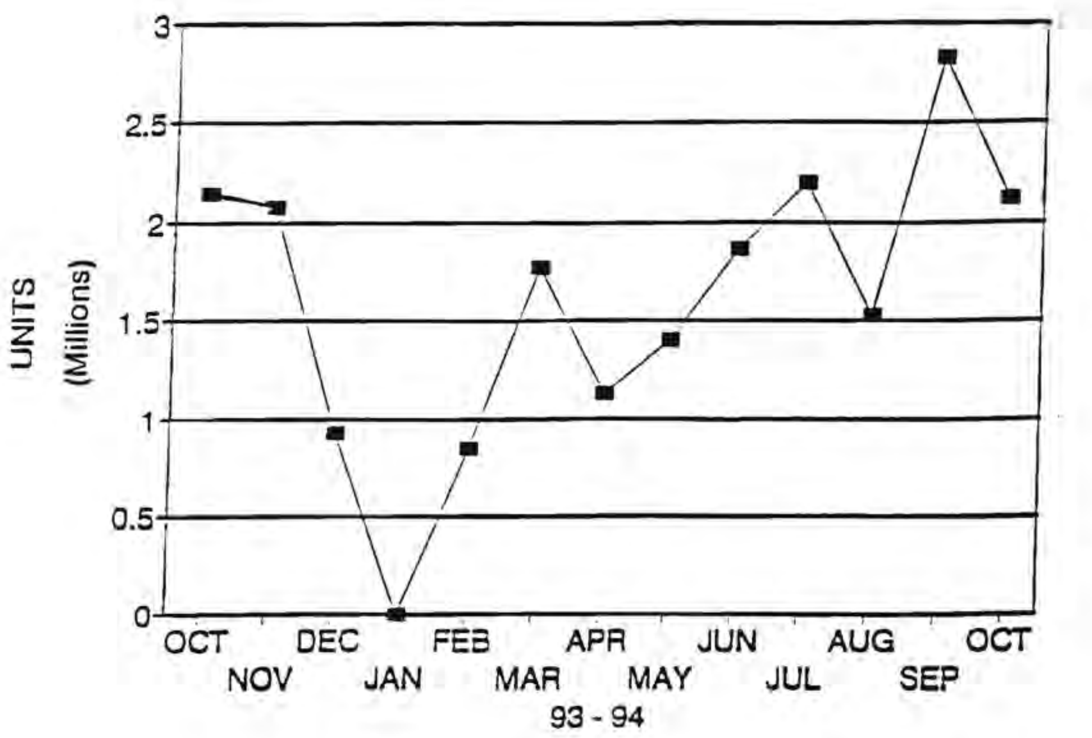

Figure 2. Monthly production figures

There was no production in January and reduced figures for December and February. The reduced production in April is to be expected due to the elections.

3. ENERGY CONSUMPTION AND COSTS

This section analyses the consumption and costs of the various types of energy used. The information used in the analysis was provided by NC3 in the form of a computer printout.

3.1 Electricity

NC3 is supplied electricity by Eskom on tariff A.

Consumption:

Figure 3 shows consumption figures over one year.

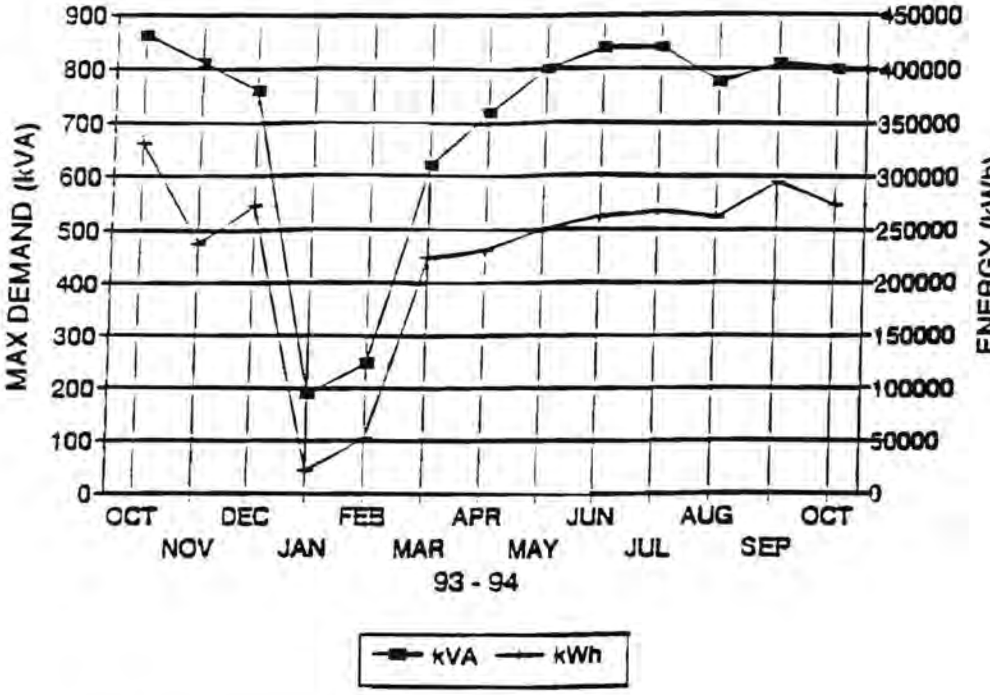

Figure 3. Electricity consumption

The maximum demand increases between February and June. At this point, power factor correction equipment was installed and from August onwards demand stabilised and then started declining. Both energy and maximum demand are down for the

December shutdown period as expected.

Cost:

Figure 4 shows the total cost of electricity per month.

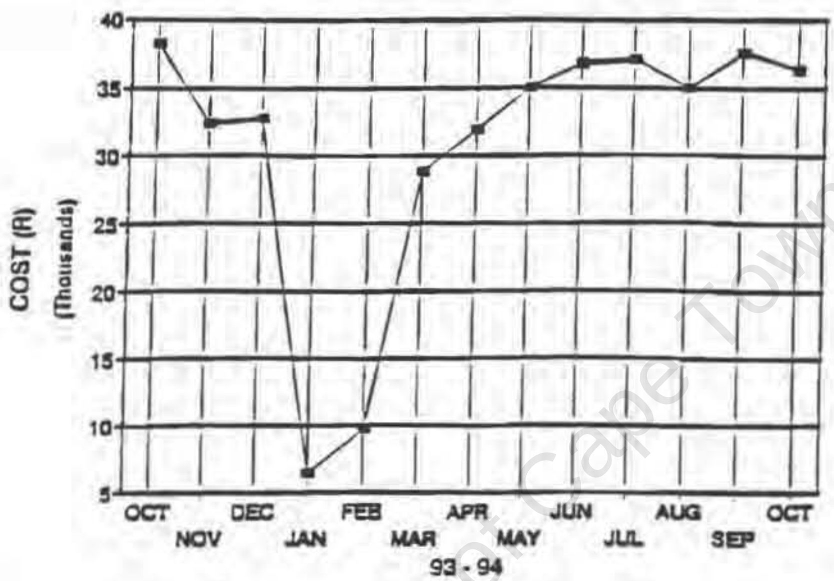

Figure 4. Total cost of electricity per month

3.2 Coal

Coal is used in three forms, duff coal in the kiln, pea coal in the drying furnaces and coal fly ash as an additive to the bricks. These types of coal will be dealt with separately.

Duff Coal:

Duff coal is the principal fuel and is used in the firing zone of the kiln. Figure 5 shows duff coal consumption.

The figures are for coal purchases; so the peak in March is due to stockpiling for the election period and the slight fall off in the following months is due to the stockpile being used up.

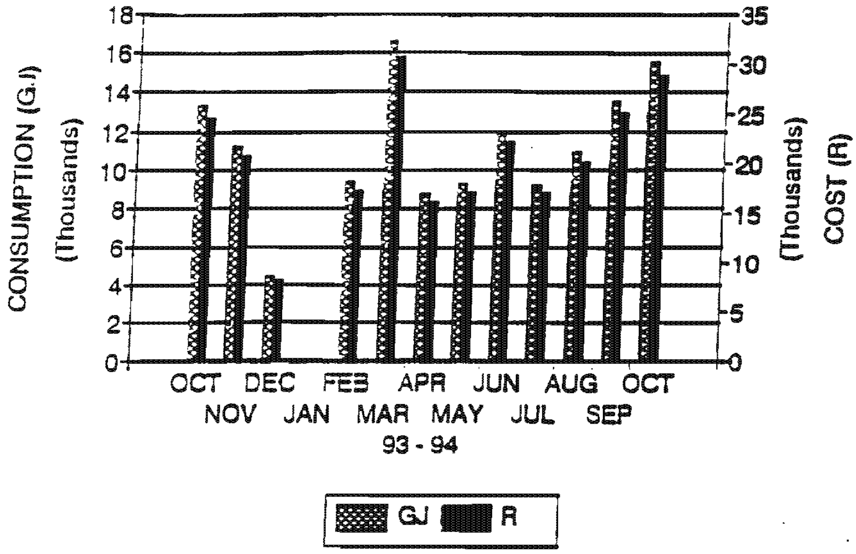

Figure 5. Duff coal consumption

Pea Coal:

The figures for pea coal consumption were not available for 1994. Figures were provided for the years 1983 to 1991 however, and the consumption was estimated from these, relative to the actual duff coal consumption. Figure 6 shows estimated pea consumption.

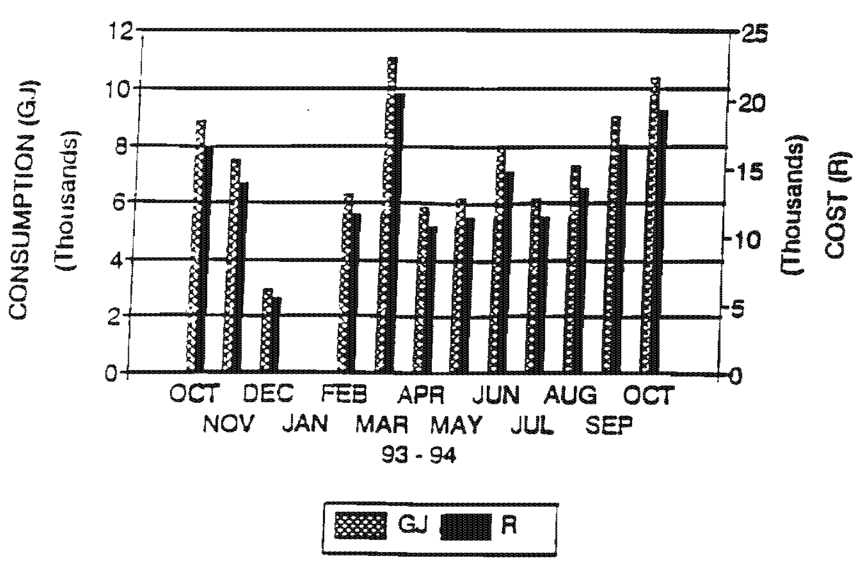

Figure 6. Pea coal consumption

Coal Fly Ash:

Coal fly ash is used as a carbonaceous additive to the clay. It has a low calorific value and is obtained at negligible cost. For the purposes of this analysis the consumption is estimated at 16 tons per month and the calorific value at 14 MJ/kg.

3.3 Diesel

Figure 7 shows diesel consumption over the year. The large purchase in April is stockpiling before elections, otherwise purchases increase steadily through the year. This increase is in line with production figures (figure 2) and other energy purchases.

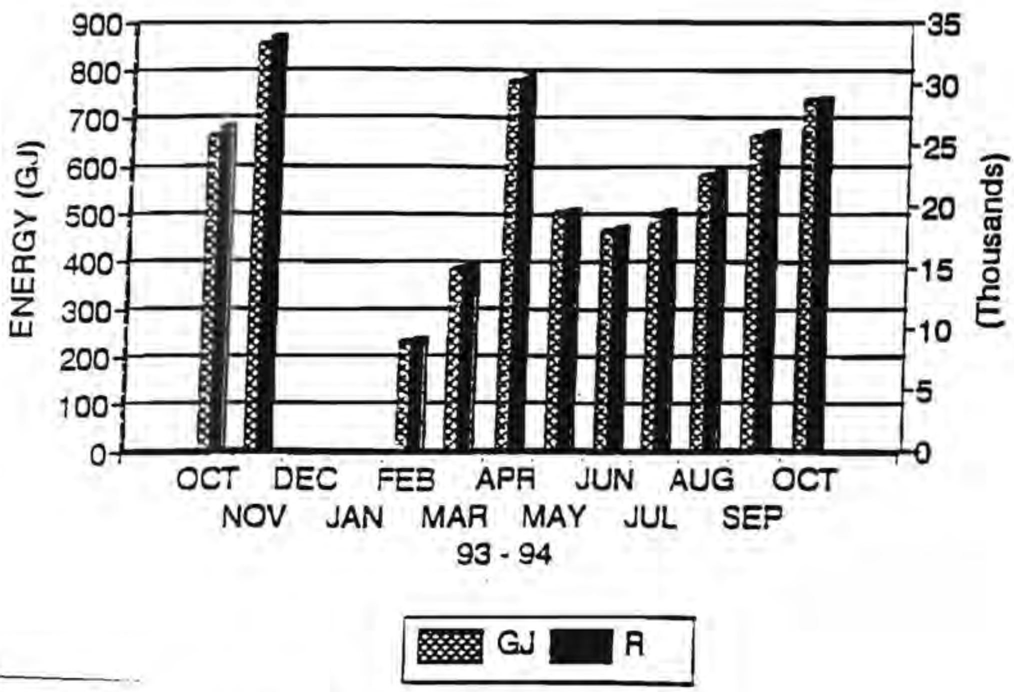

Figure 7. Diesel consumption

3.4 Total energy use

Figure 8 shows the monthly use for each energy carrier. This shows that the total energy consumption is largely influenced by the coal consumptions. Taking the costs of the respective forms of energy into account, however, shows electricity and diesel to be significant (figure 9).

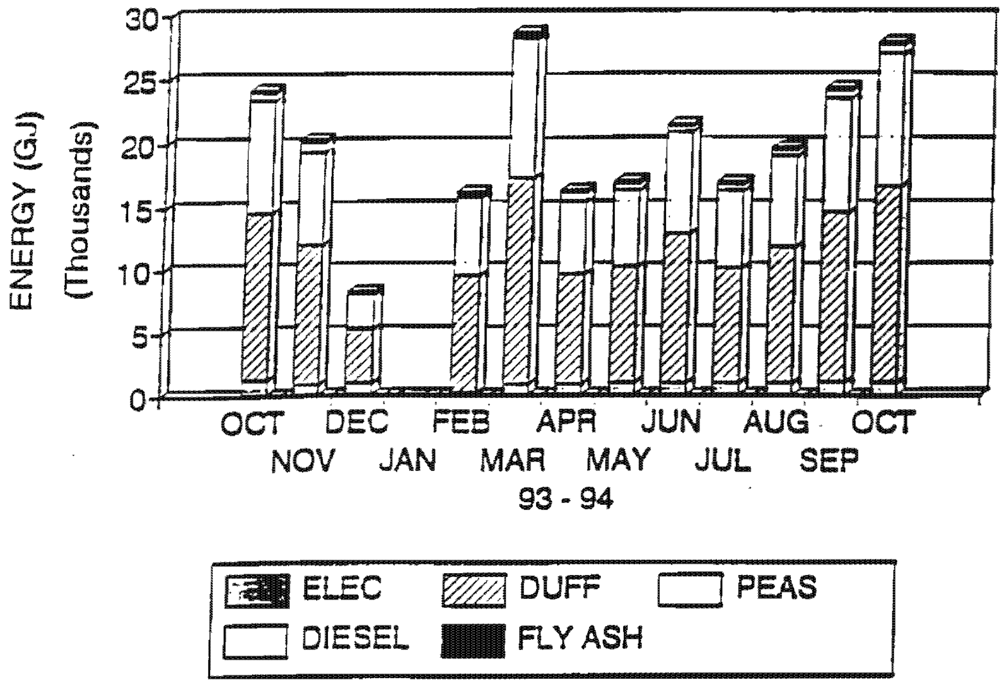

Figure 8. Total energy use per month

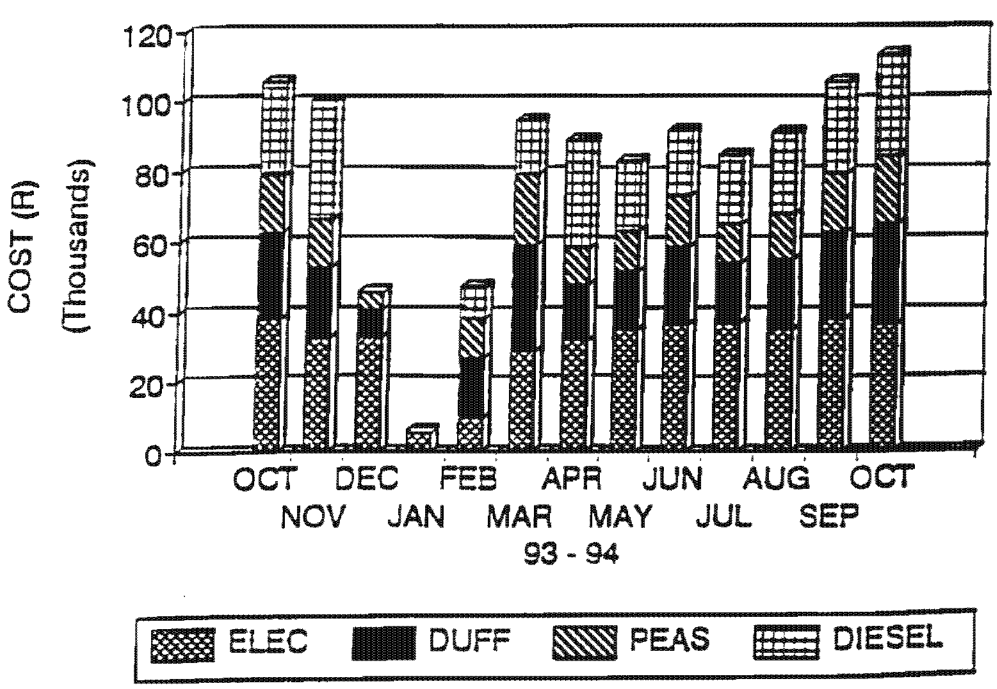

Figure 9. Total cost of energy per month

Another way of showing this difference is with a proportional split of energy per brick in figure 10 and the cost of energy per brick in figure 11.

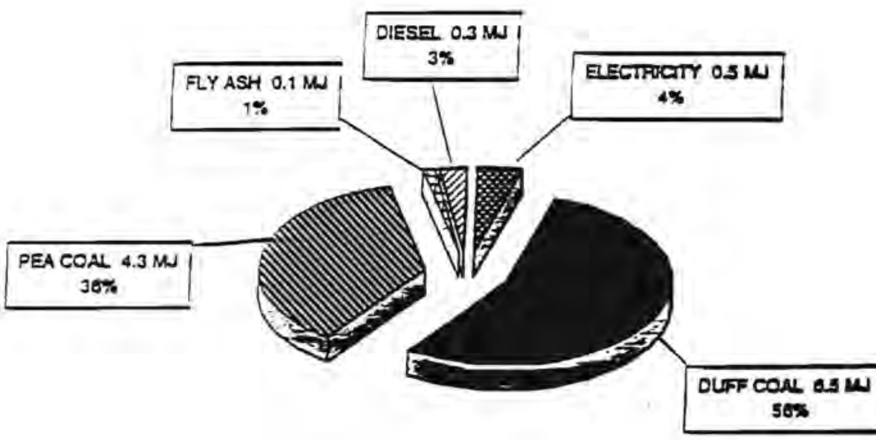

Figure 10. Energy per brick (Total energy 11.7MJ)

Figure 11. Cost of energy per brick (Total cost = R0-051)

3.5 Energy losses

Theoretically, the energy required to dry and fire a brick is as follows:

- To convert water at 30°C to water vapour at 30°C

= 0.7/3.3 kg water/kg brick x (2647-126) kJ/kg

= 0.54 MJ/kg.

- Energy necessary for reactions in the brick = 0.2 MJ/kg.

The total theoretical energy requirement therefore is 0.74 MJ/kg.

All energy supplied over this minimum goes to losses, and the energy efficient operation reduces these losses as much as economically and practically possible.

NC3's energy per brick as shown in figure 10 is 11.7 MJ. The Specific Energy Consumption (SEC), therefore, at an average 3 kg per brick, works out to 3.9 MJ/kg. Thus losses = 3.9 - 0.74 = 3.16 MJ/kg.

For a tunnel kiln, these losses can be divided as in table 2 according to percentage estimates made by Heimsoth[(2)]

Table 2. Breakdown of losses

Type of loss	MJ/kg	%	Comments on reducing losses
i) Surface losses	1,11	35	Insulation of exposed surfaces
ii) Heat exiting in bricks and kiln cars	0,44	14	More effective cooling, lower thermal mass of the cars
iii) Flue gas losses	1,39	44	Recover heat before exhausting
iv) Air leakage losses	0,22	7	Ensure all kiln doors are properly closed

3.6 Comparison of specific energy capacity

The estimated average Specific Energy Consumption in the Brick Industry in South Africa is about 4.0 MJ/kg, and the new factories overseas operate at between 1.5 and 2 MJ/kg[1]. NC3 has a SEC of 3.9 MJ/kg which is average for the industry.

4. SURVEY OF ENERGY USE AND IDENTIFICATION OF ENERGY SAVING OPPORTUNITIES

This section identifies where and how energy is used in the factory as well as noting potential energy saving opportunities. Appendix A1 gives details of calorific values and unit costs of different types of energy.

4.1 Electricity

The load factor for electrical supply is defined as the ratio of the actual kilowatt-hour consumption, to the product of maximum demand and number of hours in a month.

$$L.F = \frac{kWh}{kVA * 720}$$

In the case of NC3, the load factor ranges from 0.43 to 0.50. Improving the load factor to 0.55 for instance will save between 1 and 3 cents per kWh of electricity purchased. The annual electricity cost for NC3 assuming an unchanged demand pattern will then be R328 495 in comparison with the actual figure of R398 126. A saving of R69 631 for the year.

Improvement of load factor is achieved by reducing maximum demand. This can be done by sequencing the startup of machinery so as to avoid a sudden peak and by rescheduling high demand operations to off peak times. Devices are available such as maximum demand alarms and Programmable Logic Controllers to perform these tasks automatically.

4.2 Coal

Coal accounts for 65% of the energy used at NC3 and 40% of that coal is used in the furnaces that feed hot air to the dryers. Many factories dry their entire production using waste heat from the kiln with no additional heat being required. NC3 has only one of two dryers that use kiln heat even though the bricks are "pre-dried" for five days before being sent to the chamber dryers. It appears, therefore, that the potential exists for energy savings in drying. A thorough investigation of the drying process needs to be undertaken.

There are a number of handling problems, especially for the duff coal. The coal is delivered with too high a water content to be able to be used in the kiln immediately. In order to dry the coal, it is placed on the roof of the kiln from where it is either used, or moved to a stockpile.

Wastage occurs during these moves. Every 1% of coal lost costs approximately R4100 per year. Attention should be given to minimizing these handling losses.

The subject of moisture content of coal and its effect on the calorific value and cost per unit energy is dealt with in Appendix D2.

4.3 Fuel switching

The management of NC3 are considering changing fuels from duff coal to Coal Tar Fuel (CTF), a Sasol product similar to Heavy Furnace Oil (HFO). On line gas from Gaskor is another option that can be considered. A direct cost and cost relative to coal comparison for these fuels assuming the present energy usage is shown below using figures from Appendix D1.

	Duff	CTF	Gas
Price	50 R/ton	0.60 R/l	16.50 R/GJ 16.50
Specific Price (R/GJ)	1.78	14.63	9.3
Relative to Duff	1	8.2	

Both CTF and gas are considerably more expensive than using duff coal. Also, this comparison doesn't take into account the conversion costs associated with changing to a new fuel. The money may be better spent upgrading the coal handling system.

4.4 Insulation

There are some surfaces at NC3 that are not insulated. A duct four meters long and a half a meter in diameter with a surface temperature of 200°C above ambient loses approximately 25 kilowatts of heat. The total energy lost in a month, therefore, is 25kW * 720 * 3600 seconds = 64800MJ. This is equivalent to two tons of coal per month.

5. ENERGY MANAGEMENT AT NC3

If energy usage is closely monitored through examination of energy accounts and production figures, then large energy losses or incorrect billing can be acted on immediately. It is therefore recommended that an energy summary for NC3 be produced on a monthly basis. Such a summary can be produced on a computer using a spreadsheet. All that is required is that at the end of each month the accountant enters information from all the energy accounts into the spreadsheet. The spreadsheet will then automatically calculate energy costs and consumption and summarize the results in a table. An example of the spreadsheet is shown on the next page.

MONTHLY ENERGY SUMMARY

Month: Year:

Production :

Total energy cost : R

Energy cost/brick : R per brick

Total energy use : MJ

Energy use per brick : MJ per brick

	Quantity	Cost/Unit	Cost	Quantity/brick
Duff Coal				
Pea Coal				
Diesel				
Electricity:				
- Energy				
- Demand				

6. CONCLUSIONS AND RECOMMENDATIONS

NC3 has an average specific energy consumption. The fact that a tunnel kiln operation such as this should operate below this average prompts the first recommendation to be the undertaking of a thorough energy analysis. Detailed recommendations with supporting data and calculations can only be made after a number of days on the site. A brief visit such as this report is based on can only highlight areas for further study and these are listed below.

- Improving the electrical load factor could result in significant savings.
- Wastage occurs during the handling of the coal. Improved methods of handling could result in savings.
- The drying process needs to be examined with regard to more efficient use of kiln waste heat.
- Both Coal Tar Fuel and Gaskor Gas are options for fuel switching. This possibility needs to be thoroughly investigated since both of these will be more expensive than duff coal. Money may be better spent upgrading the coal handling system.
- Insulating all exposed surfaces is a good start towards energy efficiency. Payback periods for insulating are generally within the year. Insulating a duct four meters long and a half a meter wide with a surface temperature of 200°C above ambient saves two tons of coal per month.
- Large energy losses or incorrect billing can be acted on immediately if energy usage is closely monitored. It is recommended that an energy summary for NC3 be produced on a monthly basis to effect this.

Measures such as fuel switching and reducing electrical load factor by rescheduling production require further analysis before a firm decision can be made. A monthly energy summary, however, can and should be produced immediately as a first step towards energy efficiency.

7. REFERENCES

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(2) Heimsoth, D.A. (1984) Energy saving in ceramic firing. Paper presented at the 16th annual symposium of the South African Ceramic Society 5 September 1984.

8. BIBLIOGRAPHY

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9. ACKNOWLEDGEMENTS

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- The management and staff of NC3 for their hospitality and cooperation.

APPENDIX D1

COMPARISON OF DIFFERENT FORMS OF ENERGY - INLAND

TYPE OF ENERGY	UNITS	C.V (GJ/UNIT)	COST PER UNIT (R)	COST OF ENERGY (C/MJ)
Coal - Peas	ton	28	68	0.24
Nuts	ton	28	68	0.24
Duff	ton	28	65	0.24
Filter Cake	ton	25	55	0.22
Electricity	kWh	3600	0.22	6.09
H.F.O	litres	41000	0.67	1.64
Petrol (premium)	litres	34700	1.76	5.07
Diesel	litres	38800	1.51	4.20
Paraffin	litres	37500	1.02	2.73
L.P.G	litres	27400	1.16	4.23
Gas - Gaskor	GJ		0.17	1.65

APPENDIX D2

THE EFFECT OF MOISTURE CONTENT ON THE COST OF COAL ENERGY

Samples of various types of coal were obtained from a coal supplier. These samples were weighed and then allowed to air dry in order to determine moisture content. A sample of filter cake was obtained independently from a brick factory as delivered from a different depot of the same supplier.

The moisture contents were found to be:

Filter Cake	13 %
Duff Coal	< 1 %
Pea Coal	< 1 %
Small Nuts	< 1 %
Large Nuts	< 1 %

The samples obtained from the supplier all had a moisture content of less than one percent while the filter cake contained 13% moisture.

There could be a number of explanations for the differences. The coal is periodically sprayed with water at the depot to suppress dust and to reduce explosion and fire hazards. The moisture content would therefore vary considerably depending on when last this has been done. During transportation also the coal needs to be moist to prevent it from being blown off the back of the truck.

The calorific value of coal is usually determined on an air dried basis but will be affected by moisture content. A theoretical analysis of this effect and the cost per unit energy for different types of coal follows.

% WATER		TYPE OF COAL				
		CAKE	DUFF	PEAS	SMALL NUTS	LARGE NUTS
	COST (R/ton)	55.00	60.00	65.00	65.00	65.00
0	C.V (MJ/kg)	21.6	24.8	27.9	28.2	24.9
	COST (c/MJ)	0.25	0.24	0.23	0.23	0.26
5	C.V (MJ/kg)	20.4	23.5	26.4	26.7	23.5
	COST (c/MJ)	0.27	0.26	0.25	0.24	0.28
10	C.V (MJ/kg)	19.2	22.1	24.9	25.2	22.2
	COST (c/MJ)	0.29	0.27	0.26	0.26	0.29
15	C.V (MJ/kg)	18.0	20.7	23.4	23.6	20.8
	COST (c/MJ)	0.31	0.29	0.28	0.28	0.31
20	C.V (MJ/kg)	16.8	19.4	21.9	22.1	19.5
	COST (c/MJ)	0.33	0.31	0.30	0.29	0.33
25	C.V (MJ/kg)	15.6	18.0	20.4	20.6	18.1
	COST (c/MJ)	0.35	0.33	0.32	0.32	0.36

The following two graphs are for Duff coal. The other coal types follow a similar trend.

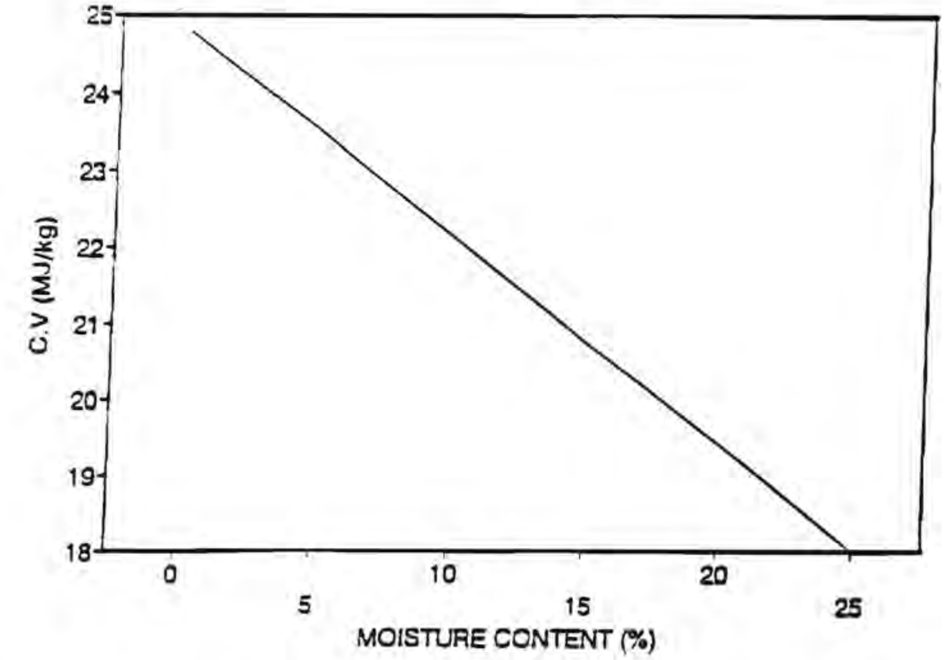

Figure D2.1 C.V vs moisture content

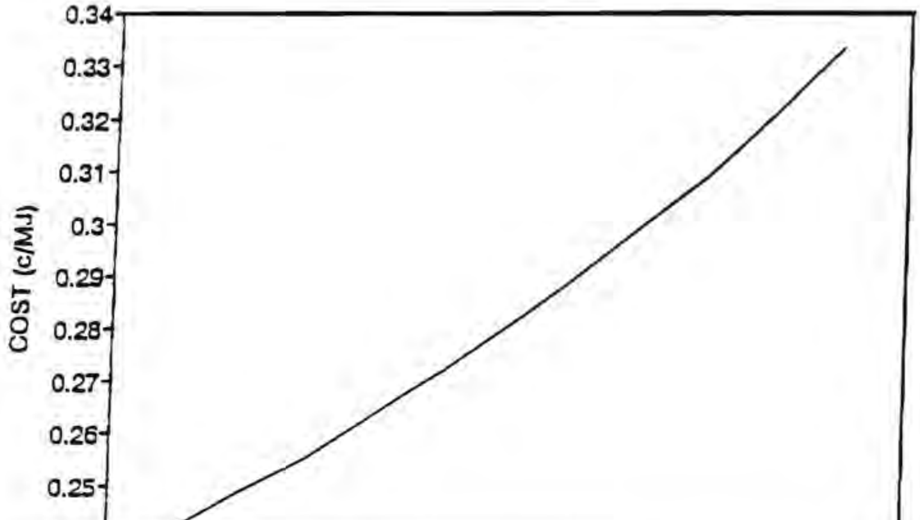

Figure D2.2 Cost per unit energy vs moisture content