Energy efficiency in South African industry

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Abstract
Energy efficiency in South African industry has only recently started receiving attention due to the low cost of South Africa's electricity, and a not too distant history of isolation leading up to democratic elections in 1994.

This study shows that strong incentives exist for energy efficiency improvement in South African industry, in particular, the potential for increasing profit, the need to reduce greenhouse gas (GHG) emissions, the need to maintain economic competitiveness, and the need to delay the cost of new peak-load electricity generation facilities.

Barriers to the implementation of energy efficiency projects need to be anticipated and addressed by managers, policy makers and energy efficiency practitioners. In particular, the lesson from the case study in this paper showed how organisation structure, financial controls and culture, can be barriers to the implementation of energy projects. By ensuring the support of top management, and by the initiation of an energy management program early on, these barriers can be avoided and results and recommendations from an energy assessment can feed into a receptive management system.

Keywords: energy efficiency, energy use, greenhouse gas emissions, South African industry

1. Introduction
The following two quotes from the *White Paper on Energy Policy of the Republic of South Africa – 1998* (DME 1998) provide a good starting point:

> Past governments devoted little attention to energy efficiency in industry, mining and commerce. Greater efficiency will provide financial and environmental benefits, with industry becoming more internationally competitive. Government needs to tap this potential.
>
> It is estimated that greater energy efficiency could save between 10% and 20% of current consumption. Government needs to facilitate increased energy efficiency. Obstacles include: inappropriate economic signals; lack of awareness; information and skills; lack of efficient technologies; high economic return criteria; and high capital costs. Government commits itself-to facilitate greater energy efficiency.

This study begins with a summary of *energy use* in South Africa. *Incentives* for and *barriers* to implementation of energy efficiency projects are discussed, followed by a short coverage of the *energy management* process. These sections provide the backdrop for the findings from the energy assessment *case study*.

The case study provides evidence that energy efficiency projects can save a significant portion of energy costs (potentially 25% in this case study). The case study highlights the importance of creating a receptive management system by ensuring the support and participation of top management in creating an energy management program.

2. Energy use and energy efficiency of South African industry
Final energy consumption in South Africa is split as shown in Figure 1. Notably, industry consumed 57.1% of total energy consumption in 1998 (EIA 2002).

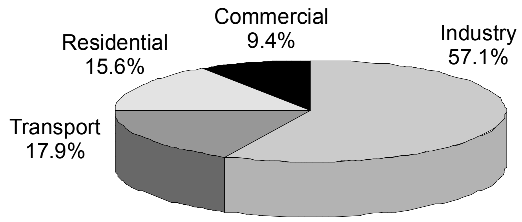

Figure 1: Energy use in South Africa – 1998
Data source: EIA (2002)

South Africa has enormous reserves of easily accessible coal and has relied on coal as its main energy source. Because of its wealth in coal, South

Africa has been slow to develop its reserves of petroleum and natural gas (EIA 2002).

Energy sources for the total primary energy supply (TPES) of South Africa and the world in 2000 are compared in Figure 2 (IEA 2003).

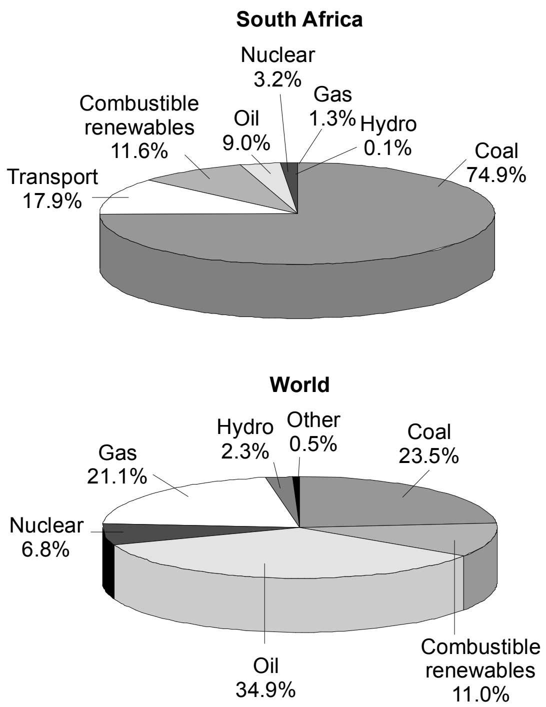

Figure 2: Energy shares of TPES for 2000 (excluding electricity trade)
Data source: IEA (2003)

The energy intensity of a country is an indicator that describes energy use against the value of production (or per capita). However, energy intensity cannot be used by itself as a comparative measure of energy efficiency unless the types of industries of the countries are similar. Developed countries have generally shifted from energy-intensive processes (mining and materials processing) with relatively low product value, to low-energy industries (computer chips, information technology) with relatively high value. Nonetheless, it is still interesting to compare South Africa's energy intensity with its neighbours, and the rest of the world.

Table 1 shows energy intensity of South Africa against that of Africa, Non-OECD countries, OECD countries and the World (HELIO International 2001). Total primary energy supply (TPES) per capita is high in OECD countries, and South Africa's TPES/capita is much higher than the African average. TPES per gross domestic product (TPES/GDP) shows that South Africa uses almost four times more energy than OECD countries to produce products of equivalent financial value. When purchasing power parity (PPP) is taken into consideration, South Africa uses just over twice as much energy as OECD countries (and the world average). Electrical consumption per capita shows how South Africa uses ten times more electricity per capita than the African average, uses double the world average and uses about 60% of the OECD average.

South African industry's high energy intensity is mainly due to large-scale, energy-intensive primary minerals extraction and processing industries. In addition, there is a heavy reliance on coal for generating most of the electricity, and for producing a significant proportion of the liquid fuels consumed in the country.

The figures for energy intensity do not prove that South African industry is inefficient but they do show that large quantities of energy are used (per unit value produced) in our industrial processes and for this reason, energy costs are a relatively large fraction of production costs. We should therefore expect significant energy cost savings through the implementation of energy efficiency projects.

3. Incentives for energy efficiency in South African industry

The driving forces for energy efficiency are:
- profit
- the need to reduce greenhouse gas emissions
- competition
- capital investment constraints.

Table 1: Comparative energy intensity of South Africa in 1998
Source: HELIO International (2001)

	TPES/capita toe/capita	*TPES/GDP toe/000 1990 US$*	*TPES/GDP toe/ 000 PPP 1990 US$*	*Elec. consumption /capita kWh/capita*
South Africa	2.68	0,88	0,57	4 509
Africa	0.64	0,87	0,39	490
Non-OECD	0.95	0,85	0,32	975
OECD	4.63	0,25	0,26	7 751
World	1.64	0,37	0,29	2 252

Note: TPES = total primary energy supply, toe = tonnes of oil equivalent, PPP = purchasing power arity, GDP = Gross domestic product

Profit

Implementing energy efficiency projects and an energy management program will increase profits.

Caffall (1995) reports that in 1980, the UK Department of Energy initiated a program that aimed to install effective energy management systems at a quarter of all UK industrial sites that used more than 26 000 GJ/year. By the end of the program in 1991, 700 energy information systems had been installed in 22 sectors. By 1987, overall annual savings of $120 million had been achieved and were forecasted to rise to annual savings of $640 million by 1995. Some of the *average* percentage energy cost savings for the sectors were 9% (paper and board), 12% (non-ferrous metals), 13% (food) and 17% (textile finishing).

A program in the USA described by Kirsch et al (1996) provided technical assistance (energy assessments) from university engineering faculties to 3612 small and medium sized industrial plants (in the USA) from 1984 to 1993. *Annual* recommended energy conservation as a percentage of consumption averaged from 9.97% to 5.24% over the period. Disappointingly, *implemented* savings averaged from 5.4% to 2.1% over the period. The reasons for this resistance are discussed in the section on *barriers*.

A project to gather and package information on energy efficiency in South Africa, using three case studies in different industries, was undertaken by the then Energy Research Institute (ERI) at the University of Cape Town. The results show that leading players in South African industry have found room for efficiency improvement. Energy cost savings for the South African Breweries Prospecton plant were R1 370 000/annum (8% of annual energy costs) with a required investment of R1 180 000 giving a payback period of ten months (ERI 2000). Energy cost savings for Anglogold's Elandsrand gold mine were R1 990 000/annum with a required investment of R1 293 000 and a payback period of eight months (ERI 2000). Sappi's Mandini plant was able to save R5 550 000/annum in energy costs (5% of annual energy costs) from an investment of R3 220 000, giving a payback period within seven months (ERI 2000).

The case study in this research is of a leading South African manufacturing plant. Opportunities for energy cost savings of 25% were identified with an overall payback period of 10 months.

Greenhouse gas emission reduction

According to Flavin (1998), human activities have added 925 billion tons of CO_2 to the atmosphere as well as other greenhouse gasses (GHG's) such as methane and nitrous oxide. These additional gasses intensify the greenhouse effect of the Earth's atmosphere, and the IIEC (1996) report that this may cause predicted global warming of 1°C by 2025 and 3°C by 2100, more severe weather conditions and rising sea level (0.65m by 2100).

In 1998, South Africa produced 1.7% of the world's carbon emissions (Grobler & den Heijer 2001). The whole of Africa produced approximately 4% and the USA approximately 24%. Contributions to CO_2 emissions by sector in South Africa for 1994 were reported by Howells & Solomon (2000) and are shown in Figure 3.

From Figure 3, notably the three largest sources of CO_2 emissions are 'Energy – public electricity and heat production' (46.67%), 'Energy – fuels and other' (15.12%) and 'Manufacturing industries and construction' (14.42%). Together, these three sectors of South African industry contributed 76.21% of CO_2 emissions in 1994. Grobler and Den Heijer (2001) state that: 'The sector that holds the greatest potential for emission reductions and energy efficiency improvements is the industrial sector, … (being) responsible for almost 63% of carbon emissions.'

The problems of global warming and greenhouse gas emissions have necessitated in an international, collective effort that has resulted in the Kyoto Protocol. Initiated by 167 nations in December 1997, the Protocol is the first international attempt to place legally binding limits on greenhouse gas emissions from developed countries.

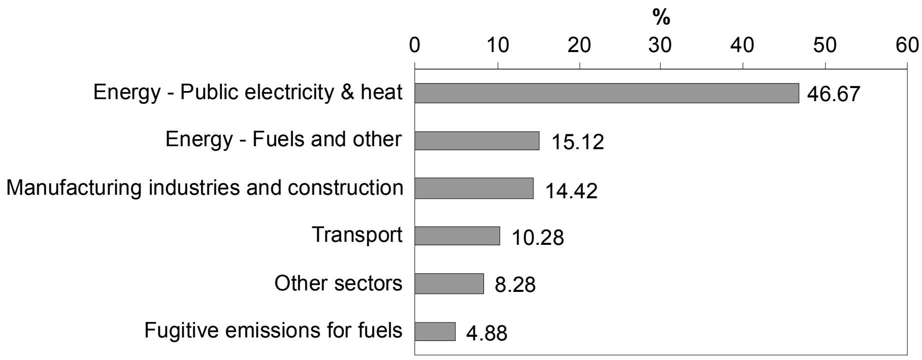

Figure 3: %CO_2 emissions for South Africa by sector
Source: Howells & Solomon (2000)

Mechanisms have been built into the Protocol to promote flexibility and cost-effectiveness for developed nations and to provide incentives for developing countries to participate in global emissions reductions without being compelled to do so (Cameron 2000). These mechanisms are:

- Emission trading – where an Annex B country with excess emission credits may sell emission credits to another Annex B country.
- The Clean Development Mechanism (CDM) – allowing industrialised countries to meet their emission objectives through implementing emission reduction projects in developing countries.
- Joint Implementation projects – where Annex B countries may work together to meet their emission targets.
- The use of emission sinks – where CO_2 is removed from the atmosphere and stored in plants. Projects include forest preservation, forest enhancement through management and the creation of new carbon sinks (plant-rich areas).

When the Kyoto Protocol is accepted, these mechanisms, particularly the CDM, will be valuable sources of funding for energy efficiency projects in South African industry.

The competitive edge

The opening up of world markets has provided new buyers for South African products but, at the same time, has introduced new international competition. Developed countries such as those belonging to the Organisation for Economic Cooperation and Development (OECD), have been steadily reducing the energy intensity of their economies over the past 25 years. In contrast, the energy intensities of developing and transitional economies have increased. Rapid industrialisation and investment in inefficient technology has exacerbated the situation.

In their report for the U.S. Initiative on Joint Implementation, the International Institute for Energy Conservation (IIEC 1996) point out that 'Developing country industries will not be able to compete when their outdated factories consume three times as much energy as more modern facilities' and 'efforts to cut energy costs and remain competitive are creating lucrative (energy) markets.'

Capital investment constraints

The public electricity supply company, Eskom, expects that R100 billion of new investment will be required over the next 25 years (Chalmers, 2001). At the same time, the government wished to privatise Eskom by 2004. In response, Eskom has chosen to invest in energy efficiency projects and demand side management in order to delay the need for investment in more generating capacity.

It is predicted that current installed capacity will not meet the projected demand in 2007, and it is intended that demand-side management (negotiated load interruption, load management and reduction) will delay the 2007 deadline to somewhere between 2015 and 2025 (Bennett, 2001).

Projects that receive financial support from Eskom need to be closely monitored, and the energy savings verified in order that Eskom can be sure that the investment is worthwhile and so that repayment of capital costs from a portion of the company's energy savings can be calculated.

4. Barriers to energy efficiency in South African Industry

The potential for significant energy cost savings through improved energy efficiency has been shown in thousands of case studies conducted in the USA and UK, and several in South Africa. Despite this record, industry often resists the adoption of energy efficiency.

Research by Kirsch et al (1996) into the reasons for rejection of energy conservation opportunities by 3612 small and medium manufacturing plants in the USA from 1984 to 1993, were for the following reasons:

- 43% was due to *unacceptable financial risk* (unsuitable investment return, high initial cost and insufficient cash flow);
- 25% was due to *postponement* (still considering after two years);
- 11,5% was due to *unacceptable plant/person risk* (personnel safety, production rate or quality jeopardised, or unacceptable inconvenience);

No comparative study was found for South African industry, however, Bennett [17] describes five reasons for resistance to the implementation of energy efficiency opportunities in South Africa. Some of these reasons are quite possibly the 'reasons behind the reasons' stated by Kirsch et al. They are:

1. *Attitude: 'I know my business best'*. 'No one can tell me how to run my business. No one outside the industry understands my energy problems like I do. I will appear incompetent if outsiders identify savings that I have not seen'.
2. *Resistance to change*. 'Everything is going along just fine. Why must we continually be changing and trying new things that will probably not work anyway?'
3. *Energy is too cheap*. Many users see energy as a minor input cost, relative to raw material and labour, and tend to concentrate on these. Very often, education and examples can provide the incentive for these users to take another look at energy.
4. *Lack of capital*. Some energy efficiency measures involve the installation of expensive capital equipment. Users are nervous that the promises

made by zealous salespersons may not be realised. Once again, education and objective information can go a long way to overcoming these misgivings.

5. *Uncertainty regarding the future*. Investors are sometimes reluctant to commit resources to long-term projects, given the financial instability both internationally and within regions. Payback periods need to be measured in terms of months rather than years, and this can exclude energy efficiency investment opportunities.

Resistance to implementation of energy conservation opportunities (including energy management) could be addressed by:

- Providing education (training) around energy issues;
- Creating capacity for energy auditing, monitoring and management;
- Disseminating information regarding best practices;
- Using benchmarking, where the specific energy use of competitors is made known (anonymously) for comparison within the industry (locally and internationally); and
- Shifting risk from the plant to the proposer/contractor of the project (capital cost being repaid from a portion of the realised energy cost saving).

5. The importance of energy management

Energy management is essential for the success of energy efficiency projects. A successful energy management system should also remove some or all of the barriers (as discussed previously).

An energy assessment can be seen as an energy management tool. Conversely, experience from the case study revealed that in the absence of an energy management system, an energy assessment is quite likely to initiate action towards the establishment of such a system.

Evaluating current energy management

An energy management matrix, such as that described by Caffall (1995) and shown in Figure 5, helps an organisation to identify the extent of their energy management practice, and gives them an opportunity to identify where they need to improve. A consistent score is desirable across all the criteria – the aim is to raise the score for each criterion up to the level of the highest scoring criterion.

Critical steps for an effective energy management program are:

1. *Obtain top management commitment* – to ensure investment in energy efficiency projects and to provide a powerful source of leadership and motivation for the program within the organisation.
2. *Create an energy policy* – that states what the organisation intends doing about energy management and the goals that they hope to achieve.
3. *Obtain commitment from all employees* – energy saving ideas must be encouraged with rewards for significant contributions to the program. Pride is generated in employees when they feel that they are partners in the planning and implementation of a program that achieves positive results. The formation of working teams to address specific energy issues can be highly successful. Once the problem is solved, the team is dissolved.

Score	Energy Policy	Organising	Motivation	Information Systems	Marketing	Investment
4	Active commitment of top management	Fully Integrated into general management	All staff accept responsibility for saving energy	A comprehensive system with effective management reporting	Extensive marketing within and outside organisation	Positive discrimination in favour of energy efficiency
3	Formal Policy but no commitment from top management	Clear delegation and accountability	Most major users motivated to save energy	Monthly monitoring and targeting for individual sections	Regular publicity campaigns	Same appraisal criteria used as for all other investment
2	No policy adopted	Delegation, but line management and authority unclear	Motivation patchy and sporadic	Monthly monitoring and targeting by fuel type	Some ad-hoc staff awareness training	Investment with short term payback only
1	Unwritten set of guidelines	Informal, part-time responsibility	Some awareness of importance of energy saving	Invoice checking	Informal contact used to promote energy efficiency	Only low cost measures taken
0	No explicit policy	No delegation of energy management	No awareness of the need to save energy	No information system or accounting for consumption	No marketing or promotion	No investment in energy efficiency

Figure 5: Energy management matrix
Source: Caffall (1995)

4. *Set up communication channels* – The purpose of these channels are to:
   - report to the organisation the results of their efforts;
   - recognise high achievers and to identify reward recipients; and
   - advertise the program and to encourage co-operation.
5. *Develop an organisational plan* for *both implementing and monitoring specific energy management programs* – This plan should address the criteria as identified in the energy management matrix.
6. *Set up a means to monitor and control the program* – Energy cannot be managed if it is not measured. Successful energy management and the identification of energy saving opportunities require clear and accurate information on energy consumption of individual buildings or departments.
7. *Investment* – A result of the environmental concerns discussed previously, is that there is growing pressure for corporate environmental responsibility to be demonstrated. Also, efficiency projects need to be appraised for their savings potential just as productivity improvement projects are appraised for their income -generating potential.
8. *Energy Assessments* – An energy assessment determines where and how energy is being used. It identifies opportunities to improve efficiency and provides a benchmark against which future efficiency can be compared. Conducting a successful energy assessment involves:
   - Following a methodical auditing procedure;
   - Determining a pattern of energy use:
     - by making use of effective instrumentation
     - from available records
     - by calculation and or estimation
   - Identifying energy conservation opportunities (ECO's);
   - Estimating and calculating energy and energy cost savings if the ECO's were implemented, as well as implementation cost and payback period.

   Following the assessment report, a *monitoring and verification plan* is necessary that describes:
   - How energy consumption should be measured and recorded;
   - How the baseline energy consumption (if the project was not implemented) is determined (and adjusted);
   - How the energy cost savings are calculated;

If the company has an energy management system in place, then the monitoring and verification process should slot into the existing system. If not, then this is the time to initiate *an energy management plan* for the company.

6 Efficiency improvement through technology

Much information is freely available (particularly from the Internet) on methods of improving energy efficiency in industrial plants. For South African industry, a comprehensive set of handbooks titled *How to save energy and money* has been produced by the then Energy Research Institute (ERI) at the University of Cape Town (UCT).

7 Case Study – Energy assessment of a South African manufacturing company

The ERI was approached by a leading South African manufacturing company, for an energy assessment of their plant. A summary of the energy conservation opportunities that were found and their associated savings, implementation costs and payback periods, is shown in Table 2.

The energy conservation opportunities (ECO's) recommended represent a total value of approximately R 10.7 million per year (representing approximately 25% of total energy costs) with implementation costs of R8.8 million – giving a simple payback of 0.82 years.

Monitoring and verification plan

Based on the findings of the energy assessment, a monitoring and verification document was produced by S Khumalo and D Van Es of the then ERI. The document covered:

- Data requirements
- Monitoring periods (pre and post-implementation of ECO's)
- Monitoring equipment
- Energy consumption baseline characterisation and adjustment
- Savings (energy, costs and emissions) calculation methodology

The document estimates the total cost of monitoring at R270 000, including a R10 000 allowance for commissioning and training. The estimated total cost of all the energy cost saving measures is R12 825 098 which makes the M & V approximately 2% of this value. In addition, an Energy Manager would cost the company a further R150 000 per year.

Lack of energy management creates barriers to implementation

Feedback from middle management on how they felt about implementation of the ECO's revealed that:

- An ECO that fell within an existing budget would be implemented if the budget holder was aware of the opportunity and had a budget that could be used to pay for the actions. For example, the air leaks (ECO 1) were tackled immediately because a budget existed that could be used for fixing air leaks. However, financing for 'improvement' projects (which is what many

Table 2: Energy conservation opportunities, with associated savings, implementation costs and payback periods

	Description	*Potential savings (R/year)*	*Implementation cost (R)*	*Simple payback (years)*
ECO 1	Repair compressed air leaks and faulty blow-down valves to achieve a 10% leakage target	1 262 000	60 000	0.04
ECO 2	Avoid and discourage misuse of compressed air	263 189	30 000	0.11
ECO 3	Switch off compressors and main cooling towers during non-production time	268 075	zero	zero
ECO 4	Install suitable power factor correction equipment	516 690	1 007 500	2
ECO 5	Use waste heat to heat phosphate bath	190 000	300 000	1.58
ECO 6	Install high efficiency lighting	179 803	628 198	3.4
ECO 7	Turn off bay lights during non-production hours	446 190	included	zero
ECO 8	Install direct acting electric heaters to air replacement plants serving colour line 1.	4 355 536	4 000 000	0.92
ECO 9	Make use of heat pump heat recovery between air replacement plant exhaust and supply air streams	3 187 385	2 750 000	0.87
	Total	10 668 868	8 775 698	0.82

ECO's are) required an application for funds at a higher management level (that had not been present at any meetings during the energy assessment).

- Energy in this company was being treated as an overhead. Section managers were not held accountable for energy consumption. Energy consumption was not a key performance indicator.
- A comprehensive energy management system was not in place (although overall energy inputs were recorded). Most of the obstacles to implementation that were being identified in the feedback meeting were the requirements for an energy management program. If the interest and support of top management had been obtained early on in the project, (as is emphasised in the energy management principles in Section 5) the budgetary and organisational obstacles that were identified in the feedback meeting with middle management might have been easily bypassed.

Top management becomes involved

Some months after the feedback obtained from middle management, the top management of this company began providing direction and leadership towards energy efficiency and environmental goals. The energy projects that were identified as well as new energy efficiency projects are now being implemented or re-examined for feasibility. An energy management program has been started; incorporating monitoring, project implementation, communication and the co-ordination of working groups and technical teams.

8 Conclusion

Strong incentives exist for energy efficiency improvement in South African industry, namely profit, reduction of GHG emissions, the need to maintain economic competitiveness and the need to delay the cost of a new peak-load electrical generation plant.

Results from extensive long-term energy projects in industry in the USA and UK show that there is significant opportunity for energy cost saving through energy efficiency improvements (particularly in the first few years). Several case study assessments of industry leaders in South Africa suggest that South African industry has an even higher potential for energy cost saving.

Organisation structure, financial controls and culture/attitude can be barriers to the implementation of energy projects. These barriers can be avoided by ensuring a high level of trust between consultant and middle management, ensuring the support of top management, and by the initiation of an energy management program early on. The results and recommendations from the first energy assessment can then feed into an existing receptive energy management system.

Further investigation into the extent of energy management in South African industry may help in estimating the impact of energy efficiency programs on energy consumption and energy intensity.

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