# Greenhouse Gas Mitigation Options in the Industrial Sector

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ABSTRACT

This report identifies the major opportunities for climate change mitigation through industrial energy efficiency and fuel switching in South Africa. The potential for greenhouse gas reduction (outlining areas of possible resultant CDM investment) in local industry, a $CO_2$ mitigation cost curve and accounting of emissions reductions in existing and future industrial plants, will provide the basis for realising these opportunities. Greenhouse gas mitigation in the industrial sector is closely linked with 2 groups: energy efficiency improvements and fuel switching; and these options are outlined in more detail in this report.

JEL Q40

## 1 INTRODUCTION

This paper quantifies the potential for GHG reduction in South African industry in the form of a $CO_2$ mitigation cost curve, which shows the cost versus carbon savings potential for each mitigation option. Other key results from this study include fuel consumption per sub-sector under a business as usual 'baseline' scenario.

### 1.1 Background

The bulk of the potential for greenhouse gas mitigation in the industrial sector is linked with energy efficiency improvements and fuel switching options. A national industrial energy efficiency program, 'the 3E strategy' (Energy Efficiency Earnings), showed that energy and therefore $CO_2$, could be saved in South African industry. Three industries, ANGLOGOLD, SAPPI KRAFT and SOUTH AFRICAN BREWERIES, with a record of active energy management were invited to be a part of this program. A summary of the results from implementing (additional) short '3E Strategies' follows:

**Table 1 Results of '3E Strategy' case studies**

| | Costs ('high cost' estimates) | Payback | $CO_2$ Abatement |
|---|---|---|---|
| South African Breweries' Prospecton plant | R 1 180 000 | 10 months | Not estimated |
| ANGLOGOLD's Elandsrand goldmine | R 1 290 000 | 8 months | 10 200 tons pa |
| Sappi Kraft's Mandini mill | R 3 220 000 | 7 months | 60 200 tons Pa |

About 60 per cent of these savings were without significant investments in new capital. Furthermore, none of the energy saving projects above had an investment payback period of over one year. This clearly indicates the potential $CO_2$ abatement.

Based on an energy efficiency case study, a carbon mitigation case study for VW Uitenhage is also described here, a further practical indication of the potential for emissions reductions possible in industry.

### 1.2 Scope of study

Owing to the complexity of the industrial sector and some generic assumptions are necessary that limit the detail of the work due to the poor availability of energy consumption data. Key differences between South African and international economies, such as fuel prices and specific processes and technologies, make the correct selection of appropriate mitigation technologies and options for the South African economy essential. This selection is done on an industrial sub-sector by sub-sector basis determined by the assumptions made to accommodate the availability of data. A 30 year period was modelled, from 1995 to 2025. The 1995 base year comprises an extensive data set. This data was then projected using various economic and other drivers to create a credible baseline. Given the options applicable and having determined the potential fuel consumption for each sub-sector for the baseline, an estimate for the reduction of energy demand and greenhouse gas emissions with the costs associated can be compiled for mitigation. The Long-range Energy Alternatives Planning System (LEAP2000) and Microsoft Excel were the tools used for modelling the energy system and compiling emissions and associated costs for the generation of a mitigation cost curve.

## 2 METHODOLOGY

The following methodology was used to determine a greenhouse gas emissions baseline from 1995 to 2025, the period modelled in LEAP2000:

1. Estimate industrial sector activity and fuel activity shares from energy consumption data.
2. Calculate the annual energy consumption by fuel using energy intensities and energy balances.
3. Estimate emission coefficients for each type of fuel for $CO_2$, $CH_4$ and $NO_2$ (IPCC Tier 1 default emission factors).
4. Multiply emission coefficients by fuel use to get total greenhouse gas emissions by type of fuel.

Population of a database and simulation and modelling of South African industry energy demand was done in LEAP2000 with some calculations on Excel spreadsheets.

### 2.1 Definition of industrial sector activity

Table 2 shows subsector energy consumption for the base year, 1995, defined through: production (activity level), energy intensity, and percentage input fuel shares in each of the respective subsectors.

### 2.2 Data collection

Energy data for the base year was taken from Department of Minerals and Energy's sectoral energy balances compiled by Cooper (1997), South African Energy Balance for 1995, unless otherwise indicated. 1999 figures were not used due to poor availability of comprehensive data. Changes made to the base year data include:

- Biomass demand from the pulp and paper industry, and the sugar industry, which were derived from a bottom-up analysis.
- Coal demand for non-ferrous metals, the pulp and paper industry, the food and tobacco industry, and households was taken from Kenny (1999) as no data was given by Cooper.
- Electricity consumption by the pulp and paper industry and the food and tobacco industry was estimated from Kenny (1999).
- Diesel demand by coal mining was estimated, and moved from mining demand to coal mining transformation.
- Electricity supply statistics were taken from Eskom (1995) and the National Electricity Regulator (1995).

## 3 ENERGY CONSUMPTION

The baseline data for the model is dependent on current (the base year 1995) and future energy consumption (projections to 2025). The major assumptions for the baseline energy consumption are detailed here beginning with a general point of view in terms of the national aggregated consumption and then on a sub-sector-by-sub-sector industrial division basis. Future projections (detailed as per the base year data set), which provide a basis for the data that was modelled are outlined below. Due to the direct link between greenhouse gasses and energy consumption via emission factors, it follows that the quantification of emissions reductions (mitigation options) depends on energy savings.

### 3.1 Basic industrial energy consumption data

The industry sector in this report includes mining, manufacturing, construction and all processing, excluding the processing of energy from one form to another. In 1996, the South African Industrial Sector constituted 39 per cent of South Africa's total final energy consumption (1057 PJ out of 2555 PJ) and 57 per cent of her electricity (306 PJ out of 535 PJ) (Kenny, 1998: 4).

**Table 2 Industrial sub-sectors and percentage activity shares by input fuels (LEAP 1995 Data)**

| | Gold Mining | Other industry | Iron & Steel | Chemicals & Petro-chemicals | Non-ferrous metals | Non-metallic minerals | Pulp & paper | Food & Beverages | Other mining |
|---|---|---|---|---|---|---|---|---|---|
| **Total sub-sector Production** | **524T** | **N/a** | **8741000T** | **7700000T** | **1518000T** | **16700000T** | **3000000T** | **N/a** | **68000000T** |
| **Energy Intensity** | **160TJ/T** | **N/a** | **32.04GJ/T** | **13.03GJ/T** | **24.3GJ/T** | **4.246GJ/T** | **34.13GJ/T** | **N/a** | **0.784GJ/T** |
| **Energy Consumption** | **83.84PJ** | **102.10PJ** | **280.06PJ** | **100.33PJ** | **36.89PJ** | **70.90PJ** | **102.39PJ** | **109.86PJ** | **53.31PJ** |
| **Percentage Split of Energy Consumption by Fuel Across Sub-sectors** | | | | | | | | | |
| **Electricity** | 95.3 | 18.5 | 24.8 | 50.9 | 93.81 | 26.2 | 16.9 | 18.5 | 58.8 |
| **Coal** | 2.9 | 45.8 | 33.9 | 42.5 | 4.0 | 61.2 | 49.5 | 39.6 | 25.9 |
| **Diesel** | 1.2 | 11.0 | | | | | | 12.6 | 12.6 |
| **H2 rich gas** | 0.5 | 3.1 | 2.8 | 1.3 | 2.2 | 8.3 | | 0.7 | 0.9 |
| **LPG** | | 3.8 | | | | | | 0.2 | 0.2 |
| **Paraffin** | | 3.5 | | | | | | 0.5 | 0.5 |
| **Fuel Oil** | 0.1 | 4.2 | 2.5 | 0.6 | | 4.4 | | 1.0 | 1.1 |
| **Coke oven coke** | | 6.8 | 27.4 | | | | | | |
| **Petrol** | | 0.2 | | | | | | | |
| **CH4 rich gas** | | 3.1 | | 1.3 | | | 0.4 | | |
| **Bagasse** | | | | | | | | 40.1 | |
| **Refinery Gas** | | | | 3.4 | | | | | |
| **Coke oven gas** | | | 8.6 | | | | | | |
| **Wood** | | | | | | | 33.2 | | |
| **Totals** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** |

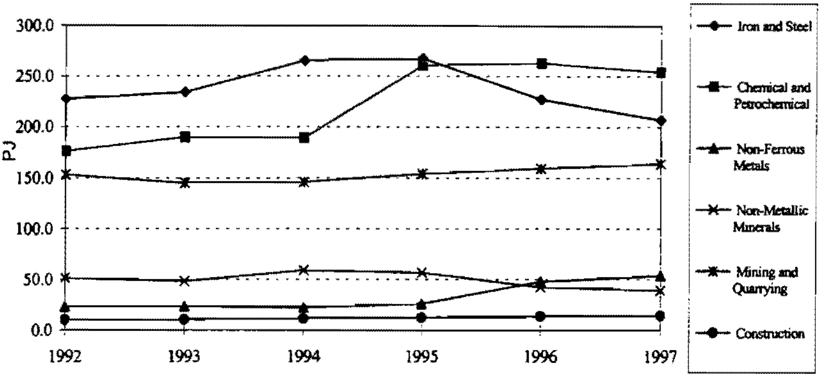
**Table 3 1996 energy consumption of industrial divisions**

| | Energy [PJ] | % of Industrial Consumption | Electricity [PJ] | % of Industrial Electricity |
|---|---|---|---|---|
| Iron & steel | 227 | 21 | 56 | 18 |
| Chemical & petrochemicals | 263 | 25 | 9.5 | 3.1 |
| Non-ferrous metals | 48 | 4.6 | 47 | 15 |
| Non-metallic minerals | 43 | 4.1 | 4.1 | 1 |
| Transport Equipment | 0.2 | 1.89 | 0.03 | 0 |
| Mining & Quarrying | 159 | 16 | 125 | 41 |
| Food & Tobacco | 109 | 10.2 | 20.4 | 6.7 |
| Paper, Pulp & Print | 106 | 10.0 | 20.1.4 | 5.7 |
| Wood & Wood Products | 2.4 | 0.2 | 2.1 | 0.7 |
| Construction | 14 | 1.4 | 0.06 | 0 |
| Textile & Leather | 1.9 | 0.2 | 1.8 | 0.6 |
| Non-specified | 79 | 7.5 | 18.3 | 6.0 |
| Total for Industry | 1057 | 100 | 306 | 100 |

Table 3 shows the energy consumption of the various divisions within the Industrial Sector in 1996. The table shows the largest user was the chemical and petrochemical division which used 25 per cent of industrial energy although only 3 per cent of its electricity. This does not include the refining of crude oil to petroleum and other products nor the conversion of coal to liquid fuels. The second largest user was the iron and steel division, which uses 21 per cent of industrial energy and 18 per cent of its electricity. In previous years, iron and steel had been the largest user (see Figure 1 below). The third largest user was mining and quarrying with 17 per cent of industrial energy; this was however the largest user of industrial electricity with 41 per cent of the total. The food and beverages division follows, with 10 per cent of energy and 7 per cent of electricity, and paper, pulp and print with 10 per cent of energy and 7 per cent of electricity. Non-ferrous metals and non-metallic minerals each use 5 per cent of total industrial energy. The largest energy user in non-ferrous metals is in the electricity intensive aluminium-smelting industry. The largest in non-metallic minerals is the manufacture of cement. The large division "Non-Specified" which consumes 7 per cent of the total energy of the industrial sector, takes the wide range of small consumers into account (Kenny, 1998: 5).

Figure 1 below shows the historical trends in total energy use by the main industrial divisions, excluding Food and Tobacco and Paper, Pulp and Print, from 1992 to 1997.

**Figure 1 Industrial energy demand by main divisions from 92 to 97**[1]




## 3.2 Future industrial energy consumption projections

Future energy demand in South African industry depends on a number of factors including economic growth, the changing structure of the economy, and the volumes and nature of our exports. It also depends on policy decisions: decisions by parastatals such as Eskom on investing, costing and subsidy; decisions by the South African Government on tariffs and support, and on environmental legislation; and decisions by the international community on environmental issues such as greenhouse gases.

### 3.2.1 *Natural gas*

The introduction of natural gas into the country via various gas fields discovered would change the balance of the types of energy in South Africa. Industry is well suited to use natural gas as it is a large user of energy and has an anchor market in big plants, unlike the residential sector. Natural gas is cleaner and easier to use than coal or oil and releases less carbon dioxide per unit of energy. Piped SASOL gas (both methane-rich and hydrogen-rich gas), is already supplying some industry. The hydrogen rich gas from Sasol 1 at Secunda is piped to the Gauteng region and also supplies the steel-making plants. It has a calorific value of about 18 to 20 MJ / cubic metre. The methane rich gas comes from Sasol 2 and 3 at Secunda and has a calorific value of 33 to 36 MJ / cubic metre. Utilisation of the Kudu gas field could be effectively be established between 2004 and 2007, and the feasibility of building a gas pipe down to Cape Town is currently being studied (Keny, 1998: 25).

### 3.2.2 *Other fuel trends*

Following electricity trends seen in other countries, it is likely that South Africa will also follow these trends of electricity taking up an increasing fraction of industrial energy. Coal use will probably increase absolutely for another ten to twenty years and then steady out or decline due to electricity being mostly generated by coal-fired power stations. The use of coke from coking ovens will probably decline further, given South Africa's poor reserves of coking coal. Liquid fuels are likely to be increasingly expensive in real terms in about ten to twenty years time and this can already be seen by the recent rises in crude price.

### 3.2.3 *Mining*

For the mining sector a 3 per cent (approx. 1.3 per cent up to 2004 thereafter 0.8 per cent/per annum) yearly increase in energy demand was assumed due to demand for minerals. This would give a total energy demand of 354 PJ, consisting mainly of electricity with some liquid fuel and a bit of coal and natural gas (*Op cit.*: 26). Gold, production is likely to decline but with increasing depths and poorer ores, the amount of energy required will increase. Ultra-deep mining, to depths down to 5000 m, could extract again almost as much gold as has been mined in the past, but is only likely to happen with a large and sustained increase in the price of gold with the increased working of mine dumps offering a limited counteraction (Minerals Bureau Bulletin, 1998: 2). Energy consumption in platinum mines is expected to show significant growth in the medium term with platinum consumption levelling off due recovery, and the less material needed for catalysis reactions. Some projections from other mining include (Prinsloo, 2001):

- A number of new platinum mines and a new smelter at Pietersburg have been proposed.
- Coal mining in South Africa is expected to show moderate growth.
- Iscor is presently building an iron and titanium mine in Empangeni.
- The future expansion of Anglo-American Namaqua sands is expected over the medium term.
- Zinc mining is expected to get a boost from future zinc plants such as Gamsberg.
- The expansion of the Premier diamond mine near Cullinan is expected to occur in the medium term.

- A feasibility study is underway looking at a large-scale expansion of the Avmin/Nkomati nickel mine in Mpumalanga at a capital expenditure of around R1.6bn.
- There are also plans to deepen and extend the life of the Black Mountain Mine which produces mainly lead and zinc.
- Over the longer term, the proposed Haib copper mine, Immediately north of the South Africa/Namibia border indicates some potential for copper mining.

### 3.2.4 *Iron and steel*

Conventional iron and steel production in South Africa is not expected to show any significant growth in the future as the demand for carbon steel has actually levelled off. The future growth of South Africa steel depends on the local market, which has been weak for nearly three decades, and the world market, which has been better but still sluggish. The SA Department of Mineral and Energy Affairs (DME) in 1992 gave the following three projections for steel production until 2015: (i) "survival" at 1.5 per cent growth per annum (ii) "moderate" at 2.7 per cent, and (iii) "fast growth" at 5.0 per cent Granville, (Stanko & Freeman, 1992: 103).

### 3.2.5 *Chemicals and petrochemicals*

Future energy consumption in the chemical and petrochemical division in South Africa is difficult to assess because of the uncertain prospects for coal, the biggest energy and feedstock source now. The products of this division are likely to have an expanding market especially in exports. Sasol Chemical Industries at Sasolburg will within the near future be using natural gas instead of coal, with natural gas used as a compliment for any expansions at Secunda. South Africa has estimated coal bed methane reserves of about 90 billion cubic metres (3300PJ), with the most promising field being at Waterberg. Sasol and African Explosives and Chemicals Industries (AECI) both wish to move towards higher value, smaller volume products which will require less energy per unit of production. Given these considerations, the maximum likely energy requirement for 2025 is a doubling of the present requirement, which would require 526 PJ in 2025 (Kenny, 1998: 30).

### 3.2.6 *Non-ferrous metals*

For Aluminium, only two more smelters are predicted to be built, pushing aluminium production up from 660 000 tons now to 1 660 000 tons by 2025, a 2.5 fold increase (*Op cit.*: 32). For Titanium an estimate of 1860 tons was assumed as Richards Bay Minerals and Namakwa Sands are both expanding their operations and Iscor has proposed projects to mine titanium ore in the Northern Province and at Richards Bay. The non-ferrous industry is projected to have a maximum energy demand of 130PJ by 2025 consisting mostly of electricity.

### 3.2.7 *Non-metallic minerals*

Cement making and brick-making dominate this division, which is almost entirely for domestic consumption. Thus, growth in energy demand depends on GDP, which is assumed to be at a 4 per cent rate between now and 2025 giving a demand of 122 PJ by 2025 (*Op cit*: 32).

### 3.2.8 *Pulp and paper*

Due to over-capacity and low prices in the pulp and paper industry, the chances of new mills being built look low. Thus, no significant growth is assumed with almost no improvement or limited improvement in energy efficiency expected for the baseline, and an expected demand of 158 PJ by the year 2025 (*Op cit.*: 33).

### 3.2.9 *Food and beverages*

Growth in the Food and Beverages division is likely to follow growth in GDP and exports. A growth rate of 4 per cent for GDP and exports was assumed, if the sugar industry, which is the dominant energy user, is able to produce increasing quantities and also assuming no improvement in energy efficiency, for the baseline, this gives a maximum energy demand of 340 MJ by 2025 (*Op cit.*: 33).

### 3.2.10 *Other industry*

The rest of industry is also assumed to grow by 4 per cent per annum to give a total demand of 243 PJ by 2025 (*Op cit.*: 33).

## 4 MODELLING AND SIMULATION

The Long-range Energy Alternatives Planning system (LEAP, 2000) was the simulation software package used to model, simulate and quantify energy and greenhouse gas emissions for South African industry. This software was chosen due to the flexibility and ease of use for structural changes, and integrated emissions factors for carbon accounting.

A baseline model was first built using an existing database of South African data with extensive revision and changes. Some structural changes (further disaggregating the demand sector structure) were made to accommodate the modelling of energy efficiency programs (mitigation options) in terms of energy demand. These changes involved the disaggregation of a subsector into two separate categories. One of the categories having a share of activities that the use only electricity (except process heating), the other the remainder of the energy consumed in the sector by all the other fuels, inclusive of electrical process heating. This allowed the modelling of energy efficiency of electrical activities (HVAC, motors) and fuel switching (electrical process heating *vs* gas). Costs, quantified in terms of the reduction in energy demand and subsequent emissions for power generation, were then applied to each of these mitigating options. The respective IPCC emissions factors applied to the power stations for electrical energy efficiency savings and to combustible fuels in the industrial demand subsectors for fuel switching enabled the collation of the actual greenhouse gas emissions reductions. The desired result, a mitigation cost curve of emissions versus costs.

## 5 RESULTS

A summary of final energy consumption (demand) can be seen in Figure 2, which forms the basis for the emissions baseline.

The total emissions from the industrial sector for the baseline can be seen summarised in the Figure 3 below (with actual figures shown alongside on the right of every entry.

**Figure 2 Baseline final energy demand for industry for 1995-2025**

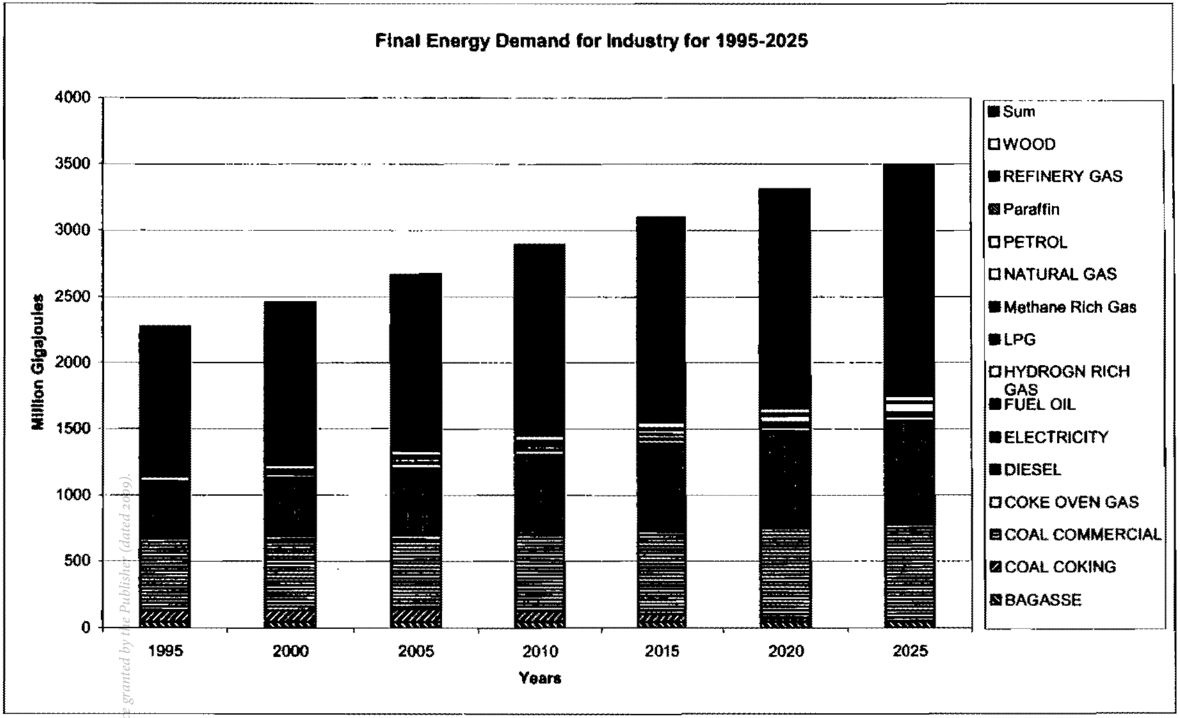
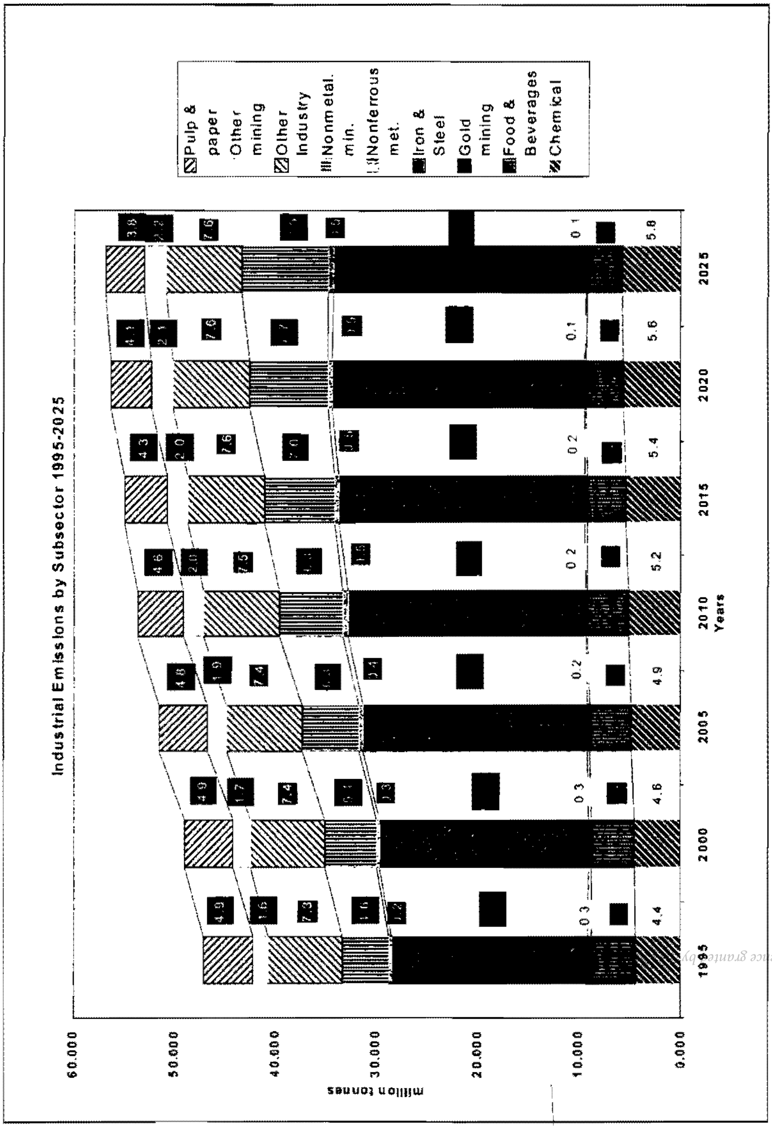


**Figure 3 Baseline industrial emissions by sub sector for 1995-2025**



## 6 MITIGATION OPTIONS

For credibility and reference, it was particularly important that the options presented should be applicable to the South African industrial sector especially for the short to medium term. This principle was used as a guideline to determine the mitigation options chosen and the extent to which they could be implemented in the longer term. Thus out of the three groups of mitigation options: process switching, fuel switching and energy efficiency; only the two groups, fuel switching and energy efficiency were considered.

### 6.1. Fuel switching

A basis for fuel switching is established through estimates of the ratio of conversion from final to useful energy for different fuels and equipment. The following efficiencies have been assumed for the equipment (mostly boilers) considered. It was assumed that steam systems were 80 per cent efficient.

**Table 4 Efficiency assumptions for technologies**

| Fuel technology | Overall efficiency including steam system losses |
|---|---|
| Electrical process heating | 75 |
| Coal fired boilers | 60 |
| Oil fired boilers | 65 |
| Wood fired boilers | 60 |
| Gas fired boilers | 70 |

Electricity can also be fuel switched, as no emissions are given off at the point of use, but coal is inefficiently transformed in power stations (compared to direct use), and it is here where the emissions are accounted.

#### 6.1.1 *Oil and coal fired boilers to natural gas*

Assumptions for switching from oil and coal to natural gas are that:

- In the baseline, natural gas becomes available in 2006 and by 2025 supplies 9 per cent of useful thermal energy to industry.
- In the mitigation option, the natural gas share was assumed to increase to 25 per cent, displacing coal and oil (14 per cent of industries consumption of fuel).
- The cost of implementing the actual mitigation option only was negligible (De Villiers, 2000) relative to the fuel cost, which takes the difference in fuel costs (of coal and oil compared to natural gas) into account.

### 6.1.2 *Electrode boilers to natural gas*

Assumptions for switching from electrical systems to natural gas are that:

- The cost of adapting a system would cost of the order of R20 000 per 1000kg/hr (*Op cit.*).
- Industrial boilers operate all day for 11 months of the year.
- 10 per cent of electrical heating could be replaced by gas over the period.

The penetration rate of natural gas over the base case is low, and that issues of reserves and distribution may limit its use as a fuel. As natural gas will likely be imported, increased use will result in a negative effect on the balance of payments. This will be offset slightly by the oil displaced, which has low quantities compared to coal.

## 6.2 Efficiency improvements

The following thermal efficiency improvements for each boiler type is given below, relative to a business as usual scenario:

**Table 5 Boiler thermal efficiency improvements**

| Boiler type | Assumed boiler losses (recoverable) | Assumed recoverable steam system losses | Overall potential savings used for this study |
|---|---|---|---|
| Coal | 20% (5-8%) | 20% | 20% |
| Oil | 15% (3-6%) | 20% | 18% |
| Gas | 10% (2-4%) | 20% | 16% |
| Electrode | 5% (1-2%) | 20% | 15% |

The cost savings data is determined by the relative costs of fuel and potential efficiency improvement. It is also assumed that the potential savings are only fully realised at the end of the scenario period.

### 6.2.1 *Compressed air*

For compressed air systems it was assumed that a 20 per cent improvement was possible by 2025. This is consistent with estimates from several studies (Kenny & Howells, Anglogold, SAB & Sappi Mandini, 2000). It was assumed that, functionally, up to 40 per cent (Fawes, Van Es, Khumalo & Howells, 2001) of compressed air could be saved in South African industry by better management. A well-managed compressed air system will have a leak rate of less than 10 per cent (Trikam, Howells & Drummond, 2000). These savings were assumed to have a payback of one month (Fawkes *et al.*, 2001) and ten percent of the cost saving per year can be dedicated to maintaining these savings. This option lowers electricity consumption, thus pollution from electricity generation should be reduced.

### 6.2.2 *Variable speed drives (for fans)*

Variable speed drives in some applications can reduce electrical demand by closely matching demand during times of low output, and thus draw less electricity and therefore less greenhouse gas emissions associated with electrical generation. It is reported that for fans savings can amount to 30 per cent (De Villiers, 2000), which was felt to be optimistic, and reduced to 25 per cent saving. It was assumed that only 25 per cent of existing fans in industry would be eligible for replacement VSDs. The application of VSDs for pumping, HVAC and other motors was in applications such as mining was not considered, due to the extra control requirements, which would need to integrated into the system. Potential in gold mining, for example, does exist for complete automation and VSD control as part of an integrated approach, consequently, VSDs have not found extensive application in Gold mining[2].

### 6.2.3 *Electrical motors*

For electrical motors mitigation option, High Efficiency Motors (HEMs) with efficiency improvements of 1-5 per cent (Geldenhuis, 2001) over the period modelled (1995-2025), are probably realisable in the South African context. Other potential savings options include: motor downsizing, minimising load, cutting the power supply during no load times and the further application of variable speed drives.

The following assumptions were made for the motor stock in South Africa:

- A modest 1 per cent improvement could be realised per motor over the base case over 25 years,
- The average life of the motor was 10 years,
- The increased capital cost per motor was \$7.3 per kW[3]
- The average load factor was assumed to be 70 per cent
- The systems that would be affected by introducing high efficiency motors include: fans, HVAC, pumping and motors.

### 6.2.4 *Lighting*

Using higher efficiency lamps, switching them off when not needed and in sunny areas making use of skylights present a significant opportunity for electricity and therefore greenhouse gas saving. Much of the lighting energy is used on the factory floor. The assumptions are taken from the VW case study[4]. The assumptions used for this mitigation option are as follows:

- A saving of 30 per cent of electrical lighting energy for 30 per cent of installations over the base case by 2025[5].

### 6.2.5 *Efficient HVAC systems*

Various measures can be taken to help improve the efficient operation of heating ventilation and cooling systems (HVAC). These include, amongst other things (Kenny, Trikam, Howells & Drummond, 2000):

- Ensuring minimum hours of operation
- Proper maintenance of heat exchanger surfaces
- Waste heat utilisation
- High efficiency motors and VSDs (this has been captured in another section, and not included here.)

It was assumed that 50 per cent of HVAC systems could have their efficiency improved by about 20 per cent. A recent report suggested that 37-25 per cent of energy consumption could be reduced in South African installations (De Villiers, 2000) over the baseline for old and new systems respectively. The measures were anticipated to have a three-year payback with ten percent of fuel cost savings dedicated to maintaining savings. Similar studies in local industry show one-year paybacks (Kenny & Howells, 2000) all with conservative costs.

## 7 EVALUATION AND DISCUSSION

This section describes the effects of some of the options outlined above, with Table 6 showing a summary and evaluation of mitigation options according to selected criteria set out by the South African country study process and then the presentation of the mitigation cost curve derived from LEAP2000. In Table 6, each option was quantified and assessed as either positive, negative or have no effect. The criteria considered include: local environmental issues, macro economic effects and social impacts and was used as a basic standard of comparison with the country study.

## 7.1 Effects of electricity based options

The effect of compressed air, VSDs, HEMs and lighting mitigation options is to lower electricity consumption, and therefore generation. This has the effect of delaying the construction of new plant, which helps optimise the electricity resource system. Pollution from the generation of electricity versus the base case should be reduced. There may be a negative impact in terms of a loss of jobs associated with reduced coal mining and new power plant activity. This however should be counterbalanced against a possible improved export markets for cleaner goods, and the extension of the life of the coal industry. The money saved would also increase economic performance, increase taxable revenue, and likely be re-invested in other sector offsetting initial job losses

## 7.2 Effects of boiler efficiencies

### 7.2.1 *Coal fired boilers*

The effect of improving coal fired boiler efficiencies extends the life of local reserves, and reduces local pollutants. There may be some negative employment effects due to reduced coal production. This however should be counterbalanced against a possible improved export markets for cleaner goods, and the extension of the life of the coal industry. The money saved would also increase economic performance, increase taxable revenue, and likely be re-invested in the economy offsetting initial job losses. The same comments are applicable for saving steam produced from coal-fired boilers.

### 7.2.2 *Oil fired boilers*

The effect of improving oil fired boiler efficiencies reduces oil consumption, and therefore crude imports and reduce local pollutants. As a result, the effect on the balance of payments would be positive. Other effects may include improved export markets for cleaner goods. The money saved would also increase economic performance, increase taxable revenue, and likely be re-invested in the economy. The same comments are applicable for saving steam produced from oil-fired boilers.

### 7.2.3 *Gas fired boilers*

The effect of improving gas fired boiler efficiencies reduces gas consumption, and therefore for LPG, crude imports; for natural gas, gas imports; and for synthetic gas lower local outputs. This measure will also have the effect of lowering local pollutants. In the case of LPG and natural gas the effect on the balance of payments would be positive due to a reduction of imports. Other effects may include improved export markets for cleaner goods. The money saved would also increase economic performance, increase taxable revenue, and likely be re-invested in the economy. The same comments are applicable for saving steam produced from gas-fired boilers.

The negative impact on the trade balance of the electricity to natural gas option is due to the importing of natural gas compared to the local electricity generation. Due to the positive cost per ton of the coal and oil to natural gas option, there is a negative impact on the trade balance and on international competitiveness.

### 7.3 Mitigation cost curve

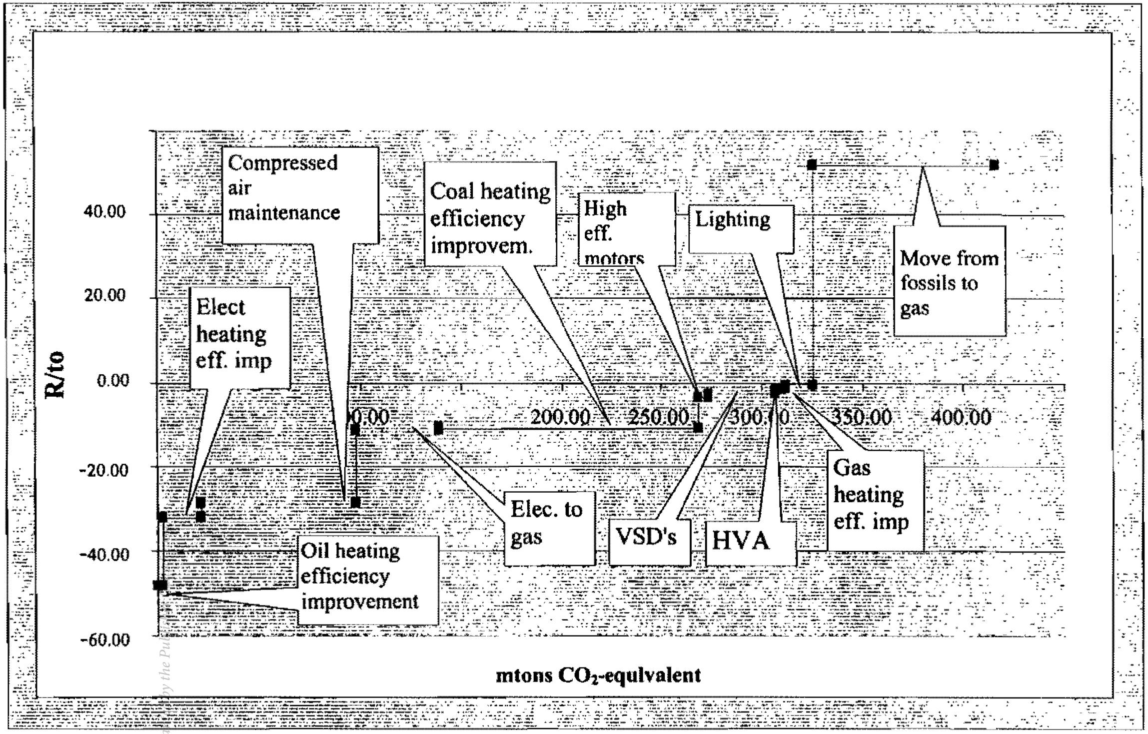
By dividing the life cycle cost (using a discount rate of 11 per cent) of the mitigation option for the period considered by the number of tons of carbon dioxide equivalent saved for the period, together with the total number of tons a mitigated 'cost curve' can be constructed. This cost curve gives an indication of the quantities of $CO_{2\ equivalent}$ that can be mitigated and the cost effectiveness of the measure. In the calculation of the total costs, all capital costs, operating and maintenance costs and fuel costs have been taken into account.

**Table 6 Summary and evaluation of mitigation options**

| | **Reduction in GHG emissions** | **Local environmental impact** | | | | **Cost effectiveness** | **Macro economic effects** | | **Social impacts** | |
|---|---|---|---|---|---|---|---|---|---|---|
| GHG mitigation measure | Million Tonnes of $CO_2$ | Soil conservation and biodiversity | Water resources and biodiversity | Air quality (non-GHG emissions) | Leakage | (R/ton) | Impact on the trade balance | Impact on international competitiveness* | Social equity and poverty alleviation | Job creation |
| Efficient oil heating | 2 | Zero | Zero | Positive | Zero | -48.4 | Positive | Positive | Zero | Positive |
| Efficient electrical heating | 19 | Zero | Zero-mildly positive | Positive | Zero | -32.5 | Zero | Positive | Zero | Positive |
| Compressed air systems | 76 | Zero | Zero-mildly positive | Positive | Zero | -28.9 | Zero | Positive | Zero | Positive |
| Electricity to natural gas | 42 | Zero | Zero-mildly positive | Positive | Zero | -11.4 | Negative | Positive | Zero | Zero |
| Efficient coal heating | 129 | Zero | Zero | Positive | Zero | -11.1 | Zero | Positive | Zero | Positive |
| Efficient motors | 5 | Zero | Zero-mildly positive | Positive | Zero | -3.8 | Zero | Positive | Zero | Zero |
| Variable speed drives | 33 | Zero | Zero-mildly positive | Positive | Zero | -2.7 | Zero | Positive | Zero | Zero |
| Efficient HVAC | 1 | Zero | Zero-mildly positive | Positive | Zero | -1.81 | Zero | Positive | Zero | Positive |
| Efficient gas heating | 4 | Zero | Zero-mildly positive | Positive | Zero | -1.7 | Positive | Positive | Zero | Positive |
| Lighting | 13 | Zero | Zero-mildly positive | Positive | Zero | -0.78 | Zero | Positive | Zero | Zero |
| Coal and oil to natural gas | 91 | Zero | Zero | Positive | Zero | 51.9 | Negative | Negative | Zero | Zero |

*Assuming that industry is bearing the cost of this mitigation option, including possible savings

**Figure 4 Mitigation cost curve for South African industry**



# 8 GHG CASE STUDY – VW UITENHAGE

## 8.1 General background

This section is based on an energy efficiency case study and an energy consumption monitoring and verification study conducted for the Volkswagen SA (VW) Uitenhage plant A. It should be stressed here that this report is intended as an illustration of greenhouse gas emissions that can be saved because of energy efficiency measures undertaken. For further information or detail on the study, please see the full reports.

### 8.1.1 *Energy forms and use in the plant*

Electrical energy is used for operating much of the process-related equipment (conveyors, robot welders, hand welders), for air conditioning in offices, for lighting, for workplace fans, water chilling fans, water chiller units, fluid pumping (water and thermic oil) and for compressing air. Heavy fuel oil (HFO) is used to heat thermic oil in boilers. Thermic oil is then pumped to ovens in the Paint Shop. Liquid petroleum gas (LPG) is used for air heating. It is used to control the temperature of air for the spray areas and for heating ovens in the Paint Shop. Paraffin is used as a solvent and for heating wax polish to a workable temperature.

### 8.1.2 *Current energy conservation and waste minimization practices*

Some significant energy and cost saving measures implemented include the following:

- High efficiency lighting (High Pressure Sodium) has been installed in the Receiving and Container Warehouses (approximately 40 per cent of existing lamps).
- Lights in the Press Shop were turned off during the daytime.
- Outside air has been ducted to intake ports of the main compressors allowing them to operate efficiently.
- Sections of old dirty fibreglass skylight panels have been replaced with clear or translucent polycarbonate in some areas of the plant thereby allowing a lot more natural light to enter the plant during the day (particularly the Press Shop and the Receiving Warehouse).
- A number of sources of wastage (compressed air, effluent, power factor) had already been identified by the engineers at Plant A. Investigations by consultants had been carried out and recommendations been made.

- In response to investigations into compressed air wastage, VW engineers have acquired airflow monitoring equipment and they are in the process of installing the sensor mountings and setting up data-logging equipment.

### 8.2 Energy and carbon accounting

Greenhouse gas emissions that are the result of energy usage can be accounted for through energy accounting via the use of the appropriate emission factors. The tracing of energy usage and costs in a plant can assist in the identification of possible areas of cost effective, greenhouse gas, emission reductions. Some common practices include:

- Energy Management
- Electric Bill Sample Calculation
- Summary of Energy Usage and Costs
- The avoided cost of energy

### 8.3 Abatement mitigation options

From on-site investigations and information gained from collected data, the following Abatement Mitigation Options (AMO) were identified and their respective energy savings, emissions reductions, costs and payback periods shown below:
AMO 1 – Repair compressed air leaks and faulty blow-down valves
AMO 2 – Avoid and discourage misuse of compressed air
AMO 3 – Switch off ER compressors and main cooling towers during non-production time.
AMO 4 – Isolate areas of the plant or individual machines that do not require compressed air during non-production time
AMO 5 – Use waste heat from refrigerant condenser to pre-heat phosphate bath
AMO 6 – Install High-Efficiency Lighting
AMO 7 – Install Skylights and photo-sensor light controls
AMO 8 – Turn off bay lights during non-production hours
Additional Items Considered (AIC) Identify and switch off equipment that is not essential during non-production time.

**Table 7 VW mitigation options summary**

| | Energy Conservation | Total $CO_2$ Emissions reduced | Cost Savings | Implementation Cost | Payback Period |
|---|---|---|---|---|---|
| AMO1 | 2222639 MJ/yr | 607.280T | R1859860/yr | R 60 000 | 2 weeks |
| AMO2 | 207981.5 MJ/yr | 56.826T | R173840/yr | R 30 000 | 2 months |
| AMO3 | 167580MJ/yr | 45.787T | R108459/yr | none | immediate |
| AMO4 | 387334 MJ/yr | 105.829T | R250686/yr | R40 000 | 2 months |
| AMO5 | 185185 MJ/yr | 29.802T | R190000/yr | R 300 000 | 19 months |
| AMO6 | 69512 MJ/yr | 182.927T | R239473/yr | R 726 936 | 3yrs |
| AMO7 | 223549 MJ/yr | 61.079T | R303314/yr | $2,844,900 | 5+ yrs |
| AMO8 | 742404 MJ/yr | 202.843T | R446190/yr | None | Immediate |
| AIC | 1633333 MJ/yr | 446.267T | R1057106/yr | Not estimated | Not estimated |

## 8.4 Monitoring and verification

The monitoring and verification of the abatement options is considered very crucial as it verifies that the projected savings to be realised and what quantities need to be monitored in order to realise these savings.

Energy and cost saving measures are only likely to be effective and sustainable where these measures form part of staff performance reviews. Ideally, where the cost of full instrumentation is possible, performance reviews could include defined monetary targets. It is recognized that review systems may not generally be in place and, consequently, any energy management recommendations rely on the diligence of departmental managers and their staff as a minimum.

The overall site electricity consumption data collection systems should remain. It is assumed that data collection would be undertaken centrally, possibly in the finance department. Disaggregated data must be sent to departmental heads for inclusion in their existing reports. Clearly, actual consumption data should be compared with target values and any variance, quoted in both energy and monetary terms, must be accompanied by an explanation. Strong consideration should be given to including energy consumption figures in departmental budgets.

For more effective energy management it is recommended that a dedicated Energy Manager be employed within the Finance Department with overall

responsibility for achieving economical operation of the whole site and co-ordinator for energy conservation measures.
Some of the abatement options have clear guidelines for monitoring and verification application, but all should consider the following:

i. Quantities to be monitored
ii. Metering equipment and costs
iii. Energy management required.

### 8.5 Total cost of M&V plan

The estimated total cost of all the monitoring is 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 per cent of this value. In addition, an energy Manager would cost the company a further R150 000 per year. These costs include measures not shown above.

## 9 CONCLUSIONS AND RECOMMENDATIONS

All mitigation options, apart from moving from fossil fuel to gas, can be considered financially feasible mitigation options in the industrial sector. It can be seen from the mitigation cost curve that the only option that has a positive cost in R/ton of $CO_{2\ \mathrm{equivalent}}$ is switching from fossil fuel to gas. Coal heating efficiency improvements provide the largest carbon dioxide equivalent emission reduction, while oil heating efficiency improvements provides most cost-effective mitigation option.

It is recommended that better data collection and iterations of the modelling process should be made to refine the quantification of the emissions reductions from the various options for each of the sub-sectors.

## ENDNOTES

1 COOPER C. S A Balances 1992-1997. Institute of Energy Studies. Rand Afrikaans University. This figure does not contain biomass data.
2 Based on comments from the control room staff at Anglogold mine Elandsrand in Carltonville, 2000.
3 'Motor master' software of the US Department of Energy's Motor challenge programme. Assuming a 75Hp motor.
4 Of the options investigated (skylights, turning lights off during non-productive hours and high efficiency lighting upgrade) high efficiency

upgrades were chosen, as this represents an easily measured option. It also does not represent the full spectrum of savings, and therefore probably understates the potential savings and at a higher cost. This is consistent with the philosophy of the report, which seeks to identify realisable mitigation options.

5 Table showing comparison of Mercury vapour to Metal Halide lights.

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