Strategy to reduce the health impacts associated with air pollution from fuel combustion

5 December 2003

DRAFT FINAL REPORT

Executive summary

Objective and scope

The primary objective of the study was provide an assessment of the social and economic impact of the phasing out of air pollution from combustible fuels in the country over a period of time, and to provide specific guidance on supply side measures to support the process.

The study investigated emissions resulting from ddomestic fuel burning, power generation industrial activity, transport and activity in the agriculture sector.

It is important to recognise that the scope of this study was limited in that it only included the quantification of inhalation exposures due to fuel burning related atmospheric emissions. It does not quantify emissions or impacts associated with other sources of emissions. The emissions identified were SO_2, NO_x, particulates, CO, lead, VOCs, (CO_2, CH_4, N_2O).

It must also be considered that although the study investigated emissions and their sources at conurbation level, impacts were considered from a national level and the overall strategy is at national level

The following conurbations were included in the study:

- Cities of Johannesburg and Ekurhuleni, Tshwane, Cape Town and Ethekwini
- Mpumalanga Highveld
- Vaal Triangle

For air pollution prediction the US-EPA approved Gaussian Puff air dispersion model was used, and limited to first order chemical transformation (secondary particulate formation), therefore excluded photochemical modelling (and ozone generation prediction). In determining impacts consideration was given to local versus global scale impacts, inhalation-related human health risks and risk of paraffin poisoning, burns. Priority was given to interventions suitable for implementation at national level

Key findings and conclusions

The strategy devised to reduce air pollution from fuel combustion is the culmination of extensive investigation, which considered international practices, the South African policy and regulatory environment, the current sources and impacts of air pollutions within different conurbations, and the socio-economic impact of various potential interventions identified.

The following are key conclusions from these investigations:

a) There are varied implementation options available for facilitating or forcing intervention, such as regulation, market mechanisms, and education.

b) Ranking of source significance should be based on impact rather than emissions. The following are at aggregate level the contribution of primary fuel burning sources to health impacts:

   - Domestic fuel burning: 69% (but reducing, 64% by 2011)
   - Vehicle emissions: 12 % (and growing, 15% by 2011)

- Electricity generation: 6% (similarly 7% in 2011)
- Coal fired boilers: 4% (similarly 4% in 2011)
- Other sources (primarily industrial sources) : 9% (and growing, 11% by 2011)

c) The results of the socio-economic impact assessment of interventions considered are summarised as follows:

	Int	Economic	Financial NPV	Employment			Financial Stakeholder Analysis (Rm)		
	No	B:C Ratio	(R millions)	Direct Jobs	Indirect Jobs	Total Jobs	Government	Firms	Households
1 Basa Njengo Magogo - DME ICHES	1	177.0	756.3	-41.2	388.4	347.2	413.9	-76.2	173.0
2 Basa Njengo Magogo - plateau roll out	2	120.1	1,123.4	-55.5	576.4	520.9	573.5	-180.7	315.3
3 Low smoke fuels	3	0.4	-3,591.8	375.1	-1,017.2	-642.1	1,177.5	1,317.5	-1,236.2
4 Housing insulation - 5% of plateau fuel burning households	4	6.0	262.9	-5.2	153.0	147.9	114.8	-32.6	106.5
5 Housing insulation - 20% of plateau fuel burning households	5	6.0	1,051.6	-20.7	612.2	591.5	459.0	-130.2	426.2
6 Housing insulation - 5% of all fuel burning households	6	7.9	426.1	-14.8	235.6	220.8	218.3	-32.8	134.1
7 Housing insulation - 20% of all fuel burning households	7	7.9	1,704.4	-59.1	942.3	883.2	873.0	-131.3	536.5
8 Electrification	8	1.2	1,044.2	1,687.0	1,948.9	3,635.9	2,035.3	1,825.3	-1,586.9
9 Stove maintenance and repair - 5% households all areas	9	16.5	325.1	-12.1	149.5	137.3	114.4	-166.4	167.6
10 Stove maintenance and repair - 20% households all areas	10	16.5	1,300.4	-48.5	597.8	549.3	457.8	-665.5	670.2
11 Desulphurisation of all PS emissions	11	0.0	-15,445.6	9,412.4	-954.5	8,457.9	1,301.0	-3,187.9	1,908.6
12 Decommissioning of PTA West PS - gas use by households	12								
13 RE technology implementation (10 000 GWh block)	13	0.3	-5,429.4	3,091.4	-600.7	2,490.7	386.9	-1,864.1	661.6
14 RE technology implementation (37 000 GWh block)	14	0.3	-6,340.7	3,167.7	-575.6	2,592.1	483.0	-2,261.9	778.1
15 Coal fired boilers for particulates (>90% control efficiency req.)	15	0.8	-190.6	577.3	374.4	951.7	446.7	-140.5	-211.3
16 Iscor coke oven gas cleaning	16								
17 Highveld Steel & Vanadium	17								
18 Desulphurisation of Sasol Secunda PS emissions	18	0.1	-1,933.6	1,011.1	-74.8	936.3	195.3	-501.4	263.6
19 Reduction of S content of petrol to 500 ppm (0.05%)	19								
20 Reduction of S content of petrol to 50 ppm (0.005%)	20	0.0	-1,115.8	0.0	0.2	0.2	-44.4	-303.1	-639.0
21 Reduction of benzene content of petrol to 1%	21	0.0	-1,094.4	-1.2	7.0	5.7	-32.9	-612.5	-323.9
22 Reduction of aromatics content of petrol to 35%	22	0.1	-1,235.3	-17.0	95.3	78.3	103.9	-422.4	-810.2
23 Phasing out of lead in petrol	23	0.0	-347.6	67.8	-72.6	-4.8	20.8	331.4	-312.0
24 Reduction of S content of diesel to <500pm (0.05%)	24								
25 Reduction of S content of diesel to <50ppm (0.005%)	25	0.5	-442.0	-33.1	237.4	204.3	276.4	-852.4	126.8
26 New passenger vehicles comply with Euro 2 standards	26	1.0	626.6	-36.0	260.7	224.8	410.1	-8.4	73.0
27 New passenger vehicles comply with Euro 4 standards	27	1.0	419.9	-29.4	213.7	184.3	279.6	-5.4	42.2
28 Taxi recapitalisation programme	28								
29 All petrol vehicles EURO 2 compliant	29	1.0	1,054.2	-73.9	536.9	462.9	702.4	-13.5	105.5
30 Conversion of 10% of petrol vehicles to LPG	30	1.0	-2,382.6	2,364.2	-215.4	2,148.8	122.6	1,702.7	-1,312.7
31 Conversion of 20% of petrol vehicles to LPG	31	1.0	-4,765.3	4,728.4	-430.9	4,297.6	245.2	3,405.5	-2,625.5
32 Electrification of paraffin burning households	32	1.3	1,410.2	1,300.4	2,035.5	3,335.8	1,659.4	1,325.5	-1,215.6

d) From a financial and economic perspective low (or existing) technology interventions in the domestic (household) sector can yield significant benefit in the short to medium term. These are Basa Njengo Magogo, housing insulation and electrification.

e) Low smoke fuels in the domestic sector is not attractive unless a lower cost technology can be developed.

f) Interventions related to changes in fuel specifications and vehicle technology standards need to be re-examined from a holistic perspective.

g) Electricity generation interventions implementing high technology on the supply side (desulphurisation of power stations, renewable energy) are not feasible from a financial and economic perspective. The study did not consider renewable technologies on the demand side, for example solar heating at household level.

h) The benefit of industrial interventions depends on scale, location and technology factors.

i) The bulk of savings due to reduced pollution would go to government, primarily due to reduced spending in the public health care industry.

j) There is a sufficient number of households in the domestic sector to allow for the implementation of multiple interventions without risk of deterioration of benefit:cost ratio's of identified interventions.

k) In practice it is not expected that the interventions proposed will result in significant employment loss, in general.

l) The implementation of an appropriate measurement and monitoring system in South Africa is a pre-requisite for implementation of this strategy (and the Air Quality Bill for that matter).

m) Market incentives as well as taxes and charges show more promise in developing countries than tradable permit systems.

The long-term goal to reduce air pollution from fuel combustion

Reduce the negative health effects associated with air pollution due to fuel combustion in the short-to-medium term, with the purpose of reducing the associated health cost (and associated cost of R 4.7 billion p/a) by 50% by 2011, in a cost effective manner

Although there is inherent variance with regards to health impacts determines (and costs calculated), a conservative approach was followed throughout the study and the numbers can be regarded to be realistic.

Over-arching themes that guides the strategy

a) Focus on reducing the effects of air pollution. A key theme that emerged from this study is that the aim of all actions to manage air pollutions should be driven by the impact of emissions, and not the emissions itself.

b) Flexible and multiple approaches in defining actions aimed at reducing the negative impacts of air pollution. A critical point is that a uniform, 'one size fits all' centrally administered regulation, that sets a single acceptable level for any emission, cannot be economically efficient. Numerous approaches ranging from education to awareness to the implementation of market mechanisms such as taxes and levies should be considered.

c) Close collaboration between national, provincial and local government in the development and implementation of initiatives and interventions. Since local and provincial quality managers be given responsibility for implementation of interventions. It is therefore imperative that national government work closely with these authorities in devising implementation strategies.

d) Focus on "low hanging fruit" in the short terms whilst developing appropriate solutions for the longer term. This study identified numerous relatively low technology solutions which if implemented in the short-to-medium term will yield significant (up to 40%) reduction in the negative health impacts associated with pollution from fuel combustion. This creates a window of opportunity to develop more high technology, and economically feasible solutions for the longer term.

Strategy to reduce the health impacts associated with air pollution from fuel combustion

The strategy is defined in terms of strategic objectives that need to be pursued and specific initiatives which if implemented should realise the objectives. The strategy also identified three cross cutting issues that need to be addressed.

Cross cutting issues:

The need for measurement and monitoring.

This relates not only to the need of a sound system for monitoring emissions levels, but also to the continuous monitoring of progress of implementation of the interventions recommended.

- Emissions and air quality monitoring systems must be put in place as soon as possible
- Provision must be made for the establishment of monitoring protocols.
- Mechanisms be established for the rapid sharing of information between local, provincial and national government.
- The proposed Air Quality Bill provides for additional human and financial resources for enforcement and management at provincial and local level. It is of utmost importance that these additional resources be deployed.

The importance of education and awareness

Education and awareness is of specific importance for a number of reasons. The first is that the health impact of pollution (and associated costs) is generally not known to stakeholders across a broad spectrum. This study provides the basis to answer many of these questions, and the value to be derived from disseminating the information collected as part of this study, and resulting from continuous monitoring as discussed, should be realised. The following are specific actions to be considered:

- Mechanisms should be implemented for communicating air quality information to the public on a routine and on-going basis
- The effect of current public disclosure programmes be assessed and used as input to such programmes

Continued research and development

Many of the initiatives recommended for implementation are only possible because they were pioneered through research. Basa Njengo Magogo can be considered to be a uniquely “African” solution, and it is commonly accepted that Eskom is a world leader in the development of low cost and appropriate solutions for electrification of low-income houses (and informal settlements). It is therefore essential that research and development continue on many fronts, with involvement of numerous stakeholders from government, industry and labour.

Strategic objectives and initiatives

***Strategic objective 1*: Implement high yield, low technology solutions in the domestic sector in the short to medium term (2007) to realise a 25% overall impact reduction by 2011**

a) *Refine and implement the DME Clean Household strategy*.

The current DME strategy includes for Basa Njengo Magogo, low smoke fuels and housing insulation as priority areas. It is proposed that low smoke fuels be abandoned as an intervention for the short to medium term, but that research in this regard continues. It is proposed that the projects aimed at finding appropriate housing insulation material be accelerated.

b) *The practical viability of implementing stove maintenance and replacement should be investigated by DME in close consultation with local and provincial authorities, in the short term. If viable, the measures should be implemented in the long term.*

Two components of research is necessary in the short-term: (i) DME should involve the DTI and the Treasury Department to investigate the creation of a subsidised programme (perhaps under the Central Energy Fund) to facilitate the implementation of this intervention at no cost to households. This can be done along similar lines to other national programmes such as the "working for water" programme. (ii) DME should initiate studies, in collaboration with local authorities, to determine the current status of stoves (e.g. % of stoves beyond repair, % of houses requiring chimneys) and the social response to the measure. The outcome of this should inform authorities as to whether or not the measure is practically feasible for implementation in the medium term.

c) *Continue the electrification programme and intensify efforts to reduce incidents of electrocution.*

d) *Ensure that progress is monitored at local and provincial government level and the results are communicated to national government.*

Provision is made for monitoring to be conducted at provincial and local government level in the Air Quality Bill as discussed previously.

Strategic objective 2: Prepare (research, plan, test, etc) technologies for implementation in long term (2007 onwards) in both the supply and demand side to further reduce health impacts

a) Continued development of the low smoke fuels programme

There are currently attractive interventions that can immediately be pursued in the domestic sector, and this should be seen as a window of opportunity to rather invest more money in development of lower cost low smoke fuel technology for implementation in the medium-to-long term.

b) Continue government's current policy around renewable energy, with the focus on implementation from 2007 onwards

Although this study has found that large-scale wind electricity generation is not feasible for the short to medium term, it is the view of this study that the current government policy provides sufficient flexibility for numerous other potential solutions (solar water heating, small scale hydro, etc) to be pursued.

c) *Continuous assessment of the potential for cost savings associated with reduced pollution*

In light of the current and proposed interventions, the opportunity will diminish in the medium to long terms. This means that assumptions in 2003 around feasibility will be different by 2007 and 2011. To this extent it is recommended that the fesibility of potential intervention periodically be assessed. The information clauses in the Air Quality Bill should be activated to that information on emission levels can regularly be fed into this assessment process

Strategic objective 3: Develop emission licensing system as well as incentive scheme to reduce impacts from coal fired boiler operations

a) Develop and manage detailed inventory of coal fired boiler operations

This study identified a large number of boiler operations and corresponding emission levels. This could be a valuable starting point. Continuous monitoring and development of such inventories should be done at local government. An additional source of information that could be utilised is the Department of Labour's boiler certification programme,

b) Develop regulatory framework at national level for implementation at local level

The next step would be the development of appropriate regulatory framework to deal with boiler operations. In this case, because it deals with health and safety, the system will be one of technical regulations. Technical regulations should clearly specify the regulatory (regulation of "controlled emitties is likely to be a municipal function), the conformity assessment requirements (probably standards) and the sanctions (fines, etc)

c) Investigate and develop a support scheme to facilitate investment by industry to reduce emissions from coal fired boilers

The study has shown that where inventment in technology is required to reduce emissions, such investments are by-and-large not financially and economically justified. It is to this extent that it is recommended that an appropriate supply side incentive be implemented to assist companies in this regard. Current incentives such as accelerated depreciation incentive, tax deductions and even the SMEDP should be investigated.

d) Launch and awareness and education campaign amongst SME boiler operators

SME boiler operators need to made aware of the harmful effects of emissions resulting from their boilers, changes to current operating procedures that should result in decreased emissions, assistance provided for technology upgrades, the potential benefits associated with increased efficiency, and the intention of government to actively regulate such operations.

Strategic objective 4: Develop a holistic and economically efficient strategy to deal with the control of exhaust emissions from road-going vehicles

a) *The DME and DEAT to revisit the scope of the strategy for the control of exhaust emissions from road going vehicles*

This study found that the phasing in of enabling fuels is not attractive from a socio-economic perspective. The strategy also does not consider alternatives such as changes in vehicle usage patterns, and improved vehicle inspection. It is therefore proposed that the DME and DEAT revisit this strategy to include for alternative solutions.

b) *The DME and DEAT to revisit the proposed fuel specifications as specified as part of the strategy for the control of exhaust emissions from road-going vehicles*.

The second component deals with the phasing in of enabling fuels (reduction of sulphur, benzene, aromatics, and lead in petrol and reduction of sulphur and polycyclic aromatics in diesel) were found to be unattractive from a socio-economic perspective, and it can therefore not be recommended that they be pursued before alternative options have been investigated. One exception is the reduction of lead, for which the benefits could not be costed, but the implementation costs are relatively low, and it is probably worthwhile to continue phasing it out.

c) *Fast-track the implementation of provisions in the Air Quality Bill for the regulation of vehicles.*

The proposed Air Quality Act makes provision for the classification of vehicles as "controlled emitters" and therefore for the establishment of national standards for vehicles (as described for coal-fired boilers). Vehicle emissions will however not be effectively controlled, even given the promulgation of the Act, until such time as they have been designated as controlled emitters and regulations put in place for their management. Substantial capacity will also be required to be developed at local authority level to ensure effective implementation and enforcement of regulations.

Strategic objective 5: Develop conurbation (and sector) specific strategies to reduce aggregate health costs

a) *DEAT to facilitate strategy development process at provincial and local government*

DME should take the lead in implanting thorough strategic and operational planning processes at provincial and local government. A key focus should be to use the flexibility inherent to the Air Quality Bill to ensure that efficient solutions prevail at conurbation level. It is strongly recommended that the information collected as part of this study be used extensively during the planning process, since significant data was obtained at conurbation level.

b) *DEAT to implement a measurement system to monitor implementation and effect of provincial and local government plans*

The need to continuously review and adjust actions and interventions as the industrial and domestic landscape changes, and as short term interventions start realising benefits were discussed earlier in the report.

Strategic objective 6: Government to further refine the policy and regulatory environment

A number of challenges remain. The first one is to ensure that the Air quality Bill is effected at national, provincial and local levels of government. The second is to ensure that cross-departmental issues are addressed in a meaningful manner. The third is to ensure that continuous assessment of the situation is done, and the policy, regulatory and operational environments adjust accordingly.

To achieve the first will require commitment from various role-players. The second can be achieved in a number of ways, for example through setting up of inter-departmental tasks teams, but the most effective way is probably to make air pollution an agenda item on Cabinet's Standing Portfolio Committee on the environment. A number of recommendations were made elsewhere in the report which should ensure that continuous measurement actually takes place.

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Acronyms and abbreviations

DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DTI	Department of Trade and Industry
DOL	Department of Labour
DOH	Department of Health
MSD	Marginal Social Damage
MAC	Marginal Abatement Cost
APPA	Atmospheric Pollution Prevention Act
AQB	National Environmental Management: Air Quality Bill
CO_2	Carbon dioxide
CO	Carbon monoxide
H_2O	Water
CH_4	Methane
NMVOCs	Non-methane volatile organic compounds
SO_x	Sulphur oxides
SO_2	Sulphur dioxide
SO_3	Sulphur trioxide
H_2S	Hydrogen sulphide
NO_x	Nitrogen oxides
NO	Nitric oxide
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
PCDD	Polychlorinated dibenzo-p-dioxins (dioxins)
PCDF	Dibenzofurans (furans)
LPG	Light petroleum gas
VOCs	Volatile organic compounds
SVOCs	Semi-volatile organic compounds
HCl	Hydrogen chloride
NH_3	Ammonia
H_2S	Hydrogen sulphide
PCB	Poly-aromatic hydrocarbons
As	Arsenic
Cd	Cadmium
Cu	Copper

Hg	Mercury
Cr	Chromium
Ni	Nickel
Pb	Lead
Se	Selenium
Zn	Zinc
HFO	Heavy fuel oil
EPA	Environmental Protection Agency
PROPER	Program for Pollution Control, Evaluation and Rating
MOE	Ontario MOE, 2002
OECD	Organisation for European Development

1 INTRODUCTION

A project has been initiated aimed at assessing identifying the need for and socio and economic implications of the phasing out of 'dirty fuels' within South Africa.

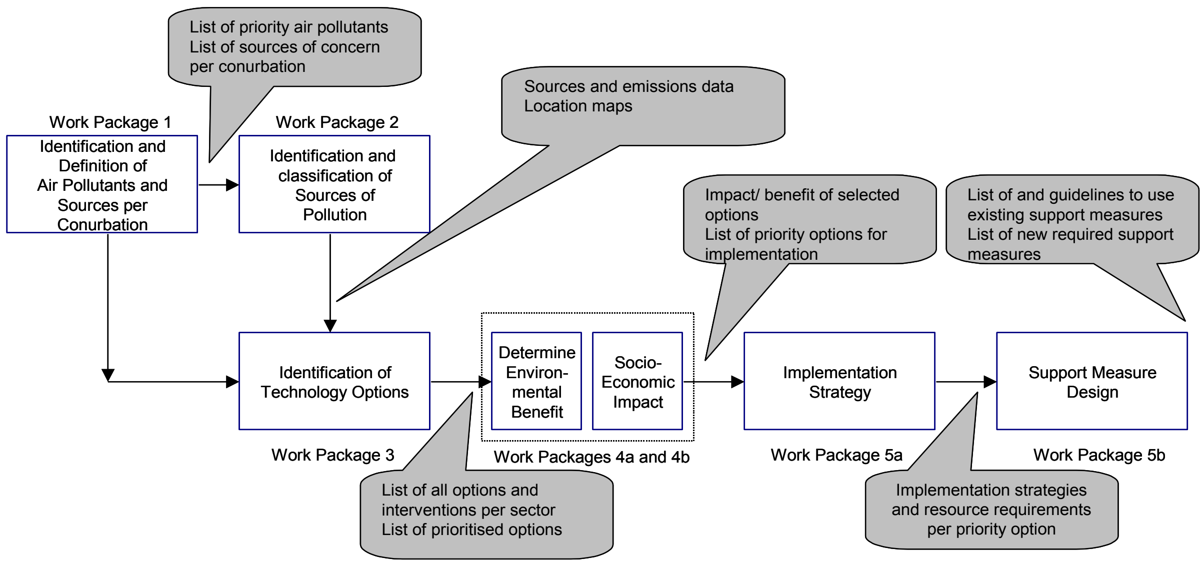
1.1 PROJECT OBJECTIVES AND APPROACH

The primary objective of the study was provide an assessment of the social and economic impact of the phasing out of air pollution from combustible fuels in the country over a period of time, and to provide specific guidance on supply side measures to support the process.

The following sub-objectives were achieved:

- Air pollutants of concern nationally and in each conurbation and their associated sources were identified, with combustion processes within all sectors having been taken into account
- Sources responsible for the major impact of each pollutant, nationally and by conurbation, were inventoried and their emissions quantified
    - Feasible technology and other options for targeting combustion-related sources (which are responsible for the major impacts of each pollutant) were identified, and requirements for the phasing in of such options established
- Social, economic and environmental costs and benefits of select options were established and presented in a manner suitable for decision-making purposes
- Types of financial assistance which may be provided by government in facilitating the phasing in of options, that target principle combustion processes, were identified, and possible methods of accessing such funds
- Recommendations based on a set of strategic objectives and how to implement the strategy over the stipulated time frames

The following chart illustrates the sequence of execution of the tasks conducted and how the deliverables culminated in the strategy as proposed.



The scope of the project was defined as follows:

Sectors:

- Domestic fuel burning
- Power generation
- Industrial
- Transport
- Agriculture

Sources of pollution:

- Fuel-burning related sources only, thefore excludes fugitive dust, diffuse, evaporative and industrial process emissions

Emissions:

- SO_2, NO_x, particulates, CO, lead, VOCs, (CO_2, CH_4, N_2O)

Conurbations:

- Cities of Johannesburg and Ekurhuleni, Tshwane, Cape Town and Ethekwini
- Mpumalanga Highveld
- Vaal Triangle

Air pollution prediction:

- US-EPA approved Gaussian Puff air dispersion model
- First order chemical transformation (secondary particulate formation), therefore excluded is photochemical modelling (and ozone generation prediction)

Impacts:

- Local vs global scale impacts
- Inhalation-related human health risks
- Risk of paraffin poisoning, burns

Interventions

- Priority was given to interventions suitable for implementation at national level

1.2 CAVEATS

This study only facilitated the quantification of inhalation exposures due to fuel combustion related atmospheric emissions. It does not quantify emissions or impacts associated with other sources of emissions.

S*ources of emission which are not accounted for include fugitive dust emissions (e.g. road dust entrainment by vehicles, wind blown dust, dust from material handling, etc.), industrial process emissions (e.g. metallurgical concentrator and furnace emissions) and evaporative losses (e.g. vapour losses from storage tanks).*

Emissions and impacts quantified in this study would account for household fuel burning emissions and vehicle emissions but would only account for a portion of the emissions from industrial operations. This should be noted in interpreting the source contribution information provided in the report.

Impacts associated with fuel burning emissions occur at several spatial scales, ranging from household- and conurbation-level (e.g. individual and community health risks) to regional and global scale impacts (e.g. transboundary pollution transportation, acid deposition and climate change). For the purpose of the current study emphasis was placed on impacts at the level of conurbations with community health risks due to inhalation exposures representing the main focus of the study.

The acquisition of dose-response relationships and damage costs applicable within South Africa represents the key challenge in the application of the damage function approach. Dose-response relationships were not available locally. Reference therefore needed to be made to dose-response relationships available in the general literature. Such relationships are published for various pollutants (particulates, SO_2, CO, NOx, lead, etc.) and human health endpoints (e.g. hospital admissions, chronic bronchitis, premature mortality).

Due to the urbanised nature of the study area selected and the proximity of many communities to sources of fuel combustion, health risks associated with such combustion represented the main focus of the study. Impacts on vegetation, including crop productivity, and material damage are expected to be substantially lower in the areas of interest. Dose-response relationships for damage to materials (e.g. through soiling and corrosion), impacts on commercial crops (in terms of productivity reductions) and on fauna and flora were found to be sparse and not readily applicable given local environments. Given that impacts on vegetation and materials are not as significant as health risks, and the complexity in quantifying such risk, it was decided to limit the quantitative assessment to human health risks.

Photochemical modelling was not undertaken due to the complexity of such modelling and the limited time period allocated for the study. It was therefore not possible to predicted ozone concentrations arising due to fuel combustion emissions. Secondary particulates formed through the conversion of sulphur oxides and nitrogen oxides to sulphates and nitrates were however modelled so as not to underestimate atmospheric particulate loadings and the associated impacts.

Second, lack of information, predominantly in the industrial secor meant that a number of industry specific interventions were not investigated. These interventions may be desirable.

Third, little marginal analysis was undertaken *within* specific interventions In consequence interventions that look inefficient as presented may be more attractive if only partially implemented. In some instances these would cost little, and would achieve real health benefits.

1.3 STRUCTURE OF THIS REPORT

The structure of this report follows the logic of the project process.

- The first section explains the background to the project, the approach and scope
- Chapter 2 provides an overview of international practices and developments.
- Chapter 3 provides an overview of the current South African policy and regulatory environment.
- Chapter 4provides an identification of air pollutants resulting from fuel combustion.
- Chapter 5 is the quantification of pollutants by source and the identification of technology options.
- Chapter 6 is the quantification of health benefits.
- Chapter 7 is the socio-economic impact assessment of technology options.
- Chapter 8 is the proposed strategy to reduce health costs associated with air pollution from fuel combustion.
- The last chapter concludes the study with a brief description of the road ahead.

Note: This report is a summary of detailed investigation, and should be read in conjunction with the supporting reports as follows:

Task 1: Definition of air pollutants

Task 2: Establishment of source inventories

Task 3: Identification and prioritisation of technology options

Task 4a: Quantification of environmental benefits

Task 4b: Socio-economic impact assessment

2 INTERNATIONAL BEST PRACTICE IN AIR QUALITY MANAGEMENT

2.1 OVERVIEW OF INTERNATIONAL PRACTICES

While evaluating the socio-economic impacts of a number of technical measures the means through which they are implemented is an important consideration. Internationally regulation, education, peer pressure, public disclosure programmes and economic instruments are among the range of implementation options for facilitating or forcing the necessary technical changes. The socio-economic impacts of reduction measures can be very different depending on which of these options is chosen.

Regulation in which uniform standards are set for polluters can result in unnecessarily high reduction costs. Regulation is, however, often the most expedient, being seen as politically superior, it is quick to initiate and shows the authorities 'getting something done'. The US EPA, a recognised centre of excellence in air pollution control, advises that command and control regulation works best when:

- Emissions reduction experience is limited and expertise is concentrated among regulators
- Solutions are clear or there are few options for reducing emissions.
- Monitoring total mass emissions is not feasible
- Emissions have serious local health impacts and trading may make such hot-spots worse.
- Emissions are toxic and the desired emission level may be zero (EPA, 2003).

On the other hand, measures that do not use legal coercion (such as self-regulation and public disclosure programmes) might achieve the same emissions reductions while saving the administrative costs associated with regulation.

Public disclosure programmes are a lesser known tool in pollution reduction. Indonesia's Program for Pollution Control, Evaluation and Rating (PROPER) highlights the potential of public disclosure programs. In the program information on pollution levels from factories is made public in an attempt to facilitate pressure being brought to bear on them by communities. Factories are rated on a five colour scale according to their compliance. For non-compliant firms, it is expected that that the program will provide enforcement 'stick' which costs less than conventional procedures. The program also offers important 'carrots' in the form of favourable ratings. The environmental authority hopes many firms will conclude that the value of these ratings for their reputations will warrant the costs associated with cleaner production. Moreover, it is important to note that because of the program, the environmental authority subjects itself to scrutiny and creates incentives to improve its performance through transparency. Preliminary results suggest that PROPER's short-term impact as a 'stick' has been substantial. No short-term impact is observable in the 'carrot' range, but this is not surprising. Attaining a favourable rating will require longer-term investments, while rapid installation of basic abatement equipment can be sufficient to avoid an unfavourable rating (Afsah, 1996).

In considering international practices there are a number of economic instruments that can be used to encourage pollution reduction. These include:

- Charges - i.e. levies charged by authorities (such charges can take a number of forms including the right to pollute up to some level, a levy on units of polluting fuels used or on units of a polluting product sold).
- Taxes - i.e. a pollutant tax set equal to the marginal external cost imposed by the emission or product involved.
- Subsidies (to cover incremental clean-up costs).
- Tradable pollution permits.

Charges and taxes have long been advocated by environmental economists and are widely used. Their advantages include:

- They internalise external costs (i.e. external costs that used to be incurred by others in society are incurred by the generators of the costs).
- They allow the polluter to choose the least-cost abatement method.
- They encourage innovation by providing a constant incentive to improve on the reduction of emissions.
- They should result in higher prices for relatively more polluting goods.
- They generate funding which can be recycled into the economy or used to fund general environmental activity.

(Convery, 1995)

According to Blackman and Harrington (1999), the effectiveness of air pollution emissions fee or charge programmes can be measured in terms of their impact on the environment, revenue generation and on regulatory administrative costs.

In a review of the Swedish, Chinese and Polish emissions charge systems, they argue that the Swedish system has been most successful when it comes to environmental impact while opinions vary as to whether and, if so, to what extent the Chinese and Polish systems have had an effect. This is not surprising when one considers that the Swedish system is characterised by relatively high charges that have a definite incentive effect, while those of the Chinese and Polish systems are relatively low (Swedish charges are 60 times those in Poland for the same type and quantity of pollutant). The Chinese and Polish systems have, however, led to substantial revenue generation as with the Swedish system.

Tradable permit systems sometimes offer a cheaper way to achieve a given level of abatement than regulation and, in some cases, charges. In any area a target level of emissions is set and total pollution permits adding up to it are allocated or sold. Since firms can trade permits, and the price is set in the market, abatement takes place at facilities with the lowest abatement costs. Their main advantage over charges is that they set a cap (i.e. maximum allowable amount) on emissions – charges do not create certainty that the hoped for pollution reductions will be achieved. Their main disadvantage is that they rely on high levels of monitoring, enforcement and administration.

Blackman and Harrington (1999) in their review of best practice in the application of economic instruments for air pollution control warn that tradable permit systems are generally not appropriate in developing countries due mainly to institutional and monitoring inadequacies. Indeed, they were not able to find any such systems in developing countries. They argue that tax or charge systems show greater promise if suitably developed. South African decision makers have clearly accorded with this view and there is not sign of a tradable permit system being introduced in this country. The bulk of emission regulation involves command and control with a small number of environmental taxes.

Charges, taxes and the purchase of pollution permits clearly impose costs on business. Firms, even those able to abate cheaply, would prefer regulation to equivalent taxation or purchase of permits unless the emissions tax/permit levy is deductible against normal company tax.

Note that official pollution controls can offer benefits to polluters: efficiency related savings and access to markets where high environmental standards are required.

2.2 RECOGNISING LIMITATIONS

While economic instruments have theoretical appeal, they are by no means a panacea and their success requires specific conditions. Their limitations were clearly pointed out in a World Bank policy working paper from which we quote (Afsah et al, 1996):

“As environmental economists, we support the view that optimum pollution is an appropriate concept for regulation. We also believe that pollution charges and tradable pollution permits can be effective regulatory instruments *under the right conditions*. However, our research and field experience (particularly in developing countries) have convinced us that the conventional regulatory approach does not pay sufficient attention to defining the right conditions.”

The authors challenge some of the conventional thinking on pollution prevention and warn against attempting to implement elaborate measures when the pre-conditions for their success (in particular adequate information and enforcement capacity) are absent. As an alternative to the traditional view, they therefore propose a model of interactions linking four agents: plant, state, community and market (see Figure 1 below). This model focuses on the *process* that leads to efficient levels of pollution, rather than on *a priori identification* of the optimum point by state regulators.

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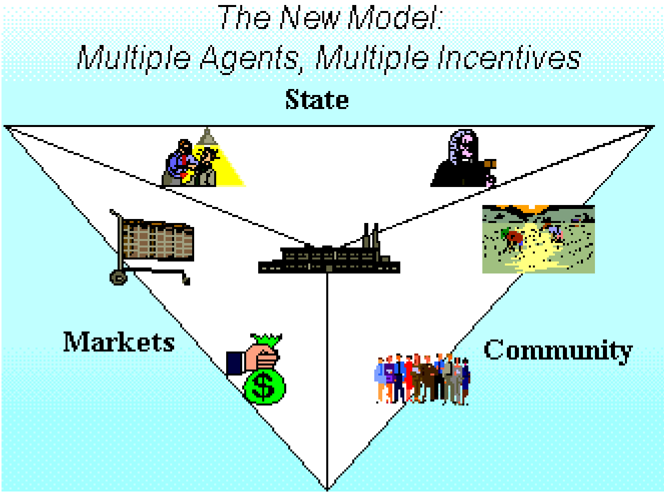


Source: Afsah et al. (1996)

Figure 1: The New Model for Pollution Regulation

“Once we introduce a world of multiple agents and multiple incentives, we must also rethink the regulator's appropriate role in pollution management. No longer is this role confined to producing, monitoring and enforcing rules and standards. Instead, the regulator can gain leverage through non-traditional programs which harness the power of communities and markets. Within the 'triangular' regulatory framework, for example, there is ample room for information-oriented approaches such as voluntary participation/compliance programs and public disclosure of factories' environmental performance. A broader implication is that one size no longer 'fits all' for regulatory policy design: Optimal combinations of regulatory tools will depend on country-specific social, economic and institutional conditions.” (Afsah, 1996)

2.3 THE OPTIMAL MIX OF IMPLEMENTATION OPTIONS

Irrespective of the approach followed, thorough research is needed before implementation options are developed. Appropriate measures should (Ontario MOE, 2002):

- Achieve reduction goals and take into account the differences among emissions sources.
- Provide clear goals, targets and timelines.
- Provide clear incentives and consequences.
- Provide transparency where the results are measurable.
- Provide certainty that reasonable emission reductions will occur.

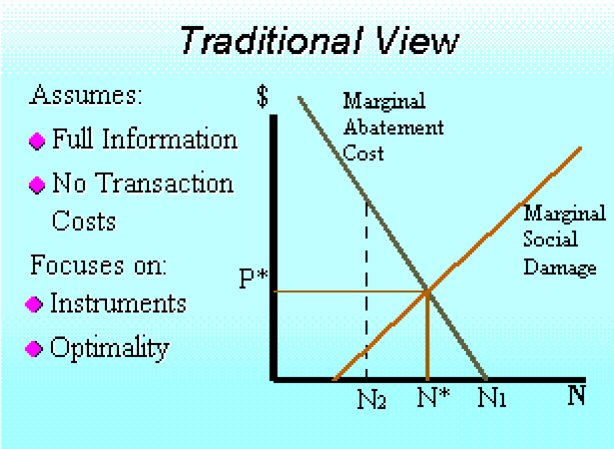
- Be flexible and cost-effective.
- Not compromise current regulations or the ongoing development of a regulatory system.

The mix of tools best suited to a conurbation will be determined by the details of the different emissions sources and by its regulatory, social and economic context.

2.4 THE OPTIMAL LEVEL OF ABATEMENT

A central question when considering the implementation of pollution abatement measures is the target level of emissions. Neoclassical economics suggests abatement should continue till the incremental cost of reducing the next unit of an emission equals the marginal benefits from this reduction (see for example Pearce & Turner, 1990).

Figure 2 taken from Afsah et al. (1996) illustrates this conventional view. Pollution (N) is measured on the horizontal axis and costs ($) are measured on the vertical axis. In this view of the problem, the regulator quantifies the benefit as the decrease in Marginal Social Damage (MSD) as the pollution level falls. There is also sufficient information to quantify increases in Marginal Abatement Cost (MAC) as polluters reduce their emissions. The regulator determines 'optimum pollution' at point N*, where MSD = MAC.



Source: Afsah et al. (1996)

Figure 2: The optimal level of pollution abatement

The regulatory problem in this world is straightforward: Having determined N* with full information, the regulator seeks to attain it by using command-and-control (mandating factories not to pollute above a determined level) or market-based instruments (setting a pollution charge P*, or allowing factories to trade pollution permits within the limit N*). Able to enforce at will because transactions costs are zero, the regulator simply dictates the terms and the factories respond appropriately. By assumption, the central regulator is and should be the sole decision agent in such a world.

In practise, optimal emissions and optimal clean-up expenditures will vary with the location and environs of point source emissions. Typically these optima will vary according to place, time of year, population etc. If one takes the abatement cost function as given, the optimal amount of abatement will depend on the benefits accruing due to a reduction in pollution (i.e. reductions in marginal social damages). Clearly these will depend on geography (topography, prevailing winds, propensity to inversions etc) and on population characteristics (number, residential density proximate to point sources of emissions, demographic profile, etc.). The critical point is that a centrally administered uniform regulation, governing acceptable levels of any given emission, cannot be economically efficient if impartially run. The optimal emission must necessarily vary from place to place. A preferable approach would be to use a national set of minimum standards, which local municipalities could then augment and enforce according to local circumstances.

The current regulatory regime does not allow for the necessary devolution of power to the provincial and local government levels required for this approach. Fortunately the Air Quality Bill will ensure that this devolution takes place.

As mentioned earlier, imposing pollution abatement by conurbation is, however, bound to attract criticism, particularly from industries that feel they may be unfairly discriminated against. Producers located in a conurbation where pollution abatement measures are imposed may experience a cost disadvantage relative to their competitors in other areas. The magnitude of the disadvantage will determine the severity of the impacts. A key issue to bear in mind is that these may be only distributional impacts. If the product is a non-tradable, cleaner producers or operators in areas with less severe regulations, will pick up the slack left by a penalised firm. In other words, at an overall level, abatement may result in net benefits to society, but some firms will lose and others may gain. It is important to investigate who will bear the costs and what their knock-on effects will be before deciding on abatement measures. This should ensure that unexpected significant impacts on industries are avoided.

One free market response is to cite Tiebout effects (Baumol & Oates, 1994). There are two dimensions to this. From the firm and city perspective, a conurbation can select tax and regulation systems to attract the type of activity it wants into the area. If clean air is a priority, taxes and regulations can be used to drive out dirty fuel users. If, on the other hand, output, employment and productive linkages are key issues, the city fathers may elect to actively encourage dirty and polluting industries into the area and reduce the barriers facing them. From the perspective of the 'victims' of pollution, those who want clean air will pay to get it, and those who don't value it will be able to buy cheap property in polluted areas.

2.5 IMPLEMENTATION STRATEGY LESSONS FROM INTERNATIONAL BEST PRACTICE

The preceding review has revealed a number of lessons that could help South Africa avoid some the pitfalls when formulating an implementation strategy. In summary, the primary lessons are:

- An integrated approach is best in which there is an appropriate combination of regulation, economic instruments, education, co-operation with industry and public disclosure programmes.
- Improved capacity for data collection, monitoring and implementation is a pre-requisite for successful regulation.
- It is better to start with lower emissions standards and gradually increase them rather than running the risk of starting with standards that are too high and either cause unnecessary damage to the economy or are unenforceable. Bear in mind though that if standards are kept too low they are unlikely to have the desired incentive for pollution reduction.
- A national set of minimum standards augmented by local standards and provincial/regional standards as necessary has the greatest chance of being effective and economically efficient.
- In a developing country context, taxes and charges seem to show more potential promise than tradable permit systems.

3 SOUTH AFRICAN REGULATORY AND POLICY REGIME

3.1 AIR QUALITY REGULATION

Currently air pollution is regulated under the provisions of the Atmospheric Pollution Prevention Act (APPA), 1965 (Act 45 of 1945). This Act is regarded as outdated for a number of reasons. It cannot accommodate the constitutional allocation of air quality control functions in respect of the role of provincial and local government. It has inadequate compliance and enforcement mechanisms for effective implementation and fosters a lack of transparency in decision making. It is largely focused on point source pollution control and does not adequately address the cumulative impacts of air pollution (Government Gazette, 2003). None of this should be surprising given that the Act is roughly four decades old and air pollution problems along with what is now known about dealing with them have both advanced significantly.

The recently gazetted Draft National Environmental Management: Air Quality Bill will repeal the Atmospheric Pollution Prevention Act It will provide the framework for governance of air quality management through the establishment of national norms and standards, a regulatory framework for an air quality management planning, a reporting regime, numerous regulatory instruments for the control of air pollution and a comprehensive approach to compliance and enforcement.

The Air Quality Bill Draft (Government Gazette, 2003), seeks to, among other things:

- Protect, restore and enhance the air quality in the country, having regard to the need to ensure sustainable development.
- Provide increased opportunities for public involvement and participation in the protection of air quality.
- Ensure that the public has access to relevant and meaningful information about air pollution.
- Reduce risks to human health and prevent the degradation of air quality by the use of mechanisms that promote (1) pollution prevention and cleaner production, (2) the reduction to harmless levels of the discharge of substances likely to impair air quality.

The Draft Bill provides for the identification of substances or mixtures of substances in ambient air which, through ambient concentrations, bioaccumulation, and deposition or in any other way, present or are likely to present a threat to health or the environment. The health impact, in terms of dosage response rates has, as analysed in Chapter 5, has been a major focus of this report. This aspect has been selected as the primary driver of the strategy to reduce air pollution from fuel combustion across all sectors of the economy.

In respect of each of these substances it establishes national standards for:

- Ambient air quality, including the permissible amount or concentration of each such substance or mixture of substances in ambient air.
- Emissions from point or non-point sources.

The Draft Bill also allows for the establishment of provincial and municipal standards. If national standards have been established for a particular substance, a provincial MEC responsible for air quality may not alter these standards except by establishing stricter standards for the province or for any area within the province. Similarly, for municipalities wanting to change local pollution standards using by-laws, they can only do so if they result in stricter standards than provincial and national standards. This allows for an approach that establishes national minimum standards augmented by provincial and local standards that can focus on hot-spots. The study's focus on conurbations and the analysis undertaken at the conurbation level will provide extremely useful information to enable improvements in air quality to be realised.

The Draft Bill also allows for the devolution of monitoring and implementation responsibilities to the provincial and local level as appropriate. In order to ensure adequate national monitoring and information management standards, national standards for the monitoring by municipalities of ambient air quality and point and non-point sources may be established. National standards may also be set for the monitoring by provinces of ambient air quality as well as the performance of municipalities in implementing the Bill. Monitoring and implementation suggestions by appropriate bodies have been considered in the suggested strategy

The Draft Bill envisages the establishment of a National Air Quality Advisory Committee [NAQAC] to advise the Minister of Environmental Affairs and Tourism on the implementation of the Draft Bill. The appointment of a national air quality officer to be responsible for co-ordinating matters pertaining to air quality management in the national government is also envisaged. In addition, the provinces and municipalities must designate their own air quality officers. The authors of this report believe that the reporting line of the NAQAC is imperative, as the implementation of the proposed strategy is cross cutting across numerous national, provincial and local Government departments.

Air quality management plans would be required at different levels of government. Each national department or province responsible for preparing an environmental implementation plan or environmental management plan in terms of Chapter 3 of the National Environmental Management Act must include in that plan an air quality management plan. Each municipality must also include in its integrated development plan envisaged in section 25 of the Municipal Systems Act, an air quality management plan. Among other requirements these plans must seek to improve air quality across the country; address the effects of emissions from the use of fossil fuels in residential applications and give effect to best practise in air quality management. We believe that this should not be applied across the board but should rather be prioritised and considered from a cost benefit standpoint. Money is a scarce resource and should be applied where the health impact can be maximised.

Four regulatory tools are proposed for the achievement of the goals set out in management plans. These tools, which are described below, include declaring priority areas, listing potentially harmful activities, setting specific standards for controlled emitters and requiring emitters to compile atmospheric impact reports.

National or provincial authorities may declare priority areas where air quality standards are being or are likely to be exceeded and the area requires specific air quality management action to rectify the situation. The basis for this declaration can essentially be derived from the information and analysis provided in this report. This will enable the execution of the interventions to be prioritised.

Activities that are deemed to pose a threat to the achievement of air quality goals can be listed by the national and provincial authorities. Anyone wanting to commence with a listed activity would then be required to apply for an emissions licence from the metropolitan and district municipalities charged with implementing the atmospheric emission licensing system. The application process would be exhaustive and the granting of a licence would be accompanied by various conditions aimed at limiting pollution to acceptable levels. An atmospheric emission license may, with the permission of the licensing authority, be transferred to another emitter. It would have to be reviewed and possibly renewed at appropriate interval to ensure it stays in line with requirements. Aside from state air pollution control officers, the state may also require holders of emissions licences to appoint a suitably qualified emission control officer depending on the size and nature of the polluting activity.

The practicality of introducing such a high order mechanism should be carefully considered, due to the fact that there are few large groups of emitters in a concentrated area where the transfer and trade of permits can occur. International experience has shown that these mechanisms are not suited to

Listed activities are meant as a category to regulate industry and other large point sources. A further category, controlled emitters refer to dispersed activities or appliances, which can be grouped to be regulated with common regulations. Examples of likely controlled emitters are vehicles, domestic fuel burning devices, filling stations, etc.

Listed activities, in relation to fuel combustion, are easily able to be derived and was considered in the development of the strategy to reduce air pollution with a view to reducing the health impact. The cost benefit analyses have also provided the ability to prioritise, which sources need to be targeted with which interventions.

If pollution control officers suspect that any person has contravened or failed to comply with the Act, they will also be allowed to demand that the person produce an atmospheric impact report.

The Draft Bill does not subscribe exactly which measures can be used to achieve air quality requirements thus allowing for flexibility. It does, however, explicitly recognises the types of measures that could be used and among these are trading schemes or incentives to encourage change in behaviour towards air pollution. Thus economic instruments have been recognised as potentially necessary measures.

The Draft Bill recognises that the Atmospheric Pollution Prevention Act effectively marginalised both provincial and local government from the area of air quality management. It seeks to increase the involvement of both these spheres of government without increasing the burden on national government. Particularly in the case of municipalities, increased personnel and organisational commitments will be needed to fulfil that which is required of them. In terms of financial implications, it is envisaged that the system of permit fees will cover the added cost of administering the Bill at provincial and local government levels. No increase in the costs associated with air quality control is anticipated at national government level.

A critical point from the previous section on best practice is that a centrally administered uniform regulation, governing acceptable levels of any given emission, cannot be economically efficient if impartially run. The optimal emission must necessarily vary from place to place. A preferable approach would be to use a national set of minimum standards, which local municipalities could then augment and enforce according to local circumstances. The current regulatory regime does not allow for the necessary devolution of power to the provincial and local government levels required for this approach. Fortunately the Draft Air Quality Bill will ensure that this devolution takes place. In addition, the Draft Bill is well suited to allow for the implementation of other lessons from best practice.

3.2 CONSIDERATION OF OTHER POLICY INITIATIVES

This study has focused explicitly on air pollution resulting from fuel combustion. However, in order to tackle air pollution in all its forms a broader, more holistic approach is needed. Until this can be achieved, it is important that any dirty fuels implementation strategy has a high degree of fit with other policy and initiatives, aside from the Draft Air Quality Bill, impacting on pollution prevention. For example, the National Treasury is working on a study entitled "Market-based Instruments to Support Environmental Fiscal Reform in South Africa" which is likely to produce recommendations with an impact on air pollution strategy.

Future trends in electricity prices should also be monitored, as they will have a direct influence on the demand for electricity and thus the amount of pollution emitted in the generation process. They would also impact on the willingness of consumers to shift from coal stoves for heating and cooking purposes and paraffin for lighting to electricity use. Other issues that need to be monitored include industrialisation and urbanisation trends.

Policies that are relevant include overall energy policy and, specifically, renewable energy policy. One also needs to be aware of other strategy documents that essentially outline how some of interventions analysed in this study would be implemented. These include the Integrated Clean Household Energy Strategy (covering the top-down ignition, low smoke fuel and housing insulation interventions) and the Strategy for the Control of Exhaust Emission from Road-going Vehicles (covering all the vehicle sector interventions). In the following sections these policies and strategies are briefly outlined. Objectives are focus on for the policies, while implementation is the focus when considering strategies.

3.2.1 OVERALL ENERGY POLICY

The following five policy objectives taken from the White Paper on Energy Policy form the foundation of South Africa's energy policy (DME, 1998):

- Increasing access to affordable energy services
- Improving energy governance

- Stimulating economic development
- Managing energy-related environmental and health impacts
- Securing supply through diversity

A key feature of the energy white paper is its focus on demand side versus supply side interventions. The stress is on making energy use more demand efficient. This will lower the costs borne by households and firms, and will also reduce problem emissions. In this regard many of the interventions evaluated in this study are in line with DME thinking. Key relevant quotes from the White Paper include:

- "Government will promote access to affordable energy services for disadvantaged households, small businesses, small farms and community services.
- Government policy is to remove distortions and encourage energy prices to be as cost-reflective as possible. To this end prices will increasingly include quantifiable externalities.
- Energy taxation will continue to remain an option within government's fiscal policy, but will be exercised with more consideration for the economic and behavioural impacts of such policies.
- Government will promote access to basic energy services for poor households, in order to ameliorate the negative health impacts arising from the use of certain fuels.
- Government will work towards the establishment and acceptance of broad national targets for the reduction of energy-related emissions that are harmful to the environment and to human health.
- Given increased opportunities for energy trade, particularly within the Southern African region, government will pursue energy security by encouraging a diversity of both supply sources and primary energy carriers.
- 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."

3.2.2 *RENEWABLE ENERGY POLICY*

In August of 2002 the Department of Minerals and Energy (DME) released their Draft White Paper on the Promotion of Renewable Energy and Clean Energy Development (DME, 2002). This Daft White Paper supplements the White Paper on Energy Policy (DME, 1998) which recognises that the medium to long term potential of renewable energy is significant. It has yet to be approved by parliament and at present only the section on the promotion of renewable energy has been released and not the section that will deal with clean energy development.

In its current form, the Draft White Paper does not list particularly clear objectives. In the main is focuses on the objectives of contributing to the global effort to mitigate green house gas emissions and enhancing energy security through the diversification into renewable energy. It states that

"Government's long term goal is the establishment of a renewable energy industry producing modern energy carriers that will offer in future years a sustainable, fully non-subsidised alternative to fossil fuels" (DME, 2002). The target set by the DME is that renewable energy will contribute an additional 10 000 GWh to final energy demand by 2012. It is recognised that renewable energy development will require financial incentives the funding for which will have to come from both South African and international sources. The initial trust of implementation is envisaged to focus more on remote rural areas where the mobile nature of many renewable energy options can provide maximum benefits.

3.2.3 THE INTEGRATED CLEAN HOUSEHOLD ENERGY STRATEGY

The Integrated Clean Household Energy Strategy recognises that the continued electrification of residential areas is ongoing and the full use of electricity for all household energy requirements remains the ultimate long-term solution. It also recognises that electricity is more expensive than coal and its price is rising. In addition, more expensive appliances are needed to exploit electricity (DME, 2002a).

An alternative is offered in the form of the Integrated Clean Household Energy Strategy, which was approved by the Minister of Minerals and Energy as a transitory measure between coal and full use of electricity. It has three thrusts, namely:

1. "Marketing and awareness of the low-smoke generating top-down ignition of coal fires ("Basa Njengo Magogo");
2. Manufacturing and distribution of Low-smoke Fuels; and
3. Implementation of housing insulation and design."

The strategy emphasises that the above are not true alternatives but rather phases in the strategy, as no single solution has the potential to reduce the coal-based air pollution to acceptable levels." (DME, 2002a)

3.2.4 STRATEGY FOR THE CONTROL OF EXHAUST EMISSION FROM ROAD-GOING VEHICLES

The final draft of the strategy for the control of exhaust emission from road-going vehicles, a joint implementation strategy between DME and DEAT, was recently released (DEAT & DME, 2003). The strategy includes a consideration of the issues raised in a report entitled "Investigation into the Optimal Future Octane Grade for South Africa" (CAE, 2003). It sets out a road map for the government, the oil industry as well as the vehicle manufacturing industry aimed at achieving improved air quality through the control of vehicle emissions (DEAT & DME, 2003):

"The backbone of the strategy is the implementation timetable of clearly defined European standards for vehicle exhaust emissions and appropriate fuel specifications. Initial emissions limits begin in 2005 for newly homologated vehicles and will come into full effect in 2006 when all new vehicles will be subject to emission controls. The fuel specifications will change in 2006 when a total ban on the use of lead in petrol will come into effect. The major challenge with the lead phase-out is the identification of suitable lead replacement additives. A number of alternatives to meet this short term objective are available and are in use in some countries. However, gaps exist in current knowledge on the long term environmental and health effects of some of these substances. As a consequence, this strategy adopts a precautionary approach where issues of human health and the environment are of concern. The long-term resolution of this challenge is the re-configuration of refinery processes in order for the refineries to produce fuels of appropriate quality without the use of heavy metals. This is Government's preferred approach and is the reason for its considered support of financial incentives to the refinery industry. National Treasury is currently investigating the possibility of providing financial incentives to facilitate cleaner fuels investments" (DEAT & DME, 2003).

4 IDENTIFICATION OF AIR POLLUTANTS FROM FUEL COMBUSTION

For this a comprehensive literature review was undertaken in the identification of air pollutants related to combustion processes and the determination of specific pollutants and related sources of concern, nationally and by conurbation. Due to the previous work undertaken in this field by members of the project team, most of the relevant literature has already been acquired.

Air pollutants emitted from combustion processes within industry, services, utilities, agriculture, transport and domestic sectors are generally well documented both locally and internationally (Britton, 1998; Graham, 1997; Wong and Dutkiewicz, 1998; EEA, 1999; US-EPA, 1996; Kalivoda and Kudrna, 1997; Fishman and Reichle, 1990; Scholes *et al.*, 1996; Jorgensen and Sorenson, 1997; etc.).

Extensive documented studies on air pollutants and sources of concern within specific regions and cities which were considered included.

4.1 OVERVIEW OF COMBUSTION-RELATED EMISSIONS

All fuels contain carbon and hydrogen, and there may be a content of oxygen, sulphur, nitrogen, water and mineral substances, depending on the fuel type. The mineral parts of the fuel form ash but the remaining constituents are converted to gaseous components. The carbon, hydrogen and sulphur content of fuels are oxidized to CO_2, H_2O and SO_2. In most stationary sources an almost complete combustion to CO_2 and H_2O is usually obtained, but smaller amounts of CO, CH_4 and NMVOCs (non-methane volatile organic compounds) may be emitted. In the internal combustion engine used in mobile sources a larger part of the carbon content leaves the combustion chamber as CO, CH_4 and NMVOCs.

Gaseous SO_x emissions from combustion are primarily in the form of SO_2 with a lower quantity of sulphur trioxide (SO_3) and gaseous sulphates being emitted. Under high temperatures and fuel-rich combustion conditions hydrogen sulphide (H_2S) may form. The extent of the SO_2 emissions is primarily a function of the % sulphur content of the fuel. If ash is present in the fuel, it may capture a small part of the SO_2. The main part of the sulphur is oxidised to SO_2 and emitted within the off-gas. Within certain generally large industrial combustion operations and various central energy generation processes flue gas desulphurization is used to reduce the extent of SO_2 emissions. The control of sulphur dioxide by smaller individual sources is not considered cost effective.

Nitric oxide (NO) is the primary component of combustion; however nitrogen dioxide (NO_2) and nitrous oxide (N_2O) are also formed in smaller amounts. The formation of these oxides follows three main reaction paths:

- *Thermal NO_x*, which is formed by the combination of atmospheric nitrogen and oxygen at high temperatures;

- *Fuel NO_x*, which is formed from the oxidation of fuel-bound nitrogen; and

- *Prompt NO_x*, which is formed by the reaction of fuel-derived hydrocarbon fragments with atmospheric nitrogen.

Typically, only a fraction of the nitrogen content in the fuel is converted to NO_x, with the major part forming N_2. The degree of conversion to NO depends on the nature of the combustion process.

The nature of the combustion process is more important in determining the extent of NO_x emissions than is fuel type. Residual oil and natural gas have, for example, been noted to have similar NO_x emissions despite the hydrocarbons in natural gas having no nitrogen content whereas residual oil may contain one to two percent (by weight) nitrogen. The reason for this is that the very high flame temperature in natural gas combustion results in the formation of thermal NO_x.

Inefficient combustion devices, such as is typical of devices used in households (e.g. stoves and braziers) result in higher CO emissions and lower NO emissions than do more efficient industrial combustion appliances.

Chlorine is released from coal combustion systems in the form of acidic gases, mostly HCl. There are three main forms of chlorine in coal, viz.: chlorine ions in brine and other waters associated with coal, inorganic chlorides, and organochlorine compounds.

Organic and carbonaceous emissions from combustion systems represent not only a fuel loss but also, in some cases, a significant pollution problem. Polycyclic aromatic hydrocarbons (PAH) are commonly produced during the combustion process.

Polychlorinated dibenzo-p-dioxins (dioxins) and dibenzofurans (furans), which attracted wide attention because of their extreme toxicity are products of incomplete combustion. PCDDs and PCDFs are formed in most combustion systems, including the burning of various fuels such as coal, wood, and petroleum products.

The emission of trace elements in the form of sub-micron size particles presents a potential health hazard and is a major environmental concern. Fly ash particles emitted from combustion systems are enriched in several potentially toxic elements such as As, Cr, Ni, Pb, Sb, Se, V and Zn. The sub-micron particles, which show the greatest enrichment in these elements, are of particular concern since modern particle collection devices do not efficiently remove the same. (Luckos, 2002).

Metals have been identified to exist in coal in three forms: included mineral matter, inherent mineral matter, and excluded mineral matter. Included mineral matter exists as inorganic entities trapped as crystalline or glassy structures throughout fuel particles containing appreciable carbon and hydrogen.

During combustion or gasification, fuel particles undergo complex changes, including devolatilization and formation of char, agglomeration of melted inclusions and vaporisation of volatile elements.

The major pollutants of concern from bituminous coal combustion are particulate matter, sulphur oxides (SO_x), and nitrogen oxides (NO_x).

Heavy fuel oil (HFO) combustion is usually a greater source of sulphur dioxide emissions than coal combustion due to its higher sulphur content (3.2% compared to the average of 1% S within coals used locally).

An understanding of the above range of combustion related pollutants is essential to finding ways to reduce emissions at point source pr conurbation level.

4.2 Combustion-related emissions within various sectors

The sector view is important to understand the context in which some of the interventions will be implemented. Government departments are aligned to sectors of the economy, many of which will play an important role in managing a pollution reduction strategy.

Combustion of solid, liquid and gaseous fuels is the major anthropogenic significant source of atmospheric emissions. Pollutants typically associated with combustion processes include: particulates (including soot, fly ash and aerosols), sulphur oxides (SO_x), oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), methane (CH_4), ammonia (NH_3), hydrogen chloride (HCl), hydrogen sulphide (H_2S), ozone (O_3) and other photochemical oxidants (as secondary pollutants) and various trace elements. Organic compounds released include formaldehyde, benzene, poly-aromatic hydrocarbons, PCBs and dioxins and furans. Trace elements may include arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn) and vanadium (V). The nature and extent of the pollutants released during combustion is primarily dependent on the *fuel type* burned and on the *nature of the combustion process*.

Coal-fired power stations account for 89% of the electricity produced in South Africa. These power stations are designed to use low-grade coals that are associated with higher emissions than the high-grade coal made available for export. In power generation and other combustion processes within the industrial sector use is made of coal, anthracite, coke, heavy fuel oil (HFO), gas (LPG, Sasol gas), diesel and paraffin. Fuel carriers, other than electricity, used by household for cooking, lighting and/or space heating purposes include primarily: coal, wood, LPG, paraffin and candles. Waste material, including old shoes and tyres (etc.), is also burned by households unable to afford other fuel carriers. Diesel and petrol (including leaded and unleaded petrol) represent the main fuels used by vehicles. Aircraft use jet fuel, marine diesel oil is typically used for ship engines, with fuel consumption by non-electrified trains including primarily diesel and coal.

4.2.1 Electricity Generation

The South African power generation sector is currently heavily dependent on coal. Based on 2001 figures in which Eskom electricity generation totalled 189 590 GWh, coal was responsible for 92.4% of Eskom's power generation. Other sources include: nuclear - 5.7%, hydro - 1.1% and pumped storage - 0.8%.

The coals used in South Africa's power stations are generally of relatively poor quality since the highest grade coals are exported. The average percentage ash and energy content of coals used by Eskom varies widely, ranging from 21% to 39% ash and 15.2 MJ/kg to 22.5 MJ/kg energy content. South African coals have however relatively lower sulphur content that do coals elsewhere. The sulphur content used by Eskom power stations is in the range of 0.59 to 1.41.

The main emission from electricity generation is therefore carbon dioxide (13%), sulphur dioxide (800 ppm), nitrogen oxides (400 ppm) and ash (25 mg/Sm^3).

The DEAT, through provincial and local government would play and important role, in conjunction with DME, in managing air pollution from combustion in this sector.

4.2.2 Industrial, Commercial & Institutional Power Generation

Power generation processes, other than for central electricity generation, include the use of boilers, furnaces, gas turbines (etc.) within industrial, commercial and institutional applications (e.g. hospitals, schools).

Coal-fired boilers range is type, fuel and method of construction. Boiler types are identified by the heat transfer method (watertube, firetube or cast iron), the arrangement of the heat transfer surfaces (horizontal or vertical, straight or bent tube) and the firing configuration (suspension, stoker of fluidized bed).

Anthracite coal is a high-ranking coal with more fixed carbon and less volatile matter than bitunimous and sub-bituminous coal. Anthracite also has higher ignition and ash fusion temperatures.

Distillate oils (e.g. kerosene, diesel fuels) are mainly used in domestic and small commercial applications. Heavier residual oils (heavy fuel oil) are mainly used in utility, industrial and large commercial applications. Distillate oils are more volatile and less viscous than residual oils, have negligible nitrogen and ash contents and generally contain less than 0.3% sulphur (by weight).

Industrial applications of both gasoline and diesel internal combustion engines include aerial lifts, fork lifts, mobile refrigeration units, generators, pumps, industrial sweepers/scrubbers, material handling equipment (such as conveyors), and portable well-drilling equipment.

Types of gas in use locally includes natural gas, Sasol gas and liquefied petroleum gas (LPG). Natural gas is typically used in industrial power, steam and heat generation processes in addition to being used in the commercial and residential sectors. Natural gas consists of a high percentage of methane, generally above 85%, and varying amounts of ethane, propane, butane and inerts such as nitrogen, carbon dioxide and helium. As for coal combustion, the main types of boilers used for natural gas combustion in commercial, industrial and utility applications are: watertube, firetube and cast iron. Emissions from natural gas-fired boilers and furnaces include NOx, CO, CO2, CH4, N2O, VOCs, SO2 and particulates.

LPG consists of propane, propylene, butane and butylenes (the product used for domestic heating is composed mainly of propane). In the US, the largest market for LPG is the domestic/commercial market, followed by the chemical industry (where it is used as a petrochemical feedstock) and the agricultural industry. Combustion processes that use LPG are similar to those that use natural gas, although the use of LPG in commercial and industrial applications may require a vaporizer to provide the burner with the proper mix of air and fuel. LPG is considered a relatively 'clean fuel' because it does not produce visible emissions.

Wood residue combustion within boilers is usually confined to industries where it is readily available as a byproduct, with combustion representing a means of generating heat energy and reducing the need for solid residue disposal. Wood residue may take various forms including sawdust, shavings, chips, bark, mill rejects, (etc.). Various boiler firing configurations are used for burning wood residue. One type of boiler used in smaller operations locally is the Dutch oven.

Waste oils combusted for power generation processes may include used crankcase oils from automobiles and trucks, used industrial lubricating oils and other used industrial oils. The emissions of waste oils reflects its composition, with potential pollutants including CO, SOx, NOx, particulates, toxic metals, organic compounds, hydrogen chloride, CO2 and CH4.

Bagasse, comprising matted cellulose fibre residue from sugar cane that has been processed in a sugar mill, is burned by the sugarcane industry for power generation purposes. Although originally burned as a means of solid waste disposal it was found to be cost-effective as an energy source when compared with fuel oil, natural gas and electricity. Bagasse varies in composition, consistency and heating value depending on the climate, type of soil upon which the cane is grown, variety of cane, harvesting method, amount of cane washing and the efficiency of the milling plant.

Particulate matter represents the most significant pollutant emitted from bagasse-fired boilers. SO2 and NOx emissions are lower than for conventional fossil fuels due to the low levels of sulphur and nitrogen associated with bagasse. Should auxiliary fuels such as fuel oil or natural gas be used during the startup of the boiler SO2 and NOx emissions will be increased. Upsets in combustion conditions are associated with increased emissions of CO and unburned organics typically VOCs.

4.2.3 Industrial Fuel Use (Non-power Generation)

Fuels are used in a large variety of industrial and waste disposal processes ranging from waste incineration, petroleum refining, inorganic and organic chemical process industry, mineral product industries - including brickworks, cement manufacturing, coal conversion (e.g. Sasol oil from coal plants at Sasolburg and Secunda), glass manufacture, metallurgical industries - aluminium production, iron and steel operations which frequently include large coking operations (e.g. Iscor), ferroalloy production, platinum smelting, lead smelting, zinc smelting (etc.)

Coal and coke represent the main fuels used by metallurgical industries. Diesel and gas are frequently used in waste incineration, although coal is used in select incinerator operations. Ash. Other pollutants which may be released include hydrocarbons, ammonia, carbon monoxide, mercury and cadmium. Whereas hydrocarbons have a high probability of occurring the other four pollutants have a low probability. Greenhouse gas emissions which are released include N_2O, methane and CO_2.

In the abovementioned two sectors the DTI has an important role to play in coordinating initiatives to reduce the impact of air pollution.

4.2.4 Domestic Fuel Combustion

Energy carriers used by households in South Africa include: electricity, coal, wood, paraffin, gas and candles. In rural areas animal dung is burned by some households, whereas in urban areas the combustion of waste takes place in households where alternative energy carriers are not available or are unaffordable.

Domestic coal burning emits a large amount of gaseous and particulate pollutants including sulphur dioxide, heavy metals, total and respirable particulates including heavy metals and inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, and benzo(a)pyrene. Polyaromatic hydrocarbons are recognised as carcinogens.

Domestic fuel burning emissions have a greater potential for impacts compared to equivalent emissions from, for example, industrial sources.

4.2.5 Transportation Related Sources

Transportation related sources include vehicles, trains, aircraft and ships. The extent of emissions from such sources is dependent on variations in the activity of such sources, e.g. travel speeds, travel distances, frequency of hot and cold starts (etc.). Given that vehicle tailpipe emissions are widespread and occur in close proximity to areas of high human exposure potentials, whereas releases from other transport sources are less extensive and more spatially confined, emphasis is frequently place on vehicle emissions.

Air pollution from vehicle emissions may be grouped into *primary* and *secondary* pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include CO_2, CO, HCs, SO_2, NO_x, particulates and lead. Secondary pollutants include: NO_2, photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, sulphates, nitric acid and nitrate aerosols.

Aircraft engine emissions, including emissions during aircraft operation in the idle, taxi, takeoff, and landing modes. These emissions include NO_x, CO, CO_2, H_2O, CH_x, NMVOC, VOC, Pb and SO_x.

Two types of emissions are given as occurring from ocean going vessels, viz.: *transit emissions*, which are characterised by the ocean going vessel entering or leaving the harbour with its main engines running, and (ii) *hotelling emissions*, characterised by the main engines being shut down while the vessel is berthed with its power requirements being provided by high speed generators. In addition to ocean-going vessels, additional emissions are released by tugs, dredgers and other vessels which are permanently confined to the extent of the harbour (collectively referred to as harbour vessels).

4.2.6 Agricultural Sector

Combustion processes for the purpose of the generation of process steam by means of burning bagasse within the sugar cane industry was addressed in Section 2.3. Other agricultural activities, e.g. poultry industry, also make use of boiler operations. Other agricultural-related processes which include significant quantities of fuel combustion include peanut roasting and fish processing.

Sugarcane, crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas.

Between 70% and 90% of all vegetation fires are anticipated to be caused by man (Helas and Pienaar, 1996). Agricultural reasons for fires include: (i) burning off of unpalatable growth left over from previous seasons, (ii) stimulation of growth during seasons when there is little young forage available on the veld and thus provide green feed for stock at a time when it does not occur naturally, (iii) to destroy parasites, particularly ticks, and (iv) to control the encroachment of undesirable plants in the veld. Other reasons for the starting of fires include: arson for hunting, modification of land use and negligence. Lightning represents the dominant natural trigger for vegetation fires.

Biomass burning is an incomplete combustion process with CO, CH4 and NO2 being emitted during the process. About 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds.

Unlike N species, only small amount of SO_2 and sulphate aerosols are emitted. Biomass burning particle emission factors range, on average, from 20 - 50 g/kg of dry matter burned, with higher emissions occurring during the smoldering phase compared to the flaming fire phase (Cachier *et al.*, 1995).

4.3 Source contributions to priority pollutants

The nature and extent of combustion processes varies considerably between different metropolitan areas within South Africa, as does the contribution of such sources to ambient air pollutant concentrations. The purpose of the current section is as follows:

- Delineation of the boundaries of the various metropolitan areas identified for inclusion in the study.
- List sources of emissions related to combustion processes which occur within each metropolitan area
- Assess readily available ambient air pollutant concentration data based on air quality guidelines and standards so as to identify pollutants of concern.
- Evaluate the findings of source apportionment studies, including studies aimed at quantifying source contributions to total emissions and those focused on assessing contributions to ambient air pollutant concentrations.
- Identify gaps in knowledge for each of the metropolitan areas.

In describing emissions associated with various combustion-related processes attention was paid to various factors which influence the impact of such emissions on near-ground ambient air quality and on human health and environmental exposures. Such factors include: the location of source in location to sensitive receptors (e.g. residential areas), the effective height of emission (taking into account actual height and plume velocity and bouyancy), and temporal variations in emissions.

4.3.1 City of Cape Town

The CCT incorporates the former Cape Metropolitan Council (CMC) and the six former Metropolitan Local Councils (MLCs), viz. South Peninsula Municipality, Blaauwberg Municipality, City of Tygerberg, Helderberg Municipality, Oostenberg Municipality and the City of Cape Town (Figure 3.1).

Significant air quality problems were noted to occur in Cape Town in the 1950s and 1960s. During that time Cape Town experienced the occurrence of a thick smog caused by three power stations operating in the area, coal-burning locomotives and tugs, industrial incinerators and heavy fuel burning appliances. In 1968 the City Council initiated a programme of air pollution control. Significant reductions in air pollution were realised within a decade. This was achieved through the implementation of measures such as the termination of the use of coal-burning locomotives and tugs, the closure of two power stations and the enforcement of standards for fuel burning appliances. However, subsequent to this a new air pollution challenge emerged, viz. 'brown haze'. This is a term used to describe a brown-coloured smog found predominantly in the wintertime in the Cape Town region. It is given as occurring from April to September due to strong temperature inversions and stable atmospheric conditions which results in the accumulation of air pollutants. The haze extends over much of the CCT but is not of uniform intensity. The haze is normally most intense in the morning, lifting and dispersing as the day progresses.

With regard to the contribution of sources to the brown haze phenomenon over Cape Town, conclusions drawn by the Brown Haze study were as follows (Wicking-Baird *et al.*, 1997) (Figure 3.10), viz.:

- Small particles are the single largest cause of the visible brown haze

- Vehicular emissions are responsible for 65% of visible degradation, of which 49% is caused by diesel driven vehicle emissions.

- Industry is also a significant source, particularly low level emitting industries, the industrial contribution being calculated to be 22%.

- Wood burning and natural sources, such as wind-blown dust and sea salt, contribute very little towards the brown haze.

- Assuming a business as usual scenario, air pollution was projected to increase by 48% over the next decade (vehicle numbers have increased by 80% in the CMA in the last 20 years; currently car ownership is 250 cars per 1000 people).

4.3.2 City of Johannesburg

Johannesburg is situated on the Highveld within the Gauteng Province (Figure 3.11). The City straddles the Witwatersrand, a string of low, rocky ridges that constitutes the watershed between the subcontinental drainage divide into the Indian and Atlantic Oceans. The city's elevation ranges from 1 500 m to 1 800 m. Following the promulgation of the Local Government Transition Act, the former 'City of Johannesburg' was amalgamated with various local authorities to form the Greater Johannesburg Metropolitan Council. (GJMC). Some of the local authorities included in the GJMC were Orange Farm in the south, Randburg, Sandton, Roodepoort, Alexandra, Soweto, up to Midrand and Diepsloot in the north. The GJMC was then divided into four substructures, viz. Northern Metropolitan Local Council, Eastern Metropolitan Council, Southern Metropolitan Council and Western Metropolitan Council. In 2002, the GJMC was restructured once again. The four metropolitan councils and Midrand were combined to form one single structure known as the City of Johannesburg (City of Johannesburg).

Sources of emission identified as occurring within Johannesburg are listed in Table 3.23. The significance of transboundary sources through their contribution to the regional aerosol component is noted in the table despite such sources not being located within the City. Pollutants released by each source are indicated, with significant sources of particular pollutants being distinguished from minor sources. Sources for which the emissions of a particular pollutant are not currently quantifiable are highlighted.

Table 4.1 Sources of atmospheric emissions within Johannesburg and their associated emissions

Sources	PM	SO_2	NO_x	CO	CO_2	CH_4	HAPs
Vehicle-tailpipe emissions	**x**	**x**	**x**	**x**	**x**	**x**	**0**
Scheduled Processes	**x**	**x**	**x**	**x**	**x**	**x**	**0**
Domestic Coal Burning	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Non-scheduled Industrial/Commercial Fuel Burning Appliances	**x**	**x**	**x**	**x**	**x**	**x**	**0**
Incineration	**0**	**0**	**0**	**0**	**0**	**0**	**x**
Vehicle-entrainment of road dust	**x**						
Biomass burning	**0**	**0**	**0**	**0**	**0**	**0**	**0**

HAP - hazardous air pollutants (includes toxins and carcinogens)

Notes:

x - indicates pollutant is emitted by particular source type

0 - indicates sources is considered a minor source of emissions of a particular pollutant

x,**0** - highlights sources for which the emissions of a pollutant are currently not quantifiable.

Source contributions to *quantifiable* PM10 emissions are depicted in Figure 3.15 to demonstrate the potential which exists for source ranking and the targeting of mitigation measures on the basis of emissions data. The uncertainties related to source contributions indicated is highlighted in the figure through making reference to the number of sources which are currently not quantifiable.

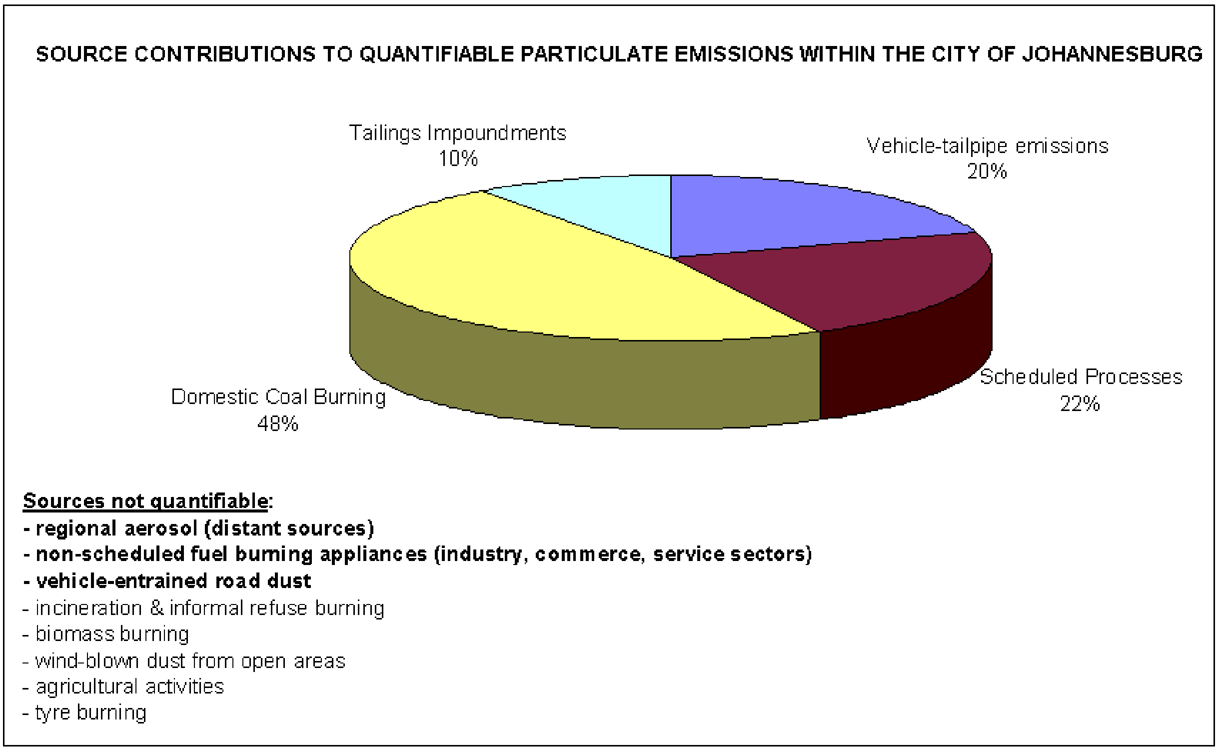


Figure 4.1 Source contributions to quantifiable particulate emissions within City of Johannesburg, with sources which are not quantifiable including local sources and regional sources known to impact on the air quality of the City, having been listed.

Due to the volume of data available it was decided to structure the analysis and discussion by addressing the following: (i) particulate and gaseous pollutant concentrations within domestic coal burning areas, (ii) particulate concentrations within non-domestic coal burning areas (ranging from residential to semi-industrial sites), (iii) criteria gaseous pollutant concentrations within non-domestic coal burning areas - including photochemical smog monitoring, and (iv) lead and volatile organic compounds concentrations within Johannesburg.

Rational	Apparent increases in NO_2 concentrations over the past decade (although not as dramatic as previously indicated in the Gauteng situation assessment). Elevated NO_2 concentrations across a large portion of the City identified through widescale passive diffusive sampling. Current exceedances of health guidelines for acute exposure due to NO_2 and O_3 episodes. Potential impact on neighbouring regions due to emissions in O_3 precursors (specifically NO) resulting in elevated O_3 concentrations elsewhere (political implications). Experience of developed countries where air quality improvements due to reductions in particulate and SO_2 concentrations through external fuel burning minimisation have been offset by increased NO_2 (and O_3) concentrations due to a growth in vehicle activity.
Main impact areas (NO_2, O_3)	Nitrogen dioxide maximums closely coincide with the City highways (N3, N1, M2, M1) and the CBD being particularly high along the Eastern Bypass, the M2 and main entry road to the south of the inner city, and the section of the N1 between the Beyers Naude off-ramp and the interchange with the Eastern Bypass. The zones of maximums thus coincide closely with the areas of high vehicle activity being particularly high at roadway sections noted by the iGoli 2010 Traffic Study to be problematic in terms of congestion Elevated nitrogen dioxide concentrations throughout the regions noted previously to have higher road densities. Elevated O_3 concentrations anticipated to occur across the City. The main impact areas associated with the emission of O_3 precursors from sources within the city are however anticipated to occur within regions to the south and southeast of the City due to the prevailing airflow patterns. (Potential for ozone impacts within Vaal Triangle and Secunda due to emissions originating within Johannesburg is, for example, being considered.)
Sources (NO_2, O_3)	Primarily vehicle tailpipe emissions Other potentially significant sources include: - Domestic and other (industrial, commercial) fuel burning appliances - Airport related emissions - Power generation (potential for impact from Kelvin Power Station on eastern suburbs) - Industrial operations (e.g. brickworks)
Indoor SO_2, CO and VOC (benzene) concentrations	
Rational	Elevated *ambient* sulphur dioxide, CO and VOC concentrations have been measured to occur at various outdoor sites but concentrations are generally within health guidelines Ambient sulphur dioxide levels appear to have stabilised with reductions being noted at certain sites. Although ambient CO levels are increasing (as for NO_x) concentrations are still below health thresholds. Indoor concentrations of sulphur dioxide and CO have been measured to significantly exceed health guidelines within domestic coal burning households. The potential for health risks due to exposures to benzene and other VOCs was noted by the CSIR (IVL, 1999). Research into CO poisoning due to coal combustion within poorly ventilated households was raised as an issue requiring further investigation at the recent Coal and Environment conference (August 2002, Mintek).
Main impact areas	Inside coal burning households
Source	Domestic coal burning

Hazardous Air Pollutant (HAP) concentrations - ambient environment	
Rational (HAPs)	Hazardous air pollutants, including various toxins, teratogens, mutagens and carcinogens are expected to be emitted within the City of Johannesburg given the types of sources present. These pollutants, despite their being emitted in trace amounts, present significant health risks in instances where residential settlements are located in close proximity to sources. The potential also exists for the bio-accumulation of certain substances (e.g. mercury) and for increased exposure due to other exposure pathways, primarily ingestion.
Main impact areas (HAPs)	- Domestic coal burning areas - Areas in close proximity to incinerators and landfills and industrial processes associated with HAP releases (see Section 3) - particularly in instances where such incineration, landfilling and/or industrial operations are not suitably controlled. - Areas in close proximity very busy, congested roads and enclosed areas where high levels of vehicle activity occurs (e.g. parking garages)
Sources (HAPs)	- Domestic coal burning - Incinerators - Landfills - Industrial operations associated with HAP releases - Vehicle exhaust emissions
Main impact areas	Residential and commercial areas located in close proximity to: sewage treatment works, landfills, abattoirs and animal rendering processes.
Sources	Includes: - sewage treatment works - poorly operated landfills - abattoirs - animal rendering plants - animal farming activities

4.3.3 City of eThekwini

The City of Ethekwini (formerly Durban) includes Durban Harbour, the Southern Industrial Basin and surrounding residential areas. The port of Durban is one of South Africa's main general cargo and container ports, the largest in the Southern Hemisphere. The industrial areas of Island View and Jacobs are located to the east and south of the Port.

Although an emissions inventory has only to date been undertaken for the South Durban area (Ecoserv, 2000) this emissions inventory provides the basis for a preliminary assessment of emissions throughout the metropolitan area. The reasons being that: (i) industry in the metropolitan area predominantly occurs in the South Durban area, (ii) emissions from vehicular traffic and locomotives within this area are given in the emissions inventory as comprising 50% of the total emissions in the metropolitan area, and (iii) emissions are included for both aircraft and ships due to the location of the harbour and Durban International Airport within the South Durban area. Sources of emission that were not quantified in the source inventory due to them not been located in the South Durban area, include domestic fuel burning and biomass burning (particularly sugarcane burning).

Table 4.2 Synopsis of emission rates from combustion-related source types within the Durban Metropolitan area

Source	PM (tpa)	NO_x (tpa)	SO_2 (tpa)	CO (tpa)
Industry and fuel burning appliances (South Durban)	2 404	7 253	12 158	18 851
Gasoline vehicles	662	9 315	445	172 328
Diesel vehicles	3 929	13 733	2 004	7 109
Ships	108	1 815	850	268
Trains	11	426	64	64
Aircraft	7 115	32 542	15 521	198 619
TOTAL (combustion sources)	**0**	**160**	**6**	**120**
Non-combustion related emissions (all sources)	323	0	27 199	0
TOTAL	**7 437**	**30 679**	**42 726**	**198 739**

From the table it is clear that all stations recorded 10-minute average exceedance of the South African sulphur dioxide concentration guidelines during 2001. Furthermore, daily average SO_2 exceedances were recorded at all stations, with the exception of the AECI. The most exceedances of the sulphur dioxide concentration guidelines were recorded at the Southworks station, namely 24 days and 182 10-minute averages. The DSSSC station, however, (although situated at the Settlers School only for the period of January 2001) recorded the highest SO_2 concentrations, representing 32%, 58%, and 43% of the 10-minute, daily and annual average guidelines respectively. NO_x levels were observed to be below the South African guidelines for all stations with the exception the AECI.

Carbon monoxide pollution predominating from the southwesterly sector, reflected as monitored concentrations less than 1 ppm, at a frequency of 9%, indicates the air quality impacts experienced at the Settlers School from the direction of Sapref Refinery operations. Similarly monitored concentrations less than 1 ppm from a northeasterly direction can be seen to originate from the direction of Engen Refinery operations at a frequency of 7%. Concentrations greater than 3 ppm were also recorded from the direction of Sapref in a 5% frequency of occurrence, this is lower than the 9% frequency of occurrence observed due to concentrations less than 1 ppm as mentioned above. Concentrations greater than 3 ppm are also observed due north of the Settlers School indicating high emissions originating from residential areas in this sector (at a frequency of 5.5%).

Annual average PM10 concentrations were recorded to be 40 µg/m^3 at Settlers School with a maximum PM10 concentration of 130 µg/m^3 having been recorded. Despite being within the lenient current SA guidelines, such concentrations represent exceedances of the air quality limits recently promulgated by other countries and organisations including the World Bank, EC, UK and Australia.

Table 4.3: The monitored NO_x and SO_2 concentrations for 2001 in the Durban South Industrial Basin.

Period	AECI		Settlers School			Southworks	Wentworth	
	NO_x (1)	SO_2 (2)	Durban Metro – NO_x	Durban Metro – SO_2	DSSSC – SO_2 (3)	SO_2 (2)	NO	SO_2
Annual	407 µg/m³	14 µg/m³	35 µg/m³	39 µg/m³	115 µg/m³	56 µg/m³	223 µg/m³	40 µg/m³
Daily*	882 µg/m³	69 µg/m³	152 µg/m³	174 µg/m³	982 µg/m³	324 µg/m³	768 µg/m³	146 µg/m³
Daily exceed		1 day		9 days	4 days	24 days		3 days
Hourly*	1434 µg/m³	354 µg/m³	470 µg/m³	871 µg/m³	1889 µg/m³	717 µg/m³	1508 µg/m³	589 µg/m³
Hourly exceed		1 hour		7 hours	35 hours	14 hours		3 hours
Instant*	8883 µg/m³	1406 µg/m³	565 µg/m³	1654 µg/m³	2005 µg/m³	1053 µg/m³	1561 µg/m³	1499 µg/m³
10-min*	3552 µg/m³	814 µg/m³	530 µg/m³	1455 µg/m³	1936 µg/m³	968 µg/m³	1561 µg/m³	916 µg/m³
10-min exceed		2		98	162	182		65

* Data has been screened for possible outliers by comparing the second highest predictions to the monitored concentrations.

(1) The concentrations for NO_x measured in ppb was converted to equivalent values in µg/m³ by averaging the calculated NO_2 and NO limits based on their molecular weights

(2) The concentrations for SO_2 measured in ppb was converted to equivalent values in µg/m³ based on the molecular weight

(3) The Durban South Sulphur Dioxide Steering Committee (DSSSC) mobile monitor was located at Settlers School for January 2001

Table 4.4: The monitored benzene concentrations for 2002 in the Durban South Industrial Basin.

Source	Highest daily concentration (µg/m³)	Average daily concentration (µg/m³)	Lowest daily concentration (µg/m³)
Mandlethu	18	9	6
Engen Recreational Club	18	6.5 (excluding single 18 value)	5

Key Sources and Priority Pollutants in Durban were elevated concentrations of sulphur dioxide, benzene, carbon monoxide, particulates and nitrogen oxides were noted to occur within Durban. Increases in CO, PM10 and NOx concentrations were noted to be correlated with poor dispersion conditions during winter, whereas sulphur dioxide concentrations were highly dependent on the prevailing wind direction from major industrial sources.

Based on the current emission estimates, vehicle emissions are estimated to be responsible for 90% of CO emissions, 70% of NO_x emissions, and ~60% of particulate emissions within the Durban metropolitan region. Diurnal trends in these pollutants have been shown to coincide with trends in traffic volumes with morning and late afternoon peaks occurring during 'rush hours'. Industrial emissions were identified as the second most significant source of particulates, NO_x and CO releases.

Industry and fuel burning appliances are responsible for over 90% of the sulphur dioxide emissions within the Durban metropolitan region according to current emission estimates. Combustion-related processes only account for 30% of the sulphur dioxide emissions from this sector. Non-combustion related emissions, which constitute the remaining 70% of the sectors contribution, comprise predominantly process emissions from the large refinery operations. The reason for this is that the refineries have already phased out 'dirty fuels' and implemented alternatives (natural gas), with the remainder of their sulphur dioxide emissions resulting from their process. The small contribution of combustion-related emissions to total sulphur dioxide concentrations within Durban is therefore anticipated to be unique to Durban and due to the control strategies (e.g. phasing out of 'dirty fuels') already implemented in the region.

4.3.4 Vaal Triangle

The Vaal Triangle is notorious for its poor air quality, with industrial and mining emissions have combined with large-scale domestic coal burning emissions to produce a formidable air quality problem in the region.

The Vaal Triangle encompasses a mixture of commercial, agricultural, and residential land use activities, all within close proximity to one another. Beyond the borders of the urban areas, the land is considered to be semi-rural and is used for low intensity farming practices.

Key Sources and Priority Pollutants in the Vaal Triangle. Elevated concentrations of particulates, SO_2, NO_x, CO, O_3, H_2S, methane, benzene and NMHCs have been noted to occur in the Vaal Triangle. Certain metals have also noted to be of concern in the vicinity of specific sources (e.g. manganese, lead and chromium). Air quality thresholds have been noted to have been exceeded for particulates, SO_2, NO_x, O_3, H_2S, benzene and certain metals. Whereas most of these pollutants are of concern due primarily to their impact on human health (and the environment), the effects of H_2S is primarily of concern due to its oderiferous nature and therefore its potential to impact on human welfare.

The most significant sources of emission contributing to widespread exposures to pollutants noted to be above acceptable air quality limits are anticipated include: various industrial emissions (combustion and non-combustion related), power generation emissions, domestic fuel burning, informal waste combustion and vehicle emissions. Fugitive dust sources such as vehicle entrainment of road dust, wind erosion of open areas (etc.) also have the potential to contribute significant to suspended particulate concentrations.

4.3.5 Mpumalanga Highveld

The Mpumalanga Highveld (formerly known as the Eastern Transvaal Highveld) has frequently been the focus of air pollution studies for two reasons (Figure 3.42). Firstly, elevated air pollution concentrations have been noted to occur in the region itself. Secondly, various elevated sources of emission located in this region have been associated with long-range transportation of pollutants and with the potential for impacting on the air quality of adjacent and more distant regions (Piketh, 1994).

The sources of emission in the Mpumalanga Highveld comprises an range of industrial, mining and agricultural activities. Categories of emissions associated with such activities are power stations, timber and related industries, metal smelters, petrochemical plants, brick and stone works, mines (primarily coal mines), fertilizer and chemical producers, explosives producers, charcoal producers, other - small additional industrial operations

Eight operational power stations (Eskom operated) fall within the defined boundaries shown on the map (Figure 3.42). The power stations are large sources of sulphur dioxide. Sulphur dioxide oxidises in the atmosphere to particulate sulphate at a rage of between 1 and 4% per hour. Fine particulate sulphate has been used to trace the transportation of power station plumes across the Southern African sub-continent.

The timber, forestry and related industries are restricted to the Escarpment. The main activity that results in atmospheric emissions involves burning of forest slash and fire breaks by the forestry industry and the burning of waste wood or timber in teepee burners by numerous saw mills in the region. One major pulp and paper industry is located in the region at Ngodwana (Sappi Ngodwana Plant located ~80 km west of Nelspruit). The process of producing paper involves the extraction of lignin primarily from wood fibre.

A concentration of metal related industries exist in the Witbank/Middleburg area including Highveld Steel and Vanadium, Transalloys and Columbus Steel. The SASOL 2 and SASOL 3 petrochemical industries are located at Secunda, co-located with fertiliser and explosive producers. The manufacturing of bricks, stone and cement is concentrated in two areas, viz. in the Witbank/Middleburg region and in the vicinity of Nelspruit. Sources of emission include coal burning within furnaces and fugitive dust emissions associated with materials handling. Coal mines are distributed throughout much of the region with large coal deposits occurring in the vicinity of Witbank. (Gold mines are located further east in the Lowveld.) Emissions from collieries include fugitive dust emissions in addition to combustion-related releases due to spontaneous combustion of discard dumps.

Key sources and priority pollutants noted to be elevated include the following: SO_2, particulates (PM10 and PM2.5), NO_x (NO, NO_2), O_3, benzene and H_2S. Of these pollutants it is anticipated that exceedances of health risk thresholds occur for SO_2, PM10, PM2.5, NO_2, O_3 and benzene and that odour thresholds for H_2S are exceeded.

Significant sources of benzene in the region include: vehicle emissions, domestic coal burning and combustion-related releases (and evaporative emissions) from the petrochemical complex at Secunda. Power generation, fuel combustion by industries and institutions, domestic fuel burning and vehicle emissions all contribute to SO_2, particulate and NO_x releases and to the formation of O_3. Impacts of H_2S has primarily noted to be an impact associated with emissions from the petrochemical complex in Secunda. Given the height at which emissions occur, such odour impacts are reported to be experienced within Johannesburg. Emissions from discard dumps represent a potentially significant contribution to the emission of combustion products.

Elevated stack emissions from several sources located on the Mpumalanga Highveld are anticipated to be significant in terms of the potential for their plumes being transported to regions further afield. Such sources include the various power stations, the petrochemical complex at Secunda and the metal smelters located in the vicinity of Witbank and possibly Middleburg.

4.3.6 City of Tshwane

The City of Tshwane, located north of Johannesburg, extends from Centrurion in the South to Temba in the North (Figure 3.44). A comprehensive emissions inventory has not been developed for the City. A qualitative description is therefore provided of the sources of emission within the region, with reference being made to certain emission estimates where available.

Combustion-related sources of emission in Tshwane include: vehicle emissions, industrial fuel and institutional fuel combustion including fuel use for incineration, central power generation, domestic fuel burning (primarily coal and wood). Industrial processes include cement and glass manufacture to various metallurgical operations, charcoal plants, gypsum production and ceramic industries including a number of brickworks.

4.4 Conclusions on pollutant identification

The identification of significant combustion-related sources and pollutants of concern on a conurbation-by-conurbation basis facilitates conclusions regarding the sources and pollutants, which represent the greatest impact from a national point of view. Given that the emissions information are incomplete for most regions and air quality monitoring data sparse for certain regions, it was necessary to draw preliminary conclusions regarding national priority sources and pollutants. Information gaps identified during this initial phase of the project were used to focus efforts during the second phase of the project during which source inventories were established for each conurbation. Preliminary conclusions regarding priority sources and pollutants are presented hereafter.

4.5 Identification of Key Sources and Pollutants on a National Basis

Given the range of combustion-related sources present within urban areas, elevated concentrations of the following pollutants are anticipated to occur within such areas:

- Particulates
- Sulphur oxides (SO_x)
- Oxides of nitrogen (NO_x)
- Carbon monoxide (CO)
- Carbon dioxide (CO_2)
- Ozone (O_3) and other photochemical oxidants
- Volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) include formaldehyde, benzene, poly-aromatic hydrocarbons, PCBs and dioxins and furans
- Methane (CH_4)
- Ammonia (NH_3)
- Hydrogen chloride (HCl)
- Hydrogen sulphide (H_2S)

- Various trace elements - including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn) and vanadium (V)

The nature and extent of the pollutants released during combustion is primarily dependent on the fuel type burned and on the nature of the combustion process. Although carbon dioxide and methane are not generally of concern in terms of human health they are considered air pollutants due to there being greenhouse gases.

In emissions inventories undertaken nationally and within certain metropolitan areas, emissions have routinely only been calculated for the most common pollutants, viz. SO2, NO_x, CO, CO2, HCs and particulates (either as TSP or PM10). Ambient air quality monitoring has similarly been largely confined to these pollutants although measurements of lead, benzene, ammonia and H2S have been undertaken in certain regions. Based on the emissions and air quality monitoring data available to date, elevated concentrations of particulates, SO_2, NOx, CO, CO_2, HCs, O_3, benzene, ammonia and H_2S concentrations have been found to occur over urban areas. Of these pollutants health risk thresholds have to date been noted to have been exceeded for particulates (PM10 and PM2.5), SO2, NO2, O3 and benzene. H2S concentrations have been noted to exceed odour thresholds in select areas. CO has been noted to be increasing in certain areas but has not yet been noted to exceed health based limits. Reductions in ambient lead concentrations (and in the blood lead level of children) have been noted to occur. This is believed to be due to the introduction of unleaded fuels, with further reductions anticipated with the phasing out of leaded fuel by January 2006.

4.5.1 Key Sources

A synopsis of the most significant combustion-related sources which contribute to pollutants noted to be of concern is given in Table 4.1.

Table 4.5 Significant sources contributing to priority pollutants within South Africa

Pollutants	Main Contributing Sources	Points of Note
PM10, PM2.5	- Vehicle tailpipe emissions (primarily diesel vehicle emissions) - all areas - Household fuel combustion - primarily coal burning on the highveld and wood and paraffin burning at coastal cities - most areas affected (impacts are notable given high exposures) - Industrial, commercial and institutional fuel burning appliances - all areas (less significant in Durban where the phasing out of 'dirty fuel' use within industry has been initiated) - Central power generation - concentration of large coal-fired power stations on Mpumalanga highveld - single coal-fired power stations operate in the Vaal Triangle, Johannesburg and Tshwane - Diesel-powered locomotives (all areas) and shipping emissions (harbour cities such as Cape Town and Ethekwini) - Biomass burning including wild fires and crop burning practices - Other sources including: informal waste combustion, tyre burning.	Domestic fuel burning is typically associated with low-level emissions in areas of high human exposure potentials. Household fuel combustion has therefore been highlighted as being of primary significance in terms of its potential for health risk impacts. The contribution of vehicle emissions to suspended particulate concentrations has not received adequate attention locally. The impact of 'diesel particles' on human health is however receiving increasing attention due to their toxicity. Vehicle emissions similarly occur near the ground within or in proximity to residential settlement and thus have the potential to result in widespread exposures.

Pollutants	Main Contributing Sources	Points of Note
NO_2 and CO	- Vehicle emissions - all areas - Industrial and other fuel burning processes - specifically gas burning appliances) - all areas - Central power generation - specifically Mpumalanga highveld but also including the Vaal Triangle, Johannesburg, Tshwane and Cape Town - Household fuel combustion - most areas experience domestic burning of either coal or wood - Diesel powered locomotives (all areas) and shipping emissions (harbour cities such as Cape Town and Ethekwini) and airports (cities with international airports such as Cape Town, Johannesburg, Durban) - Biomass burning including wild fires and crop burning practices - Tyre burning, etc. as minor sources	Vehicles appear to represent the most significant source of NO_2 and CO emissions in various urban areas. Diesel-powered vehicles were found to be slightly more significant in terms of NOx emissions whereas petrol-driven vehicles are clearly the predominant source of CO emissions. Increases in vehicle activity rates have been associated with increases in ambient NO_2 and CO concentrations. CO emissions associated with household coal combustion has been noted to be of concern due to such emissions occurring indoors in frequently poorly ventilated houses. The potential for very high indoor CO concentrations and resultant CO poisoning has been raised.
Ozone	- Secondary pollutant associated with NO_x and other precursors releases - Same sources as for NO_x	Large spatial variations in ozone concentrations have been noted based on available monitoring data. Due to this being a secondary pollutant,
SO_2	- Industrial, commercial and institutional fuel burning appliances - all areas (except Ethekwini where the phasing out of dirty fuels has dramatically reduced the contribution of this sector) - Central power generation - specifically Mpumalanga highveld but also including the Vaal Triangle, Johannesburg, Tshwane and Cape Town - Household fuel combustion - particularly coal burning areas located on the highveld - Vehicle emissions (primarily diesel-powered vehicles) - all areas - Diesel-powered locomotive related emissions (most areas) and shipping emissions (harbour cities) - Biomass burning including wild fires and crop burning practices	SO_2 concentrations are generally elevated within domestic fuel burning areas and in close proximity to non-domestic fuel burning appliances and specific industrial processes (e.g. petrochemical and metallurgical industries) In Ethekwini the recent phasing out of 'dirty fuels' has resulted in non-combustion related industrial process emissions being the primary contributor to SO_2 emissions in the region

4.6 Gaps in current knowledge

A comprehensive, up-to-date emissions inventory forms the basis for establishing source contributions to health and environmental impacts and therefore for establishing effective and fair emission reduction measures implementable to reduce such impacts. No comprehensive, up-to-date emissions inventory exists, either nationally, or for any of the metropolitan areas or regions within South Africa. The gaps in the emissions inventories of various regions include the following:

Ethekwini - the emissions inventory needs to be extended to include the whole of the City (currently confined to Durban South), with other potentially significant sources (particularly sugar cane burning and other biomass burning and household fuel combustion) being included.

Cape Town - the emission inventory currently only includes non-domestic fuel burning appliances and needs to be extended to include other sources (particularly vehicle emissions, household fuel combustion, biomass burning, all Scheduled Processes)

Cities of Johannesburg and Tshwane - although combustion-related sources have been identified and efforts made to quantified certain of these sources, no emissions inventory currently exists.

Vaal Triangle - although an emissions inventory was established in 1995 for this region, the inventory only identified and quantified sources of particulate emissions and was not subsequently maintained. This information will need to be extended to include other sources (particularly industrial and institutional fuel burning, industrial processes, household fuel combustion, vehicle emissions and biomass burning)

Mpumalanga Highveld - although emissions data were collected previously for the most significant point sources (i.e. power stations, petro-chemical plant, metallurgical industries) such data were not stored in a readily available data base for the region (due primarily to the sensitive nature of the data). These data will need to be (negotiated for) and collated. Source and emissions data will also need to be collected for other sources including: household fuel burning, industrial and institutional fuel burning, vehicle emissions and biomass burning.

4.7 SOURCE INVENTORY CONCLUSIONS

In order to effectively (and fairly) introduce emission reduction measures aimed at reducing impacts on health and the environment due to combustion-related emissions it is necessary to undertake comprehensive emissions inventories for the conurbations selected. Such emissions inventories should aim to quantify the following sources where they occur (and to identify and quantify potentially significant sources not previously identified and listed below):

- Industrial, commercial and institutional fuel combustion
- Household fuel combustion
- Vehicle emissions, including petrol- and diesel-powered vehicles
- Shipping operations
- Biomass burning, including wild fires, crop burning, burnign of forest slash and fire breaks and waste wood burning by saw mills (etc.)
- Aircraft emissions and diesel-powered locomotives

As a minimum emissions should be calculated for the following pollutants: PM10, SO_2, NO, NO_2, CO, lead, CO_2 and total VOCs. Where the availability of emission factors permit, the emission calculations should be extended to include methane, ammonia, hydrogen chloride, hydrogen sulphide, individual organic compounds (e.g. formaldehyde, benzene), poly-aromatic hydrocarbons, PCBs and dioxins and furans, in addition to certain trace elements such as As, Cd, Cr and Pb.

Significant differences exist currently with regard to the manner in which emissions are estimated and represented. It is recommended that the procedure for estimating and representing source and emissions data be standardised during the emissions inventory phase (Task 2) to facilitate the comparisons between regions and national conclusions.

In the ranking of sources, the implications of individual source types in terms of increasing ambient air pollutant concentrations and receptor exposures will need to be taken into account. Attention will therefore be paid to 'effective' release heights and the proximity of sources to sensitive receptors, in addition to the extent and duration of emissions. It is therefore recommended that efforts made to ensure that the emission inventories include the source information necessary to effectively characterise source receptor relationships. Such information includes: source location, release height, gas exit temperatures and efflux velocities (where appropriate), the dimensions of area sources.

5 SOURCE INVENTORY ESTABLISHMENT AND TECHNOLOGY OPTION IDENTIFICATION

Source or emissions inventories for each of the conurbations formed the basis for the prioritisation of technology and other options. In the establishment of emissions inventories sources of emissions to atmosphere are identified and each source's atmospheric releases quantified.

The quantification of emissions from combustion-related activities within the agricultural, transport and domestic sectors was based on reference documents, published summary data and information obtained from central sources.

In the identification of potential options and interventions which may be implemented to reduce atmospheric emissions from fuel combustion-related sources attention was paid to technological and 'other' options. Other options include legislative and regulatory tools, market interventions and education and awareness programmes.

Following the identification of several possible interventions for 'significant' source, such options were prioritised based on a qualitative assessment of their environmental benefits, technological viability and socio-economical acceptability.

5.1 Conurbation emissions inventories

A synopsis is given of each conurbation of the total annual emissions estimated for each fuel burning sector. The total emissions per sector across all conurbations are summarised in the following table:

Pollutant totals across all conurbations - estimated total annual emissions from fuel burning activities (tpa)

Pollutant	Industrial, Commercial & Institutional Fuel Burning	Electricity Generation	Vehicles	Shipping	Aircraft	Biomass Burning	Domestic Fuel Burning	TOTAL
TSP	81 807	70 986	8 704	227	33	11 441	16 370	189 567
PM10	12 920	63 887	8 704			5 720(a)	7 670	98 901
SO_2	571 860	1 519 288	42 448	2 064	219	686	17 351	2 153 917
NO_X	288 238	687 434	266 495	3 136	1 459	3 547	2 919	1 253 229
CO	80 136	767 614	918 380	268	3 056	74 365	194 232	2 038 051
CH_4	116	2 528	4 393			2 746	6 648	16 431
CO_2	102 337 668	162 361 750	21 681 104			1 876 281	2 922 506	291 179 308
TOC	299	5 055	151 212	479	1 388	6 292	10 106(b)	174 832
NMTOC	137	2 528	116 276		91	3 547		122 578
Benzene	4	42	1 877				255	2 179
Formaldehyde	6		910					916
Acetaldehyde	1		470					471
Lead	60	18	820				8	906
N_2O	76	2 120	748		15	172		3 131
1,3 Butadiene			1 460			186	33	1 679

(a) Given as PM2.5 (particulate matter <2.5 micron).
(b) Given as VOCs (volatile organic compounds).

The following are summaries of the pollutant levels across conurbations.

- In *Ethekwini and Cape Town* emissions from industrial/commercial/institutional fuel burning contributes most significantly to TSP, PM10 and SO2 emissions. This sector also contributes to NOx and to greenhouse gas emissions (CO2, N2O). Vehicle emissions are the most significant source of NOx, CO, TOC, NMTOC, benzene, formaldehyde, acetaldehyde, lead and 1.3 butadiene emissions. Vehicle emissions also contribute significantly to greenhouse gas emissions (CO2, CH4 but particularly N2O) and contribute ~30% of fine particulate and SO2 emissions. Shipping contributes marginally to NOx and SO2 levels with emissions more important in terms of their being localised within the harbour area. The contribution of aircraft and rail-related emissions (where available) was found to be small. Aircraft emissions are also expected to be more important as a localised source. Domestic fuel burning represents a significant source of fine particulates and also contributes to greenhouse gas emissions (CO2 and CH4). Despite the relatively small emissions from domestic fuel burning, compared with industry, the significance of domestic fuel burning emissions is enhance due to the low level at which emissions occur, the peaks in emissions and the proximity of releases to high exposure areas. Biomass burning contributes to fine particulate and methane emissions, representing a potentially important localised source of episodic emissions particularly in Cape Town.

- In the *Vaal Triangle* industries and power generation are the most significant sources of total particulate and sulphur dioxide. These sectors are also estimated to be larger sources of NOx than vehicles, and contribute substantially to ghg emissions. Vehicle emissions are the most significant source in term of TOC, NMTOC, benzene, formaldehyde and acetaldehyde releases as in other conurbations. Domestic fuel burning is a significant contributor to TSP, PM10, CO, CH4, TOC and benzene emissions. The significance of this sector is enhanced due to the low level at which emissions occur, the peaks in emissions and the proximity of releases to high exposure areas. As in Mpumalanga and elsewhere biomass burning was estimated to contribute to fine particulate, CO, CH4, TOC, NMTOC and N2S emissions, and to represent a potentially important localised source of episodic emissions.

- In the *Mpumalanga highveld* power generation is the most significant source sector in Mpumalanga in terms of total particulate, sulphur dioxide, NOx and CO emissions. This sector also contributes significantly to greenhouse gas emissions (CO2 and N2O). The industrial fuel burning sector is primarily important in terms of its contribution to TSP and SO2 emissions, but also contributes to CO2 and NOx emissions. Vehicle emissions are the most significant source of TOCs, NMTOCs, benzene, formaldehyde, acetaldehyde emissions from fuel burning processes. Domestic fuel burning also contributes significantly to particulate, CO, CH_4 and benzene emissions. The significance of this sector is enhance due to the low level at which emissions occur, the peaks in emissions and the proximity of releases to high exposure areas. Biomass burning contributes to fine particulate, CO, CH_4, TOC, NMTOC and N_2S emissions, representing a potentially important localised source of episodic emissions.

- In *City of Johannesburg* the industrial, biomass burning and domestic fuel burning sectors are the largest contributors of particulate and SO2 emissions. The domestic fuel burning sector is considered to be the most significant given the low level of emissions, the winter-time early morning or evening peaks in emissions and the release of emissions within high human exposure areas. Domestic fuel burning also contributes significantly to CO, CO2, CH4, TOC and benzene emissions. Biomass burning represents a potentially important localised source of episodic emissions, also contributing to TOC and ghg emissions (CH4, N2O). Vehicles are the most significant source of NOx, CO, TOC, benzene, formaldehyde, acetaldehyde, lead, N2O and 1.3 butadiene emissions. This source also contributes ~30% to total fine particulate and SO2 emissions from fuel burning. The significance of vehicle emissions is enhanced by the low level at which emissions occur and their proximity to residential areas. Aircraft emissions at the Johannesburg International Airport contributes marginally to NOx, TOC, SO2 and N2O emissions. Such emissions are expected to be more important as a localised source.

- In *Tshwane and Ekurhuleni* the contribution of the industrial and power generation sectors are estimated to be more significant in Tshwane compared to City of Johannesburg. The industrial and commercial fuel burning sector is also more significant in Ekurhuleni in terms of particulate and SO2 emissions when compared to City of Johannesburg. Domestic fuel burning is still evident as an important source of low level particulate and SO2 emissions in both metropols.

5.2 Significance rating of sources

The significance of domestic fuel burning emissions is enhanced due to three factors:

(i) the low level of emissions,

(ii) the coincidence of peak emissions, typically a factor of 10 greater than it total annual emissions were averaged, with periods of poor atmospheric dispersion (i.e. night-time, winter-time), and

(iii) the release of such emissions within high human exposure areas with high contributions to both indoor and outdoor pollution concentrations.

The significance of biomass burning is similarly enhanced as a localised source of episodic emissions due the low level of release and the fact that most emissions occurring during the burn season.

The significance of vehicle emissions in terms of the contribution to air pollutant concentrations and health risks is similarly enhanced by the low level at which emissions occur and the proximity of such releases to high exposure areas. Vehicle emissions also tend to peak in the early morning and evenings at which time atmospheric dispersion potentials are reduced.

The significance of fuel burning within industrial and power generation sectors in terms of their contributions to air pollutant concentrations and health risks is frequently lower than would be expected given the extent of emissions. This is due to these sources generally being characterised by constant, high level releases with such emissions also likely to be more remote from residential settlement compared to household fuel burning and vehicle emissions.

Taking the above considerations into account the most significant sources were identified as follows (not ranked):

- *Industrial and commercial fuel burning sector* - significant source of particulates and SO_2 in all areas but particularly Cape Town, Ethekwini, Vaal Triangle, Ekurhuleni and Mpumalanga. This sector was also noted to contribute to NO_x emissions and to various ghg emissions (CO_2, N_2O).

- *Vehicle emissions* - significant source of CO, NOx, TOC, NMTOC, benzene, lead, acetaldehyde, formaldehyde, 1.3 butadiene emissions in all conurbations. This sector also contributes ~30% to total fine particulate and SO_2 emissions from fuel burning processes and it a significant source of ghg emissions (CO_2, CH_4 but particularly N_2O). The contribution of vehicles to CO, NOx and SO_2 emissions were however noted to be lower in regions/conurbations with higher industrial and power generation emissions, e.g. Vaal Triangle and Mpumalanga.

- *Domestic fuel burning* - significant source of low level fine particulate and sulphur dioxide emissions. This sector also contributes significantly to CO, TOC and benzene emissions and to ghg emissions (CO_2, CH_4). The contribution of this sector to fine particulate concentrations within Cape Town and Ethekwini is enhanced due to the extent of wood being burned. Sulphur dioxide emissions from the sector are higher for inland areas where coal burning is more widespread.

- *Electricity generation* - significant source of particulate, SO_2, NO_x, CO and TOC emissions in Mpumalanga and Vaal Triangle and to a lesser extent Tshwane. Despite the high level at which emissions are released important contributions to local ground level concentrations are possible during unstable atmospheric conditions. The sector is also an important contributor of ghg emissions (CO_2, N_2O).

- *Biomass burning* - significant source of localised, episodic fine particulate emissions. This sector also contributes to TOC and ghg emissions (CH_4, N_2O).

The contribution of shipping, aircraft and railway emissions were shown to be relatively small although it was recognised that shipping and aircraft emissions could contribute significantly to localised, low level emissions.

5.3 FORECAST CHANGES IN EMISSIONS GIVEN 'BUSINESS AS USUAL'

In the electricity generation sector, given a 'business as usual' scenario it is expected that emissions from the electricity generation sector will increase accordingly (with the likely exception of particulates due to the controls currently in place and proposed).

Coal consumption by the *industrial, commercial and institutional sector* (including liquid fuels) increased by 19% during the 1989 to 1999 period despite the consumption of petroleum products by this sector having remained relatively constant during this period.

Fuel burning by the chemical and petrochemical, textile manufacture, pulp and paper, food and tobacco (particularly sugar refining and breweries), iron and steel and other metallurgical processing, non-metallurgical or ceramic processes, commercial and institutional fuel burning.

A general discussion of the expected changes in the demand for products and in energy requirements within specific sub-sectors is provided.

In *domestic fuel burning* a wide array of factors affecting the extent of household fuel combustion including: population growth, availability of electricity, household income, degree of urbanisation, and percentage of informal (unserviced) households. Population growth, reductions in household income levels and increase in informal (unserviced) households have been noted to result in increased household fuel burning. These factors will need to be continuously monitored and tracked as targets are pursued to reduce pollution in this sector.

The following trends in key drivers associated with domestic fuel burning have been noted:

- Population growth rates are projected to increase by 1.6% in the short term 2003 - 2007, but are expected to reduce to a zero growth rate during the first half of 2010 (ABSA, 2002).

- The quantity of coal consumed by the merchants and domestic sector has decreased by a factor of 2.3 over the 1989 to 1999 period (Doppegieter *et al.*, 2000).

- The Integrated National Electrification Programme is on-going with it being envisaged that all houses will be electrified by 2010/2011.

Given these trends it is anticipated that domestic fuel burning will persist in the short-term (2003 - 2007). It is however likely to start to decrease in the medium-term as a result of lower population growth rates and on-going electrification. This is an important consideration in the development of objectives to reduce air pollution from this source.

In terms of *vehicle emissions* the main factors affecting vehicle transport energy demand include: economic trends, demographics, fuel accessibility and supply, spatial structure and transport infrastructure (urban sprawl), intermodal competition, lifestyle norms and regulation.

The consumption of petroleum products by the total transportation sector increased by a factor of 2.7 during the 1970 to 1998 period. Whereas increased vehicle activity rates imply an increase in emissions from this sector, it is notable that improvements in the fuel efficiency of vehicles, the incorporation of emission controls by new vehicles and past and proposed changes in fuel composition are responsible for realising emission reductions.

In the event that measures are implemented within the next ten years substantial changes in the nature and extent of vehicle emissions would be anticipated. The project proponent advised however that due to the DME's strategy not having been finalised the proposed measures - including proposed changes in fuel composition - not be considered in the 'business as usual' projections. Despite the projected increase in the number of vehicles fitted with catalytic converters emissions of most compounds are estimate to increase due to increased vehicle activity rates (projected on the basis of fuel sales). Substantial reduction in lead is anticipated to occur due to on-going growth in the use of unleaded petrol, even in the absence of regulations requiring the phasing out of lead. These considerations have been taken cognisence of in setting objectives for reducing vehicle emissions.

5.4 Pollutant significance ratings of sources given future trends

The extent of emissions from the majority of source sectors is not anticipated to change substantially in the short-term, with projections being certain for the medium-term, i.e. beyond 2007. Emissions from the power generation sector, the household fuel burning sector, the industrial and commercial fuel burning sector and biomass burning are likely to either remain relatively constant or to increase during this period. The only notable change foreseen for the industrial sector is the large emission reductions from the Sasol Sasolburg plant anticipated to occur in 2004 due to the switching from coal to natural gas. This will result in a reduction in the significance of the chemical and petrochemical sector to total fuel burning emissions within the Vaal Triangle.

Vehicle emissions are expected to increase, assuming an absence of future controls, with various pollutants predicted to increase by up to 27% in 2007 and by up to 44% in 2011.

The recommendation has being made that emission reduction opportunities be identified for the following source groups:

- Domestic fuel burning
- Coal-fired power stations
- Industrial, commercial and institutional fuel burning, notably the chemical and petrochemical - specifically refineries utilising coal and HFO, pulp and paper, food and tobacco - specifically sugar refineries, metallurgical processes - specifically iron and steel, non-metallurgical processes - specifically brick and cement manufacture and commercial & institutional fuel burning sub-sectors
- Vehicle emissions

These were considered in the study in the light of the health impact and the socio-economic impact of appropriate interventions in terms of whether they should be targeted for reduction.

5.5 Option identification and prioritisation for emission reduction opportunities

Following the inventory of possible options the feasibility of such options were *qualitatively* assessed in order to select the most beneficial and feasible measures for possible quantitative evaluation. Options unlikely to realise emission reductions and result in human health risk reductions were excluded from further consideration and the remaining options prioritised taking into account the environmental benefits, technical feasibility, economic viability and social and political acceptability of such options.

Emission reduction measures implementable within various sectors have been identified for possible quantitative assessment. Provision is made for the evaluation of measures within sectors considered to be significant sources within one or more of the conurbations under investigation.

The emission reductions associated with each component of the DME's strategy (e.g. reduction of sulphur content of fuel; stipulation of EURO2 and EURO4 technology for new vehicles) has been individually estimated and the resultant air quality improvement and predicted assuming that the impact of vehicle emissions is found to be significant. In addition to the changes in vehicle technology, fuel efficiency and fuel composition stipulated in the proposed implementation strategy, other measures able to afford alternative or additional emission reduction opportunities for vehicles may be considered. Measures associated with cleaner technology introduction, traffic volume reduction and vehicle emissions testing and vehicle maintenance are listed as possible additional or alternative measures.

Table 6. Emission reduction measures identified for quantitative assessment during Task 4.

Sector	Sub-sector	Measure	Location for Implementation	Likely Timeframe for Implementation
Residential	Coal, wood and paraffin burning communities	Top down ignition	City of Johannesburg, Ekurhuleni, Tshwane, Vaal Triangle	Short-term
		Stove maintenance and replacement	City of Johannesburg, Ekurhuleni, Tshwane, Vaal Triangle	Short- to medium-term
		Insulation of existing homes	City of Johannesburg	Short- to medium-term
		Electrification	National	Short- to medium-term
		Low smoke fuel implementation	National	Medium-term
		Switching to LPG and natural gas	City of Johannesburg, Ekurhuleni, Vaal Triangle, parts of Mpumalanga Highveld	Medium- to long-term
		Solar passive design implementation	National	Medium-term
Electricity generation	Eskom, municipalities, private	Implementation of a CCT, viz. fluidised bed combustion	National	Medium-term
		Gas-fired plant implementation	National	Medium-term
		Nuclear plant, viz. PBMR implementation	National	Medium-term
		Imported hydro	National	Medium-term
		Large-scale solar energy system	Conurbation to be selected	Medium-term
Industrial	Clay brick manufacture	Fuel switching from coal to gas	Various conurbations, specifically Tshwane	Short to medium-term
	Iron and steel and other select metallurgical processes	Waste gas recovery and use	Primarily Vaal Triangle and Mpumalanga Highveld	Short to medium-term
		Improved dust emission control	Primarily Vaal Triangle and Mpumalanga Highveld	Short-term
		Coke oven improvements and controls (where applicable)	Primarily Vaal Triangle and Mpumalanga Highveld	Short to medium-term
	Sugar refiners	Implementation of energy efficiency measures to reduce coal consumption	Ethekwini	Short to medium-term
	Pulp and paper	Implementation of energy efficiency measures to reduce coal consumption	National	Short to medium-term
		Conversion of coal-burning facility to a cleaner burning fuel (gas)	National	Medium-term
	Cement manufacturers	Minimisation of fuel energy use by preheating and precalcination (to the extent possible given existing kiln system configuration)	National	Short-term
		Heat recovery from waste gas	National	Medium-term
	Petrochemical	Conversion of coal-burning facilities to a cleaner burning fuel (ga)	Vaal Triangle, Mpumalanga Highveld	Medium-term
	Cross-sectoral	Enforcement of international best practice emission limits	National	Short- to medium-term
Transportation	Vehicles	Improved vehicle technologies and fuel reformulation as stipulated in the DEAT/DME Implementation Strategy (version 2, 4 March 2003)	National	Short- to medium-term
		Implementation of a vehicle maintenane requirement and emission testing programme	National	Short- to medium-term
		Implementation of a cluster of traffic control measures with emphasis on the provision of alternatives to reduce reliance on single-occupancy vehicles (e.g. public transit improvements; economic incentives; public eduction)	City of Johannesburg, Cape Town or Ethekwini	Short- to medium-term

		Implementation of CNG and/or LPG driven public buses	City of Johannesburg, Cape Town or Ethekwini	Medium-term

6 QUANTIFICATION OF ENVIRONMENTAL BENEFITS

This task was aimed at the quantification of the environmental benefits associated with the implementation of prioritised technological and other interventions.

In assessing current environmental costs and potential environmental benefits (and related savings) which may be achieved by interventions a damage function approach was adopted. This systematic approach links emissions and resource impacts related to an activity to changes in environmental quality, in this case air quality. Such changes are in turn associated with environmental, social and health impacts.

Air quality impacts associated with sources inventoried during previous tasks were determined through the application of atmospheric dispersion modelling. The potential for and extent of health impacts arising due to fuel combustion related air emissions was subsequently established through the application of dose-response relationships.

6.1 AIR QUALITY IMPACTS DUE TO CURRENT FUEL COMBUSTION PRACTICES

Air pollutant concentrations were predicted for various source groupings in order to facilitate the quantification of air quality improvements achievable through intervention implementation. A synopsis of the main findings for each conurbation is given in the table on the next page.

Cape Town	Sources contributing significantly to ambient particulate concentrations in the Cape study region included primarily domestic wood burning, coal fired boiler operations and 'other sources'. The latter category included a range of small-scale operations including wood-fired pizza ovens. The largest contributions to sulphur dioxide concentrations were HFO-fired boilers, coal-fired boilers, Sappi and Caltex. Wood waste burning, vehicle tailpipe emissions, boiler operations and the Sappi and Caltex operations represented the most significant sources of nitrogen oxide concentrations.
Ethekwini	The main sources of particulate concentrations were predicted to include: domestic coal and wood burning, coal-fired boilers, diesel vehicles and the Sappi Saiccor and Hugletts plants. Elevated sulphur dioxide concentrations were associated with domestic coal burning, petrol vehicle, coal boiler, Sappi and Hugletts emissions. Ambient pollutant concentrations were noted to be higher than expected, with exceedances of the lead guideline anticipated due to petrol vehicle emissions. Such elevated concentrations may be a function of the manner in which vehicle emissions were spatially allocated, i.e. based on fuel sales data by magisterial district, road densities and types and select traffic count data.
City of Johannesburg & Ekurhuleni	Domestic coal burning and coal fired boilers were noted to be the most significant fuel-burning related sources of airborne particulates in this region. Coal boiler operations included the operations undertaken at the Zwartkoppies pump station (south of City of Johannesburg CBD), Impala Refinery (Springs) and NCP (Chloorkop). The highest sulphur dioxide concentrations were predicted to be due to emissions from domestic coal burning, petrol-driven vehicles and various coal boiler operations. Ambient benzene and lead emissions were primarily the result of petrol vehicle emissions as may be expected.
Tshwane	The most significant fuel combustion related sources in the region are the two local power stations (Pretoria West and Rooiwal), various brickwork operations and domestic fuel burning. The Rooiwal Power Station was estimated to be one of the largest point sources. Most of the brickworks are located in close proximity to each other within the Moot valley located west of the Pretoria CBD. Although estimates of the air quality impact of coal-fired boilers was relatively low it is noted that the emissions inventory compiled for the region did not include the many small-scale boiler operations in the region.
Vaal Triangle	Household fuel combustion represents a large contributor to low level particulate concentrations. The coke oven operation at Iscor Vanderbijlpark Works represents one of the most significant industrial fuel related operations impacting on the region. The highest ground level sulphur dioxide concentrations were associated with Lethabo power station emissions, with Sasol power stations and HFO combustion by Natref also contributing to ambient SO_2 levels. Vehicle emissions were predicted to result in relatively slight ambient pollutant concentrations in this region.
Mpumalanga study area	Potentially significant sources of fuel combustion related particulate concentrations in the Mpumalanga study region included domestic coal burning, brickwork operations and coal combustion by Highveld Steel and Vanadium. Fuel-combustion related sources predicted to contribute significantly to ambient sulphur dioxide concentrations included Sasol Secunda Complex, Eskom's various coal-fired stations, Highveld Steel and Vanadium and the combined impact of various brickworks. The contribution of domestic fuel burning to ambient sulphur dioxide concentrations was noted to be relatively small.

Predicted air pollutant concentrations due to biomass burning related emissions were found to be unrepresentative. This is likely to be due to the difficulty in modelling such emissions accurately. Due to their episodic nature and unpredictable duration biomass burning could not be adequately modelled using the dispersion modelling methodology adopted for the study. It was therefore decided not to use the results generated for the purpose of informing the decision making process.

Based on their contribution to ambient air pollutant concentrations the following sources were flagged as being of potential interest:

- Domestic coal combustion (particularly City of Johannesburg, Vaal Triangle)
- Domestic wood combustion (Cape Town)
- Coal-fired boilers (Cape Town, Ethekwini, City of Johannesburg, Ekurhuleni)

- HFO-fired boilers (Cape Town)
- Brickwork operations (Tshwane and Mpumalanga)
- Power generation (Mpumalanga, Tshwane, Vaal Triangle)
- Vehicles (Cape Town, Ethekwini, City of Johannesburg, Ekurhuleni, Tshwane)

Individual operations which were found to contribute significantly to ambient pollutant concentrations included: Sappi Fine Papers and Caltex Refinery (Cape Town), Sappi Saiccor and Huglett sugar (Ethekwini), Impala Platinum,Refinery (Springs), NCP and Zwartkoppies pump station (Ekurhuleni), Sasol Secunda and Highveld Steel & Vanadium (Mpumalanga), and the coke oven operations at Iscor Vanderbijlpark (Vaal Triangle).

6.2 Health Risk Impacts due to Current Fuel Combustion Practices

A synopsis of the health impacts associated with all inventoried fuel combustion sources is given in Table 1. Total respiratory hospital admissions across all conurbations was calculated to be in the order of ~118 900 representing 0.64% of the population. Cardiovascular hospital admissions of ~860 per annum were estimated (0.005% of population). Exposure to fuel combustion related pollutant concentrations was found to be associated with ~300 premature deaths, with 0.002% of the population affected. Incidence of chronic bronchitis and cancer cases were estimated to be ~110 615 and ~230 respectively (i.e. 0.59% and 0.001% of population affected).

A total of ~795 000 restricted activity days was estimated, representing 67.2 days per potentially economically active person (i.e. persons 20 to 65 years of age). Approximately ~6000 children were predicted to be exposed to annual average lead concentrations of >2 µg/m3, which represents the thresholds above which reductions in IQ points have been noted to occur (i.e. 0.23% of children). An estimated 7.7% of the total population was predicted to be exposed to annual lead concentrations above the level proposed as the new South African limit (i.e. 0.5 µg/m3).

Table 1. Health impacts associated with human exposures to all fuel burning emissions predicted for the base year 2002.

HEALTH ENDPOINT	CAPE TOWN	ETHEKWINI	CITY OF JOHANNESBURG & EKURHULENI	TSHWANE	VAAL TRIANGLE	MPUMALANGA	TOTAL
Respiratory hospital admissions (due to PM10, SO2 and NO2 exposures)	29,481.7	27,072.0	34,021.1	10,205.3	9,440.0	8,685.3	**118,905.4**
Cardiovascular hospital admissions (due to PM10 exposures)	234.9	201.1	262.2	57.0	71.0	34.5	**860.8**
Premature mortality (due to PM10 and SO2 exposures)	90.9	79.5	71.5	18.8	19.9	16.8	**297.4**
Chronic bronchitis (due to PM10 exposures)	28,806.6	18,792.8	38,550.4	8,567.6	9,457.5	6,440.1	**110,615.0**
Restricted activity days (RAD, due to PM10 exposures)	217,563.3	189,118.3	238,326.3	56,064.1	62,546.5	31,542.8	**795,161.3**
Minor restricted activity days (MRAD, due to SO2 exposures)	9,320,431.4	7,570,321.9	12,396,320.4	5,663,333.1	6,128,743.4	32,135,642.1	**73,214,792.2**
Leukemia cases (due to 1.3 butadiene and benzene exposures)	26.7	44.2	67.4	71.9	9.1	6.4	**225.7**
Nasal carcinoma cases (due to formaldehyde exposures)	0.5	0.8	1.5	1.7	0.2	0.3	**5.0**
Number of children exposed to > 2µg/m3 & hence to potential for IQ point reductions	0	669.9	5,285.8	5.5	0	0	**5,961.1**

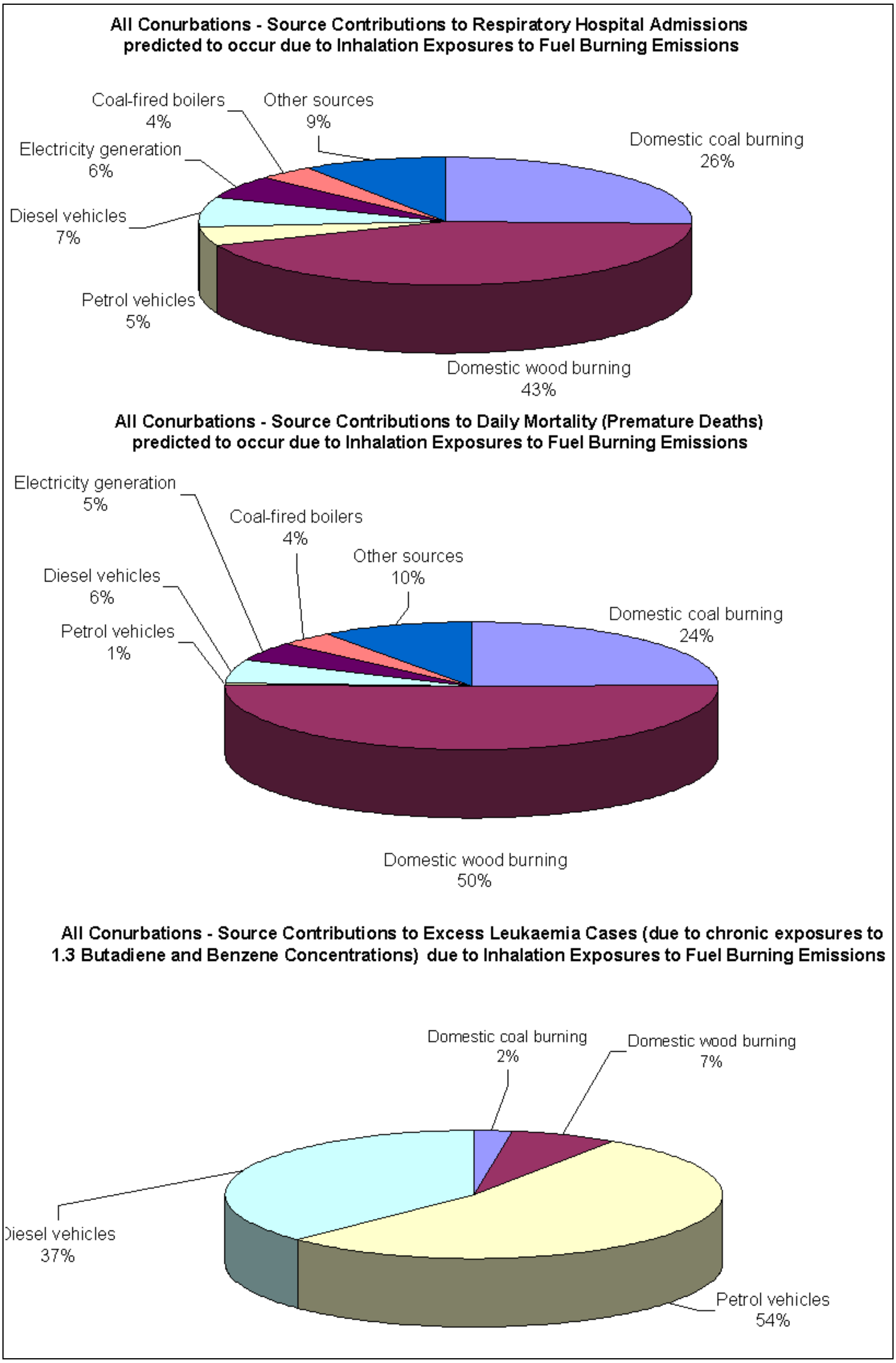


Figure 1 Source contributions to health risks associated with exposures to fuel burning emissions across all conurbations (2002).

Source contributions to health risks across all conurbations are illustrated in Figure 1. Domestic fuel burning was estimated to result in the greatest non-carcinogenic health risks across all conurbations. This source accounted for ~70% of all respiratory hospital admissions (RHA) and ~75% of all premature mortalities predicted. Vehicle emissions were associated with 12% and 6% of the RHA and daily mortality cases respectively. (The lower contribution of vehicles to daily mortality is primarily due to the absence of a dose-response function linking NO2 exposures to mortality.) Electricity generation is predicted to account for 6% of the RHA and 5% of the premature deaths respectively. Coal-fired boiler operations are the most significant industrial source grouping, estimated to account for 4% of the RHA and mortality cases.

The most significant individual point sources associated with non-carcinogenic health risks include: Highveld Steel & Vanadium, Iscor Vanderbijlpark Works, Sasol Secunda and Hugletts (Ethekwini). Vehicle emissions are responsible for ~95% of the leukaemia risks associated with exposures to fuel burning related 1.3 butadiene and benzene concentrations. The remaining risk is primarily due to coal-fired boilers, power generation and domestic fuel burning.

Assuming business as usual it is estimated that health effects due to exposures to ambient pollutant concentrations resulting from burning emissions will increase during the next decade in the following order:

- Cape Town (3% to 22%)
- Ethekwini (0% to 23%)
- City of Johannesburg and Ekurhuleni (4% to 21%)
- Tshwane (14% to 26%)
- Vaal Triangle (0% to 19%)
- Mpumalanga (0% to 23%)

The small rate of increase in the Vaal Triangle was due to the predominance of domestic fuel burning effects and the assumption made that domestic fuel burning will not increase(1). The most significant fuel burning sources, in terms of human health risk, having been identified it is possible to consider interventions tailored to the realisation of emission reductions from such sources.

[1] Evidence was found during Task 2 of a decline in the quantity of fuel used by households. Ambient particulate concentrations recorded in Soweto over the last decade also indicates a downward trend in household fuel usage.

The main sources of fuel combustion related health risks identified for each individual conurbation are described in the following table:

Cape Town	In Cape Town 80% of the respiratory ailments resulting in increased hospitalisation was predicted to be due to domestic wood burning, with domestic coal burning only responsible for 2%. Boiler operations represented the second largest source of respiratory hospital admissions accounting for 9% of incidence. Vehicle exhaust emissions was estimated to be responsible for most of the remaining cases (2% due to petrol vehicles; 3% due to diesel vehicles). Fuel combustion related emissions from the Sappi, Caltex and Athlone Power Station were calculated to be responsible for 0.2%, 0.5% and 0.4% of the total respiratory hospital admission incidence respectively. Source contributions to premature mortality was similar to that for respiratory hospital admissions with domestic fuel burning, boiler operations and vehicle emissions responsible for 83%, 10% and 2% of cases respectively. Fuel combustion was predicted to be responsible for 26.7 additional cases of leukaemia reflecting a cancer risk of (~1:150 000) and 0.5 cases of nasal carcinoma (1 in 8.2 million). The greatest cancer risks was associated with exposures to vehicle emissions which accounted for over 90% of the risk of leukaemia, with domestic wood burning responsible for much of the remaining estimated risk.
Ethekwini	In this conurbation 75% of the respiratory hospital admissions was predicted to be due to domestic fuel burning (65% due to wood burning and 10% due to coal burning). Vehicle emissions was estimated to be responsible for 18% of incidence (6% due to petrol vehicles; 12% due to diesel vehicles). There are few HFO fired boilers in Ethekwini due to the recent programme initiated to reduce the extent of "dirty fuels" used, particularly in the Durban South industrial area. Whereas HFO-fired boilers was estimated accounted for only 0.1% of all respiratory cases, coal-fired boiler emissions was estimated to be responsible for 1.9% of such cases. The most significant single point sources was predicted to be coal burning at Hugletts (~2% of respiratory cases) and Sappi Saiccor (0.2% of cases). Fuel combustion was predicted to be responsible for 44 additional cases of leukaemia reflecting a cancer risk of (~1:83 000) and 0.8 cases of nasal carcinoma (1 in 4.5 million). The leukaemia risks were due primarily to vehicle emissions (58% due to petrol-driven vehicles, 40% due to diesel vehicles), with domestic wood burning estimated to be responsible for 2% of risks.
City of Johannesburg & Ekurhuleni	Domestic fuel burning also represented the most significant source of respiratory hospital admissions and premature mortalities, estimated to account for 77% and 84% of such cases respectively (56% and 61% due to coal burning, remainder due to wood burning). Vehicle emissions were associated with 12% of the risks of respiratory hopitalisations (7% due to diesel vehicles). Coal fired boilers combined were estimated to be responsible for 7% of all respiratory hospitalisations and premature mortality, with the coal boiler operations at NCP, Zwartkoppies pump station and Sappi Enstra estimated to account for 1%, 0.6% and 0.5% of respiratory hospital admissions respectively. Kelvin Power Station was calculated to be responsible for ~0.7% of cases. Domestic fuel burning was estimated to be responsible for 3.6 excess leukaemia cases, with vehicle related emissions predicted to account for a further 64 cases. Emissions from petrol-driven vehicles were estimated to result in ~5300 children being exposed to lead concentrations in excess of 2 $\mu g/m^3$ which represents the threshold above which IQ point deficits have been noted to occur.
Tshwane	Vehicle emissions were estimated to account for ~40% of hospitalisations due to all respiratory conditions (petrol 18% and diesel 23% of cases). Domestic fuel burning accounted for 24% of cases, primarily due to coal combustion (20%). Power generation (primarily the Pretoria West Power Station) was estimated to be responsible for 11% of all respiratory hospital cases. Brickworks combined accounted for 4% of the respiratory hospitalisation risk and 6% of the premature mortality risk. Other sources (including furnaces) accounted for 20% of hospital admission cases. Fuel burning emissions were predicted to be responsible for 72 excess leukaemia cases, with vehicle related emissions predicted to account for much of this risk.

Vaal Triangle	Fuel combustion related emissions were estimated to account for ~9 400 cases of respiratory hospitalisations. Approximately 77% of such cases were predicted to be due to domestic fuel burning; 57% due to coal and 20% due to wood burning. The contribution of vehicles was small (0.7% of cases) compared to the conurbations considered previously. The largest point sources included coal-fired boilers combined (2% of cases), Iscor Vanderbijlpark Works (coke oven plant) (~5% of cases), Sasol Sasolburg (steam stations) (~1% of cases) and Lethabo Power Station (~9% of cases). Domestic fuel burning was estimated to be responsible for 90% of the excess leukaemia cases predicted to be due to exposures to fuel burning emissions, with vehicle related emissions predicted to account for a further 9% of such risks.
Mpumalanga study area	A relatively small number of "all respiratory" cases was predicted to occur within the Mpumalanga highveld study area (~8 700 cases) compared to the other conurbations. Of the cases predicted, the combined impact of the seven operational coal-fired (Eskom) power stations was estimated to be responsible for 51% of such cases. Domestic fuel burning represented the second largest source of respiratory ailments, with coal burning accounting for 12% of cases and wood for 7% of cases (19% combined). Emissions from the steam stations at the Sasol Secunda plant were predicted to be responsible for 17% of cases. Other significant sources included: Highveld Steel & Vanadium (7%) and coal fired boiler operations (2%). The risk of leukaemia due to exposure to fuel combustion related emissions was predicted to be due primarily to domestic fuel burning exposures (~90% of cases), with vehicle emissions representing the second largest source of such risks (~10%).

6.3 Intervention implementation

A synopsis of the interventions quantified during the current study and their related control efficiencies is given Table 2. The various assumptions made regarding the spatial scale and timeframe for implementation of the various interventions is outlined in the relevant tables were described in the precious section.

Interventions considered to reduce emissions from domestic fuel burning included several of the measures highlighted for possible implementation by the Department of Minerals and Energy in its Integrated Clean Household Energy Strategy (ICHES).

Measures included in the DME's draft strategy for vehicle emission reduction were similarly also considered in the development of the stratgy. Due to the absence of detailed spatial traffic flow data it was not feasible to accurately assess the implications of certain vehicle related interventions such as the taxi recapitalisation project and measures aimed at curbing vehicle activity reductions. Measures were only quantified if they were clearly able to result in an emission reduction. Emphasis was placed on short- and medium-term interventions able to realise emission reductions and health risk improvements in the next ten to fifteen years.

Health risk reductions realisable through the implementation of the selected interventions are given in the Tables 3 and 4 for interventions implementable by 2007 and 2011 respectively.

Interventions which target domestic fuel combustion were associated with the most significant reductions in respiratory hospital admissions and premature mortality as was expected given the health impacts associated with this source. Low smoke fuel implementation was associated with the most significant non-carcinogenic impact reductions. Electrification resulted in the second greatest RHA reductions followed by large scale housing insulation implementation.

The requirement of all petrol vehicles to be compliant with EURO 2 standards was the fourth most successful intervention in terms of RHA reduction. The restriction of particulate emissions from coal-boiler operations was the industry related intervention which resulted in the greatest RHA reductions. The manner in which such particulate reductions could be realised was not stipulated given that a range of methods could be implemented (e.g. fuel switching, clean coal technology implementation, fuel efficiency improvements, abatement technology). The electricity generation intervention resulting in the largest RHA reductions was the desulphurisation of all power station emissions.

Interventions targeting vehicle emissions were predicted to result in the greatest reductions in cancer risks as was expected. Interventions involving the requirement of technologies compliant with EURO standards, large scale conversion of petrol vehicles to LPG and the restriction of the benzene content of fuels were associated with the most significant cancer risk reductions.

Table 2. Synopsis of Interventions selected for quantitative health risk assessment and their associated spatial scales, timeframes and emission reductions

Number	**Sector**	**Measure**	**Spatial scale**	**Sub-sector**	**Location**	**% Emission Reduction**							**Timeframe**
						PM10	SO2	NOx	Benzene	1.3 Butadiene	Formaldehyde	Lead	
1	Residential	Top down ignition - DME ICHES	DME areas only	Domestic coal	City of Johannesburg	20	8	8	8	8	8	8	2011
					Mpumalanga	15	6	6	6	6	6	6	2011
2	Residential	Top down ignition - plateau roll out	Plateau roll out - all study areas	Domestic coal	Plateau	20	8	8	8	8	8	8	2011
3	Residential	Low smoke fuels	Plateau implementation - supported by legislation	Domestic coal	Plateau	50	0	0	0	0	0	0	2011
4	Residential	Housing insulation - 5% of plateau fuel burning households	Plateau (5% of hh)	Domestic fuel (space heating)	Plateau	2	2	2	2	2	2	2	2011
5	Residential	Housing insulation - 20% of plateau fuel burning households	Plateau (20% of hh)	Domestic fuel (space heating)	Plateau	8	8	8	8	8	8	8	2011
6	Residential	Housing insulation - 5% of all fuel burning households	All study areas (5% of hh)	Domestic fuel (space heating)	All areas	2	2	2	2	2	2	2	2011
7	Residential	Housing insulation - 20% of all fuel burning households	All study areas (20% of hh)	Domestic fuel (space heating)	All areas	8	8	8	8	8	8	8	2011
8	Residential	Electrification	National implementation	Domestic fuel (space heating)	All areas	see emission reductions per conurbation (a)							2007
9	Residential	Stove maintenance and replacement - 5% households all areas	All study areas (5% of hh)	Domestic fuel (space heating)	All areas	1	1	1	1	1	1	1	2011
10	Residential	Stove maintenance and replacement - 20% households all areas	All study areas (20% of hh)	Domestic fuel (space heating)	All areas	4	4	4	4	4	4	4	2011
11	Electricity Generation	Desulphurisation of all PS emissions	All power stations in study areas	Electricity generation	All areas (except Ethekwini)	(6)	94.7	(6)	(6)	(6)	(6)	(6)	2011
12	Electricity Generation	Decommissioning of Pretoria West PS - gas use by households	Tshwane - Pretoria West PS only	Electricity generation	Tshwane	100	100	100	100	100	100	100	2011
13	Electricity Generation	RE technology implementation through financial incentives (10 000 GWh block)	Vaal Triangle & Mpumalanga	Electricity generation	Mpumalanga, Vaal Triangle	5.19	5.19	5.19	5.19	5.19	5.19	5.19	2011
14	Electricity Generation	RE technology implementation through financial incentives (37 000 GWh block)	Vaal Triangle & Mpumalanga	Electricity generation	Mpumalanga, Vaal Triangle	18.96	18.96	18.96	18.96	18.96	18.96	18.96	2011
15	Industrial	Emission reduction requirements for coal fired boilers for particulates (>90% control efficiency required)	National implementation	Coal-fired boilers	All areas	90	0	0	0	0	0	0	2011

Number	Sector	Measure	Spatial scale	Sub-sector	Location	% Emission Reduction							Timeframe
						PM10	SO2	NOx	Benzene	1.3 Butadiene	Formaldehyde	Lead	
16	Industrial	Iscor coke oven gas cleaning project	Iscor Vanderbijlpark Works (Vaal Triangle)	Industry - iron & steel	Vaal Triangle	15	74	45	5	0	0	0	2007
17	Industrial	Highveld Steel & Vanadium - replace coal use with CO use	Highveld Steel & Vanadium (Mpumalanga highveld)	Industry - iron & steel	Mpumalanga	95	0	0	100	0	0	0	2007
18	Industrial	Desulphurisation of Sasol Secunda PS emissions	Sasol Secunda	Industry - petrochemical	Mpumalanga	(6)	94.7	(6)	(6)	(6)	(6)	(6)	2007
19	Transport	DME Strategy - Reduction of S content of petrol to 500 ppm (0.05%) (b)	National implementation	Vehicles - petrol	All areas	0	0	0	0	0	0	0	2007
20	Transport	DME Strategy - Reduction of S content of petrol to 50 ppm (0.005%)	National implementation	Vehicles - petrol	All areas	0	(b)	0	0	0	0	0	2011
21	Transport	DME Strategy - Reduction of benzene content of petrol to 1%	National implementation	Vehicles - petrol	All areas	0	0	0	50	0	0	0	2011
22	Transport	DME Strategy - Reduction of aromatics content of petrol to 35% (b)	National implementation	Vehicles - petrol	All areas	0	0	0	0	0	0	0	2011
23	Transport	DME Strategy - Phasing out of lead	National implementation	Vehicles - petrol	All areas	0	0	0	0	0	0	100	2007
24	Transport	DME Strategy - Reduction of S content of diesel to <500ppm (0.05%) & second grade diesel with 50 ppm S content available	National implementation - second diesel grade (50 ppm S content used by 10% of vehicles)	Vehicles - diesel	All areas	31.9	84.8	0	0	0	0	0	2007
25	Transport	DME Strategy - Reduction of S content of diesel to <50ppm (0.005%)	National implementation	Vehicles - diesel	All areas	37	98.3	0	0	0	0	0	2011
26	Transport	DME Strategy - new passenger vehicles comply with Euro 2 standards (assume fuel specs changed)	National implementation	Vehicles - petrol	All areas	0	30	37	37	38	37		2007
27	Transport	DME Strategy - new passenger vehicles comply with Euro 4 standards (assume fuel specs changed)	National implementation	Vehicles - petrol	All areas	0	38	30	39	38	38		2011
29	Transport	All petrol vehicles EURO 2 compliant (assume fuel spec changes in place)	National implementation	Vehicles - petrol	All areas	0	77	95.8	95.6	99	96		2011
30	Transport	Conversion of 10% of petrol vehicles to LPG	National implementation	Vehicles - petrol	All areas	9.2	10	9.4	10	10	10	10	2011
31	Transport	Conversion of 20% of petrol vehicles to LPG	National implementation	Vehicles - petrol	All areas	18.4	20	18.8	20	20	20	20	2011
32(a)	Residential	Electrification of paraffin-burning households (1 year post ectrification)	National implementation	Domestic fuel (paraffin)	All areas	33	33	33	33	na	na	na	2007

Number	Sector	Measure	Spatial scale	Sub-sector	Location	% Emission Reduction							Timeframe
						PM10	SO2	NOx	Benzene	1.3 Butadiene	Formaldehyde	Lead	
32(b)	Residential	Electrification of paraffin-burning households (10 year post electrification)	National implementation	Domestic fuel (paraffin)	All areas	78	78	78	78	na	na	na	2007

Notes:

(a) Percentage emission reduction per conurbation: Cape Town (7.2%), Ethekwini (11%), City of Johannesburg & Ekurhuleni (9.9%), Tshwane (11%), Vaal Triangle (12.7%), Mpumalanga (13.8%).

(b) The sulphur and aromatics content of the petrols tested by Wong (1999) on which the emission estimates for the current study was based were noted to have been below 0.05% and 35% respectively. No emission reduction was therefore assumed to be achievable. (It is however noted that the aromatics content of current fuels is much higher, with maximums in the order of 48%).

Table 3 Reductions in health impacts due to interventions implementable by 2007, given as the reduction in actual number of admissions, cancer cases and restricted activity days.

No.	Intervention	Respiratory Hospital Admissions (due to PM10, SO2 & NO2 exposures)	Cardiovascular Hospital Admissions (due to PM10 exposures)	Total Annual Mortality (due to PM10, SO2, benzene & 1.3 butadiene exposures)	Chronic Bronchitis (due to PM10 exposures)	Restricted activity days (RAD, due to PM10 exposures by 20-65 year olds)	Leukemia Cases	Nasal Carcinoma Cases
8	Electrification	-7946.43	-65.49	-21.53	-8404.83	-61209.62	-2.48	0.00
16	Iscor coke oven gas cleaning project	-102.87	-0.51	-0.18	-53.60	-466.30	0.00	0.00
17	Highveld Steel & Vanadium - replace coal use with CO use	-581.42	-4.91	-1.47	-750.90	-4585.92	0.00	-0.01
18	Desulphurisation of Sasol Secunda PS emissions	-469.53	0.07	-1.85	12.35	67.09	0.00	0.00
19	DME Strategy - Reduction of S content of petrol to 500 ppm (0.05%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	DME Strategy - Phasing out of lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00

No.	Intervention	Respiratory Hospital Admissions (due to PM10, SO2 & NO2 exposures)	Cardiovascular Hospital Admissions (due to PM10 exposures)	Total Annual Mortality (due to PM10, SO2, benzene & 1.3 butadiene exposures)	Chronic Bronchitis (due to PM10 exposures)	Restricted activity days (RAD, due to PM10 exposures by 20-65 year olds)	Leukemia Cases	Nasal Carcinoma Cases
24	DME Strategy - Reduction of S content of diesel to <500ppm (0.05%) & second grade diesel with 50 ppm S content available	-2151.91	-17.11	-7.58	-3257.18	-16594.57	0.00	0.00
26	DME Strategy - new passenger vehicles comply with Euro 2 standards (assume fuel specs changed)	-2122.58	0.00	-2.72	0.00	0.00	-45.35	-1.65
32 (a)	Electrification of paraffin-burning households – 1 year post	-83.44	-0.42	-0.28	-42.06	-386.44	0.00	0.00
32 (b)	Electrification of paraffin-burning households – 10 years post	-196.93	-0.98	-0.67	-99.04	-911.18	0.00	0.00

Table 4. Reductions in health impacts due to interventions implementable by 2011, given as the reduction in actual number of admissions, cancer cases and restricted activity days.

No.	Intervention	Respiratory Hospital Admissions (due to PM10, SO2 & NO2 exposures)	Cardiovascular Hospital Admissions (due to PM10 exposures)	Total Annual Mortality (due to PM10, SO2, benzene & 1.3 butadiene exposures)	Chronic Bronchitis (due to PM10 exposures)	Restricted activity days (RAD, due to PM10 exposures by 20-65 year olds)	Minor restricted activity days (MRAD, due to SO2 exposures by 20-65 year olds)	Leukemia Cases	Nasal Carcinoma Cases
1	Top down ignition - DME ICHES	-3807.10	-31.58	-9.03	-4973.86	-29990.26	-343469.89	-0.15	0.00
2	Top down ignition - plateau roll out	-5298.35	-43.95	-12.31	-6577.01	-41248.61	-469374.96	-0.44	0.00
3	Low smoke fuels	-13021.61	-109.87	-30.50	-16442.54	-103121.52	0.00	0.00	0.00
4	Housing insulation - 5% of plateau fuel burning households	-746.67	-6.07	-1.73	-898.91	-5711.06	-117472.46	-0.36	0.00
5	Housing insulation - 20% of plateau fuel burning households	-2986.70	-24.27	-6.90	-3595.66	-22844.25	-469889.83	-1.42	0.00
6	Housing insulation - 5% of all fuel burning households	-1640.11	-13.54	-4.50	-1739.56	-12662.99	-156952.91	-0.42	0.00
7	Housing insulation - 20% of all fuel burning households	-6560.43	-54.14	-18.01	-6958.25	-50651.95	-627811.64	-1.69	0.00
9	Stove maintenance and replacement - 5% households all areas	-820.05	-6.77	-2.25	-869.78	-6331.49	-78476.45	-0.21	0.00
10	Stove maintenance and replacement - 20% households all areas	-3280.22	-27.07	-9.00	-3479.12	-25325.98	-313905.82	-0.85	0.00
11	Desulphurisation of all PS emissions	-1519.52	1.87	-6.37	301.33	1766.27	-33513620.96	-0.05	0.00
12	Decommissioning of Pretoria West PS - gas use by households	-941.30	-5.99	-2.53	-675.36	-5613.70	-1227795.28	0.00	0.00
13	RE technology implementation through financial incentives (10 000 GWh block)	-348.32	-1.07	-0.66	-198.54	-1007.73	-1656194.72	0.00	0.00
14	RE technology implementation through financial incentives (37 000 GWh block)	-1272.47	-3.91	-2.40	-725.29	-3681.42	-6050376.08	-0.01	0.00
15	Emission reduction requirements for coal fired boilers for particulates	-4268.77	-36.02	-10.97	-4198.54	-35074.60	0.00	0.00	0.00

No.	Intervention	Respiratory Hospital Admissions (due to PM10, SO2 & NO2 exposures)	Cardiovascular Hospital Admissions (due to PM10 exposures)	Total Annual Mortality (due to PM10, SO2, benzene & 1.3 butadiene exposures)	Chronic Bronchitis (due to PM10 exposures)	Restricted activity days (RAD, due to PM10 exposures by 20-65 year olds)	Minor restricted activity days (MRAD, due to SO2 exposures by 20-65 year olds)	Leukemia Cases	Nasal Carcinoma Cases
	(>90% control efficiency required)								
20	DME Strategy - Reduction of S content of petrol to 50 ppm (0.005%)	-2.72	0.00	-0.02	0.00	0.00	-78162.91	0.00	0.00
21	DME Strategy - Reduction of benzene content of petrol to 1%	0.00	0.00	-0.90	0.00	0.00	0.00	-18.02	0.00
22	DME Strategy - Reduction of aromatics content of petrol to 35%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	DME Strategy - Reduction of S content of diesel to <50ppm (0.005%)	-2887.28	-22.97	-10.19	-4359.88	-22272.42	-4116494.61	0.00	0.00
27	DME Strategy - new passenger vehicles comply with Euro 4 standards (assume fuel specs changed)	-2269.73	0.00	-2.87	0.00	0.00	-1704580.47	-48.88	-1.85
29	All petrol vehicles EURO 2 compliant (assume fuel spec changes in place)	-5702.28	0.00	-7.10	0.00	0.00	-3806896.39	-122.83	-4.55
30	Conversion of 10% of petrol vehicles to LPG	-567.38	0.00	-0.77	0.00	0.00	-568193.49	-12.53	-0.47
31	Conversion of 20% of petrol vehicles to LPG	-1134.76	0.00	-1.54	0.00	0.00	-1136386.98	-25.07	-0.95

6.4 Conclusions on the environmental benefits of implementation of options

In the formulation of the strategy the following points were noted in interpretation the study findings:

- Only inhalation exposures due to fuel burning related atmospheric emissions were quantified. Emissions and associated impacts due to other sources of emissions were not quantified. Sources of emission which were not accounted for include fugitive dust emissions, industrial process emissions and evaporative losses. Household fuel burning emissions and vehicle emissions are largely accounted whereas only a portion of the emissions from industrial operations is included. This should be noted in interpreting the source contribution information provided.

- Exposures to ozone concentrations (and other photochemical products) were not quantified during the study. Ozone precursors include NOx and VOCs. Since these pollutants are released from all fuel burning sources it is evident that the impact of such sources is likely to be greater than was estimated in the current study. The underestimation is greatest for significant sources of NOx and/or VOC emissions (e.g. vehicle emissions).

- Given the methodology employed in the quantificationof health risks, viz. application of dose-response functions developed based on epidemiological studies, it was not possible to quantify exposures to indoor air pollutant concentrations. This is expected to have resulted in an underprediction of the health impacts associated with domestic fuel burning emissions as discussed in the previous section.

- The current task focused on assessing baseline air quality impacts and health risks and on quantifying air quality improvements and health risk reductions achievable through the implementation of interventions. The social acceptability, political desirability, technical feasibility and economic viability of the interventions was not examined in depth for such interventions. This is the purpose of the subsequent task (Task 4b).

Based purely on health risk reductions achievable, interventions which target household fuel combustion and vehicles were found to be the most beneficial. Interventions aimed at reducing household fuel combustion resulted in the most significant reductions in respiratory hospital admissions and premature mortality. Various vehicle related interventions were more effective for reducing cancer risks.

Interventions which may be given priority, from a health risk reduction perspective, are outlined in the table overleaf.

Sector	Intervention	Health Endpoint - most significant risk reduction
Domestic fuel burning	Low smoke fuel implementation[(2)]	Respiratory hospital admissions, chronic bronchitis, premature mortality
	Electrification of all unelectrified households	
	Large scale housing insulation	
	Large scale top down ignition roll-out	
Vehicles	Requirement of all petrol vehicles to comply with Euro 2 standards	Cancers
	Requirement of new petrol vehicles to comply with Euro 4 (Euro 2) standards	
	Large scale conversion of petrol vehicles to LPG	
	Restriction of benzene content of petrol to 1%	
Power Generation	Desulphurisation of all power station emissions	Respiratory hospital admissions, premature mortality
Industry, commercial & service sector	Restriction of particulate emissions from coal-fired boiler operations	Respiratory hospital admissions, chronic bronchitis, premature mortality

Although the results serve to highlight interventions likely to achieve the greatest health impact reductions, interventions which result in lower reductions were not be excluded prior to the initiation of Task 4b. The reason being that interventions associated with relatively low health impact reductions may be readily and cost-effectively implemented.

The spatial distribution of vehicle emissions was coarsely allocated for the purpose of the current study. Given the health risks predicted to be due to vehicle emissions it would be beneficial to undertake a more detailed study, comprising photochemical modelling, to further inform vehicle emission regulations.

2 The low smoke fuel intervention comprises making suffient fuels available for the entire plateau household coal market at a cost equivalent to that of coal coincident with the passing of legislation restricting the use of coal by households.

7 SOCIO-ECONOMIC IMPACT OF AIR POLLUTION REDUCTION FROM FUEL COMBUSTION

The objective of the socio-economic assessment was to determine financial, economic and social (impact on employment) impact of the proposed interventions to finally enable the strategy to reflect the most cost effective and beneficial interventions to reduce air pollution from fuel combustion. The outcome is clear understanding of the financial and economic feasibility of the interventions, their impact on direct and indirect employment creation or reduction, as well as the financial and economic impact on affected stakeholders, which include government, firms and households.

The approach to the socio-economic impact assessment was to use successive rounds of analysis:

- The first is a simple financial Cost Benefit Analysis (CBA)
- The second corrects this for price distortions and missing markets to give an economic CBA.
- The third round incorporates a stakeholder analysis and a macroeconomic analysis.
- Finally a comparison with the theoretical approach of conventional neoclassical economics is offered.

The interventions were modelled over a 20 year period, and a discount rate of 8% was assumed. The detailed assumptions around various factors such as capital costs, operational costs, etc are reflected in the detailed report on the socio-economic impact assessment.

The following constraints to the socio-economic impact assessment were recognised and taken cognisence of in the ddvelopment of the strategy

- The benefits cited in the study are confined to morbidity and mortality reductions, plus improvements in worker productivity associated with pollution reduction. The summation of them gives an indication of the broadly defined health costs air pollution imposes in South Africa's cities
- First, the study focused only on dirty combustible fuels and not on all activities that result in air emissions. In consequence there are other potential interventions that might also be desirable but have not been included in the study.
- Second, lack of information meant that a number of industry specific interventions were not investigated. These interventions may therefore be desirable.
- Third, little marginal analysis was undertaken *within* specific interventions (insulation of houses and the introduction of EURO 2 and EURO 4 technologies are partial exceptions). In consequence interventions that look inefficient as presented may be more attractive if only partially implemented. Conversion of refineries to produce low sulphur diesel is a case in point: it is clearly non-viable, the costs outweighing the benefits. On the other hand, a portion of South Africa's diesel is gas based and has little sulphur. A viable intervention would be to divert this component to high density urban areas. This would cost little, and would achieve real health benefits.

7.1 Micro-level socio-economic impact assessment results

If we consider all of the interventions analysed, there are potential savings simply due to illness (morbidity) prevention of R3.2 billion per annum, with a present value of R17.51 billion. Such interventions would add R2.27 billion to worker productivity and save 161.3 deaths per annum from respiratory conditions, and 14.5 fewer deaths per annum from cancer.

If we only consider economically justifiable interventions (i.e. those with a cost-benefit B/C ratio greater than one) the PV of the morbidity saving is R14.05 billion (i.e. 80 % of the total available health benefits), the productivity gain is R 1.67 billion while 87.0 fewer deaths per annum would occur from respiratory conditions while cancers would result in the deaths of 11.3 fewer persons per annum.

Comparing monetary expenditures and saving of lives is sometimes controversial. This report covers a range on approaches to the problem. Cost-benefit analysis is used as the primary assessment tool; supplementary economic analysis provides additional information particularly on indirect and distributional or stakeholder impacts. The latter includes direct sectoral and indirect (national) employment impacts.

The table below summarises the net present values (NPVs) and Benefit/Cost ratios of the measures evaluated, as well as the impact on employement and the various stakeholder groups.

	Int No	Economic B:C Ratio	Financial NPV (R millions)	Employment			Financial Stakeholder Analysis (Rm)		
				Direct Jobs	Indirect Jobs	Total Jobs	Government	Firms	Households
1 Basa Njengo Magogo - DME ICHES	1	177.0	756.3	-41.2	388.4	347.2	413.9	-76.2	173.0
2 Basa Njengo Magogo - plateau roll out	2	120.1	1,123.4	-55.5	576.4	520.9	573.5	-180.7	315.3
3 Low smoke fuels	3	0.4	-3,591.8	375.1	-1,017.2	-642.1	1,177.5	1,317.5	-1,236.2
4 Housing insulation - 5% of plateau fuel burning households	4	6.0	262.9	-5.2	153.0	147.9	114.8	-32.6	106.5
5 Housing insulation - 20% of plateau fuel burning households	5	6.0	1,051.6	-20.7	612.2	591.5	459.0	-130.2	426.2
6 Housing insulation - 5% of all fuel burning households	6	7.9	426.1	-14.8	235.6	220.8	218.3	-32.8	134.1
7 Housing insulation - 20% of all fuel burning households	7	7.9	1,704.4	-59.1	942.3	883.2	873.0	-131.3	536.5
8 Electrification	8	1.2	1,044.2	1,687.0	1,948.9	3,635.9	2,035.3	1,825.3	-1,586.9
9 Stove maintenance and repair - 5% households all areas	9	16.5	325.1	-12.1	149.5	137.3	114.4	-166.4	167.6
10 Stove maintenance and repair - 20% households all areas	10	16.5	1,300.4	-48.5	597.8	549.3	457.8	-665.5	670.2
11 Desulphurisation of all PS emissions	11	0.0	-15,445.6	9,412.4	-954.5	8,457.9	1,301.0	-3,187.9	1,908.6
12 Decommissioning of PTA West PS - gas use by households	12								
13 RE technology implementation (10 000 GWh block)	13	0.3	-5,429.4	3,091.4	-600.7	2,490.7	386.9	-1,864.1	661.6
14 RE technology implementation (37 000 GWh block)	14	0.3	-6,340.7	3,167.7	-575.6	2,592.1	483.0	-2,261.9	778.1
15 Coal fired boilers for particulates (>90% control efficiency req.)	15	0.8	-190.6	577.3	374.4	951.7	446.7	-140.5	-211.3
16 Iscor coke oven gas cleaning	16								
17 Highveld Steel & Vanadium	17								
18 Desulphurisation of Sasol Secunda PS emissions	18	0.1	-1,933.6	1,011.1	-74.8	936.3	195.3	-501.4	263.6
19 Reduction of S content of petrol to 500 ppm (0.05%)	19								
20 Reduction of S content of petrol to 50 ppm (0.005%)	20	0.0	-1,115.8	0.0	0.2	0.2	-44.4	-303.1	-639.0
21 Reduction of benzene content of petrol to 1%	21	0.0	-1,094.4	-1.2	7.0	5.7	-32.9	-612.5	-323.9
22 Reduction of aromatics content of petrol to 35%	22	0.1	-1,235.3	-17.0	95.3	78.3	103.9	-422.4	-810.2
23 Phasing out of lead in petrol	23	0.0	-347.6	67.8	-72.6	-4.8	20.8	331.4	-312.0
24 Reduction of S content of diesel to <500pm (0.05%)	24								
25 Reduction of S content of diesel to <50ppm (0.005%)	25	0.5	-442.0	-33.1	237.4	204.3	276.4	-852.4	126.8
26 New passenger vehicles comply with Euro 2 standards	26	1.0	626.6	-36.0	260.7	224.8	410.1	-8.4	73.0
27 New passenger vehicles comply with Euro 4 standards	27	1.0	419.9	-29.4	213.7	184.3	279.6	-5.4	42.2
28 Taxi recapitalisation programme	28								
29 All petrol vehicles EURO 2 compliant	29	1.0	1,054.2	-73.9	536.9	462.9	702.4	-13.5	105.5
30 Conversion of 10% of petrol vehicles to LPG	30	1.0	-2,382.6	2,364.2	-215.4	2,148.8	122.6	1,702.7	-1,312.7
31 Conversion of 20% of petrol vehicles to LPG	31	1.0	-4,765.3	4,728.4	-430.9	4,297.6	245.2	3,405.5	-2,625.5
32 Electrification of paraffin burning households	32	1.3	1,410.2	1,300.4	2,035.5	3,335.8	1,659.4	1,325.5	-1,215.6

From the above it can be seen that benefits exceed costs for the following interventions.

- Interventions 1 and 2 – Basa Njengo Magogo or top down ignition of coal stoves (Scenario 1 and 2).
- Interventions 4, 5, 6 and 7 – All of which focus on improved housing insulation.
- Interventions 8 and 32 – Electrification of fuel burning households.
- Intervention 9 and 10 - coal stove maintenance and replacement.

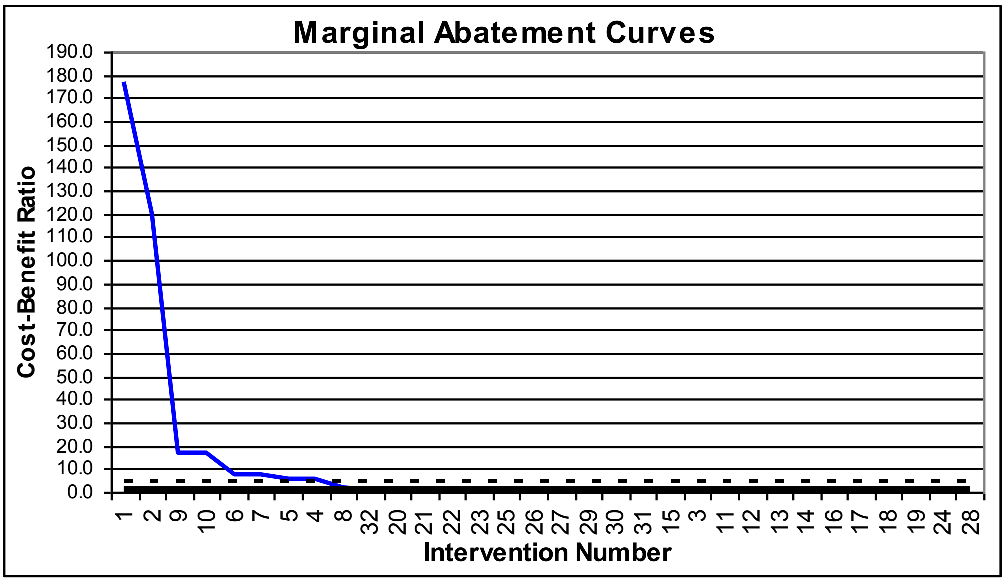
- Intervention 26, 27 and 29 – vehicle standards – these cover the adoption of 'Euro 2' and 'Euro 4' technology standards on new vehicles. We take the view that since adoption of these technologies is not a true decision variable (the market will introduce it regardless to some high proportions, as evident by current introduction of Euro 2 and better on 50 % of cars without any regulatory requirements). Such costs are akin to 'sunk costs' in that they should be excluded from cost benefit analyses. Each outcome is therefore the present value of the benefits associated with the measure and is reported for information purposes only.

All of the genuine interventions with positive NPVs lie in the household sector. Such household level interventions offer relatively cheap measures that deliver substantial health benefits. It should be recognised that some industrial interventions might have positive NPVs at lower levels of implementation. Further studies are recommended in this regard.

At an industry level, intervention 15 – stricter emission requirements for coal fired boilers, yielded a benefit/cost ratio of 0.8 indicating that costs exceed benefits by 20%. It is possible that a less stringent reduction of boiler emissions would pass muster; it seems inappropriate to discard this measure altogether at this stage and further work is recommended.

Intervention 23, the introduction of lead free petrol, is already under way in South Africa and elsewhere in the world. It is not suited to evaluation through cost benefit analysis. The benefits accrue as improved intellectual capacity as children grow to maturity. This introduces twin problems: valuation of such benefits in the distant future is difficult, and the process of discounting reduces their significance profoundly. The costs involved are relatively low if viewed in rands per child in South Africa. 'Business as usual' analysis showed that 12 686 people benefit in 2011. Mostly in Durban and only a percentage are children. No analysis, however, is offered, as lead reduction is already in process. In a case like this it makes sense to follow the precautionary principle and encourage the transition. It is already under way with 6% annual growth in unleaded fuel's market share.

The costs of all other measures exceeded their benefits comprehensively. This should enable ready prioritisation of air quality interventions.



7.2 Interventions with unfavourable socio-economic impacts

Numerous interventions did not pass the cost:benefit test. However, they should not necessarily be discarded. The following table summarises these interventions and make preliminary recommendations on possible future activities.

The table below contains suggestions for how they could still form part of ongoing strategy. The issue of marginal or incremental analysis within interventions becomes important here. For example, the Eskom power station desulphurisation programme was assessed assuming that all sulphur emissions are removed from all stations. However, it may be that only partial desulphurisation yields significant benefits and is therefore a favourable option. The only way to establish this is to conduct marginal analysis in which the additional benefits associated with gradual increases in desulphurisation are measured in order to determine whether there is an optimal level of desulphurisation.

Table 7: Considerations for interventions with unfavourable benefit cost ratios

Interventions with unfavourable benefit/cost ratios

Intervention Nr. and name		Recommendations
3	Low smoke fuels	Continued R&D effort.
11	Desulphurisation of all PS emissions	Re-examine using marginal analysis, check costs of measure, assess imapct on electricity price
13	Renewable Energy technology implementation through financial incentives (10 000 GWh block)	Increase R&D effort. Consider incentives
14	Renewable Energy technology implementation through financial incentives (37 000 GWh block)	
15	Emission reduction requirements for coal fired boilers for particulates (>90% control efficiency required)	Re-examine using marginal analysis once other options exhausted
16	Iscor coke oven gas cleaning project	Can't comment due to lack of data
18	Desulphurisation of Sasol Secunda PS emissions	Re-examine using incremental increases in desulphurisation once other options exhausted
17	Highveld Steel & Vanadium - replace coal use with CO use	Can't comment due to lack of data
19	DME Strategy - Reduction of S content of petrol to 500 ppm (0.05%)	Consider tax incentives to encourage implementation
20	DME Strategy - Reduction of S content of petrol to 50 ppm (0.005%)	
21	DME Strategy - Reduction of benzene content of petrol to 1%	
22	DME Strategy - Reduction of aromatics content of petrol to 35%	
24	DME Strategy - Reduction of S content of diesel to <500ppm (0.05%) & second grade diesel with 50 ppm S content available	Consider tax incentives to encourage implementation
25	DME Strategy - Reduction of S content of diesel to <50ppm (0.005%)	
30	Conversion of 10% of petrol vehicles to LPG	Monitor R&D in the field
31	Conversion of 20% of petrol vehicles to LPG	

Sensitivity analysis indicated that the intervention rankings and the cost:benefit test were robust with respect to discount rates as well as variations in the value of statistical life and productivity.

Stakeholder analyses were conducted for each intervention to gauge impacts on the government, households and firms associated with first round expenditure changes. Note that it was not possible to analyse the impacts on all stakeholders that may be affected by expenditure changes. For example, in the case of Basa Njengo Magogo, the stakeholder analysis shows that expenditures on coal (a dirty fuel) and health care are reduced. It is not clear what expenditure items (or savings options) will take the place of these items, but they could well be more productive. Such second (and subsequent) round redirections of expenditure are not captured in our analysis, but should be borne in mind when reading the stakeholder analysis.

7.3 Findings of the macro-level assessment when combining interventions

In addition to the analysis of individual interventions with favourable benefit/cost ratios, a scenario model was developed for the purposes of illustrating the outcome of combining interventions. It should not be inferred that these combinations of interventions are being recommended, but rather decisions about recommendations of interventions need to be taken at a policy level.

Some interventions were excluded from the strategic analysis at the outset because they are to be implemented regardless. This is the case either because of current national legislation or because of imported vehicle technology. The interventions that will be implemented as part of national legislation are interventions 19, 20, 21, 22, 23, 24 and 25 and relate to vehicle fuel specifications. The imported technology interventions relate to interventions 26, 27 and are Euro 2 and Euro 4 for new petrol vehicles and passenger vehicles.

In addition to this it was shown earlier, of the interventions where there is any choice, only those interventions at a household level have a benefit: cost ratio of more than one. Economic efficiency requires a ratio of more than one. If the ratio is less than one it means that the intervention is costing more to implement than it is benefiting society). Therefore, in consequence, the strategic scenario analysis was confined only to household interventions. Specifically these interventions are top down ignition (Basa Njengo Magogo), housing insulation, housing electrification and stove replacement and/or maintenance.

The analysis was undertaken in a number of phases. In the first phase four criteria were chosen and the scenario model was used to rank interventions according to these criteria. The criteria that were chosen are:

- The highest benefit:cost ratio
- The highest NPV
- The greatest generator of direct and indirect jobs
- The highest contribution to GDP

Careful attention was paid in each scenario to the number of households that were being impacted. If more households were targeted by a combination of interventions than actually allowed for, then it would mean that some households would be implementing more than one intervention. If this happened, which is practically quite possible, the emission reduction and benefits reported would not be attained and would then have to be reduced. For example, if the exact same households implemented stove maintenance and the top-down (Basa Njengo Magogo) method of ignition, then the overall benefits would be less than summation of the two interventions. In scenarios 1 and 2 the benefits that are reported are the actual benefits because (as is shown below) the total number of targeted households is not exceeded.

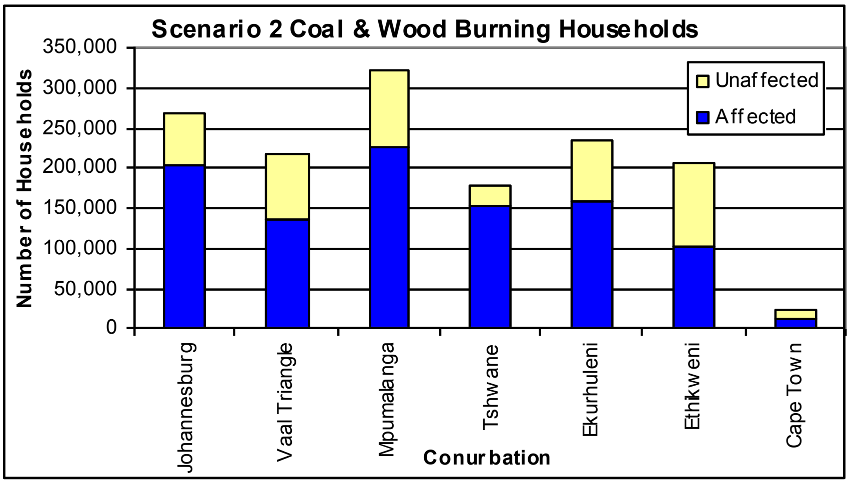
It was found that the interventions with the highest benefit: cost ratios are interventions 1 (Basa Njengo Magogo for Johannesburg and Mpumalanga only), 10 (stove maintenance and replacement for 20% of all households), 7 (housing insulation for 20% of all households) and 8 (electrification of households in all conurbations). This has been called Scenario 1.

It was also found, and will be shown below, that the combination and ranking of interventions were identical for the highest NPV, job creation and contribution to GDP. In order of greatest impact these interventions are 7, 10, 2 (Basa Njengo Magogo for all conurbations) and 8. This has been named Scenario 2.

The table below shows the possible number of households that could be approached for each type of intervention in Johannesburg (the identical process was followed for all other conurbations).

Intervention	Type of households targeted	Possible number of h/holds affected in Jhb only	Expected number of h/holds retaining intervention
Basa Njengo Magogo	Coal burning only	205 660	82 264
Housing insulation	Coal & wood burning	270 018	54 004
Electrification	Unelectrified Only coal and wood unelectrified	96 152 25 612	 14 086
Stove maintenance	Coal & wood burning	270 018	54 004
		TOTAL	**204 358**

A maximum of 204 358 households could be reached if each of the interventions is implemented completely exclusive of the others. The table above shows that there are more coal and wood burning households (270 018) or even coal burning households only (205 660) than would be affected by all four interventions together. It can therefore be seen that there will still be a large number of households that can be further targeted by increasing any of the Basa Njengo Magogo, housing insulation or stove maintenance and replacement interventions. The implication of this is that the combining of interventions as is done below will not result in the theoretical situation were more households are targeted than actually exist



As illustrated in the figure above, for scenario 2 none of the total households in any of the conurbations were exceeded. The same is true of scenario 1.

As a result of these findings only two scenarios could be modelled based on the strict interventions that were analysed at micro-level. In consequence it was decided to continue modelling various scenarios by scaling up some of the household interventions and determining the overall impact of these scaled up interventions. The starting point of these considerations was to take a critical view of the impact on the continued use of heating fuel because of household electrification. An implicit assumption was made that electrification would result in households switching away from coal, wood and paraffin in favour of electric heating. A further assumption was made that the average household expenditure would be R35 per month. In addition to this an allowance was made that Eskom would incur administrative and other overhead costs of R25 per household.

This is a net electricity cost of R60 a month and, even if considered in the light of poor households receiving some form of additional subsidy, is not sufficient for the purposes of using electricity as the sole means of heating. In consequence it is very likely that the electrification of households will result in some reduction in the use of other types of fuel for the purposes of heating but will not result in their elimination. As a result the electrification of households and other household interventions are not mutually exclusive and could be used in conjunction with each other.

Three further scenarios were developed on the basis of this premise and are based on variations in the degree of interventions in Scenario 2. These scenarios all include electrification of all non-electrified households and an assumption that this will result in the reduction of coal consumption by fifty percent. It should be recognised that these three scenarios *are not an attempt to reflect potential reality but rather to map the upper limits of the costs and benefits of household interventions*.

Scenario 3 takes intervention 7 (housing insulation for 20% of households) and scales this up to 100% of targeted households.

Scenario 4 takes Scenario 3 as its starting point and scales intervention 10 (stove replacement and maintenance) from 20% of households to 100% of targeted households.

Scenario 5 takes Scenario 4 as its starting point and scales up intervention 2 (Basa Njengo Magogo for all conurbations) from 40% of uptake of households approached to 100% of households approached.

The results to the five scenarios are given in the figures below. The financial and economic (in brackets) NPVs of scenarios 1 to 5 would be R4.8 billion (R4.0 billion), R5.2 billion (4.3 billion), R12.0 billion (R10.2 billion), R17.2 billion (R14.6 billion) and R18.9 billion (R16.1 billion) respectively. The economic benefit:cost ratios would be as follows:

Scenario 1: 2.0

Scenario 2: 2.1

Scenario 3: 3.1

Scenario 4: 3.9

Scenario 5: 4.2

The impact on GDP of scenarios 1 to 5 would be R13.5 billion, R14.5 billion, R26.0 billion, R33.9 billion and R36.5 billion respectively. The impact on direct and indirect (in brackets) job creation of scenarios 1 to 5 would be 1538 (3724), 1524 (4065), 1287 (7835), 1093 (10226) and 1010 (11090) respectively.

The stakeholder analysis of the scenarios shows that for:

- Scenario 1, the government and firms would experience benefits with PVs of R3.8 billion and R952 million respectively, while households would incur costs with a PV of R207 million.

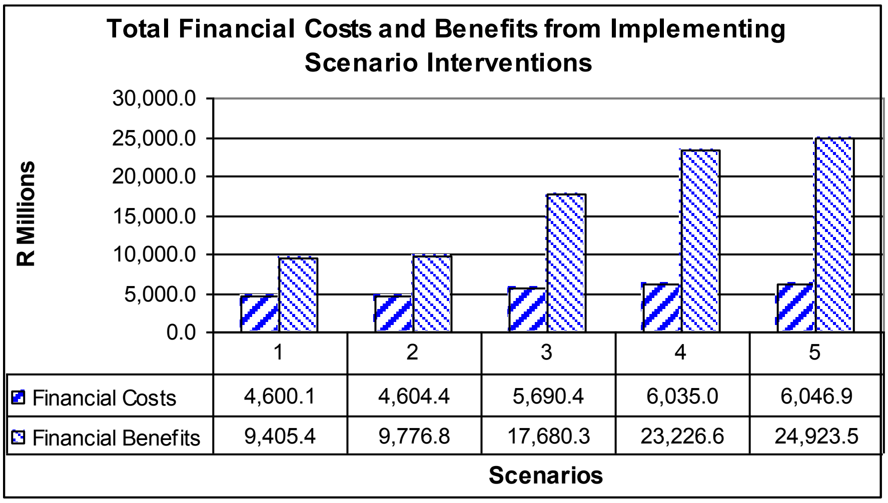
- Scenario 2 would result in the government and firms experiencing benefits with PVs of R3.9 billion and R848 million respectively, while households incur costs with a PV of R65 million.

- Scenario 3 would result in the government, firms and households experiencing benefits with PVs of R7.4 billion, R322 million and R2.1 billion respectively.

- Scenario 4 would result in the government and households experiencing benefits with PVs of R9.3 billion and R4.8 billion while firms incur costs with a PV of R2.3 billion.

- Scenario 5 would result in the government and households experiencing benefits with PVs of R10.1 billion and R5.2 billion while firms incur costs with a PV of R2.6 billion.

The impact on reduced morbidity benefits of scenarios 1 to 5 would have PVs of R5.3 billion, R5.4 billion, R10.1 billion, R12.0 billion and R12.8 billion respectively. The impact on increased mortality of scenarios 1 to 5 would have PVs of R783 million, R766 million, R375 million, R125 million and R27 million respectively. The impact on increased productivity of scenarios 1 to 5 would have PVs of R707 million, R749 million, R1.4 billion, R1.8 billion and R2.0 billion respectively.



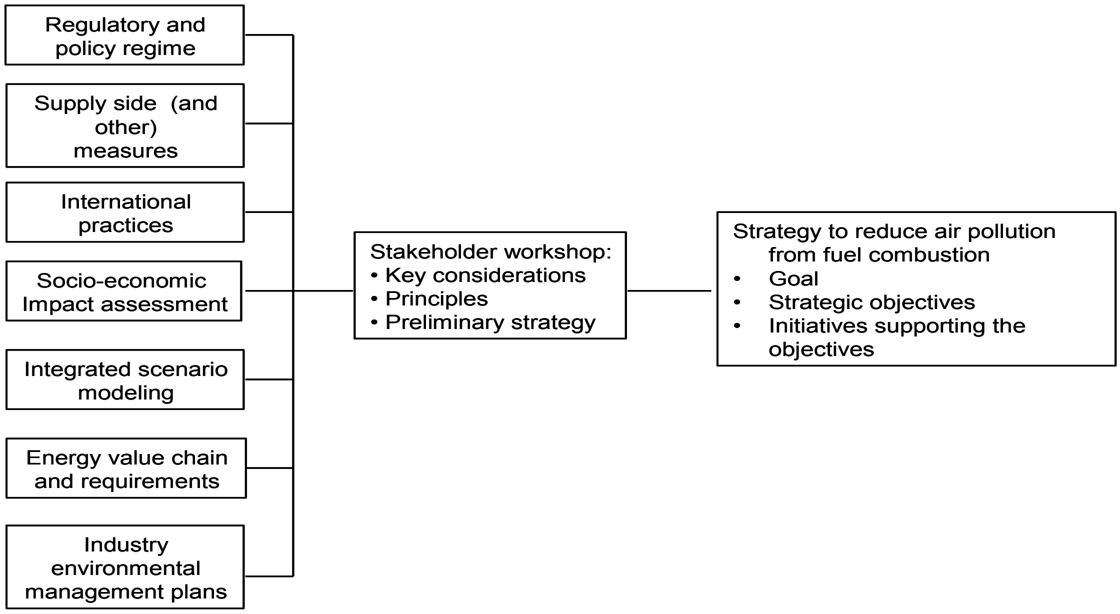
	1	2	3	4	5
Financial Costs	4,600.1	4,604.4	5,690.4	6,035.0	6,046.9
Financial Benefits	9,405.4	9,776.8	17,680.3	23,226.6	24,923.5

The scenario models have been used to illustrate the possible impact of various combinations of interventions on the economy at large and the relevant stakeholders. It should however not be inferred that these combination of interventions or the scaling up of the interventions is necessarily the desired combination. One of the key challenges was to adequately model the impact of interventions where the most difficult of these were the household interventions and, in particular, the impact of household electrification on the use of dirty fuels for the purposes of heating and cooking in households

8 PROPOSED STRATEGY TO REDUCE AIR POLLUTION FROM FUEL COMBUSTION AND REDUCE ASSOCIATED HEALTH COSTS

8.1 STRATEGY DEVELOPMENT PROCESS, SCOPE AND STRUCTURE

- This proposed strategy is the culmination of an extensive quantitative research process, qualitative discussions with stakeholders, and an intensive strategy-brainstorming workshop with representatives from relevant government departments, industry and labour. The following graph illustrates how the outcomes of the research in a number of areas were considered and synthesised into a coherent strategy.



It is worthwhile re-iterating a number of issues related to the scope of the strategy

- The strategy is aimed at reducing air pollution as a result of fuel combustion only. It does not deal with air pollution in general and caused by other factors such as fugitive dust, diffuse, evaporative and industrial process emissions.

- The strategy is developed at national level. Although many initiatives recommended are to be implemented at provincial / local government, the strategy is intended to inform national policy and planning.

- The strategy considered the current policy and regulatory arena. It did not attempt to identify initiatives in isolation to current activity. Where applicable, specific recommendations are made to change or enhance the current policy and regulatory system. One of the key assumptions is therefore that the proposed National Environmental: Air Quality Bill will be implemented

The structure of the proposed strategy is as follows:

- It starts of by identifying an overall long-term goal. The long- term goal defines and quantifies the long-term end-state, which should be strived at.
- A number of over-arching themes are defined. These *themes* or *grand strategies* provide the context for the formulated strategic objectives, in ensuring that they remain aligned to what is envisaged in the future.
- A key set of strategic objectives is defined. These objectives are the heart of the strategy, and developed with consideration of specific issues such as linkage to the long term goal, the measurability of the what must be done, the impact should these objectives be attained, responsibility for implementation and the practical implementation of supporting initiatives.
- Specific initiatives are recommended under each strategic objective. These initiatives are specific actions, which need to be implemented if the objectives and long-term goal is to be attained.

8.2 STRATEGY TIMEFRAMES

The study focused on interventions implementable in the short- to medium-term. In defining such terms attention was paid to the timing of activities proposed for implementation by government (e.g. DME's vehicle emission strategy). The following time frames have been considered and are deemed to be appropriate for the execution of the strategy.

- Baseline - 2003
- Short term - 2003 - 2006
- Medium term - 2007 - 2010
- Long term - 2011 onwards

8.3 KEY CONSIDERATIONS FOR THE STRATEGY DEVELOPMENT

The research conducted resulted in a number of findings that were deemed of specific importance for the development of the strategy. The following is a short summary of these considerations. Detailed aspects of these issues are further elaborated on in the next section, which deals explicitly with strategic objectives and initiatives to address these issues.

a) Varied implementation options for facilitating or forcing intervention. There are numerous approaches that can be followed to facilitate change in air pollution. These include education, regulation, public disclosure initiatives and market mechanisms such as economic instruments. The latter includes charges, levies, subsidies and tradable pollution permits. The proposed Air Quality Bill recognises and provides for the various approaches.

b) **Ranking of source significance should be based on impact rather than emissions.** A key theme that emerged from this study is that the aim of all actions to manage air pollutions should be driven by the impact of emissions, and not the emissions itself. Hospital admissions due to respiratory ailments were found to account for 79% of the health costs quantified in the study. The contribution of primary fuel burning sources to respiratory hospital admissions were as follows:

- Domestic fuel burning: 69% (but reducing, 64% by 2011)
- Vehicle emissions: 12 % (and growing, 15% by 2011)
- Electricity generation: 6% (similarly 7% in 2011)
- Coal fired boilers: 4% (similarly 4% in 2011)
- Other sources (primarily industrial sources) : 9% (and growing, 11% by 2011)
- The results of the socio-economic impact assessment of interventions considered are summarised as follows (see next page)

	Int No	Economic B:C Ratio	Financial NPV (R millions)	Employment Direct Jobs	Employment Indirect Jobs	Employment Total Jobs	Financial Stakeholder Analysis (Rm) Government	Firms	Households
1 Basa Njengo Magogo - DME ICHES	1	177.0	756.3	-41.2	388.4	347.2	413.9	-76.2	173.0
2 Basa Njengo Magogo - plateau roll out	2	120.1	1,123.4	-55.5	576.4	520.9	573.5	-180.7	315.3
3 Low smoke fuels	3	0.4	-3,591.8	375.1	-1,017.2	-642.1	1,177.5	1,317.5	-1,236.2
4 Housing insulation - 5% of plateau fuel burning households	4	6.0	262.9	-5.2	153.0	147.9	114.8	-32.6	106.5
5 Housing insulation - 20% of plateau fuel burning households	5	6.0	1,051.6	-20.7	612.2	591.5	459.0	-130.2	426.2
6 Housing insulation - 5% of all fuel burning households	6	7.9	426.1	-14.8	235.6	220.8	218.3	-32.8	134.1
7 Housing insulation - 20% of all fuel burning households	7	7.9	1,704.4	-59.1	942.3	883.2	873.0	-131.3	536.5
8 Electrification	8	1.2	1,044.2	1,687.0	1,948.9	3,635.9	2,035.3	1,825.3	-1,586.9
9 Stove maintenance and repair - 5% households all areas	9	16.5	325.1	-12.1	149.5	137.3	114.4	-166.4	167.6
10 Stove maintenance and repair - 20% households all areas	10	16.5	1,300.4	-48.5	597.8	549.3	457.8	-665.5	670.2
11 Desulphurisation of all PS emissions	11	0.0	-15,445.6	9,412.4	-954.5	8,457.9	1,301.0	-3,187.9	1,908.6
12 Decommissioning of PTA West PS - gas use by households	12								
13 RE technology implementation (10 000 GWh block)	13	0.3	-5,429.4	3,091.4	-600.7	2,490.7	386.9	-1,864.1	661.6
14 RE technology implementation (37 000 GWh block)	14	0.3	-6,340.7	3,167.7	-575.6	2,592.1	483.0	-2,261.9	778.1
15 Coal fired boilers for particulates (>90% control efficiency req.)	15	0.8	-190.6	577.3	374.4	951.7	446.7	-140.5	-211.3
16 Iscor coke oven gas cleaning	16								
17 Highveld Steel & Vanadium	17								
18 Desulphurisation of Sasol Secunda PS emissions	18	0.1	-1,933.6	1,011.1	-74.8	936.3	195.3	-501.4	263.6
19 Reduction of S content of petrol to 500 ppm (0.05%)	19								
20 Reduction of S content of petrol to 50 ppm (0.005%)	20	0.0	-1,115.8	0.0	0.2	0.2	-44.4	-303.1	-639.0
21 Reduction of benzene content of petrol to 1%	21	0.0	-1,094.4	-1.2	7.0	5.7	-32.9	-612.5	-323.9
22 Reduction of aromatics content of petrol to 35%	22	0.1	-1,235.3	-17.0	95.3	78.3	103.9	-422.4	-810.2
23 Phasing out of lead in petrol	23	0.0	-347.6	67.8	-72.6	-4.8	20.8	331.4	-312.0
24 Reduction of S content of diesel to <500pm (0.05%)	24								
25 Reduction of S content of diesel to <50ppm (0.005%)	25	0.5	-442.0	-33.1	237.4	204.3	276.4	-852.4	126.8
26 New passenger vehicles comply with Euro 2 standards	26	1.0	626.6	-36.0	260.7	224.8	410.1	-8.4	73.0
27 New passenger vehicles comply with Euro 4 standards	27	1.0	419.9	-29.4	213.7	184.3	279.6	-5.4	42.2
28 Taxi recapitalisation programme	28								
29 All petrol vehicles EURO 2 compliant	29	1.0	1,054.2	-73.9	536.9	462.9	702.4	-13.5	105.5
30 Conversion of 10% of petrol vehicles to LPG	30	1.0	-2,382.6	2,364.2	-215.4	2,148.8	122.6	1,702.7	-1,312.7
31 Conversion of 20% of petrol vehicles to LPG	31	1.0	-4,765.3	4,728.4	-430.9	4,297.6	245.2	3,405.5	-2,625.5
32 Electrification of paraffin burning households	32	1.3	1,410.2	1,300.4	2,035.5	3,335.8	1,659.4	1,325.5	-1,215.6

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- From a financial and economic perspective low (or existing) technology interventions in the domestic (household) sector can yield significant benefit in the short- to medium-term. The national electrification programme, the Basa Njengo Magogo intervention, housing insulation and stove maintenance and repair are the interventions that were found attractive from a financial and economic perspective. Careful consideration should however be given to certain social boundary conditions such as the cost to households (stove maintenance and repair) and social acceptability. Higher technology solutions such as low smoke fuels were found to be unattractive from a financial and economic perspective, suggesting that alternatives should be explored in the short to medium term.

- Interventions related to changes in fuel specifications and vehicle technology standards need to be re-examine from a holistic perspective. Implementation of the proposed fuel specifications will require interventions that are unattractive from a financial, economic and social perspective in the short- to medium-term. These interventions relate to the aggressive reduction of the sulphur, benzene and aromatic content of petrol and the reduction of the sulphur content of diesel. The implementation of EURO2 and EURO4 vehicle technology standards to new vehicles are considered inevitable due to market pressures, the costs are considered sunk, and the change will have a positive impact on reducing health costs associated with vehicle emissions. The study did not consider other alternatives to deal with vehicle emissions, for example changes to vehicle usage patterns and improved vehicle inspection and maintenance, due to uncertainties in the spatial allocation of vehicle emissions.

- Electricity generation interventions implementing high technology on the supply side (desulphurisation of power stations, renewable energy) are not feasible from a financial and economic perspective in the short- to medium-term. The study did not consider renewable technologies on the demand side, for example solar heating at household level

- The benefit of industrial interventions depends on scale, location and technology factors. In general it was found that large industries implementing high technology solutions will not be feasible for such industries from a financial and economic perspective. Other factors such as corporate reputation, international standards requirements, etc. should however be considered in decision-making. Coal-fired boilers, as an industrial source grouping, was found to be a significant source of health risks. The implementation of emission reduction options for this grouping was found to be marginally not feasible from a financial and economic perspective. The potential however exists for the intervention to be feasible if the implementation focussed on uncontrolled boilers located in close proximity to communities.

- If it is considered that there are hundreds of uncontrolled boilers situated in close proximity to communities, there should be merit in devising a strategy to deal with them, even though as a whole they are marginally non-feasible from a financial and economic perspective. It is noted that industry is opposed to having pollution reduction measures specified, but would prefer being given emissions limits to comply with.

- The bulk of savings due to reduced pollution would go to government. Since most savings are linked to reduced mortality and morbidity, and considering than in excess of 70% of patients are treated at government hospitals, it is not surprising that government would be the primary benefactor in monetary terms.

- There is a sufficient number of households in the domestic sector to allow for the implementation of multiple interventions without risk of deterioration of benefit:cost ratio's of identified interventions.

-

Intervention	Type of households targeted	Possible number of h/holds affected in Jhb only	Expected number of h/holds retaining intervention
Basa Njengo Magogo	Coal burning only	205 660	82 264
Housing insulation	Coal & wood burning	270 018	54 004
Electrification	Unelectrified	96 152	
	Only coal and wood unelectrified	25 612	14 086
Stove maintenance	Coal & wood burning	270 018	54 004
		TOTAL	**204 358**

- In practice it is not expected that the interventions proposed will result in significant employment loss, in general. Theoretically all interventions will result in reduced need for healthcare in both the public and private sector. It is however recognised that the current public healthcare system is stretched and it is doubtful whether any real job losses will occur. A limited number of jobs could be lost in the coal distribution system due to decreased coal usage. It is not expected that reduced coal demand will have a negative impact on the coal mining industry since less than 2% of coal produced is consumed in the household sector. Because the majority of feasible interventions rely on low technology and limited capital investment requirements, employment creation in supply industries such as machinery and equipment will be limited. Some jobs will however be created as part of educational processes associated with interventions such as Basa Njengo Magogo

- The implementation of an appropriate measurement and monitoring system in South Africa is a pre-requisite for implementation of this strategy. **Monitoring is**

required in at least three main areas: (i) emission monitoring/estimation (ii) ambient air quality monitoring – supplemented by modelling, and (iii) health effect monitoring, e.g. no. and duration of hospital visits by persons suffering from respiratory illnesses; cancer incidents (etc.). Provision must be made for the development and maintenance of comprehensive, current emissions inventory data bases to enable progress to be tracked with regard to emission reductions realised by various interventions. Ambient air pollution concentration data and health effect information are needed to determine whether the total intervention implementation strategy is realising real air quality improvements and health risk reductions. The Air Quality Bill makes provision for local and provincial authorities to establish and maintain emissions inventory data bases and ambient air quality monitoring networks. Emissions inventory and air quality monitoring protocols will be established following the promulgation of the Air Quality Act to ensure the standardisation of these tasks. Although the collection of health data is improving in certain areas (mainly through the initiatives of local government Environmental Health departments and the Department of Health) it is required that mechanisms be put in place to standardise health data collation and to facilitate the communication of such data to air quality managers.

- Market incentives as well as taxes and charges show more promise in developing countries than tradable permit systems. Tradable permit systems requires a highly sophisticated monitoring and management system, which currently does not exist in South Africa. In the short- to medium-term it is therefore advisable that market incentives, other than emissions trading, be considered.

8.4 THE LONG TERM GOAL OF THE PROPOSED STRATEGY TO REDUCE AIR POLLUTION FROM COMBUSTION

- Since this study included a detailed technical investigation into fuel-combustion related emissions and their sources, a thorough assessment of opportunities for technology based intervention, and the use of advanced micro- and macro economic modelling to derive the socio-economic impacts of such interventions, it provides an ideal basis to formulate a realistic and quantified long term goal based on factual evidence.

- The long-term goal is as follows:

- Reduce the negative health effects associated with air pollution due to fuel-combustion in the short- to medium-term in a cost effective manner, with the purpose of reducing the associated health costs (R 4.7 billion p/a) by 50% by 2011

The costs reductions are calculated as follows:

- Reductions due to interventions in the domestic sector: R 1.1 billion p/a (25% of total cost)

- Reductions from coal fired boilers: R 150 million p/a (3-5%)

- Reductions from vehicle emissions : R 150 million p/a (3-5%)

- Other reductions due to improved monitoring and management: R 150 million (3-5%)
- Other reductions due to continuous development of technology and other solutions for the long term, e.g renewable energy solutions, low smoke fuels, etc (up to 10%)

Note: There is inherent variability to health cost calculations done as part of this study.

Two factors should however be considered, which is the opinion of the authors point to a conclusion that the above numbers can be considered to be realistic. The first is that the approach throughout was to be conservative when assumptions were formulated or uncertainty encountered. The second is that no effort was spared to obtain "best available" data. A good example is the cost of treating patients who fall ill with diseases caused by air pollution. To obtain accurate costs a database of more than 60 000 cases were analysed to determine factors such as cost in private sector healthcare versus public sector healthcare, absenteeism days due to treatment, etc.

8.5 STRATEGIC THEMES

A number of overarching themes, or grand strategies were derived.

8.5.1 FOCUS ON REDUCING THE EFFECTS OF AIR POLLUTION

At the heart of the debate on pollution in environmental economics is a key proposition. The key problem is not emissions themselves but the damages associated with them. A given emission in a city has very different consequences to the same emission in a rural area. There are a number of reasons for this.

- The number of potential 'victims' is greater in a city.
- The level of ambient pollution is likely to be higher in a city; this is a problem if damage is an increasing function of pollutant concentrations.
- The environment's ability to assimilate pollutants may be weaker in a city than in a rural area.

The true aim of this strategy and other initiatives (such as the Air Quality Bill) should be to efficiently reduce the *impacts* of air pollution. It is for this reason that this study focuses on major conurbations and identified health impacts averted as the measure of benefits.

8.5.2 *FLEXIBLE AND MULTIPLE APPROACHES IN DEFINING ACTIONS AIMED AT REDUCING THE NEGATIVE IMPACTS OF AIR POLLUTION:*

If the aim is to efficiently minimise the negative externalities associated with air pollution, two broad categories of responses immediately present themselves.

- Reduce Emissions – this broad category includes all interventions that substitute a cleaner fuel (e.g. LPG for petrol), improve an existing fuel (e.g. low sulphur diesel), reduce emissions associated with an existing fuel (e.g. addition of lime to reduce SOx emissions from coal fired power stations), or improve the efficiency of fuel use (e.g. Basa Magogo), or negate the need for fuel use (e.g. energy efficient housing design).

- Reduce Impacts – the classic methods are:

    a. To relocate the emission source *directly* (e.g. relocating a factory to a new site that is 'out of town').

    b. Relocate the emission *indirectly*; the most obvious example is electrification of high density townships. Since the bulk of electricity is from coal fired generators, one is replacing inefficient combustion of coal in urban households with low chimneys, with combustion of the same coal in more efficient furnaces, with higher stacks, and often in rural areas

    c. Relocate the 'victim' population or at least ensure that they are fully aware of the consequences of moving into the problem area (the 'clean' zone around a nuclear power station is an example of the former, the Tiebout argument mentioned in Task 4b is an example of the latter).

    d. Engage in defensive expenditures (for example, if it is more expensive to clean up an emission than it is to issue face masks to the affected population, then the later option is preferable).

The abovementioned approaches have been considered in the development of the specific strategic objectives that need to be pursued.

When considering implementing a system to achieve any of the above responses, a multi-dimensional and flexible approach should be considered. Command and control solutions are more than often not the ideal system, but often the first to be considered.

- Where a single identified fixed point is the source of a problem, monitoring is relatively cheap and easy, and the problem can be addressed through regulation, public disclosure tax or allocation of a property right (the last mentioned is stressed here since historic justice and public rent seeking are potential issues in such arguments).

- Very different approaches are likely to be economically viable. Monitoring and policing would be difficult and expensive, meaning simple regulation will fail. Taxes on coal would be regressive and property rights approaches like tradable permits pointless. The only viable options left are; to educate the public to improve their coal burning technology, to improve the coal itself, or to provide a viable substitute. Multiple mobile emissions (such as vehicle exhausts) can be addressed in a number of ways: through stricter policing, variable pricing, education of vehicle users, traffic management, regulation, new vehicle technology and new fuel technology. In the developed world these tend to be in joint use.

8.5.3 CLOSE COLLABORATION BETWEEN NATIONAL, PROVINCIAL AND LOCAL GOVERNMENT IN THE DEVELOPMENT AND IMPLEMENTATION OF INTERVENTIONS

Local and provincial air quality managers will primarily be given responsibility for the identification and implementation of cost-effective emission reduction opportunities in coming years under the impending Air Quality Act. It is therefore essential that national government, in identifying and developing interventions and in drafting implementation strategies, do so in close consultation with the local and provincial authorities responsible for the air quality management within the areas of interest. Interventions requiring local implementation (e.g. most of the low technology interventions for the domestic sector) can only be successfully implemented if national DME/DEAT/DoT strategies are specifically linked to local and provincial air quality management plans. Certain high technology vehicle interventions (e.g. fuel specification changes) are not dependent on collaboration with local authorities. Low technology or spatially varied alternative vehicle interventions (e.g. traffic management measures, public transportation development along specific routes, etc.) – not considered in the current study – would however also necessitate close collaboration of national, provincial and local government departments.

8.5.4 FOCUS ON "LOW HANGING FRUIT" IN THE SHORT TERMS WHILST DEVELOPING APPROPRIATE SOLUTIONS FOR THE LONGER TERM

This study clearly showed that there is ample opportunity to reduce the health impacts of pollution by significant amounts by implementing relatively low technology solutions in the domestic sector. Since these solutions are low technology (or proven technology in the case of for example electrification) the risk of failure is relatively low. The study also showed that some of the higher technology solutions currently under consideration (low smoke fuels, renewable energy, fuel specifications etc) couldn't be justified from and financial and economic perspective if pursued at this point in time. This does not mean that such solutions should be discarded altogether. It means that further work is required to reduce the costs (or increase the benefits) associated with them. It is therefore advocated that attention be paid in the short- to medium-term to those interventions proven to be beneficial.

8.6 STRATEGIC OBJECTIVES AND INITIATIVES TO REDUCE AIR POLLUTION FROM FUEL COMBUSTION

In order to attain the long-term goal, as defined, a number of strategic objectives, with corresponding interventions need to be pursued. Before these are discussed, mention must be made of three highly important crosscutting issues, and how they are dealt with.

The need for measurement and monitoring.

This relates not only to the need of a sound system for monitoring emissions and ambient air pollution concentration levels, but also to the continuous monitoring of progress of implementation of the interventions recommended. On the first issue it is worth noting that international experience shows that improved monitoring (and disclosure) of emission levels and associated sources often result in actions to reduce such emissions by itself. The publication of air quality information, typically expressed to the public as user-friendly air quality indices, has similarly been found to prompt improvements through the raising of public interest in and scrutiny of sources of emission contributing to air pollution concentrations.

Since the need for measurement and monitoring is relevant for many initiatives proposed, and elaborated on in discussion of the strategic objectives, it is not defined as a stand-alone strategic objective. It is however of such importance that the following should specifically be considered:

- Emissions and air quality monitoring systems must be put in place as soon as possible; with implementation at local and provincial government level
- Provision must be made for the establishment of monitoring protocols to ensure the implementation and standardisation of quality assurance/quality control systems
- Mechanisms must be established for rapid emissions and air quality information sharing between national, provincial and local government and for the routine reporting of pertinent air quality information to the public.

The Air Quality Bill makes provision for most of the above, but the extent to which its provisions will be implemented, the timeframe for implementation and how effectively the monitoring will be conducted is still a matter of concern. It is strongly recommended that any strategy aimed at air quality improvement support the timely implementation of comprehensive, standardised and transparent emissions monitoring, emissions inventory and air quality monitoring tools for the purpose of providing air quality managers and the public with timely access to credible information.

The importance of education and awareness

Education and awareness is of specific importance for a number of reasons. The first is that the health impact of pollution (and associated costs) is generally not known to stakeholders across a broad spectrum. Society is in general ignorant of the negative health impacts, and for example do not include pollution as a factor when deciding on issues such as such as where to live, mainly because such information is not readily available and the consequences unknown. Government decision makers, except for a limited number of individuals intimately involved in this arena do not know the huge health bill associated with pollution. Workers in factories have a right to work in a clean air environment, and more than often do not know the quality of the air they work in.

This study provides the basis to answer many of these questions, and the value to be derived from disseminating the information collected as part of this study, and resulting from continuous monitoring as discussed, should be realised. The following are specific actions to be considered:

- Mechanisms should be implemented for communicating air quality information to the general public on a routine, on-going basis. Careful consideration should be given to the manner in which air quality information is reported, with attention being paid to local experience gained (e.g. City of Cape Town, Ethekwini initiatives) and to international protocols developed (e.g. UK banding approach, US-EPA pollution system index).

- The effect of current public disclosure programmes, for example the Bellville initiative recently initiated in Cape Town, should be assessed and used as input to the development of such programmes at all local levels of government

- Specific education and awareness programmes as identified in the subsequent sections should be pursued

Continued research and development

Many of the initiatives recommended for implementation are only possible because they were pioneered through research. Basa Njengo Magogo can be considered to be a uniquely "African" solution, and it is commonly accepted that Eskom is a world leader in the development of low cost and appropriate solutions for electrification of low-income houses (and informal settlements). It is therefore essential that research and development continue on many fronts, with involvement of numerous stakeholders from government, industry and labour.

The following are the specific strategic objectives of the strategy proposed

Strategic objective 1: Implement high yield, low technology solutions in the domestic sector in the short to medium term (2007) to realise a 25% overall health cost reduction by 2011

Strategic objective 2: Prepare (research, plan, test, etc) technologies for implementation in long term (2011 onwards) in both the supply and demand side to further reduce health impacts/costs

Strategic objective 3: Develop emission licensing system as well as incentive scheme to reduce impacts from coal fired boiler operations

Strategic objective 4: Develop a holistic and economically efficient strategy to control exhaust emissions from road-going vehicles

Strategic objective 5: Develop conurbation (and sector) specific strategies to reduce aggregate health costs

Strategic objective 6: Government to further refine the policy and regulatory environment

The rationale for each objective, the initiatives that should be pursued to achieve the objective, its expected impact and the roles and responsibilities of various stakeholders are individually discussed in subsequent subsections.

8.6.1 Strategic objective 1: Implement high yield, low technology solutions in the domestic sector in the short to medium term (2007) to realise a 25% overall impact reduction by 2011

The study clearly showed that a number of interventions implemented for the domestic sector could make a significant contribution to reduce health costs due to impacts associated with the sector's emissions. The total estimated impact by 2011 is a 25% reduction in total health costs in excess of R 1 billion per annum.

The following specific interventions are recommended:

a) **Refine and implement the DME Clean Household strategy.** The current DME strategy makes provision for Basa Njengo Magogo, low smoke fuels and housing insulation as priority areas. It is proposed that low smoke fuels be abandoned as an intervention in the short to medium term, but that research in this regard continue with a view of finding a lower cost technology, involving a range of stakeholders (Higher Education Institutions, Science Councils, private sector, etc.) under the guidance of DME. This project assessed impact of roll-out of Basa Njengo Magogo to the plateau areas. The DME strategy specifically makes provision for the following implementation areas: Mpumalanga Highveld (Witbank/Kwa-Guqa), mountainous area of KZN & Free State (Voksrust, to Qwa-qwa), Free State (Bloemfontein), North Cape (Kimberly), Gauteng (Soweto, Alexandra, Orange Farm) and NW Province (Potchefstroom). From a cost-benefit point of view there are no reasons why other areas should not be identified and targeted.

   It is proposed that the projects aimed at finding appropriate housing insulation material be accelerated. The focus should initially be on new households, but retrofitting of existing households should be considered. In this regard the same barriers apply to low-income households as those identified for stove maintenance and repair. Similar solutions as those identified in the next section should be considered.

   In refining interventions and establishing strategies for implementation it is crucial that the DME collaborate with local and provincial authorities in the potential implementation areas with the purpose of integrating the interventions into provincial and local air quality management plans. Some steps are already underway to develop this link[3] but further attention and motivation is required in this area.

[3] The City of Joburg developed an air quality management plan in 2003. The measures included in the plan for the management of household fuel-combustion related emissions included provision being made for the linking of locally developed measures (e.g. smokeless mbowulas, top down ignition) to the DME clean household energy strategy. The Plan called for the establishment of a Working Group on Domestic Fuel Burning comprising representatives from DME, GDACEL, DEAT and the City of Joburg. The focus of the working group being to consolidate efforts to manage household fuel burning emission impacts and to promote the development of a single strategy for the city. The DME has similarly taken steps by including representatives from GDACEL and the City of Joburg on the project steering committee of its Basa Magogo pilot project in Orange Farm. Such links are absent in other areas.

b) **The practical viability of implementing stove maintenance and repair should be investigated by DME, in close consultation with local and provincial authorities, in the short-term. If viable, the measure should be implemented in the medium-term.**

The socio-economic impact assessment for the stove maintenance and repair intervention found a positive net impact on households (and the majority are low income) due to reduced expenditure on coal in the long term. It was highlighted however that households will be reluctant to make an up-front investment in stove maintenance and repair. The practicality of ensuring that this measure is successfully implemented was also questioned. It is for these reasons that it is recommended that research be conducted in the short-term to inform this intervention and that, depending on the outcome of the research, it be implemented in the medium-term.

Two components of research is necessary in the short-term: (i) DME should involve the DTI and the Treasury Department to investigate the creation of a subsidised programme (perhaps under the Central Energy Fund) to facilitate the implementation of this intervention at no cost to households. This can be done along similar lines to other national programmes such as the "working for water" programme. (ii) DME should initiate studies, in collaboration with local authorities, to determine the current status of stoves (e.g. % of stoves beyond repair, % of houses requiring chimneys) and the social response to the measure.

Pending the outcome of the above research, the decision should be taken by authorities (national, provincial and affected local authorities) as to whether or not the measure is practically feasible for implementation in the medium term. The potential exists for the intervention to prove viable in one area and not viable in another. The implementation strategy for this measure should be tailored accordingly.

The socio-economic assessment calculated that a limited number of jobs can be created through the implementation of this initiative. In reality it can be expected that this intervention could create numerous jobs in the informal sector, if the above-mentioned barriers can be overcome.

c) **Continue the electrification programme and intensify efforts to reduce incidents of electrocution**. This study has shown that the national electrification programme would make a significant positive contribution to reduce pollution (and the associated cost) in the domestic sector. The study also showed that electrocution (suspected to be mainly as a result of theft) would have a dramatic negative impact on the economy.

To this extent there should be renewed efforts by role-players (DME, Eskom, SAP, local authorities) to curb this through education and policing.

d) **Ensure that progress is monitored at local and provincial government level and the results are communicated to national government.** Provision is made for monitoring to be conducted at provincial and local government level in the Air Quality Bill as discussed previously. The integration of interventions into the air quality management plans of local and provincial authorities will ensure that progress made is routinely monitored. It must be ensured that results from such monitoring is not only communicated to national environmental authorities (DEAT) but also that it is readily available by other national authorities (e.g. DME, Department of Health, DoT).

8.6.2 STRATEGIC OBJECTIVE 2: PREPARE (RESEARCH, PLAN, TEST, ETC) TECHNOLOGIES FOR IMPLEMENTATION IN LONG TERM (2007 ONWARDS) IN BOTH THE SUPPLY AND DEMAND SIDE TO FURTHER REDUCE HEALTH IMPACTS

This study has shown that high technology solutions on the demand side are not feasible for the short to medium term. In the power generation sector the desulphurisation of power stations are prohibitingly expensive, as are current large-scale renewable energy solutions on the supply side. In the domestic sector low smoke fuels are also prohibitingly expensive, as already discussed. This does not mean that these solutions be abandoned, or government's policy on having a 10 000 GWh block of energy supplied through renewable energy be changed. It is advocated rather that further work be done in the interim.

a) Continued development of the low smoke fuels programme

Although much progress has been made in the development of low smoke fuels (laboratory scale investigations and Qalabotjha pilot programme) subsidised implementation is not recommended in the short to medium term. There are currently attractive interventions that can immediately be pursued in the domestic sector in the short-term. Further work is required during this period to facilitate the development of lower cost low smoke fuel technology for implementation in the medium-to- long term.

The aim should be to have low smoke fuel technologies ready by 2007, which then can be implemented without government subsidy in the long term. This intervention should be driven by DME in co-operation with DEAT, provincial and local government, industry solutions providers, Science Councils and Higher Education Institutions.

b) Continue government's current policy around renewable energy, with the focus on implementation from 2007 onwards

Although this study has found that large-scale wind electricity generation is not feasible for the short to medium term, it is the view of this study that the current government policy provides sufficient flexibility for numerous other potential solutions (solar water heating, small scale hydro, etc) should to be pursued.

Government (DME in specific) should continue looking at international funding options, and specifically how the Clean Development Mechanism be utilised. An area of concern is that government's strategy assumes the continued weakening of the Rand, which would result in increased competitiveness of South African fuels with US dollar denominated fuels, thereby creating opportunities for energy export. This seems an unlikely scenario, at least on the short term, which means the focus of energy producers will remain the domestic market, therefore limiting the entry opportunity for alternative sources.

c) Continuous assessment of the potential for cost savings associated with reduced pollution

The financial and economic feasibility of interventions are by-and-large driven by the opportunity for health cost reductions. In light of the current and proposed interventions, the opportunity will diminish in the medium to long terms. This means that assumptions in 2003 around feasibility will be different by 2007 and 2011. To this extent it is recommended that the feasibility of potential intervention periodically be assessed. The information clauses in the Air Quality Bill should be activated so that emissions and air quality data which will routinely be measured in future be regularly fed into this assessment process.

8.6.3 STRATEGIC OBJECTIVE 3: DEVELOP A REGULATORY MECHANISM AND INCENTIVE SCHEME TO REDUCE IMPACTS FROM COAL FIRED BOILER OPERATIONS

This study found that there are literally hundreds of boiler operations within close proximity of communities, which are currently poorly regulated. Two options exist for the regulation of these sources under the Air Quality Bill: (i) boiler operations can be classified as "listed activities" and as such these operations would require an atmospheric emissions licence to operate. Licence requirements which would need to be met would typically include emission limits, operating procedures, control device availabilities, monitoring requirements (etc.)[(4)]; (ii) boiler operations can be classified

[4] Boiler operations are currently listed as a Schedule Process in the Second Schedule of the Atmospheric Pollution and Prevention Act, Act 45 of 1965 (which will be superceded by the Air Quality Act). As such these operations require permits to operate. It should however be noted that a cut off of 10 t/hr of coal consumption was typically used, with only the boilers consuming more than 10 t/hr being considered as a scheduled process and regulated by the

as a group of “controlled emitters” by the Minister of Environmental Affairs and Tourism or by provincial MECs. In the latter case, a single standard is published for the group to which individual boiler operations would need to prove compliance. Similar in nature to individual facility licences, the standard can include emission limits, operating conditions, control device availabilities, monitoring requirements (etc.). Large industries (e.g. Iscor coke ovens, Highveld Steel and Vanadium boilers etc) will be designated and regulated as “listed activities” rather than as “controlled emitters”.

a) Develop and manage detailed inventory of coal fired boiler operations

The first step is to identify such operations and build up an inventory of sources and emissions. This study identified a large number of boiler operations and corresponding emission levels. This could be a valuable starting point. Provision is made in the Air Quality Bill for the establishment and maintenance of comprehensive emissions inventories by local authorities tasked with air quality management. Mechanisms are therefore already in place for the implementation of this recommended step.

An additional source of information that could be utilised is the Department of Labour’s boiler certification programme, which requires all companies that operate boilers and pressure vessels to register such equipment for regular safety inspection. Local air quality management authorities should be made aware of such sources of information.

b) Develop regulatory framework at national level for implementation at local level

The next step would be the development of appropriate regulatory framework to deal with boiler operations. In this case, because it deals with health and safety, the system will be one of technical regulations. Technical regulations should specify outcomes, rather than processes for demonstrating conformity For the technical regulations to be effective three dimensions need to be clearly specified:

- **The regulator:** This entity should carry the mandate of government to enable it to adopt regulations, assign conformity assessment responsibilities and enforce sanctions. The Air Quality Bill makes provision for district municipalities and metropolitan municipalities to

DEAT. It has however been found that often small boilers located in close proximity to communities are problematic and the regulation of such boilers by local authorities ineffective.

regulate “listed activities”. The monitoring and regulation of “controlled emitters” is likely to be a municipal function.

- **The conformity assessment requirements:** Conformity assessment requirements should provide assurance of the desired outcomes but allow for a variety of routes, for example, compliance with an international or national standard, the latter the most likely solution in this case.

- **Enforcement:** Effective enforcement of technical regulations will require and effective monitoring and inspection regime, as already mentioned. The sanctions could entail a range of options (fines, withdrawal of operating licence, etc), but the key principle is that sanctions are specified that are sufficient to act as a deterrent to offences.

c) Investigate and develop a support scheme to facilitate investment by industry to reduce emissions from coal fired boilers

Two issues need to be considered in this regard. The first is that many of the smaller boiler operators can reduce emissions significantly purely by improving operating processes. This will not require capital investment, and the next intervention deals with this angle. The second consideration is that many boiler operators, especially the larger ones have advanced operating processes in place, but need to upgrade or replace their technology.

The study has shown that such investments are by-and-large not financially and economically justified. It is to this extent that it is recommended that an appropriate supply side incentive be implemented to assist companies in this regard. Current incentives such as accelerated depreciation incentive, tax deductions and even the SMEDP should be investigated. It must however be kept in mind that such incentives should be balanced by an effective regulatory system. The lead in this regards should be taken by DEAT, and involve the DTI and the Treasure Department.

d) Launch and awareness and education campaign amongst SME boiler operators

SME boiler operators need to made aware of the harmful effects of emissions resulting from their boilers, changes to current operating procedures that should result in decreased emissions, assistance provided for technology upgrades, the potential benefits associated with increased efficiency, and the intention of government to actively regulate such operations. This initiative should be driven by DEAT in association with the DTI, and very important, relevant industry associations

8.6.4 *STRATEGIC OBJECTIVE 4: DEVELOP A HOLISTIC AND ECONOMICALLY EFFICIENT STRATEGY FOR CONTROLLING OF EXHAUST EMISSIONS FROM ROAD-GOING VEHICLES*

Government (DME and DEAT) recently published a draft strategy to deal with exhaust emissions from vehicles. The two major components of the strategy were assessed as part of this study, and it is concluded that the strategy needs to be re-visited, primarily in terms of its scope and the potential negative socio-economic consequences of proposed changes to fuel specifications

a) The DME and DEAT to revisit the scope of the strategy for the control of exhaust emissions from road going vehicles

The proposed strategy (jointly developed by DEAT and DME) has two components. The first is the phasing in of emission standards for new road going vehicles (EURO 2 and EURO 4). The second deals with the phasing in of enabling fuels (which is not attractive from a socio-economic perspective). The strategy therefore does not consider alternatives such as changes in vehicle usage patterns, and improved vehicle inspection.

It is therefore proposed that the DME and DEAT revisit this strategy to include for alternative solutions. The most practical approach is probably to establish a task team with representatives from all stakeholders (e.g refineries, vehicle manufacturers, taxi associations, etc) to investigate this issue. Provision should be made for the collation of spatially- and temporally-resolved vehicle fleet and vehicle activity data, for photochemical modelling, and health risk assessment. Given the complexity of such studies it would be beneficial to select one conurbation to conduct the modelling and to tend various interventions.

b) The DME and DEAT to revisit the proposed fuel specifications as specified as part of the strategy for the control of exhaust emissions from road-going vehicles

The first component of the existing strategy (EURO2 and EURO 4 compliance) are regarded to be sound since these standards are international and it can readily be expected that South African motor vehicle manufacturers will adopt these standards because of market forces.

The second component deals with the phasing in of enabling fuels (reduction of sulphur, benzene, aromatics, and lead in petrol and reduction of sulphur and polycyclic aromatics in diesel). These interventions were found to be unattractive from a socio-economic perspective, and it can therefore not be recommended that they be pursued before alternative options have been investigated. One exception is the reduction of lead, for which the benefits could not be costed, but the implementation costs are relatively low, and it is probably worthwhile to continue phasing it out.

c) Fast-track the implementation of provisions in the Air Quality Bill for the regulation of vehicles.

The proposed Air Quality Act makes provision for the classification of vehicles as "controlled emitters" and therefore for the establishment of national standards for vehicles (as described for coal-fired boilers). Vehicle emissions will however not be effectively controlled, even given the promulgation of the Act, until such time as they have been designated as controlled emitters and regulations put in place for their management. Substantial capacity will also be required to be developed at local authority level to ensure effective implementation and enforcement of regulations.

8.6.5 STRATEGIC OBJECTIVE 5: DEVELOP CONURBATION (AND SECTOR) SPECIFIC STRATEGIES TO REDUCE AIR POLLUTION FROM AND AGGREGATE HEALTH COSTS

It has been mentioned that this study was done at national level. However, the implementation of effective air quality management is the responsibility of provincial and local government. There is therefore a need to develop conurbation and sector specific strategies. This will not only facilitate the implementation of many interventions specifiesd in this strategy, but also result in a process of continued search for interventions.

a) DEAT to facilitate strategy development process at provincial and local government

DME should take the lead in implanting thorough strategic and operational planning processes at provincial and local government. A key focus should be to use the flexibility inherent to the Air Quality Bill to ensure that efficient solutions prevail at conurbation level. These strategies should consider various relevant sectors, and the process followed in this study could be replicated. In fact, it is strongly recommended that the information collected as part of this study be used extensively during the planning process, since significant data was obtained at conurbation level.

b) DEAT to implement a measurement system to monitor implementation and effect of provincial and local government plans

The need to continuously review and adjust actions and interventions as the industrial and domestic landscape changes, and as short term interventions start realising benefits were discussed earlier in the report.

8.6.6 *GOVERNMENT TO FURTHER REFINE THE POLICY AND REGULATORY ENVIRONMENT*

A number of challenges remain. The first one is to ensure that the Air quality Bill is effected at national, provincial and local levels of government. The second is to ensure that cross-departmental issues are addressed in a meaningful manner. The third is to ensure that continuous assessment of the situation is done, and the policy, regulatory and operational environments adjust accordingly.

To achieve the first will require commitment from various role-players. The second can be achieved in a number of ways, for example through setting up of inter-departmental tasks teams, but the most effective way is probably to make air pollution an agenda item on Cabinet's Standing Portfolio Committee on the environment. A number of recommendations were made elsewhere in the report, which should ensure that continuous measurement actually takes place.